

Weighted Moving Average of Forecasting Method for Predicting Bitcoin Share Price using High Frequency Data: A Statistical Method in Financial Cryptocurrency Technology

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Abstract— Bitcoin is a type of cryptocurrency that implemented decentralized digital currency method. The transaction is monitored and validated by peer-to-peer system using hash programming. These transactions are verified by network nodes through the use of cryptography and recorded in a public distributed ledger called a blockchain. The objective of this study is to forecast the Bitcoin exchange rate using weighted moving average method. Data selected in this study are selected hourly from 14th December 2017 until 18th December 2017. The forecasting method is using weighted moving average. Then, the validity of the forecasting model is validated using mean absolute percentage error (MAPE) calculation. Results indicated mean absolute percentage error is 0.72%. Therefore, the moving average method is considered as reliable forecasting method for Bitcoin exchange rate. The finding of this study will help investors to make best decision regarding suitable portfolio for their investment.

Keywords— Bitcoin, Financial technology, Forecasting method, Statistical approach, Cryptocurrency

I. INTRODUCTION

Bitcoin is a type of cryptocurrency that implemented decentralized digital currency method. The transaction is monitored and validated by peer-to-peer system using hash programming. These transactions are verified by network nodes through the use of cryptography and recorded in a public distributed ledger called a blockchain.

Bitcoin become popular when the price for 1 Bitcoin was aggressively increased. This condition was attracted more investors to invest in Bitcoin cryptocurrency transaction. Bitcoin was developed by Satoshi Nakamoto. Bitcoin is a crypto-currency based on open-source software and protocols that operates in peer-to-peer networks as a private irreversible payment mechanism. The protocol

allows cross-border payments, for large and small items, with little or no transactional costs (Nakamoto, 2009).

The bitcoin transactional system is often described as an anonymous system, although it might be more accurate to describe the system as one in which users can invoke privacy. The ledger of account for all Bitcoin transactions is public and distributed (Simser, 2015). According to Christopher (2014) Bitcoin operates via a peer-to-peer (P2P) network. P2P networks are created when multiple individuals run the necessary software on their individual computers and connect to each other.

Bitcoin is different with traditional method of payment. Abu Bakar et al. (2017) highlight several main differences between traditional digital currency and cryptocurrency transaction process. In definition, current fiat money is money in any form when in actual use or circulation as a medium of exchange, especially circulating banknotes and coins. This type of money is government-issued currencies. Comparing to cryptocurrency, Bitcoin is digital currency in which encryption techniques are used to regulate the generation of units of currency.

Even there are many advantage using a Bitcoin cryptocurrency but the problem arises is either Bitcoin cryptocurrency can be a good medium of exchange due to high volatility and risk. Therefore, this study tries to fulfill this gap by forecasting Bitcoin exchange rate using weighted moving average.

II. LITERATURE REVIEW

Over the last few years, a wide range of digital currencies, such as BitCoin, LiteCoin, PeerCoin, AuroraCoin, DogeCoin and Ripple, have emerged (Ciaian et al., 2014). The most popular is Bitcoin. It has been getting a lot of media attention, and its total market value has reached 20 billion USD in March 2017 (Chiu and Koepl, 2017). The price of the Bitcoin cryptocurrency has risen from December 2016, moving to USD 13282.29 in early December 2017. This value show the Bitcoin

cryptocurrency was attracted more investors to involved in this transaction. As investors, the main objective of the investment is to get high profit. Therefore, Bitcoin cryptocurrency are looking as a good platform for investment (Abu Bakar and Rosbi, 2017).

Bitcoin is a type of digital coins (cryptocurrency) which is not issued by any government, bank or organization. However, bitcoin is relying on cryptographic protocols and a distributed network of users to perform mining, storing, and transferring activities. Bitcoin currency is a monetary value that is accepted for payment purposes by persons other than the issuer, with the unit of account matching that of the physical currency (Ram, et al., 2016; Bal, 2013).

Wijk, (2017) stated the main users of the Bitcoin are technologically interested geeks who want to use the newest innovations, anarchists who have lost trust in the governments and the banking systems, and speculative risk-seekers looking for a new gamble. However, this is quickly changing due to the increase in the value of the Bitcoin and the attention that it gets in the news.

