

Analysis of the Interaction Between Bitcoin Price and Crude Oil Futures Price

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Abstract: The aim of this thesis is to analyze the interaction between Bitcoin price and crude oil futures price over the past seven years using the Ordinary Least Squares (OLS) method. Bitcoin, as a virtual currency, is characterized by high price volatility, while crude oil futures, as an important commodity, are also affected by a variety of factors. By collecting and analyzing data on the price of Bitcoin and crude oil futures in the past seven years, this research aims to investigate the interaction between Bitcoin price and crude oil futures price and explore their correlation and causation. The results of the study will provide investors and policymakers with important information about the bitcoin and crude oil futures markets in order to better understand market dynamics and formulate relevant strategies. Meanwhile, the time span of the study includes both the New Crown Epidemic period and the Post-Epidemic period, which is generalizable and more conducive to research and analysis under different era conditions.

Keywords: OLS (Ordinary Least Squares), Bitcoin, crude oil futures

1. Introduction

This study will explore the characteristics of Bitcoin, the factors influencing its price, its relationship with fiat currencies and other assets, as well as its connection with crude oil. Additionally, it will summarize relevant studies conducted in the past seven years.

In 2008, when the subprime mortgage crisis occurred, governments around the world adopted loose monetary policies, which led to severe global inflation, a significant shrinkage in the wealth of the people of various countries, and the people's distrust of the fiat currency credit system represented by the U.S. dollar. Against this backdrop, Satoshi Nakamoto [1] published a groundbreaking article, "Bitcoin: A Peer-to-Peer Electronic Cash System," which led to the emergence of Bitcoin. Bitcoin is a type of cryptocurrency, which means it is a digital currency that uses cryptographic algorithms and relies on passwords and checksums to create it. Compared to fiat currencies, Bitcoin is decentralized, irreversible, privacy-protected, with limited supply, global, and highly secure [2]. These features cater to the global citizenry's demand for reform of the existing sovereign monetary system. As a result, in recent years, digital currencies such as Bitcoin, Ether, Litecoin, and others have proliferated and have been recognized and sought after by investors all over the world.

However, there are many skeptical voices about the development of Bitcoin, such as whether Bitcoin can be used as legal tender, how Bitcoin relates to real resources, and whether Bitcoin can hedge against investment risks. Currently, there are also such controversies in academia. Previous

research by Bouojyour [3] indicates a correlation between the returns of gold, silver, and Bitcoin, but Bitcoin's role as a hedge is not consistent over time. In the short term, Bitcoin is similar to a weak safe-haven asset, while in the long term, it can only be considered as a hedging tool. Bouri et al. [4] argue that cryptocurrencies are related to commodity markets. Ji, Q al. [5] examined the relationship between Bitcoin and other assets, and they concluded that cryptocurrencies relate to energy commodities. In addition, they used a network causality structure, arguing that there is a lagged and significant relationship between Bitcoin and other assets. Selmi et al. [6] summarize studies suggesting that cryptocurrencies can hedge crude oil price risk. Krause, M.J., Tolaymat, T. [7] compared the relationship between crude oil and Bitcoin as a complementary offering and considered that crude oil is the primary resource for Bitcoin mining. The crude oil price is influenced by the energy consumption of Bitcoin mining.

The above findings highlight the significance of understanding the relationship between Bitcoin and the crude oil market. Crude oil, as a vital energy source and raw material, is considered a strategic material by countries worldwide due to its scarcity, non-renewability, and importance in production. Therefore, its price fluctuations have a direct impact on the macroeconomy, capital market stability, and individual investors' decisions. To mitigate the risks associated with crude oil price volatility, crude oil has been financialized since the 1980s, leading to the development of crude oil futures. Crude oil futures are currently the largest commodity futures varieties in the global futures market, with hedging as well as price discovery and smoothing of oil prices to stabilize the market, with a large trading volume and turnover, and a pivotal position in the international spot trade, which has been widely recognized by international investors [8]. Despite existing studies in this field, we believe it is crucial to investigate the interaction between Bitcoin price returns and crude oil futures price returns. This study will collect monthly data on WTI crude oil futures price and return, as well as Bitcoin's price and return, from February 2016 to August 2023. The OLS regression method will be used to study and infer the impact of Bitcoin on crude oil futures at the price level.

