The Effect of Cryptocurrency on Exchange Rate of China: Case Study of Bitcoin

Riska Dwi, Astuti and Nadia, Fazira

Faculty Economics and Business, Universitas Gadjah Mada, Indonesia, Faculty Economics and Business, Universitas Gadjah Mada, Indonesia

12 September 2018

The Effect of Cryptocurrency on Exchange Rate of China: Case Study of Bitcoin

Riska Dwi Astuti

Faculty Economics and Business, Universitas Gadjah Mada, Indonesia
riska.dwiastuti93@gmail.com

Nadia Fazira

Faculty Economics and Business, Universitas Gadjah Mada, Indonesia
nadiafzra@gmail.com

ABSTRACT

In recent years, there have been many significant changes in commercial transactions. Not only e-commerce continues to grow, but also the form of payment services and service providers are consistently growing, such as virtual currency. One of virtual currency that quite popular is cryptocurrency especially Bitcoin. China became the country with the largest Bitcoin market in the world in the past few years. However, due to the concerns about money laundering and threats to China's financial stability and affecting the domestic currency, the Chinese government has formed a strict policy on Bitcoin. Therefore, nowadays, China is no longer the largest Bitcoin market in the world. Regarding the recently implemented policy, this study aims to analyze whether Bitcoin does affect China's exchange rate. The main independent variables in this research is specified to Bitcoin price volatility from BTCE, and controlled with variable of current account, inflation and money supply. Monthly time series data from November 2012 until July 2017 is analyzed using autoregressive distributed lag (ARDL). The estimation results show that Bitcoin price volatility significantly affect the exchange rate in the long run. The higher of Bitcoin price volatility implies higher risk. Negative sign in the coefficient suggests that when Bitcoin's price volatility increases, investors tend to switch their investments on real currency will be preferable so that the exchange rate will be appreciated.

Keywords: Cryptocurrency, Bitcoin, Exchange Rate, ARDL, China

JEL Classification: D13, I31, J22, K31*

INTRODUCTION

In recent years, there have been many significant changes in commercial transactions. Not only e-commerce continues to grow, but the form of payment services and service providers are also growing, one of which is the virtual currency. There are different types of virtual currencies, including virtual currencies deployed in closed systems, such as cyberspace. These virtual currencies are generally not obtainable by legal tender and also cannot be exchanged for legal tender. The second type is a virtual one-way currency, such as Amazon Coins or Facebook Credits and Microsoft Points that have now been deleted. This virtual currency can be purchased from a legal tender, but cannot be converted back into a legal tender. The last type is a two-way virtual currency. This virtual currency can be obtained from a legal tender and can be redeemed with a legal tender. The main example is cryptocurrency, such as Bitcoin, because it is not issued by the central authority (Vandezande, 2017).

In addition to Bitcoin, there are also other cryptocurrencies, such as Litecoin (LTC), Ethereal (ETH), Ripple (XRP), etc. The website https://coinmarketcap.com/currencies/ counts up to 641 of the money. However, as we can see in Figure 1, Bitcoin represents 89% of the cryptocurrency market (Bariviera et al, 2017).

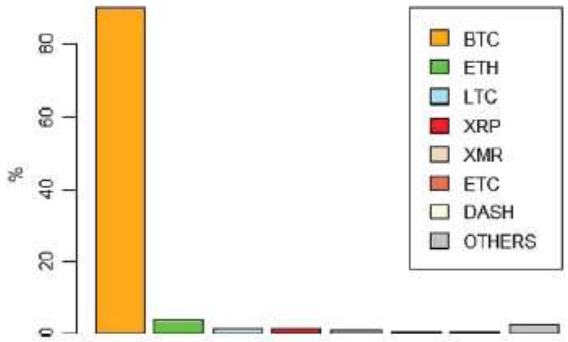

Figure 1. Share from criptocurrencies
Source : Bariviera et al (2017)

In November 2016, China became the largest Bitcoin market in the world due to the prevailing permissive policies with respect to cryptocurrency. On December 3, 2013, because of the deep concerns about money laundering and threats to China's financial stability as well as affecting the domestic currency, the Central Bank of China and four other government offices jointly issued notice to prevent Bitcoin's risk of banning domestic banks from providing banking services to businesses Bitcoin. Bitcoin prices tumbled after the release of the notice, but then recovered and rose again to reach a series of new price peaks. During several closed-door meetings between the Central Bank of China and the cryptocurrency trading platform in early 2017, the central bank requested a platform to enact anti-money laundering and foreign exchange regulations. However, the meeting did not have a major effect on the price of cryptocurrency (Pilarowski & Yue, 2017).