Abu Bakar and Rosbi (2017) show a statistical analysis, for Bitcoin return is 0.006 (mean) and the deviation is 0.04458. The standard error indicates the volatility for Bitcoin is 4.458 %. This value is considered as high value of volatility. High value of volatility indicates the investment in Bitcoin is categorical as high risk investment. The important of this study is to assist investors to develop better investment portfolio in targeting better profit and lowering the loss. While Buchholz , et al. (2012) show the strong explanation and validation of the existence of a market bubble in the bitcoin currency market.

Abu Bakar and Rosbi (2017) shows the distribution of Bitcoin exchange rate with first difference is follow normal distribution with probability of 0.722. The result show the distribution of data after second stages of outliers deletion treatments is high normal distribution characteristics. This finding concludes that Bitcoin data is highly volatile with existence of many outliers.

III. RESEARCH METHODOLOGY

This section describes normality test, weightage moving average method and mean absolute percentage error calculation.

3.1 Shapiro Wilk Normality test

This section describes the mathematical procedure to perform normality test (Shapiro and Wilk, 1965).

Consider $m' = (m_1, m_2, \dots, m_n)$ as the vector of expected values of standard normal statistics. Then, $V = (v_{ij})$ is represented as $n \times n$ covariance matrix.

Next, $x_1 \leq x_2 \leq \dots x_n$ denotes as ordered random sample of size n from a normal distribution data with mean 0 and variance 1. Therefore, below equations were derived.

$$E(x)_i = m_i, \text{ where } (i = 1, 2, \dots, n) \dots\dots\dots (1)$$

$$\text{cov}(x_i, x_j) = v_{ij}, \text{ where } (i, j = 1, 2, \dots, n) \dots\dots\dots (2)$$

Then, consider $y' = (y_1, \dots, y_n)$ represents as a vector of ordered random observation. The objective of this test is to derive a test for the hypothesis that this is a sample from a normal distribution data with unknown value of mean μ and unknown variance σ^2 .

Clearly, if $\{y_i\}$ is a normal sample, then y_i may be expressed as:

$$y_i = \mu + \sigma x_i, \text{ where } (i = 1, 2, \dots, n) \dots\dots\dots (3)$$

Utilizing the generalized least-squares theorem that the best linear unbiased estimates of μ and σ are those quantities that minimize the quadratic form:

$$(y - \mu 1 - \sigma m)' V^{-1} (y - \mu 1 - \sigma m) \dots\dots\dots (4)$$

where, $1' = (1, 1, \dots, 1)$.

Next, the estimates of μ and σ are described as below equation.

$$\hat{\mu} = \frac{m' V^{-1} (m 1' - 1 m') V^{-1} y}{1' V^{-1} 1 m' V^{-1} m - (1' V^{-1} m)^2} \dots\dots\dots (5)$$

$$\hat{\sigma} = \frac{1' V^{-1} (1 m' - m 1') V^{-1} y}{1' V^{-1} 1 m' V^{-1} m - (1' V^{-1} m)^2} \dots\dots\dots (6)$$

The symmetric data distribution indicates,

$$1' V^{-1} m = 0 \dots\dots\dots (7)$$

Therefore,

$$\hat{\mu} = \frac{1}{n} \sum_{i=1}^n y_i = \bar{y} \dots\dots\dots (8)$$

$$\hat{\sigma} = \frac{m' V^{-1} y}{m' V^{-1} m} \dots\dots\dots (9)$$

Next, let

$$S^2 = \sum_{i=1}^n (y_i - \bar{y})^2$$

denote the usual symmetric unbiased estimate of $(n-1)\sigma^2$.

Therefore, the W test statistic for normality is defined by

$$W = \frac{R^4 \hat{\sigma}^2}{C^2 S^2} = \frac{b^2}{S^2} = \frac{(a' y)^2}{S^2}$$

$$W = \frac{\left(\sum_{i=1}^n a_i y_i \right)^2}{\sum_{i=1}^n (y_i - \bar{y})^2} \dots\dots\dots (10)$$

where,

$$R^2 = m'V^{-1}m$$

$$C^2 = m'V^{-1}V^{-1}m$$

$$a' = (a_1, \dots, a_n) = \frac{m'V^{-1}}{(m'V^{-1}V^{-1}m)^{\frac{1}{2}}}$$

$$b = \frac{R^2 \hat{\sigma}}{C}$$

Thus, b is, up to the normalizing constant C , the best linear unbiased estimate of the slope of a linear regression of the ordered observations, y_i , on the expected values, m_i , of the standard normal order statistics. The constant C is so defined that the linear coefficients are normalized.

