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Evaluating the relationship between the price of Bitcoin and other asset portfolio groups (Case study of US financial indexes, S&P 500 and Nasdaq Composite)

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Abstract

With the inclusion of Bitcoin in the portfolio of individuals, it is necessary to evaluate this asset from different financial aspects. In this research, first the relationship between the Bitcoin price, S&P500 and Nasdaq Composite is evaluated using VAR model. Since in VAR models individual coefficients do not lead to statistical inferences, IRFs are being evaluated. It was found that one standard deviation shock on the value of the Nasdaq Composite has a gradual incremental effect on the price of Bitcoin. Also, one standard deviation shock on the value of S&P 500 has a negative downward effect on the price of Bitcoin while one Bitcoin's standard deviation shock is ineffective on S&P500 and Nasdaq Composite. In addition, considering the Granger causality test, S&P500 and Nasdaq Composite cause bitcoin price changes, but the opposite is not true. Having concluded statistical causality of S&P500 and Nasdaq Composite in the previous steps, the price of Bitcoin based on diagnostics being done is regressed as a dependent variable and influenced by the S&P500 and Nasdaq Composite indexes and also needed dummy variable using the ARDL model. The short-term to long-term estimated adjustment coefficient in ECM model is -0.009 and is significant. The overall explanatory power of the model is 99%. Since the normality test and homoscedasticity test were not supported, considering the ability of Robust estimation method to adjust these conditions, this method was used to regress ARDL model. The explanatory power of the model is between 64% and 99%.

Highlights

- The theme of this research is looking into statistical causation between Bitcoin price changes and two main financial market indexes.
- Using econometric criteria such as VAR, IRFs, Granger causality test, ARDL and Robust estimation, the causal relationship was found.
- Inferences of the tests led to existence of statistical causality for Bitcoin price changes.

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1. Introduction

In 2008, by registering Bitcoin.org domain and uploading an article titled "Bitcoin peer-to-peer electronic cash system" Bitcoin was introduced as a digital currency with a decentralized peer-to-peer payment network. Satoshi Nakamoto (the person or group behind the digital currency) stated in this article that "we have proposed a system for electronic transactions without relying on trust" [1]

Bitcoin is an intangible digital currency with more technical regulations than other currencies. The basic variables such as money supply, block reward, block time, hardness and mining algorithm are the creator of the Bitcoin network, which are explained briefly in the following. Bitcoin's total supply will eventually reach 21 million units. The reward value of finding blocks or mining at the beginning birth of the Bitcoin was 50 units. This is halved every four years. Currently, the reward is 3.125 units of Bitcoin. Blocks are created at the same interval of averaging 10 minutes. The hardness variable is an exogenous variable and shows the difficulty of building blocks at a constant level of hash power. This variable goes up and down based on the network's computing power. After every 2016 blocks is built (after about two weeks) on the network, the network checks to find out how much time took for the average the block being created and based upon that hardness of production is being re-evaluated. The basic mining algorithm used in the Bitcoin network is SHA-256. Bitcoin mining is a process in which new Bitcoins enter the Bitcoin inventory cycle and is also a route to confirm transactions. Mining is a vital element in maintaining and expanding the ledger or blockchain. Bitcoin mining is done by complex hardware that solves complex mathematical problems. The probability that a miner solves a mathematical problem depends on his/her computing power over the computing power of the entire network. Central and monetary authorities do not have direct oversight of Bitcoin, and Bitcoin replaces the central authorities with a distributed computing system and a proof-of-work algorithm.

Issues such as preventing Bitcoin from being re-spent, low transaction fees on the Bitcoin network, better performance of Bitcoin than credit cards (because the seller and buyer are authenticated), and the acceptance of this network by people make the network valuable (Van Alstyne, 2014). Therefore, there is a wide range of incentives to include Bitcoin in the portfolio of investors.

Although in the definitions or discussions about Bitcoin, it is most often referred to as a digital currency, it should be noted that as money in the portfolio is counted as part of the owner's property, the inclusion of Bitcoin in the portfolio of individuals as asset must also be considered, particularly now that it has been accepted to be ETF[2] in US financial market since January 2024.