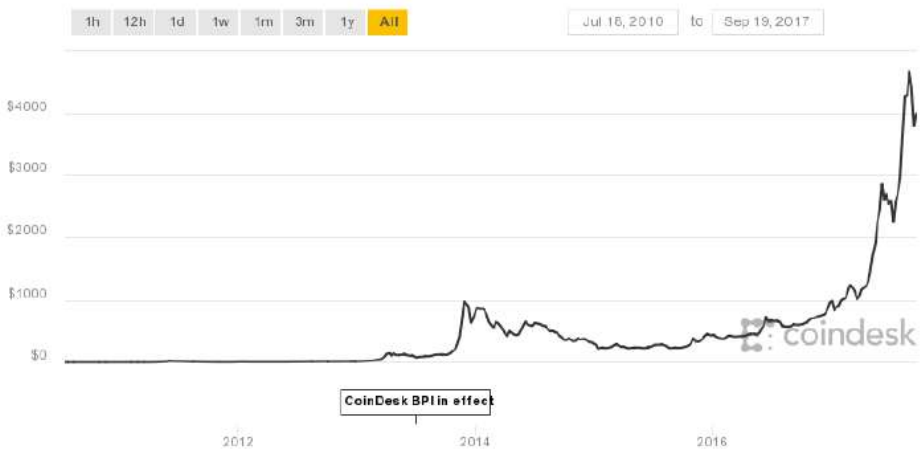

Figure 2. Cryptocurrency (coindesk) development in China
Source : Coindesk in Pilarowski & Yue (2017)

Since the beginning of 2017, the number of ICO platforms (Initial Coin Offering) in China has also increased sharply and became one of the causes of the development of cryptocurrency in China. According to China's ICO Development Report for the first half of 2017 issued on July 26, 2017 by the National Internet Finance Association of China, an association guided by MIIT, on July 18, 2017, the value reached 2.62 billion, which is roughly equivalent to US $ 400 million, increased through 65 ICO programs operated by 43 ICO Platforms. Prior to 2017, only five ICO programs were operated in China (Pilarowski & Yue, 2017).

Then on September 15, 2017, the Beijing Internet Finance Risk Working Group, a working group organized by the Beijing municipal government, held a meeting with senior officials of the cryptocurrency trading platform in Beijing and required each platform to: (i) specify the time limit for which the platform will stop all cryptocurrency trades; (ii) immediately stop registering new clients; and (iii) prepare details of the refund plan to return the asset to the client. So the largest cryptocurrency platform in China released an announcement informing their clients that the BTCChina, Uobi, OKCoin and ViaBTC platforms will stop operating. As a result Bitcoin price fell below the level of significance of US $ 3,000 per coin on September 15, 2017 for the first time in recent months.

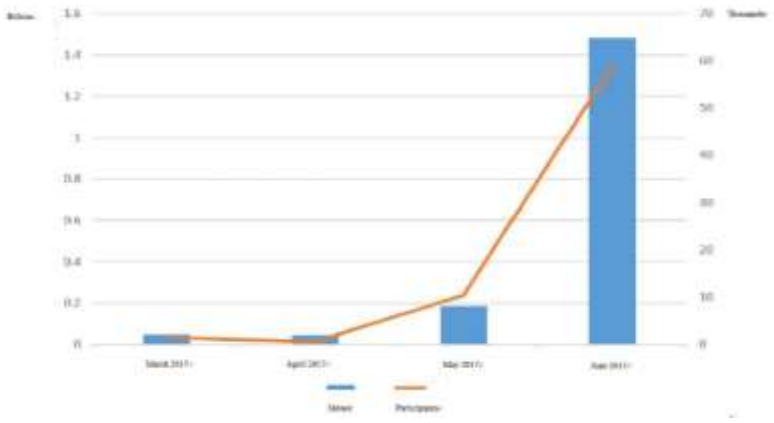

Figure 3. ICO development in China
Source : National Internet Finance Association of China in Pilarowski & Yue (2017)

In previous years, the Chinese market accounted for more than ninety percent (90%) of all Bitcoin trades. Currently, the Chinese market accounts for only about ten percent (10%) of all Bitcoin trades, as many investors have shifted cryptocurrency trades to exchanges in Japan, South Korea and the United States (Pilarowski & Yue, 2017).

The establishment of a strict policy on Bitcoin by the Chinese government provides a framework for the analysis of this paper. Is it true that cryptocurrency affects the domestic exchange rate so far? Subsequently part two of this paper discusses the description of Bitcoin. Part three, data and research methods used. Then the estimation results will be explained in part four and the conclusions in section five.

