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AN ANALYSIS ON CRYPTOCURRENCIES AND MACROECONOMIC VARIABLES USING VECTOR ERROR CORRECTION MODEL (VECM)

Syafiqah Ismail[1] and Mohamad Yazis Ali Basah[2]
[1]Graduate School of Muamalat, Islamic Science University of Malaysia
Bandar Baru Nilai, 71800, Nilai, Negeri Sembilan, Malaysia.
[2]Faculty of Economics and Muamalat, Universiti Sains Islam Malaysia
Bandar Baru Nilai, 71800, Nilai, Negeri Sembilan, Malaysia.
yazis@usim.edu.my

Abstract: Cryptocurrency symbolizes of a new development in the financial sector since it is the world's first entirely decentralized digital payment system. The cryptocurrency known as virtual money is one of the most important innovations brought on by digitalization. The purpose of this study is to analyze the relationship between the cryptocurrency (Bitcoin, Monero, and Stellar) with macroeconomics variables known as stock price index (Dow Jones dan Nikkei), oil price (Brent Oil dan WTI), and exchange rates (Australian Dollar, Euro, and Pound Sterling). The data was obtained from investing.com on monthly basis for the period between January 2016 untuil December 2020. The analysis were conducted based on unit root test, co-integration and vector error correction model (VECM) in order to identify the relationship between the three selected cryptocurrencis with macroeconomic variables. The findings of this paper showed that there is cointegration between the variables. The Vector Error Correction Model (VECM) indicates that the Bitcoin model and Stellar model did not have a long-run relationship. While for the second model, Monero found to have a long-run relationship with the variables. This research contributes to the growing study on cryptocurrency while extend and complement the literature by sourcing the latest research paper on this related field.

Keywords: Bitcoin, Monero, Stellar, Dow Jones, Nikkei, Brent Oil, Australian Dollar, Euro, and Pound Sterling.

INTRODUCTION

Cryptocurrencies are digital money based on cryptography principles. The value of cryptocurrencies is growing. There are centralized virtual or digital tokens that can be traded or spent using blockchain technologies. This type of digital currency is to seeks to improve privacy and confidentiality, with varying degrees of effectiveness. A few of these currencies allow all purchases to be seen by the public, while others make privacy optional. Cryptocurrencies purposely react as a compliment as well as a substitute of the fiat currencies since they are not backed by the government but depend on the investor activity based on demand and supply in the value assigned to that currency. The cryptocurrencies implement blockchain technology as they used a decentralized control system to access, confirm and record the transactions that happened.

The advantages of Cryptocurrencies over the usage of fiat money, firstly, will be decentralized currencies, in which the fundamental system is based on a vast network of interconnected users, making it impossible for anybody or government to control. Secondly, because cryptocurrencies have a set supply, they are not prone to manipulation, unlike fiat money, which does not allow for any manipulation in terms of overprinting. The security and trustworthiness of information transmitted inside the system, as well as the flexibility of transactions, are the primary benefits of digital currencies (1). This property is particularly common in decentralized peer-to-peer networks that are managed in a dispersed manner.

Syafiqah Ismail, Graduate School of Muamalat, Islamic Science University of Malaysia, 011-12948136

This paper will address the relationship of the three types of cryptocurrencies (Bitcoin, Monero and Stellar) with the 3 different group of independent variables which consists of stock market, Dow Jones (DJI) and Nikkei225 (JP225), the second factor consists of oil prices, Brent Oil (B) and West Taxes Intermediate (T) and the third factor related to the exchange rates which consists of Australian Dollar (AUD), Euro (EUR) and Pound Sterling (GBP). Bitcoin was originated using a scheme outlined by Satoshi Nakamoto (2) and he introduced the first 50 Bitcoins into circulation in the year 2009. The name Satoshi Nakamoto is synonymous with the individual or group of people who published the first Bitcoin white paper in 2008 and worked on the first bitcoin program in 2009. Monero is a cryptocurrency that focuses on privacy and was launched in 2014. It is one of the industry's top 20 most successful cryptocurrencies. As of November 2017, it is one of the most popular cryptocurrencies at a market capitalization of USD 1.5 Billion (3). Stellar cryptocurrency is digital or virtual money that was created by the Stellar Development Foundation. It is a peer-to-peer digital currency network that was established in 2015. The core concept behind Stellar was to build a cryptocurrency that could minimize transaction costs while still serving as a bridge between fiat, digital, and other currencies. It also supports efficient markets between tokens from different issuers (4).