The structure of this paper is as follows. Section II describes the types of data used in this paper and the sources of the data, followed by visual image analysis of the data, and finally statistical computational analysis of the data. Section III shows the regression analysis methods used in this paper and the results of the calculations, which are also analyzed for statistical significance. Section IV presents the findings of the comprehensive study, delving into the correlation between Bitcoin price fluctuations and crude oil futures. It thoroughly examines the data processing and analysis procedures, shedding light on the underlying factors and mechanisms that drive the relationship. The section concludes by presenting the conclusive outcomes of the entire research endeavor. Section V summarizes the full text, draws conclusions from this study, and analyses the shortcomings of this study and the outlook for future research.

2. Data

In this study, the calendar year data on the price of crude oil futures and bitcoin were collected through the INVESTING.COM database, and the monthly closing price and increase/decrease of crude oil futures and bitcoin from February 1, 2016, to August 1, 2023, were selected. The data images were visualized using the Excel plotting tool, and the figure below shows line graphs of the crude oil futures and bitcoin closing prices and declines about time, both in US dollars.

2.1. Image Visualization and Analysis

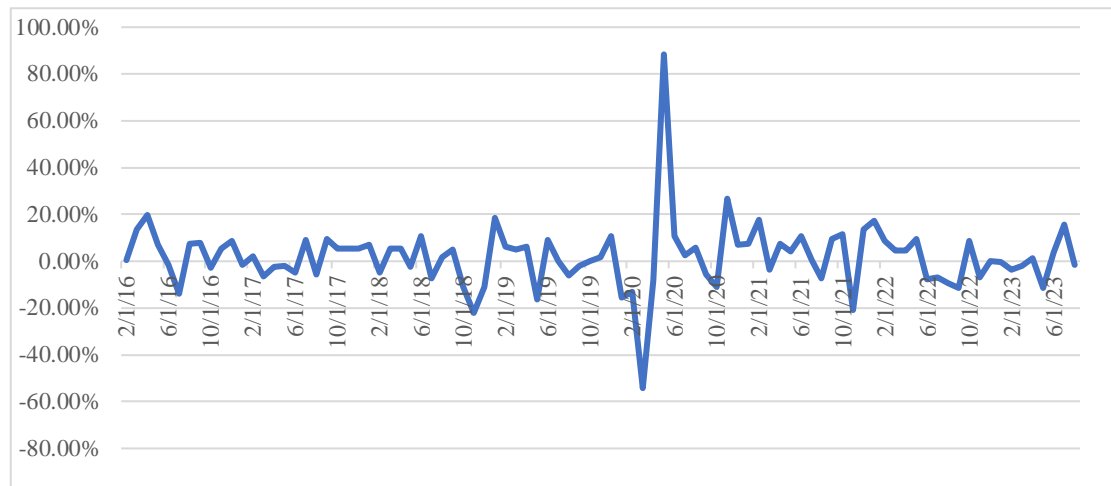


Figure 1: WTI Crude Oil Futures Price Gains and Losses over Time.

Since February 2016, WTI crude oil futures prices have remained largely within minus 20% of each other every month, with only a few periods of higher volatility. For example, in March 2020, its average monthly gain or loss briefly reached 88.38%, while in May of the same year, its average monthly gain or loss fell to -54.24% (inextricably linked to the impact of the New Crown epidemic on financial markets that year). Except for a few exceptional times, crude oil futures have fluctuated gently, making them a relatively stable financial derivative.