BITCOIN OVERVIEW

With the continuous expansion of human activities and activities the emergence of high transaction frequency, the traditional real currency gradually evolved into a credit currency to meet the needs, comfort and increased security. Commercial transactions in digital and virtual currencies are becoming widespread thanks to the popularity of the internet. In 1982, David Chaum, founder of the digital currency, proposed a new primitive for cryptography that is Blind Signature and a digital cash system with anonymity and based on dexterity that is considered the earliest monetary theory of digital. Several further works have improved many aspects of this theory, but the model remains centralized. The centralized scheme raises the risk of trust and additional transaction costs. A number of startup companies, such as Peppercoin and DigiCash, intend to translate theory into practice but ultimately fail. Then in 2009, Bitcoin emerged as the first and most popular cryptocurrency or virtual money and managed to date (Wang et al., 2017). In January 2017, there were 16 million Bitcoin in circulation with an overall value of about 16 billion US dollars, although the Bitcoin exchange rate showed enormous fluctuations (Vranken, 2017).

Initially Bitcoin was introduced by a group of programmers, under the pseudonym of Satoshi Nakamoto. Bitcoin comes from mathematical cryptography and is understood as an alternative to government-backed currencies (Cheah & Fry, 2015). Bitcoin is an open source based online payment system. Payments are recorded in a common ledger, known as block chain, using its own account unit, also called Bitcoin, symbolically represented as BTC or XBT (Hayes, 2017). Bitcoin is based on a distributed structure through a P2P computer network. There is no central trust authority to manage / maintain this system and participants may transact with other participants free of control or supervision under authority (Wang et al., 2017).

Bitcoin is quite liquid so someone can exchange any currency with Bitcoin anytime. Then, the Bitcoin protocol does not restrict transfers even if the identity of its users is unknown. This gives the flexibility and speed of international transfers very large compared to other currencies managed by banks (Dyhrberg, 2016).

Although Bitcoin is so popular, Figure 4 shows that Bitcoin is unlike other major asset classes. The price of Bitcoin is very volatile since it was first introduced, plus Bitcoin is used as an asset and not as a currency (Dyhrberg, 2016; Glaser et al., 2014). In particular, the volatility is much higher than the volatility of gold, US dollars, or the stock market (represented by the MSCI World Index) (Baur, Dimpfl, & Kuck, 2017). Therefore, the Bitcoin market is currently highly speculative and more volatile and susceptible to speculative bubbles that would have a correlation with domestic currency

exchange rates (Katsiampa, 2017). So the demand for the Yuan currency increases and the Yuan will be appreciated. Figure 5 presents a series of asset recovery times of Bitcoin, USD FX index, gold and MSCI world and strengthens the previous statement because Bitcoin return dispersion is about 10 times higher than gold, US dollar, or MSCI World. Observing very different price lines may be surprising given that the Bitcoin design has a major feature similar to gold (mining, decentralization, unsupported by the government, globally traded 24 hours a day, 7 days per week) and currency (exchange medium) (Baur et al., 2017).

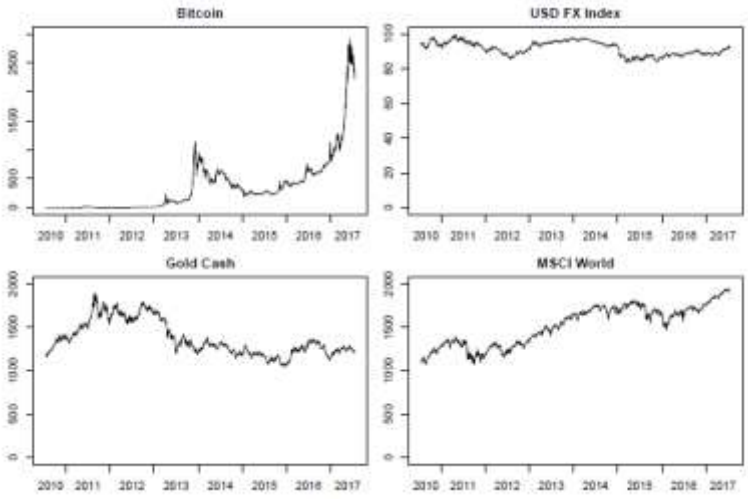

Figure 4. Bitcoin, USD FX Index, Gold and MSCI World
Source : Baur, Dimpfl, & Kuck (2017)

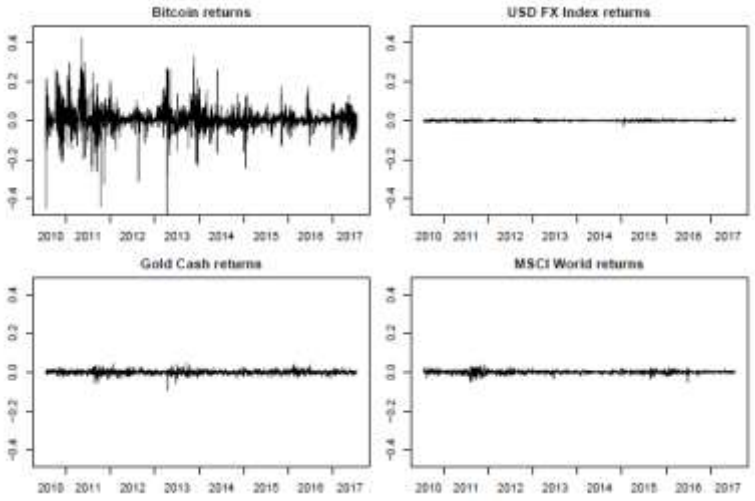

Figure 5. Bitcoin, USD FX Index, Gold and MSCI World Returns
Source : Baur, Dimpfl, & Kuck (2017)