Independent variables encounter the 3 important aspects to evaluate the crypto. Dow Jones is regarded as a key indicator of the health of the US economy (5), it comprises 30 of the most well-capitalized and powerful firms towards the economy of the United States. While Nikkei225 comprises Japan's top 225 companies listed on the Tokyo Stock Exchange and reacts as a key indicator of the Japanese stock markets. The world crude oil markets are driven by the anticipation of the investors on the supply and demand factor, and the oil prices are very volatile and highly influenced by consumer and investor sentiment. Brent crude's price reacts as the benchmark for African, European, and Middle Eastern crude oil, and the WTI is the benchmark crude for North America. Since both types of oil are used as a benchmark for each region, they are a good indicator of how to examine the relationship towards cryptocurrency. Cryptocurrency involved with an international business, evaluating the fluctuation in exchange rates will show an effect on the return of the crypto (6).

Some previous research studies had been analyzed to give a foundation for this research paper and will reveal the factors that have a relationship with cryptocurrencies. Even though the previous research was scarce, we had found some research papers that will contribute an insight towards this paper. The degree of macroeconomic and financial development can be reflected in stock price indexes. A research paper from (7) had discussed that the price volatility of bitcoin is considerably larger compared to bonds, stocks, commodities, and other currencies. The position of macroeconomic and financial growth is highlighted using a series of key variables such as stock market indexes, exchange rates, and oil prices, among others (8). On the price of the BTC, a negative effect of the oil price, a positive effect of the Dow Jones index, and a negative effect of the Nikkei index. The global economy's macroeconomic and financial trends are reflected in equity indices. These innovations can encourage the usage of BTC in the exchange, thus the demand for the cryptocurrency, which may have a positive effect on its price. This is also the case for the Dow Jones index, which has a positive impact on the price of Bitcoin in the short and long term. The Nikkei 225 index, on the other hand, had a negative impact on the BTC market, indicate there was a strong connection with the US economy than the Japanese economy.

The oil price can imply general price volatility, which may lead to a decline (or appreciation) in the price of the BTC (9). Research from (8) figured out the interactions between the Bitcoin and the crude palm oil type "Western Texas Intermediate" (WTI Oil). The paper from (10) had examined the volatility connections between the 10 types of cryptocurrencies with crude oil and their results indicated both bidirectional and unidirectional spillovers between the crude oil market and the cryptocurrency markets. They had analyzed the relations between the most popular cryptocurrencies and a range of selected fiat currencies purposed to identify any pattern and causality between the variables(11). Empirical findings from (12) had suggested a high positive correlation between Bitcoin and oil markets and confirm that there were a strong correlation and a positive relationship between Bitcoin and crude oil prices.

A paper from (11) found that the involved fiat currencies in their research proved that there was no relationship between Bitcoin, Ethereum, Ripple, Litecoin, Monero, and Dash with the Australian Dollar. While a finding from (13) showed an absence of bidirectional cross-market shock and volatility spillover between Bitcoin and the US dollar. Another side of findings from (8) investigate the relationship between the value of Bitcoin with different stock and commodity indices such as the Euro-Dollar & Yen- Dollar exchange rates, the DJIA, FTSE, Nikkei, and the oil price. The study concludes that DJIA, Euro-Dollar exchange rate, and oil prices have shared a significant short-term, short-run association with the cryptocurrency (Bitcoin). A paper from (14) examined the effect of exchange rates on

bitcoins returns covering the period from 2014 to 2019 through the ARMA model using Maximum Likelihood Type of Estimation. Results showed that the bitcoin return is not significantly affected by the values in foreign currencies when 0.95 confidence was measured. Based on (9) had stated that the effect of an exchange rate on bitcoin prices as was stated that the rate of exchange can reflect the development of inflation and therefore have a positive effect on the bitcoin. Bitcoin's volatility is a lot higher than the volatilities of other widely used currencies. The bitcoin can react as a medium of exchange and a unit of account. There is zero correlation between Bitcoin's daily exchange rate with the U.S dollar and the dollar's exchange rates against the British pound, Swiss franc, euro, yen, and gold (15).