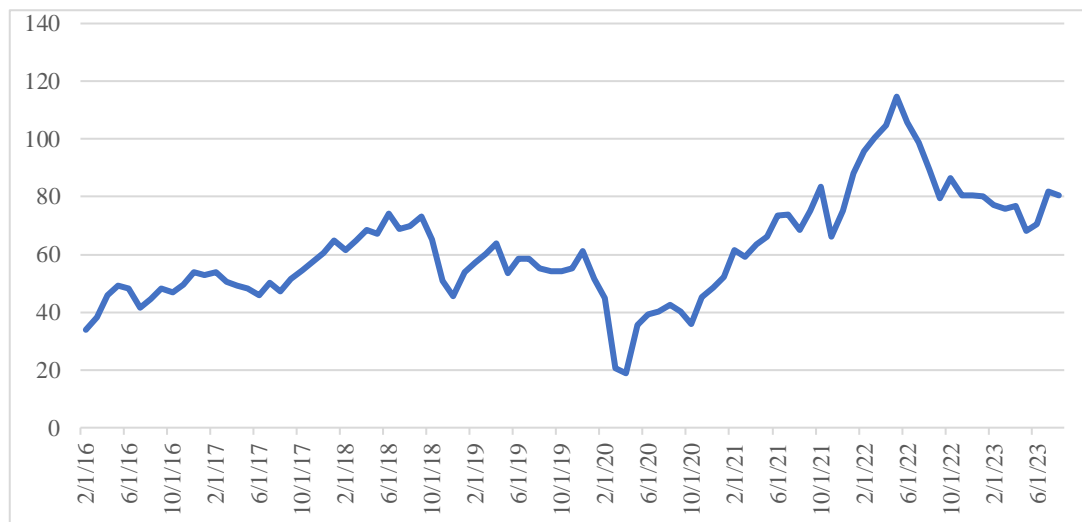


Figure 2: Closing Prices of WTI Crude Oil Futures over Time.

As can be seen from the above chart, since February 2016, the monthly closing price of WTI crude oil futures has shown an overall upward trend, during which time the price reached a low of \$18.84 during the 2020 New Crown Epidemic, which was only half of the February 2016 closing price, and in May 2022, it reached its highest value since 2016 at \$114.67, which was about tripled. in late 2022 to date, its price has remained steady at around \$80.

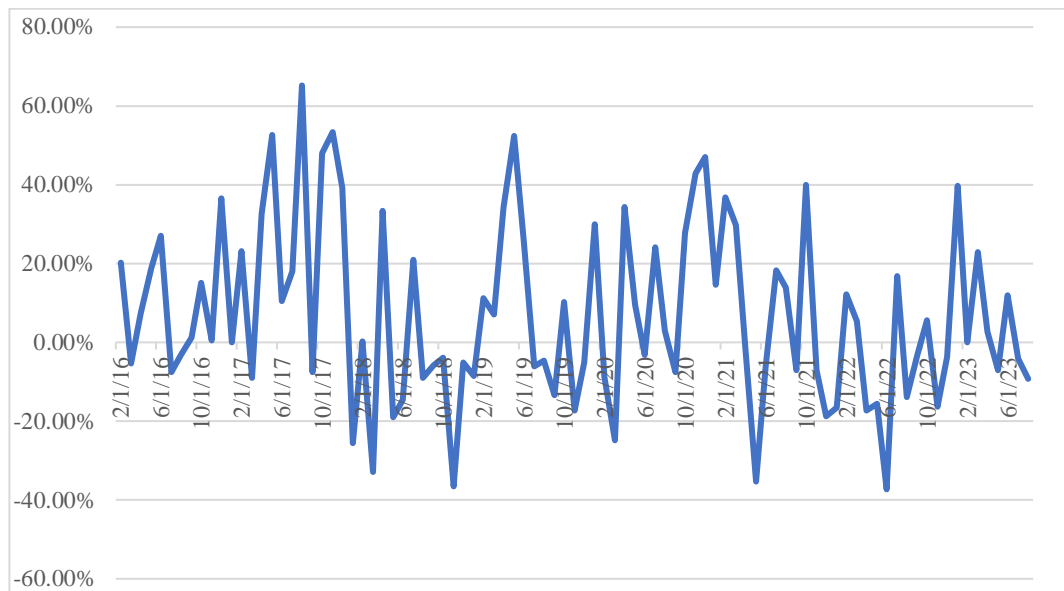


Figure 3: BTC Price Gains and Losses over Time.