It may be noted that if one is indeed sampling from a normal population then the numerator, b^2 , and denominator, S^2 , of W are both, up to a constant, estimating the same quantity, namely σ^2 .

3.2 Weighted moving average

This section describes the forecasting method using weighted moving average. Weighted moving average is a forecasting method that more responsive to changes because more recent periods may be more heavily weighted.

A weighted moving average may be expressed mathematically as:

Weighted moving average

$$= \frac{\sum ((\text{Weight for period } n)(\text{Exchange rate in period } n))}{\sum \text{Weights}}$$

In this study, we assigned the weightage according to next equation.

$$EXF_t = \alpha EX_{t-1} + \beta EX_{t-2} + \gamma EX_{t-3} \dots \dots \dots (11)$$

where,

EXF_t is forecast value of exchange rate at period t ,

EX_{t-1} is actual value of exchange rate at period $t-1$,

α is weightage for EX_{t-1} , we set as 0.8,

EX_{t-2} is actual value of exchange rate at period $t-2$,

β is weightage for EX_{t-2} , we set as 0.1,

EX_{t-3} is actual value of exchange rate at period $t-3$, and

γ is weightage for EX_{t-3} , we set as 0.1.

3.3 Mean absolute percentage error calculation

One of the indicators for detecting a reliable and robust model of forecasting is using mean absolute percentage error (MAPE). The MAPE is computed as the average of the absolute difference between the forecasted and actual values, expressed as a percentage of the actual values.

That is, if we have forecasted and actual values for n periods, the MAPE is calculated as:

$$MAPE(\%) = \frac{\sum_{i=1}^n \left(\frac{|Actual_i - Forecast_i|}{Actual_i} \times 100 \right)}{n} \dots \dots \dots (12)$$

The MAPE has advantage that easily interpreted in term of percentage to the actual values.

IV. RESULT AND DISCUSSION

This study performed analysis of normality for data distribution and performed weighted moving average as prediction method.

4.1 Dynamic behavior of Bitcoin exchange rate

This study analyzed hourly data of Bitcoin exchange rate starting from 14th December 2017 until 18th December 2017. The starting value for Bitcoin exchange rate on 14th December 2017, 01:00 is USD 16600 for each Bitcoin. The minimum value of Bitcoin exchange rate is USD 16169 on 14th December 2017, 03:00. Meanwhile, the maximum value of Bitcoin exchange rate is USD 19704.80 on 17th December 2017, 12:00. The ending value of Bitcoin exchange rate on 18th December 2017, 24:00 is USD 18960.52.

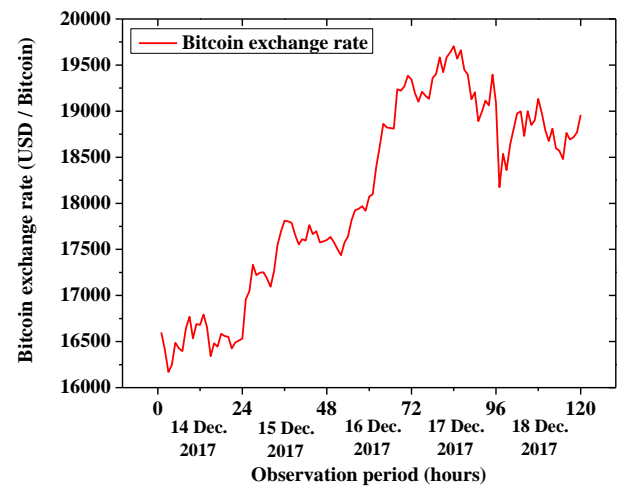


Fig. 1: Dynamic behavior of Bitcoin exchange rate

4.2 Normality test for first difference of Bitcoin exchange rate

Then, this study calculated the changes of Bitcoin exchange rate. The changes are calculated by difference between current observations with previous observation of Bitcoin exchange rate. The calculation is represented by Equation (13).

$$\Delta EXC_t = EXC_t - EXC_{t-1} \dots \dots \dots (13)$$

Where:

ΔEXC_t is first difference of exchange rate;

EXC_t is Bitcoin exchange rate on period t ;

EXC_{t-1} is Bitcoin exchange rate on period $t-1$.