Since, this cryptocurrencies can be considered as a new investment alternative there is limited studies in this area. Therefore, this study is important to analyse the short run and long run relationship between cryptocurrencies and macro economic varaibles. Cryptocurrencies has been well accepted by investors and also government. Therefore, the understanding of its market behaviour is important. Thus, the study is conducted to provide some information on cryptocurrencies market interaction with macroeconomics variables.

METHOD

A quantitative study was conducted in order to meet the goals of this research report. In an attempt to explain the observed research questions, an econometric technique implements to classify characteristics, analyze them, and build statistical models. The study adopted the use of the sourced secondary data from investing.com. Based on data availability, the scope of the study covers from January 2016 to December 2020.

The unit root is a stationary test that necessary before carrying out the regression analysis because if the time series is non-stationary, the regression result will become spurious (not make any sense, meaningless). The data is said to be weak or covariance stationary if the mean and autocovariance of a series not depending on the time (16). The development of unit root theory was initially proposed by Dicker and Fuller that had spawned a generation of unit root research. If non-stationary data is regressed for the analysis, spurious regression is a risk due to the nature of the data, which is a time series. The purpose of a unit root test is to determine the order in which the series data is integrated. An Augmented Dickey-Fuller test was adopted with a null hypothesis of ADF of the unit root in the series. The equation of the Dickey-Fuller test looks as follows:

$$\Delta \boldsymbol{y_t} = \boldsymbol{\alpha y_{t-1}} + \boldsymbol{u_t}$$

Where $\boldsymbol{u_t}$ reacts as a white noise of the variables. The ADF method tests the null hypothesis of a unit root in the data, $\boldsymbol{\alpha = 0}$. The alternative hypothesis is when $\boldsymbol{\alpha < 0}$ which indicates that there is no unit root and the data is stationary.

There are several methods in estimating the cointegration while for this research paper we have conducted a Johansen Cointegration method. This method procedure for testing co-integration is used to establish the presence and the number of co-integrating relationships and/or lack of them (17). Johansen introduced a test based on maximum likelihood to analyze if multiple time series form cointegrating relationships. The estimation model takes the form (18):

$$\boldsymbol{Y_t} = \boldsymbol{XY_{t-1}} + .. + \boldsymbol{X_n Y_{t-n}} + \boldsymbol{Bx_t} + \in_t$$

In the equation, $\boldsymbol{Y_t}$ is the vector for the I (1) independent and dependent variables. The concept of cointegration is basically to see the long-term balance among the observed variables. The cointegration relationship among the variables can be determined through trace statistics and the maximum eigenvalue likelihood ratio statistics. There are cointegrations if the trace value and max eigenvalue are greater than their critical value.

VECM method had adopted in this research purposely to distinguish whether the model exists with a short-run and long-run relationship. This method deals with non-stationary data and applies regression after differencing the variables while the second advantage distinguishes the short-run and long-run relationship between the variables (19). If the variables are found to have a cointegrating vector, the VECM can be used to estimate the cointegrating vectors. The general form of the VECM model used below:

$$\Delta \boldsymbol{Y\,t} = \boldsymbol{a_1} + \boldsymbol{a_2 ec\,t - 1} + \boldsymbol{a_3}\Delta\,\boldsymbol{Y\,t - 1} + \boldsymbol{a_4}\Delta \boldsymbol{X\,t - 1} + \in_t$$

A crucial parameter in the estimation of the VECM dynamic model is the coefficient of the error correction term $\boldsymbol{ec\,t - 1}$. To establish the joint effect of variables, under VECM all those chosen variables are taken as endogenous $\Delta \boldsymbol{Y}$ and exogenous $\Delta \boldsymbol{X}$ to estimate the long and short-run relationship in the model. Implementing the VECM method was possible to analyze the data and fulfill the objective of the study. This will, in turn, provide some valuable insight into the study field and greatly assist us in obtains detailed information regarding this topic.

RESULT AND DISCUSSION

Analysis on Bitcoin:
This study based on time series, spurious regression by regressing a non-stationary series appears to be a major threat for this paper. Augmented Dickey-Fuller (ADF) test has been adopted to analyze the stationarity for each of the variables.