Rogojanu (2014) addresses the advantages and disadvantages of using Bitcoin as money by relying on Hayek's view on the characteristics of money. According to this research, the benefits of using Bitcoin are saving ability,

[1] 2008, Page 8
[2] Exchange – traded fund

avoiding third-party commissions, minimizing costs, flexibility for business, unknowingness of the exchange parties, being anti-inflationary, and avoiding central intervention. The disadvantages of using Bitcoin are high price fluctuations, large speculative attacks and negative effects, uncontrolled transactions, limited trust in Bitcoin and vulnerability by cyber theft.
While money has three functions of being a means of exchange, a unit of account and a store of value, a financial asset mainly encompasses only the third property, reserve of value.

From the theoretical stand point (Baur, 2018), if digital currencies are used mainly as medium of exchange, they must compete with fiat currencies such as dollar and thus influence both the value and policies of the fiat currencies in such a competition. On the other hand, if the digital currencies mainly take on the role of asset for investment then they are compared and evaluated to a range of assets as such government bond, stock, commodities, etc.

Studies done on Bitcoin describe it as a speculative instrument and so compare its properties with other assets such as stocks, commodities and bonds during periods of financial stability or periods of financial turmoil. Various studies and perspectives have also been made about the financial instrument of Bitcoin as a speculative instrument (e.g., Kajtazi, 2019), a hedge tool (e.g., Fang, 2019), or portfolio diversifying (e.g., Baur, 2017).

Bitcoin's market capitalization on September 20, 2023 was about $530 billion. Due to the relatively high investment on Bitcoin, different aspects of evaluation in the placement of Bitcoin in the portfolio of investors need to be more fully evaluated in order to make wiser decisions in using it either in combinations with other assets or substituting them.

Many recent asset models evaluating portfolios are based on the central theorem presented by Harry Markowitz (1952) in a paper titled Portfolio Selection. In such Modern models theory does not rely only on risk assessment and expected return as two simple dimensions for evaluating and choosing optimal portfolios. Markowitz argued that the portfolio risk and return is not determined only by looking at the risk and return of individual shares, but also should take into consideration relationship of combination as regards to covariances and coming up with an appropriate diversified portfolio. In fact, the unsystematic risk of the portfolio decreases with diversification. So it is built by modern theory a portfolio that presents less risk for a certain level of return on investment.

Correlation or lack of correlation between the elements of the portfolio is one of the topics that could lead to specific decisions in portfolio management. The weak correlation between Bitcoin and other assets could increase profits from diversification. In the case of a strong correlation, the profit from diversity decreases.

It should be noted that in rational decision making for evaluating portfolio along with the correlation between components, evaluating cause and effect relationships through statistical diagnostic tests can also promote optimal decision

making. Assessment of correlation or cause and effect for Bitcoin and other assets should be done in the global market. However, due to the lack of appropriate base data, in this paper, cause and effects are estimated using sample of US financial market, which has more transparent data.

Since stocks in the New York financial markets are mainly represented by the S&P500 indexes, Nasdaq Composite and Dow Jones indexes, in our analysis we are looking for finding the statistical causal relationship between the changes in the price of Bitcoin and these indexes.

Although, these three indicators measure general aspects of performance of the US Financial market, each indicator represents different assets and at the same time their variation depends on the changes in economic conditions prevailed. These indicators differ from each other in three ways:

1) Their method for allocating weight to each company covered by the index;
2) The sectors that each index includes; and
3) Criteria used to select the stocks included in each index.

Considering the comprehensiveness of the two indexes of S&P500 and Nasdaq Composite indexes as compared to Dow Jones index and to avoid the econometric problem of multi-colinearity, in this evaluation, only S&P500 and Nasdaq Composite indexes have been selected to represents the asset exchange of US economy.