Figure 2 shows changes of Bitcoin exchange rate. The mean of the data is 19.83. The standard deviation is 179.25. The maximum value of changes is USD 427.17. There is one outliers exists which is 97th observation. The value of outliers is -912.15. This finding is validated with normal percentiles plot in Figure 3. A normal percentile plot shows one outliers exists in Figure 3. This value is considered as outliers because that observation is deviated far from normal reference line.

Then, this study performed numerical normality test using Shapiro-Wilk method. The probability value is 0.000 less than 0.05. Therefore, the distribution of data follows non-normal distribution.

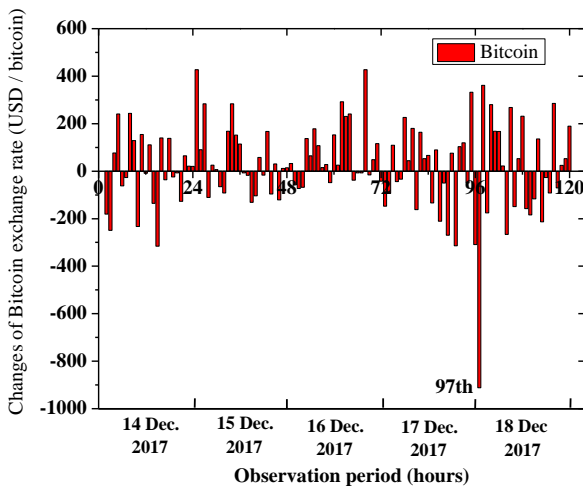


Fig. 2: Changes of Bitcoin exchange rate

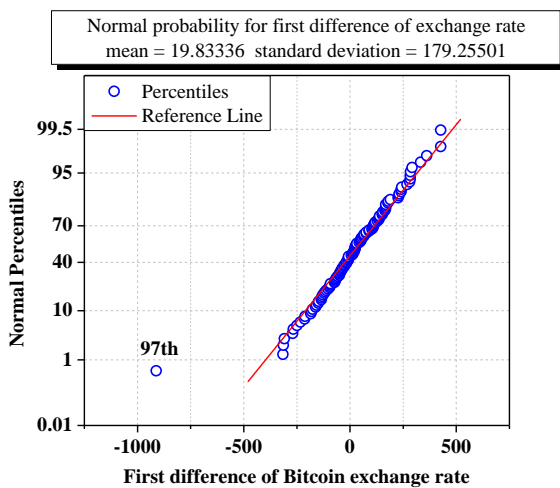


Fig. 3: Normal Percentiles

Table 1: Statistical normality test

Shapiro-Wilk test		
Statistics	Degree of freedom	Probability value
0.939	119	0.000

4.3 Normality transformation for data

This section describes the normality transformation for first difference of exchange rate data. This study started with detecting outliers. Therefore, the 97th observation (18th December 2017, 01:00, with value -912.15) is considered as outliers. This study eliminated this data point to evaluate the effect to the normality characteristics.

This study validated the normality characteristics using graphical method and numerical method. Graphical method is implemented using histogram and normal probability plot. Figure 4 shows the histogram for first difference of Bitcoin exchange rate. The distribution of data is near to normal distribution line (red line). Therefore, distribution of data follows normal distribution.

In addition, this study performed the second graphical method namely normal probability plot. Figure 5 shows the normal percentiles for first difference of Bitcoin exchange rate. Result shows all the data points are distributed closely to normal reference line (red line). Therefore, the distribution of first difference of Bitcoin exchange rate follows normal distribution.

Then, we performed numerical testing to validate the normality characteristics of data distribution. Table 2 shows the Shapiro-Wilk normality test for first difference of Bitcoin exchange rate. The null hypothesis of this test is that the sample data is normally distributed. Table 2 shows the probability value is 0.795. This value is larger than chosen alpha (0.05). Therefore, this study fail to reject null hypotheses. The distribution of data is normally distributed.