Table 1: Unit root test on Bitcoin

Variables	P-Value	ADF t-statistic	Critical value
			5%level
BTC	0.0000	9.693163	2.913549
XMR	0.0000	6.732708	2.915522
XLM	0.0000	8.785731	2.938987
DJI	0.0000	6.893613	2.917650
JP225	0.0000	6.852122	2.917650
B	0.0000	5.921639	2.917650
T	0.0000	5.799979	2.917650
AUD	0.0000	7.052338	2.917650
EUR	0.0000	6.305689	2.916566
GBP	0.0000	8.447329	2.914517

This test examined the null hypothesis that the considered variable has a unit root (series non-stationary) against the alternative hypothesis that the variable is stationary. The result of the ADF test presented in the table below reveals that the series of variables were found to be stationary at a first difference level.

After conducting a stationary test for the variables, we found that all variables are stationary at first difference. This study established cointegration between the variables by implementing a Johansen Cointegration method. Analysis of data was based on the null hypothesis of no cointegration.

The result from the table above indicates that both the trace test and maximum eigenvalue test in the Johansen procedure each detected cointegrating vectors. Trace test indicates 8 cointegrating equations, while for Max-Eigenvalue test showed 3 cointegrating equations. Thus, the study rejects the null hypothesis of no cointegration at a 5% level of significance.

Rejection of the null hypothesis of no cointegration at a 5% significance level among the variables implies that the variables and BTC (Bitcoin) have a significant positive long-run relationship that conforms to a priori expectation. The result proves that the model was stationary and has a cointegration, the VECM method can be evaluated in order to study the short-run and long-run properties of the cointegrated series.
Table 2: VECM on Bitcoin

Error Correction:	CointEq1
D (BTC)	-0.103292*
	(0.07409)
	[-1.39417]
D(DJI)	0.033799*
	(0.01857)
	[1.81999]
D(JP225)	-0.000997*
	(0.02030)
	[-0.04912]
D(B)	0.005064*
	(0.05074)
	[0.09979]
D(T)	-0.029892*
	(0.05798)
	[-0.51555]
D(AUD)	0.047647*
	(0.00988)
	[4.82401]
D(EUR)	0.026283*
	(0.00615)
	[4.27192]
D(GBP)	0.026495*
	(0.00960)
	[2.75984]
Note. Values in ( ) are std errors while values in [ ] are t-statistics, * Implies statistical significance at 5% level of significance.	
R-squared	0.637380
Adjusted R-squared	0.479315
F-statistic	4.032390
Prob(F-statistic)	0.000157

The coefficients of the error correction term for the VECM with negative and statistically significant at 5 % level of significance will validating the existence of a long-run relationship among variables and BTC (Bitcoin). The coefficient result showed at the value of -0.103292 was in negative sign with insignificant value indicates that there was no long-run relationship between the variables and Bitcoin. JP225 (Nikkei) and WTI (West Taxes Intermediate) were found to have a negative and significant value at a 5% level which validates the existence of a long-run relationship with Bitcoin. The value of R-squared is 0.637380 and we can accept the model. The probability value of F-statistic,

0.000157 showed a significant value meaning that our data of this model is fitted well.

The table below shows a result from a Wald Test in examined the short-run relationship of the variables. The probability value at the 5% significance level showed that there was an existence of the short-run relationship of the variables towards Bitcoin.

Table 3: Wald test on Bitcoin

BTC	**Value**	**Probability**
DJI	6.049412	0.0486
JP225	6.874696	0.0321
B	1.143604	0.5645
T	0.858935	0.6509
AUD	4.967654	0.0834
EUR	6.601996	0.0368
GBP	1.609289	0.4472

The result reveals that there were three variables with a 5% significance level which consists of DJI, JP225, and EUR. This exposed that the variables have a short-run relationship with Bitcoin.

Analysis on Monero:
Augmented Dickey-Fuller (ADF) test has been adopted to analyze the stationarity for each of the variables. This test examined the null hypothesis that the considered variable has a unit root (series non-stationary) against the alternative hypothesis that the variable is stationary. The result of the ADF test presented in the table below reveals that the variable series were found to be stationary at a first difference level.