Bitcoin's monthly rise and fall have been in a large fluctuation since February 2016. Between the more factors affecting the price of Bitcoin, its monthly rise and fall change rules and reasons are more difficult to predict. Overall, however, the definite integral of the part of the rise and fall greater than zero is much larger than the part of the rise and fall less than zero, and it can be hypothesized that the price of Bitcoin has been growing for the last seven years.

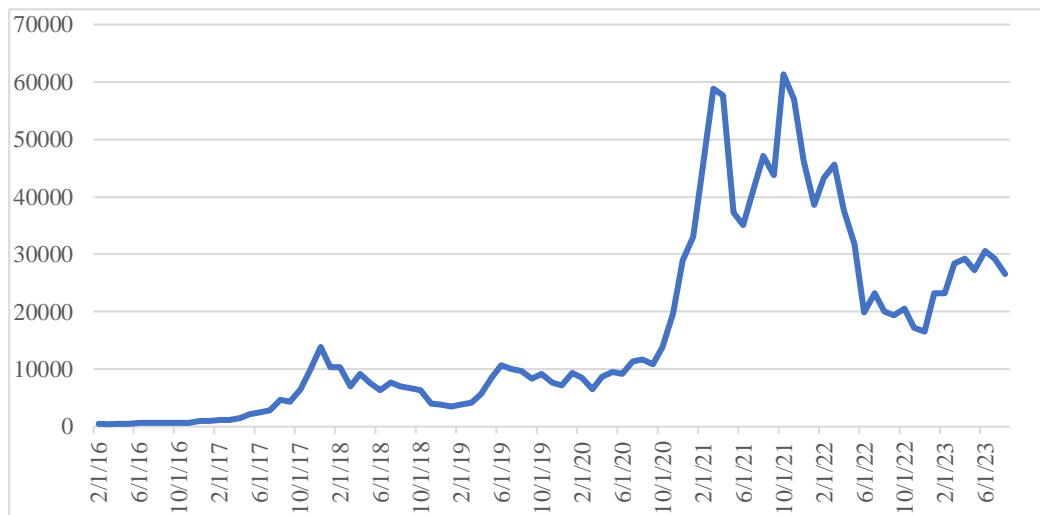


Figure 4: BTC Closing Prices over Time.

As inferred in Figure 3 above, Bitcoin's closing price was essentially on the rise from February 2016 through October 2021, reaching a high of \$61,330 in October 2021, a staggering 140 times the February 2016 price of \$439.2. Since Bitcoin's closing price peaked, it has fallen back a bit, staying between \$20,000-\$30,000 so far in May 2022, but still dozens of times its initial price. The surge in Bitcoin's price reinforces its appeal and importance in today's financial markets.

The graph above visually depicts the correlation between the prices of crude oil futures and Bitcoin over a period of time, but the relationship between the two needs to be further calculated and analyzed,

the use of Excel's data analysis tools can be used to carry out multi-dimensional correlation analysis of the two.

2.2. Statistical Computational Analysis of the Data

First of all, the descriptive statistics function of Excel is used to obtain a descriptive statistics table to get the mean, median, standard deviation, minimum, and maximum values of the four groups of data, which provides data support for the subsequent data calculation.

Table 1: Descriptive statistics table (Results are retained to the nearest thousand).