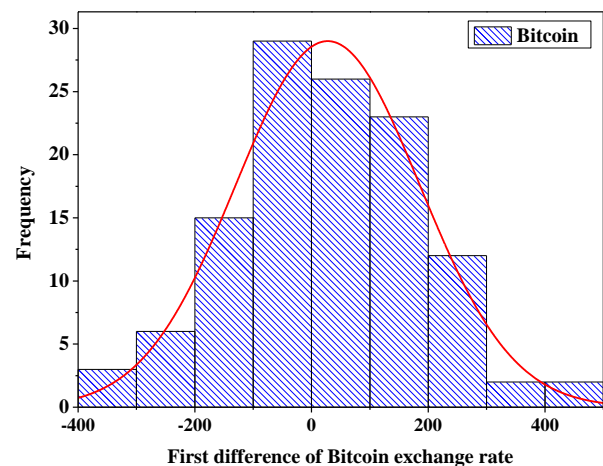


Fig. 4: Histogram for first difference of Bitcoin exchange rate

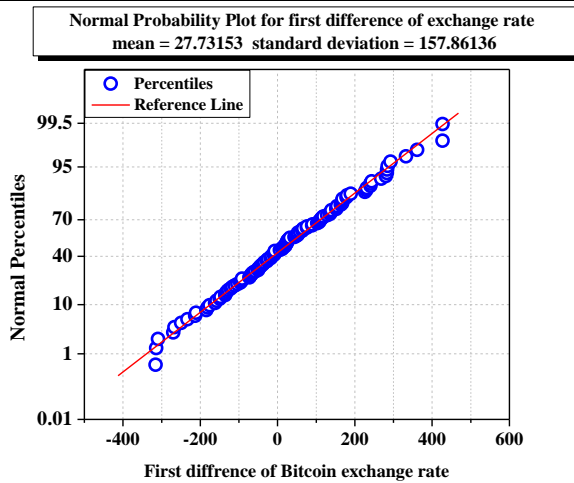


Fig. 5: Normal probability plot for first difference of Bitcoin exchange rate

Table 2: Statistical normality test for first difference of Bitcoin exchange rate

Shapiro-Wilk test		
Statistics	Degree of freedom	Probability value
0.993	118	0.795

4.4 Forecasting method using weighted moving average

This section describes the result of forecasting using weighted moving average. Figure 6 shows the comparison between actual data and forecast data using weighted moving average. Forecast data is represented by red line. The maximum value of forecast data is USD 19686.26 for each Bitcoin on 17th December 2017, 13:00. Meanwhile, the minimum value of forecast data is USD 16237.75 for each Bitcoin on 14th December 2017, 04:00.

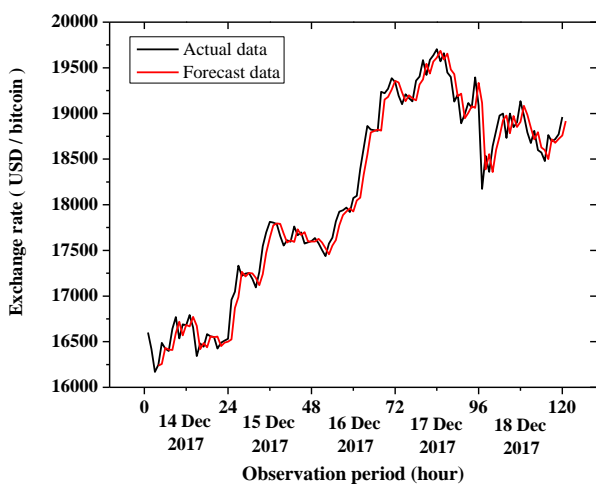


Fig. 6: Forecasting using weighted moving average

Then, this study developed residual plot to evaluate the reliability of the forecasting model. Figure 7 shows the residual plot for forecasting method using weighted

moving average. Figure 7 shows one data (97th observation, 18th December 2017, 01:00) that shows large residual. This data point is the outliers in the data set. Therefore, it contributes to large residual between actual value and forecast value.