As the total assets in the financial market of US excluding Bitcoin are several times of Bitcoin asset values of US, it seems that the price of Bitcoin should be depended to indexes representing other major financial assets such as S&P500 and Nasdaq Composite. However, to avoid prejudgment and making inferences based on econometric diagnostic tests, first the model representing the relation in VAR1, which is more general and not necessary one way directional relationship, is estimated. Then, using Impulse Response Functions (IRFs) and Granger causality tests as statistical diagnostic tools and determining the dependent variable and independent variables, for the data being considered the ARDL2 model is estimated which means price of Bitcoin is regressed under the influence of the S&P500 and Nasdaq Composite indexes and necessary evaluations are being made. No doubt, to use OLS in the ARDL model, normality and not having heteroscedasticity are required. In absence of these conditions and considering the ability of Robust3 estimation method to adjust the absence of normal distribution and also the existence of variance heterogeneity, regression form of ARDL model is estimated using this method.

2. Literature Review

With the emergence of Bitcoin, various studies were conducted on whether it is a money or an asset. Chowdhurg & Mendelson (2013) consider the following advantages of using Bitcoin as money: lower transaction costs, cheap money

[1] Vector Autoregression
[2] Autoregressive Distributed Lag
[3] Robust Least Square

transfer system, lack of involvement of central authorities and lack of strict capital controls.Some disadvantages of using Bitcoin as money are not being widely accepted, lack of guarantee to help in case of various types of risk, high price fluctuation, uncontrolled transactions, attack by big traders, lack of trust in Bitcoin and cyber theft (Rogojanu, 2014). Peetz & Mall (2017) by introducing money as a tool that facilitates transactions between sectors, acknowledge that money is a medium of exchange that helps buyers and sellers find the true price at which a transaction can be made. This price is the same as the market settlement price and is important because it gives the market clarity and prediction. When the money valuation mechanism is not accurate, the market clearing mechanism does not work. For reasons such as the lack of an accepted valuation model for Bitcoin, a lack of precedent as a monetary acceptance, absence of accepted intrinsic value credentials, and having potential consequences of deflation, Bitcoin is not accepted as money in this paper.

However, with the placement of Bitcoin in the investor's portfolio as is done for stocks, various studies were conducted on how it relates to other assets in portfolio. In recent studies, Bitcoin has been considered as a speculative instrument, a portfolio diversification and a risk hedging tool. Below, some of the studies conducted on the correlation of bitcoin with other financial assets, oil, gold etc. are presented.

Jiang (2023), based on linear regression (univariate regression that market index is considered as its independent variable), evaluated he correlation between the price of Bitcoin and the stock market. Using data from this model, it is concluded that the stock market and Bitcoin have a high correlation. Jiang et al. (2023) used The GARCH dynamic conditional correlation model and wavelet coherence analysis and concluded the internal interaction and contagion as the reasons for the price fluctuations of virtual currencies. One of the findings is that the price fluctuations of virtual currencies are very closely related, and in the short term, Bitcoin is the most important factor in the transmission of the price fluctuations of virtual currencies; however, in the long run Ethereum and Ripple have more effect and are new contagionists sources. Bitcoin, Ethereum and Ripple are among the internal causes of the volatility of the virtual currency market.

Bendob et al. (2022) state that as the stock market and crypto move in tandem, financial instability shocks are transferred. The results of their study (which applies conditional correlation DCC-GARCH model) showed that financial assets including Bitcoin, gold and oil have different conditional variance with stock market returns in different Arab countries. The conditional variance of the Bitcoin market is statistically insignificant compared to the conditional variance indexes of stock markets in Arab countries. Kartal & Can (2022) evaluated the correlation between Bitcoin (as the dependent variable) and S&P500 index, 10-year Treasury Bonds and some altcoins, using the Granger causality test. According to the value of covariance, Bitcoin has an incremental linear relationship with Ethereum, Cardano and Chainlink, and a decreasing linear

relationship with FED interest rates and 10-year Treasury bonds. Bitcoin is also unrelated to the S&P 500 index.