At first, the initial transaction in Bitcoin seemed to work as planned, and then began reporting that Bitcoin was used to buy illegal drugs. Policymakers around the world are becoming concerned about the anonymity provided by Bitcoin. Additional concerns arise as to how such anonymity can also be used to buy child pornography. Beyond the potential to fund criminal activities, economists have voiced concern that, due to price dynamically, Bitcoin serves more as a speculative asset than as a traditional exchange medium. Because of its anonymity, Bitcoin may be the target of speculators (Blau, 2017). Furthermore, with the lack of legislation and supervision, through Bitcoin can also be

money laundering. This doubles the possible negative effects and reduces the protection of the people (Dibrova, 2016).

Bitcoin can be obtained through "mining". Mining is done by special hardware that has a certain amount of computing power, measured in hashes per second. Hash can be considered somewhat similar to the processing power of the CPU microchip, which is measured in hertz to determine how many individual calculations can be achieved per second. The aggregate Bitcoin network has a cumulative computing power additive for all mining operations employed worldwide. For every one GigaHash per second (1 GH / s = 109 hash) each individual miner puts online, for example, the amount will be added to the overall network power. Mining is quite competitive, in the sense that someone mines with more computing power, or with greater efficiency, has a better chance of finding new Bitcoin than others (Hayes, 2017). In addition to mining, Bitcoin can also be obtained in exchange for domestic currency such as dollars, euros, yuan, etc.

METHOD, DATA, AND ANALYSIS

This study use autoregressive distributed lag (ARDL) to analyze the research problem. The exchange rate of Yuan to US dollar is used as dependent variable as natural logarithm form. The independent variables consist of the bitcoin price volatility of the BTCE, current account, inflation and natural logarithm of money supply. A sample of 57 observation consists of monthly data in November 2012 to July 2017 from People's Bank of China, IMF, National Bureau of Statistics and Ministry of Finance. The model specification in this research is as follows:

$$ER_t = \beta_0 + \beta_1 VOL\_BTCE_t + \beta_2 CA_t + \beta_3 INF_t + \beta_4 L\_MS_t + \varepsilon_t$$

ER is natural logarithm of exchange rate, VOL_BTCE is the price volatility of BTCE bitcoin, CA is the current account, INF is inflation and L_MS is natural logarithm of money supply.

Cointegration of the ARDL Bound test does not require all the integrated variables at the same order. It is developed on the basis of the variables integrated in order I (0) and I (1), or when all the variables are integrated in order I (1). Bound test is done to find out the long run relationship based on theory. Without information about the long-run relationship of the variables in the model, unrestricted error correction (UEC) estimates using equation presented below:

$$\begin{aligned}\Delta(ER) = {} & \beta_0 + \beta_1(ER)_{t-1} + \beta_2(VOL\_BTCE)_{t-1} + \beta_3(CA)_{t-1} + \beta_4(INF)_{t-1} + \beta_5(L\_MS)_{t-1} \\ & + \sum_{I=0}^{P} \beta_6(VOL_{BTCE})_{t-1} + \sum_{I=0}^{P} \beta_7(CA)_{t-1} + \sum_{I=0}^{P} \beta_8(INF)_{t-1} + \sum_{I=0}^{P} \beta_9(L\_MS)_{t-1} \\ & + \varepsilon_t \dots\dots\dots eq(1)\end{aligned}$$

The symbol “p” denotes the optimum lags in the model, ln is logarithm operation, Δ indicates first-differencing and ε_t is error term. In the Bound test, the combination of F-statistic whose unstandardized asymptotic distribution in the null hypothesis that there is no cointegration. According to equation 1:

$$H_O = \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$$

$$H_1 = \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq 0$$

In this step, F-statistic will be compared to the critical value that tabulated by Pesaran (1997) and Pesaran et al (2001). If the F-statistic is higher than upper critical, null hypothesis (no cointegration) can be rejected so long-run relationship does exist. F-statistic that is smaller than lower critical value implies that there is no cointegration since we cannot reject null hypothesis. Meanwhile, F-statistic that greater than lower critical value however smaller than the upper critical value means the cointegration cannot be decided. For model with all variables stationary at first order (I(1)), decision is made based on upper critical value whereas for model whose variables stationary in the level, lower critical value must the single consideration.