Mean value for residual is USD 29.68 for each Bitcoin. The standard deviation for data is USD 179.49 for each Bitcoin. Figure 7 indicates the distribution of residual is follows white noise pattern. Therefore, the residual analysis shows the moving average model is a reliable forecasting method.

Then, this study performed the calculation of absolute percentage error analysis. Figure 8 shows the absolute percentage error for each of the observations. The mean absolute percentage error is 0.72%. Therefore, the moving average method is considered as reliable forecasting method for Bitcoin exchange rate.

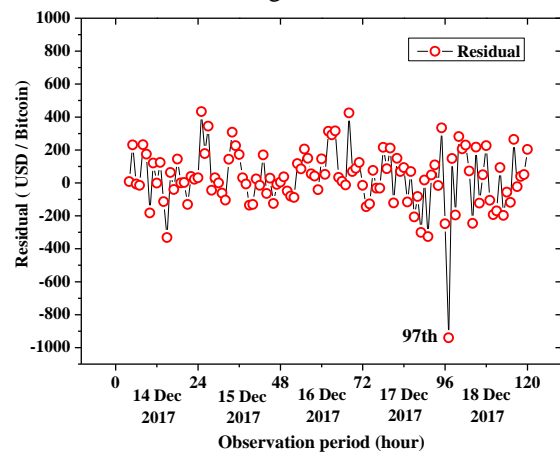


Fig. 7: Residual plot for forecasting method using weighted moving average

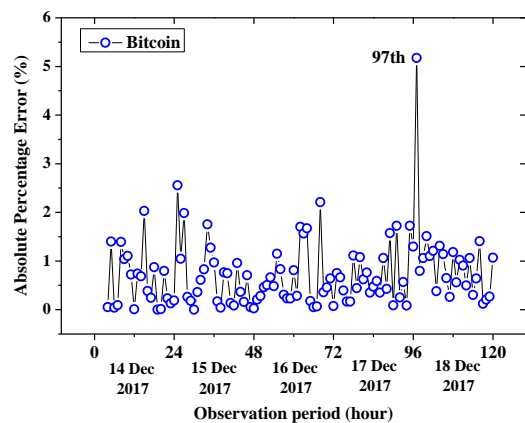


Fig. 8: Absolute percentage error analysis

V. CONCLUSION

The objective of this study is to develop forecasting methods for high frequency data for Bitcoin exchange rate data. This study proposed weighted moving average to forecast the dynamic movement of Bitcoin exchange rate.

The main findings concluded from this study are:

- (a) This study analyzed hourly data of Bitcoin exchange rate starting from 14th December 2017 until 18th December 2017. The starting value for Bitcoin exchange rate on 14th December 2017, 01:00 is USD 16600 for each Bitcoin. The minimum value of Bitcoin exchange rate is USD 16169 on 14th December 2017, 03:00. Meanwhile, the maximum value of Bitcoin exchange rate is USD 19704.80 on 17th December 2017, 12:00. The ending value of Bitcoin exchange rate on 18th December 2017, 24:00 is USD 18960.52.
- (b) Next, this study performed analysis to first difference of Bitcoin exchange rate. The mean of the data is 19.83. The standard deviation is 179.25. The maximum value of changes is USD 427.17. There is one outliers exists which is 97th observation. The value of outliers is -912.15.
- (c) Then, this study performed numerical normality test for first difference of Bitcoin exchange rate using Shapiro-Wilk method. The probability value is 0.000. Therefore, the distribution of data follows non-normal distribution.
- (d) In addition, this study performed the forecast using weighted moving average. The maximum value of forecast data is USD 19686.26 for each Bitcoin on 17th December 2017, 13:00. Meanwhile, the minimum value of forecast data is USD 16237.75 for each Bitcoin on 14th December 2017, 04:00.
- (e) Mean value for residual is USD 29.68 for each Bitcoin. The standard deviation for data is USD 179.49 for each Bitcoin. Result indicates the distribution of residual is follows white noise pattern. Therefore, the residual analysis shows the moving average model is a reliable forecasting method.
- (f) The mean absolute percentage error is 0.72%. Therefore, the moving average method is considered as reliable forecasting method for Bitcoin exchange rate.

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