	BTCR	BTCP	WTIR	WTIP
Mean	0.071	16439.610	0.019	61.528
Median	0.012	9452.100	0.023	58.580
Standard deviation	0.225	16167.170	0.142	18.340
Minimum	-0.373	416.000	-0.542	18.840
Maximum	0.652	61330.000	0.884	114.670

3. Method and Results Analysis

This study utilizes the OLS regression model to analyze the interaction between crude oil futures and Bitcoin. Excel is used as the calculation and analysis tool.

OLS regression is an estimation modeling technique used to determine the relationship between dependent and independent variables. It estimates parameters in such regression equation by minimizing the sum of squared errors, i.e., by minimizing the sum of the distances between the observed and estimated points to seek the best function fit the data.

In this study, we analyze and calculate the relationship between Bitcoin's monthly closing price (independent variable) and crude oil futures' monthly closing price (dependent variable). To ensure data smoothness, we logarithmized the price data before performing data analysis.

3.1. The Basic OLS

As shown in the following figure. Let us take the example of a single independent variable regression model, the OLS model is:

$$y_i = \beta_0 + \beta_1 x_{i1} + \varepsilon_i \quad (1)$$

In the equation shown above, y_i and x_{i1} denote the dependent and independent variables in the OLS model, respectively, the intercept term β_0 and the coefficients of x_{i1} , which are named β_1 , in the regression model must be estimated, and the data regression calculation must be performed in Excel.

3.2. Results Analysis

Based on the understanding of the OLS method in the previous section, we can import the data into Excel and directly use Excel as a data analysis tool. Firstly, we can use its data analysis function to calculate the correlation coefficients between the crude oil futures monthly closing price and the Bitcoin monthly closing price. It has been shown in the table below:

Table 2: Correlation coefficient analysis table.

	BTCP	WTIP
BTCP	1	
WTIP	0.561	1

According to the information in the table, we can see that the correlation coefficient between the independent variable and the dependent variable is 0.561, which is a moderate linear correlation. The linear correlation coefficient (r), also called Pearson's correlation coefficient, ranges from -1 to 1 and is calculated in (2):

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}} \quad (2)$$

The magnitude of the correlation coefficients corresponding to the degree of linear correlation is tabulated below:

Table 3: The relationship between the value of r and the correlation.

Range of values of r	Level of relevance
$ r < 0.3$	Low linearly correlated
$0.3 \leq r \leq 0.5$	Low-to-moderate linear correlated
$0.5 \leq r \leq 0.8$	Moderate linear correlated
$0.8 \leq r \leq 1$	Highly linearly correlated

Continuing with the regression analysis of the data after the change in the logarithm of the price of crude oil futures versus Bitcoin, the following table is obtained:

Table 4: Regression statistics analysis table.

Regression Statistics	
Multiple R	0.524
R Square	0.274
Adjusted R Square	0.266
standard error	0.266
Observations	90

According to Table 4, Multiple R in Table 4 is the same parameter as the correlation coefficient r calculated in (2), i.e., the correlation coefficient between the crude oil futures monthly closing price and Bitcoin monthly closing price typically falls within the range of $[-1,1]$. From the properties of the parameters, if the absolute value is closer to 1, the correlation between the two is greater, on the other hand, the absolute values closer to 0 indicate a weaker correlation. The multiple R in the table above is approximately 0.524, indicating a moderate correlation between the independent and dependent variables.

R-square (r^2), also known as the coefficient of determination or goodness of fit, represents the square of the correlation coefficient, which measures the extent to which a linear regression model fits the dataset. Generally, if the R-square (r^2) value is more than 0.7, it suggests a good fit, and if the value is below 0.6, it may indicate the need for model correction. The R-square in the table above is around 0.274, suggesting a weak fit that may require adjustments.

Adjusted R is the adjusted R square, which is used to address overfitting in models with multiple independent variables, but its significance is diminished when there is only one independent variable, as in this analysis.