Table 4: Unit root test on Monero

Variables	**P-Value**	**ADF t-statistic**	**Critical value**
			5%level
XMR	0.0000	6.732708	2.915522
DJI	0.0000	6.893613	2.917650
JP225	0.0000	6.852122	2.917650
B	0.0000	5.921639	2.917650
T	0.0000	5.799979	2.917650
AUD	0.0000	7.052338	2.917650
EUR	0.0000	6.305689	2.916566
GBP	0.0000	8.447329	2.914517

After conducting a stationary test for the variables, we found that all variables are stationary at first difference. This study established cointegration between the variables by implementing a Johansen Cointegration method. Analysis of data was based on the null hypothesis of no cointegration.

The result from the table above indicates that both the trace test and maximum eigenvalue test in the Johansen procedure each detected cointegrating vectors. Trace test indicates 4 cointegrating equations, while for Max-Eigenvalue test showed 3 cointegrating equations. Thus, the study rejects the null hypothesis of no cointegration at a 5% level of significance.

Rejection of the null hypothesis of no cointegration at a 5% significance level among the variables implies that the variables and XMR (Monero) have a significant positive long-run relationship that conforms to a priori expectation. The data had been tested with unit root test and found that all series are stationary as well as the data was found to have cointegration from the Johansen Cointegration Test. From the previous findings, we can apply VECM to evaluate the short-run and long-run properties of the cointegrated series.

Table 5: VECM on Monero

Error Correction:	CointEq1
D(XMR)	-0.072566*
	(0.06659)
	[-1.08968]
D(DJI)	-0.004009*
	(0.00552)
	[-0.72601]
D(JP225)	0.005710*
	(0.00580)
	[0.98475]
D(B)	0.009842*
	(0.01486)
	[0.66223]
D(T)	0.022173*
	(0.01701)
	[1.30391]
D(AUD)	-0.014038*
	(0.00282)
	[-4.98515]
D(EUR)	-0.006472*
	(0.00185)
	[-3.49250]
D(GBP)	-0.004043*
	(0.00278)
	[-1.45391]

Note. Values in ( ) are std errors while values in [ ] are t-statistics,
* Implies statistical significance at 5% level of significance.

R-squared	0.620094
Adjusted R-squared	0.454494
F-statistic	3.744527
Prob(F-statistic)	0.000323

The coefficients of the error correction term for the VECM with negative and statistically significant at 5 % level of significance will validating the existence of a long-run relationship among variables and XMR (Monero). The result at coefficient -0.072566 was in negative sign with insignificant value indicates that there is no long-run relationship between variables and Monero. DJI (Dow Jones), AUD (Australian Dollar), EUR (Euro), and GBP (Pound Sterling) were found to have a negative and significant value at a 5% level which validates the existence of a long-run relationship with the Monero. The value of R-squared is 00.620094 and we can accept the model. The probability value of F-statistic, 0.000323 showed a significant value meaning that our data of this model is fitted well.

The table below shows a result from a Wald Test in examined the short-run relationship of the variables.

Table 6: Wald test on Monero

XMR	**Value**	**Probability**
DJI	1.373301	0.5033
JP225	2.392197	0.3024
B	1.525665	0.4663
WTI	1.928890	0.3812
AUD	1.901623	0.3864
EUR	0.038707	0.9808
GBP	4.900112	0.0863

The result indicates that all the probability values of the variables were greater than 5% significant level thus proved that there was no short-run relationship between the variables and XMR.

Analysis on Stellar:
The test of Augmented Dickey-Fuller (ADF) has been examined to analyze the stationarity for each of the variables. This test examined the null hypothesis that the considered variable has a unit root (series non-stationary) against the alternative hypothesis that the variable is stationary. The result of the ADF test presented in the table below reveals that the series of variables were found to be stationary at a first difference level.

Table 7: Unit root test on Stellar

Variables	P-Value	ADF	Critical value
		t-statistic	
			5%level
XLM	0.0000	8.785731	2.938987
DJI	0.0000	6.893613	2.917650
JP225	0.0000	6.852122	2.917650
B	0.0000	5.921639	2.917650
T	0.0000	5.799979	2.917650
AUD	0.0000	7.052338	2.917650
EUR	0.0000	6.305689	2.916566
GBP	0.0000	8.447329	2.914517

After conducting a stationary test for the variables, we found that all variables are stationary at first difference. This study established cointegration between the variables by implementing a Johansen Cointegration method. Analysis of data was based on the null hypothesis of no cointegration.