RESULTS

Stationary test is essential for making sure the characteristic of the data is relevance to be analyzed using ARDL. In this study, augmented Dickey-Fuller (ADF) is employed for the unit root test. Prior to this test, the data is plotted to investigate the behavior of the data. Figure 6 indicates several variables in the model experience a trend. It is possible that some variables are not stationary at the level.

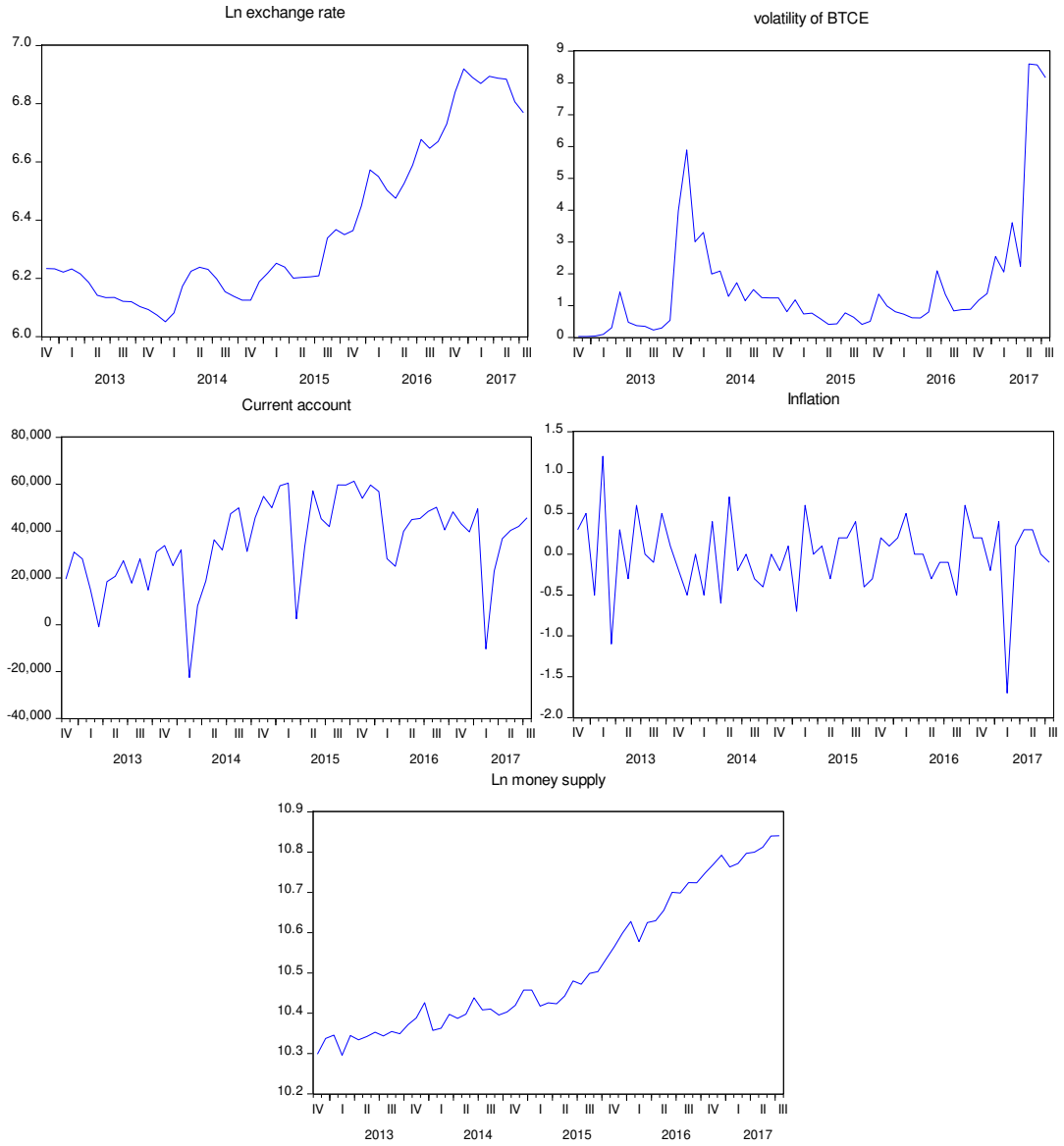

Figure 6. Plotting results

Furthermore, unit root test using augmented Dickey-Fuller method gives the information that the variable of exchange rate, the volatility of BTCE bitcoin price and money supply are stationary at first differencing while the current account and stationary inflation at level (I(0)).