Standard error and R-square are employed to assess the goodness of fit between the regression model and the actual data. A smaller standard error indicates a better fit, but there is no specific threshold to determine what constitutes a good fit. Observations, on the other hand, are how many sets of independent variables there are.

An analysis of variance (ANOVA) is then conducted on the regression model to assess the regression effect using an F-test. The ANOVA table, shown below, serves the main purpose of determining the regression effect of the model through the F-test.

Table 5: The analysis of the variance table.

ANOVA					
	df	SS	MS	F	Significance F
Regression analysis	1	2.362	2.362	33.293	1.16E-07
Residual	89	6.244	0.071		
Total	90	8.607			

According to Table 5, it presents various degrees of freedom (df) values. Total df is equal to the number of samples minus one (90 in this model). Regression df represents the number of independent variables (1 in this model). Residual df is calculated by the total df minus the regression df (89 in this model).

SS (sum of squares) measures the deviation of the prediction from the mean. SSR (sum of squares for regression) stands for the total deviation of the dependent variable's prediction. SSE (sum of squared errors) measures the total deviation of the dependent variable from its predicted values. The larger the SSE, the worse the fit. SST (total sum of squares) is calculated by $SST = SSR + SSE$.

MS represents the mean square deviation, which is calculated as shown in (3) below, and MSR and MSE can be calculated separately according to the previous calculations, where MSE is the residual mean square deviation, and its value is as small as possible.

$$MS = \frac{SS}{df} \quad (3)$$

The F value is used for the determination of linear relationship and its value is the result of MSR/MSE. The most important result for F-test is the value of Significance F. Under the significance level F_α , Significance F is the critical value, i.e., the P-value of the F-test, which stand for the probability of denying the truth (to be more specific, the possibility of denying the truth is, the probability of the model is inexact, obviously $1-P$ is the probability of the model is true, which can be seen that the smaller P-value is the better). The significance F value is generally less than 0.05, and the smaller the better, $1-\alpha$ for the confidence level. In this case, this value is 1.16E-07, which is much smaller than 0.05, obviously, the confidence level of the regression model is over 95%.

The next table below shows the regression parameters and demonstrates a few of the most important parameters of the regression equation.

Table 6: Table of regression parameters.

	Coefficients	standard error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	2.977	0.193	15.421	9.58E-27	2.594	3.361
LNBTCP	0.121	0.021	5.770	1.16E-07	0.080	0.163

Where the Intercept row in the Coefficients column corresponds to the intercept term of the regression equation, and the LNBTCP row represents the coefficient of the independent variable term (The price of Bitcoin after the logarithmic change). From these two data, the equation (4) of this regression model can be obtained, and thereafter, for each input of the independent variable LNBTCP, the dependent variable LNWTIP can be predicted based on this regression equation:

$$LNWTIP = 0.121 * LNBTCP + 2.977 \quad (4)$$

And for the standard error, the smaller the error value, the higher the parameter precision; t stat is the t-value of t-test statistics, used to test the model parameters, need to consult the table to decide, t value is the ratio of each coefficient and its standard error, usually one-dimensional regression can see the F test or regression statistics to support the basic judgment, but for multiple linear regression, t-test is essential.

The P-value is the most important calculation in this table, which indicates the P-value corresponding to the t-test. If the P-value is smaller than 0.05, we consider the model significant at the level of $\alpha = 0.05$ or rather the level of confidence has reached 95%; If the P-value is less than 0.01, we consider the model significant at the level of $\alpha = 0.01$, which means the level of confidence has reached 99%; whereas when the P-value is much bigger than 0.05, the result is obviously not statistically significant. Obviously, a P value smaller than 0.05 in this regression model means that the independent variable is significant and should never be eliminated in a multivariate regression model.

Figure 5 below is obtained by calculating according to the regression equation (4), which predicts the WTIR and its residuals by substituting the 90 sets of independent variables LNBTCP from the original data, combined with the folded fluctuations in the figure, the degree of fitting of the regression model is indicated.