The result from the table above indicates that both the trace test and maximum eigenvalue test in the Johansen procedure each detected 4 cointegrating vectors. Thus, the study rejects the null hypothesis of no cointegration at a 5% level of significance. Rejection of the null hypothesis of no cointegration at a 5% significance level among the variables implies that the variables and XLM (Stellar) have a significant positive long-run relationship that conforms to a priori expectation.

In order to achieve short-run and long-run estimates of this model, the VECM methodology has been applied to the dataset. The data had been tested with unit root test and found that all series are stationary as well as the data was found to have cointegration from the Johansen Cointegration Test. From the previous findings, we can apply VECM to evaluate the short-run and long-run properties of the cointegrated series.

Table 8: VECM on Stellar

Error Correction:	CointEq1
D(XLM)	-0.566864*
	(0.23149)
	[-2.44872]
D(DJI)	-0.003103*
	(0.01737)
	[-0.17863]
D(JP225)	0.006155*
	(0.01659)
	[0.37097]
D(B)	0.095941*
	(0.04170)
	[2.30081]
D(T)	0.112006*

	(0.04662)
	[2.40254]
D(AUD)	-0.006396*
	(0.00904)
	[-0.70748]
D(EUR)	0.004333*
	(0.00561)
	[0.77286]
D(GBP)	0.014093*
	(0.00762)
	[1.84914]
Note. Values in ( ) are std errors while values in [ ] are t-statistics, * Implies statistical significance at 5% level of significance.	
R-squared	0.707800
Adjusted R-squared	0.509103
F-statistic	3.562218
Prob(F-statistic)	0.002032

The coefficients of the error correction term for the VECM with negative and statistically significant at 5 % level of significance will validating the existence of a long-run relationship among variables and Stellar (XLM). The result at coefficient -0.566864 was in negative sign with insignificant value indicates that there is no long-run relationship between variables and Stellar. DJI (Dow Jones) and AUD (Australian Dollar) were found to have a negative and significant value at a 5% level which validates the existence of a long-run relationship with the Stellar. While other variables did not fulfill the conditions of VECM with a negative and significant value to show the long-run relationship. The value of R-squared is 0.707800 and we can accept the model. The probability value of F-statistic, 0.002032 showed a significant value meaning that our data of this model is fitted well.

The table below shows a result from a Wald Test in examined the short-run relationship of the variables.

Table 9: Wald test on Stellar

XLM	Value	Probability
DJI	4.990675	0.0825
JP225	1.480207	0.4771
B	6.346469	0.0419
WTI	3.885396	0.1433
AUD	2.690848	0.2604
EUR	3.074180	0.2150
GBP	2.143789	0.3424

The result indicates the existence of the short-run relationship between the B (Brent Oil) towards XLM at 0.0419 with a 5% level of significance. While the other variables were found to be absent with a short-run relationship of the variables.

The findings showed that there is an existence of cointegration in these 3 models (Bitcoin, Monero, and Stellar) with the macroeconomics variables. Based on the result gained from a Vector Error Correction Model (VECM), the first model on Bitcoin, and the third model, Stellar was found to not have a long-run relationship. While for the second model, Monero found to have a long-run relationship with the variables.

CONCLUSION

This study examined the relationship between cryptocurrencies and macroeconomic factors using monthly time series data from January 2016 until December 2020. This study examined the relationship between cryptocurrencies and macroeconomic factors using monthly time series data from January 2016 until December 2020. The effect of macroeconomics factors on cryptocurrencies was examined using the Johansen Cointegration test, and Vector Error Correction Model (VECM). This made it possible for the study to establish the association of a long-run relationship between the variables. In general, the findings of this research paper had clearly explained all the time series variables (cryptocurrencies and macroeconomics variables) relationships and the correlation between them. The Vector Error Correction Model (VECM) indicates that the Bitcoin model and Stellar model did not have a long-run relationship. While for the second model, Monero found to have a long-run relationship with the variables. This method provides an important implication for hedging, financial regulation, and portfolio diversification.

This study has a potential limitation. The historical data about a series for the variables were limited since this cryptocurrency can be considered a young instrument in the financial sector. This cryptocurrency market is still relatively new, and there is a lack of studies on the various models for instance in estimating market volatility (20). Further study on different continuous-time series models should be implemented for the knowledge expansion in this cryptocurrency. An extended study on other variables factors would be better for modeling the series regarding this research topic.

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