Table 1. Unit root test using Augmented Dickey-Fuller

Level

Variable	*t-Statistic*	*Critical Value*			*Remarks*
		5%	10%	p-value	
Exchange Rate	-2.580491	-3.493692	-3.175693	0.2905	*Not stationary*
Volatility of BTCE	-0.32712	-1.946764	-1.613062	0.5631	*Not stationary*
Current Account	-4.307887	-2.914517	-2.595033	0.0011	*Stationary*
Inflation	-11.42065	-1.946764	-1.613062	0.0000	*Stationary*
Money Supply	-1.894222	-3.492149	-3.174802	0.6443	*Not Stationary*

First difference

Variable	*t- statistics*	*Critical value*			*Remarks*
		5%	10%	p-value	
Exchange Rate	-5.073225	-1.946996	-1.612934	0.0000	*Stationary I (1)*
Volatility of BTCE	-8.766874	-1.946878	-1.612999	0.0000	*Stationary I (1)*
Money Supply	-8.402025	-1.946878	-1.612999	0.0000	*Stationary I (1)*

Optimum lags of ARDL model are selected based on Akaikae Information Criterion (AIC). Using software EViews 10, this procedure is processed automatically. For this study, 4 0 0 0 0 is chosen as the most optimum lags as displayed in table 2 and described in figure 7.

Table 2. Autoregressive distributed lag estimates

Selected ARDL (4 0 0 0 0) based on AICE Akaike information criterion
Dependent variable: Ln exchange rate

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
ER(-1)	1.054130	0.131633	8.008120	0.0000
ER(-2)	-0.528218	0.204525	-2.582651	0.0132
ER(-3)	-0.047018	0.208705	-0.225283	0.8228
ER(-4)	0.162998	0.123239	1.322616	0.1928
VOL_BTCE	-0.008269	0.002760	-2.996525	0.0045
CA	-7.01E-07	3.01E-07	-2.327842	0.0246
INF	0.018857	0.010728	1.757757	0.0857
L_MS	0.674401	0.117026	5.762807	0.0000
C	-4.770473	0.812119	-5.874103	0.0000

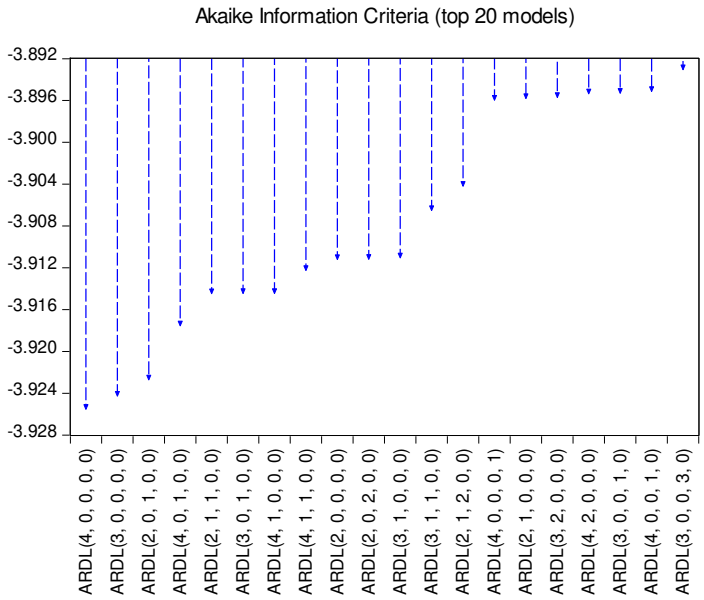

Figure 7. Optimum lags based on Akaike Information Criteria (AIC)

After determining the stationarity level of each variable, the next step is to test whether there is a long-term relationship between variables in the equation using the bound test approach. In table 3, the F-statistic (F-statistic = 7.553641) is higher than the critical upper Bound (4.37) at 1% significance, meaning the null hypothesis of the absence of cointegration is rejected. There is a linear combination of variables in stationary and integrated models which also indicate a long-term relationship between exchange rate dependent variable and independent variable volatility BTCE, current account, inflation, and money supply.

Table 3. Bound test

Dependent variable: Ln exchange rate

F- statistics = 7.553641 K= 4

Significant level	*Lower bound*	*Upper bound*	
1%	3.29	4.37	*Exist relationship*
5%	2.56	3.49	*Exist relationship*
10%	2.20	3.09	*Exist relationship*

Table 4 displays the long-term estimation for 4 0 0 0 ARDL based on Akaike information criteria. Variables of volatility of BTCE and current account are positively significant while natural logarithm of money supply are negatively significant on affecting the exchange rate in the lomg-term.