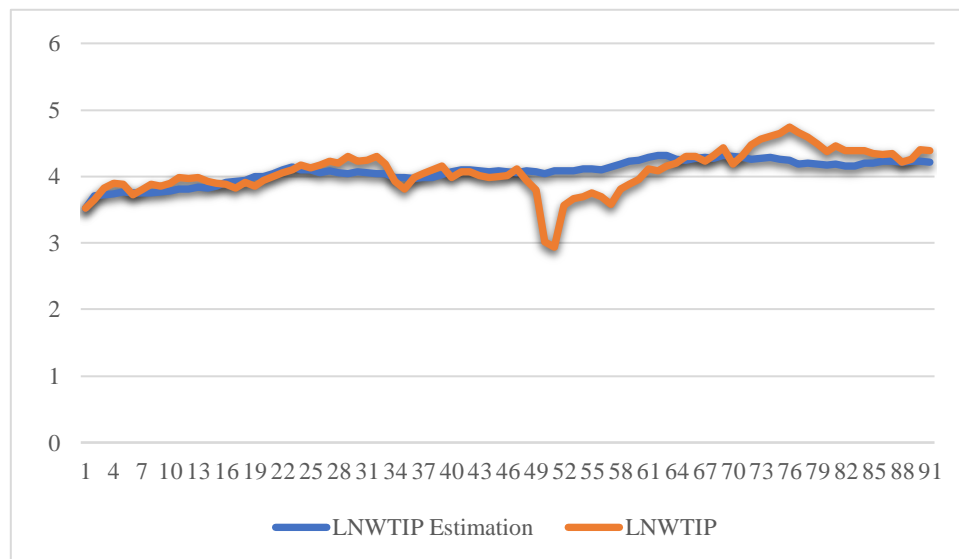


Figure 5: Comparison of estimated data with real data.

4. Discussion

According to the analysis of the regression results in the previous section, it is obvious that a conclusion can be reached that there is some correlation between Bitcoin's monthly closing price and crude oil futures' monthly closing price, and the rationale for the analysis of the correlation between the two can probably be elaborated in several possible ways: First of all, crude oil is a vital and indispensable part of the world's energy so that its price reflects the energy market to a large extent. Bitcoin mining consumes a significant amount of energy, and its demand can impact the energy market and the supply dynamics of crude oil. Higher energy prices, coupled with increased mining costs, can affect the price of Bitcoin and its supply relationship. Secondly, crude oil serves as a major input cost for various goods and services. When inflation expectations rise, crude oil prices may increase. Some investors perceive Bitcoin as a safe-haven asset, which is also true during times of inflation expectations, they may turn to Bitcoin, leading to price appreciation. Finally, Investor sentiment and market sentiment may impact crude oil and bitcoin prices. When investors are optimistic about the global economic outlook, they may be more inclined to invest in crude oil. And when investor sentiment is risk averse, they may be more inclined to invest in safe-haven assets such as Bitcoin.

5. Conclusion

This paper investigates the interaction between Bitcoin monthly closing price and WTI crude oil futures monthly closing price using OLS modeling. Our model was created using OLS methodology to determine the regression relationship. The model is able to fit the interrelationship between the Bitcoin price and the WTI crude oil futures price better based on calling the last seven years of price data. This makes it possible to make a simple prediction of the volatility trend of crude oil futures based on the price of Bitcoin, while the underlying logic of the interaction between the two is analyzed at three levels of probability, namely in terms of energy consumption, investment risk aversion, and investor and market sentiment.

This study has limitations, including the use of a single regression analysis method (OLS) and a lack of further analysis on the underlying causes of the interaction between Bitcoin price and crude oil price. This research also fails to provide direct data supporting specific reasons for the observed impacts.

Future research should employ diverse and precise analytical methods for regression analysis. Additionally, updating the research model with up-to-date data will provide more definitive and practical investment suggestions for Bitcoin and crude oil futures.

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