Table 4. Long-term effects estimation

ARDL (4 0 0 0 0) Based on AIC (Akaike information criteria)
Dependent variable: Ln exchange rate

Variable	Coefficient	Std. Error	t-Statistic	Prob.
VOL_BTCE	-0.023091	0.008890	-2.597556	0.0127
CA	-1.96E-06	7.43E-07	-2.636003	0.0115
INF	0.052658	0.030892	1.704568	0.0953
L_MS	1.883236	0.114536	16.44237	0.0000
C	-13.32134	1.182983	-11.26080	0.0000

Note: significant level 5% [p-value ≤ 0.05]

Results will be an estimation for short term and long term. After performing cointegration tests, the error correction model (ECM) is estimated to capture short-term dynamics. ECM results on the exchange rate imply that all independent variables in the short term have an exchange rate effect except inflation variable due to insignificancy. One-period long-term residual lagged residual estimate with negative and significant coefficients at a significant level of 5%, ensuring that long-term equilibrium convergence can be achieved. In addition, Bannaerjee et al (1998) claims that high levels of ECM significance suggest evidence of a long-term relationship. The speed adjustment of the ECM model is -0.358108, which shows that about 36% of the deviation from long-run equilibrium is adjusted every year. It also shows that once disequilibrium occurs, it will take more than a year to adjust to equilibrium.

Table 5. Elasticity in the short term

ECM Regression				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(ER(-1))	0.412237	0.102101	4.037527	0.0002
D(ER(-2))	-0.115980	0.116207	-0.998047	0.3237
D(ER(-3))	-0.162998	0.105099	-1.550892	0.1281
CointEq(-1)	-0.358108	0.050407	-7.104369	0.0000

Stability test are conducted using CUSUM and CUSUM of squares (CUSUMSQ) test that reflect the stability of the estimated coefficients of the model while presenting the existence of a structural change in the correlation. The results are shown in figure 8 below. It is noted as the limitation of this study as the CUSUMSQ route exist outside the limits of the significance interval at the 5% threshold. The coefficient appear unstable around the period November 2014 until September 2015.

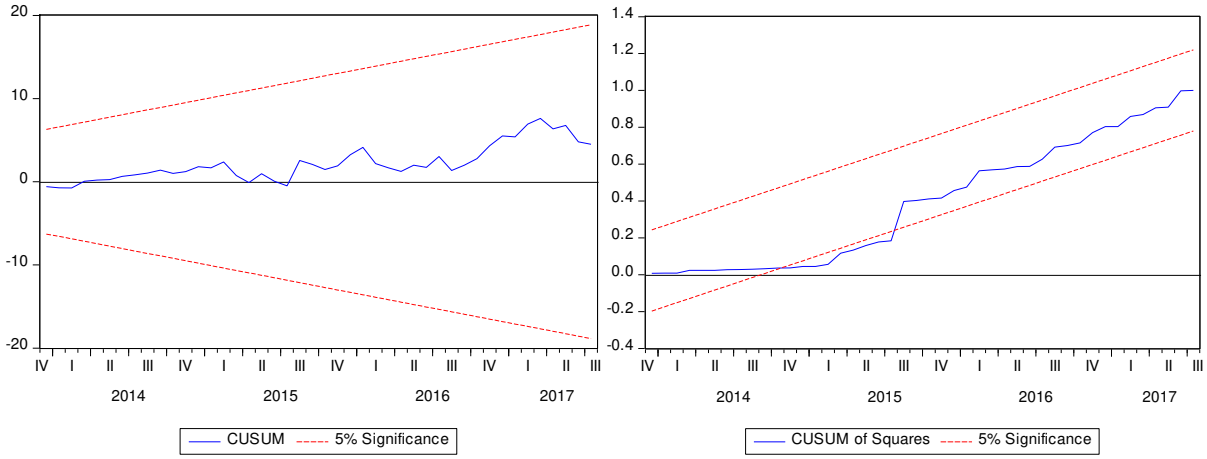

Figure 8. CUSUM and CUSUMSQ stability test

Table 6. Diagnostic tests

	F- statistic	*P-value*	
A. Serial correlation Test	*0.264038*	*F (2,42)*	*0.7692*
B. Heteroscedastic Test	*0.933033*	*F(8,44)*	*0.4993*

The other diagnostic tests are the issue of heteroscedasticity and serial correlation. Table 6 indicates that there is no issue of autocorrelation error and heteroscedasticity since the F-statistic are higher than the critical value so the insignificant of P-value confirm this statement for both of the tests.

DISCUSSION

In the long-term, the variable of volatility of BTCE and current account has a significant negative effect on the exchange rate, while money supply have a significant positive effect on the exchange rate. Decrease in price volatility of BTCE and current account lead to an increase in exchange rates while an increase in money supply increases the exchange rate.

The negative coefficient mark on the current account corresponds to the theory that when an increase in current account or an increase in exports the exchange rate will appreciate. While the variable money supply has a sign of positive coefficient which means that the increase in the amount of money in circulation will cause the exchange rate to rise or the depreciation of the domestic currency. This result is also in accordance with the results of empirical studies by Michael Adusei and Eddie Yaw Gyapong (2017). Based on the size of the coefficient, the influence of current accounts and money supply is relatively small to exchange rate changes.

Bitcoin price volatility in the long term significantly affects exchange rate at the level of significance of 1%. The negative sign on the volatility variable coefficient indicates that the increase in volatility has a tendency to appreciate the value of the domestic currency. Bitcoin as a virtual currency can serve as a means of payment for investment. However, some countries do not recognize bitcoin as a valid paying tool and for countries that permit bitcoin, not all producers/sellers accept bitcoin as a means of payment. Therefore, bitcoin is more often used as an investment tool. High price volatility gives high risk consequences so that the higher the bitcoin volatility the higher the risk. In the long term, if bitcoin prices are more volatile it will cause people to be less reluctant to invest in bitcoins. Hence, people tend to switch bitcoin to the regular currency so that the domestic currency will be appreciated.

CONCLUSION

In the late of 2016, China became the largest Bitcoin market in the world due to the prevailing permissive policies with respect to cryptocurrency. However, due to deep concerns about money laundering and threats to China's financial stability as well as affecting the domestic currency, the Central Bank of China and four other government offices jointly issued notice to prevent Bitcoin's risk of banning domestic banks from providing banking services to businesses Bitcoin. From the results of analyzed above, it can be concluded that the volatility of bitcoin prices in the long term has a significant negative effect on the exchange rate. The higher the volatility the higher risk. So that when the price volatility increases, people will switch to other investments besides bitcoin. The magnitude of the risk of investing in virtual money will tend to lead people to investments in regular currency so that the domestic currency will be appreciated.

REFERENCES

Adusei, Michael. (2017). The impact of macroeconomic variables on exchange rate volatility in Ghana: The Partial Least Squares Structural Equation Modelling approach. *Research in International Business and Finance, 42,* 1428-1444.

Bariviera, A. F., Basgall, M. J., Hasperué, W., & Naiouf, M. (2017). Some stylized facts of the Bitcoin market. *Physica A: Statistical Mechanics and its Applications*, *484*, 82–90. https://doi.org/10.1016/j.physa.2017.04.159

Baur, D. G., Dimpfl, T., & Kuck, K. (2017). Bitcoin, Gold and the US dollar – A Replication and Extension. *Finance Research Letters*. https://doi.org/10.1016/j.frl.2017.10.012

Blau, B. M. (2017). Price dynamics and speculative trading in bitcoin. *Research in International Business and Finance*, *41*(December 2015), 493–499. https://doi.org/10.1016/j.ribaf.2017.05.010

Cheah, E. T., & Fry, J. (2015). Speculative bubbles in Bitcoin markets? An empirical investigation into the fundamental value of Bitcoin. *Economics Letters*, *130*, 32–36. https://doi.org/10.1016/j.econlet.2015.02.029

Dibrova, A. (2016). Virtual Currency: New Step in Monetary Development. *Social and Behavioral Sciences*, *229*, 42–49. https://doi.org/10.1016/j.sbspro.2016.07.112

Dyhrberg, A. H. (2016). Bitcoin, gold and the dollar – A GARCH volatility analysis. *Finance Research Letters*, *16*, 85–92. https://doi.org/10.1016/j.frl.2015.10.008

Glaser, F., Zimmermann, K., Haferkorn, M., Weber, M. C., & Siering, M. (2014). Bitcoin - Asset or Currency? Revealing Users' Hidden Intentions. *Twenty Second European Conference on Information Systems*, 1–14.

Hayes, A. S. (2017). Cryptocurrency value formation: An empirical study leading to a cost of production model for valuing bitcoin. *Telematics and Informatics*, *34*, 1308–1321. https://doi.org/10.1016/j.tele.2016.05.005

Katsiampa, P. (2017). Volatility estimation for Bitcoin: A comparison of GARCH models. *Economics Letters*, *158*, 3–6. https://doi.org/10.1016/j.econlet.2017.06.023

Pilarowski, G., & Yue, L. (n.d.). *China Bans Initial Coin Offerings and Cryptocurrency Trading Platforms*.

Vandezande, N. (2017). Virtual currencies under EU anti-money laundering law. *Computer Law and Security Review*, *33*(3), 341–353. https://doi.org/10.1016/j.clsr.2017.03.011

Vranken, H. (2017). Sustainability of bitcoin and blockchains. *Current Opinion in Environmental Sustainability*, *28*, 1–9. https://doi.org/10.1016/j.cosust.2017.04.011

Wang, Q., Qin, B., Hu, J., & Xiao, F. (2017). Preserving transaction privacy in bitcoin. *Future Generation Computer Systems*. https://doi.org/10.1016/j.future.2017.08.026