Chu et al. (2021) showed that the relationship between Bitcoin price and technology stocks were very close; however, he considers the reasons for the fall of Bitcoin and stock market to be different. Many factors outside the Bitcoin market such as the closure of Bitcoin exchanges and China's announcement of a fire wall to limit people's investment in Bitcoin caused a sharp fall in price. Akhtharuzzaman et al. (2021) answered the question of how Bitcoin is diversifying America's industrial portfolios. Using empirical evidence and the DCC GARCH model, less dynamic conditional correlation between Bitcoin and industrial portfolios has been proposed, which allows investing in Bitcoin to play a risk-hedge role against industrial portfolios. The biggest impact of Bitcoin's risk hedging has been on small service segments. Gunawan & Anggono (2021) evaluated crypto security against the Indonesian stock market during the COVID-19 period. Using the GARCH model and DCC GARCH, they concluded that digital currencies cannot be considered a safe asset in Indonesia. Lopez-cabarcos et al. (2021) evaluated the correlation between Bitcoin price, market volatility and investor excitement using the GARCH and EGARCH model. The findings suggested that the market volatility and investor excitement both affect the price of Bitcoin, while S&P 500 has a greater effect on the price of Bitcoin. Ghorbel and Jeribi (2021) examined the relationship between stocks, Bitcoin, gold and energy indexes in G7 countries using the Marko switching GARCH model. The results showed that the spillover effect of volatility is from energy to financial assets. Cryptos were also high-risk investments during the COVID-19 period.

Sami & Abdallah (2021) assessed the effect of cryptocurrencies on the stock market performance in MENA countries using GMM estimators from 2014-2018. The results showed that the volume of cryptos and returns negatively affect stock market performance in Gulf countries (Gulf Fringe countries). However, in non-Gulf countries, crypto yields have a negative effect on the stock market, while the effect of crypto volume is insignificant. In the Gulf States, 1% increase in the digital currency yields could result in 15% decline in the stock market performance while in MENA countries, each 1% increase in digital currency yields would result in 13% increase. Bonelli (2020) evaluated the correlation between the Nasdaq index and the price of Bitcoin using the regression model. Since 2017, there has been a strong correlation between Bitcoin and the Nasdaq (Even during the COVID-19 era. Heidari et al. (2020) pointed out that Bitcoin has some of the characteristics of gold such as world-class exchange and lack of government backing. The analysis of the co-movement and correlation of Bitcoin, gold and the dollar rate is important to analyze the adjusted risk of asset return. In this article, using the time series data from 2011 to 2020 and through the wavelet analytical approach, the correlation and relationship between Bitcoin, gold and dollar is evaluated. One of the findings of this research is that in the short and mid-term time horizon, the relationship between the rate of return of Bitcoin and the exchange rate has been in the opposite direction. Between 2013 and 2017, the

rate of gold return moves after Bitcoin, but between 2017 and 2019, the reverse was true.

Salehifar (2019) tested two hypotheses: 1) Bitcoin returns and risk are significantly different compared to competing markets in the country; 2) in terms of risk and return, Bitcoin stands between gold and currency. In order to answer the hypotheses, descriptive statistics are used. In the inferential statistics section, in order to compare the risk and return in the Bitcoin market with the exchange and gold markets, Spearman correlation coefficient is used to assess the severity and correlation between risk and return in different markets. In order to analyze the risk behavior and return of Bitcoin in comparison with other investment opportunities, the GARCH and GjR- GARCH models are used. The results suggest that Bitcoin cannot be considered to be like gold and dollars. Another result of the research is the lack of correlation between the Bitcoin return and return on investment in the stocks and exchange markets.

Baur et al. (2017) used statistical criteria for Bitcoin's return and characterized its non-correlation with other traditional assets such as stocks, bonds and commodities either during normal periods or periods of financial turmoil. As such, Bitcoin could have many benefits for diversifying the portfolio of assets. In this article, Bitcoin return is compared to 16 other assets. Bitcoin's return has shown a high degree of skewness and negative elongation compared to other assets. By regression of Bitcoin returns on foreign exchange fluctuations, the return of the S&P500 and also specific percentiles related to these two variables with the help of regression coefficients is decided about whether Bitcoin is a risk hedger and or safe haven against exchange rate fluctuations and S&P 500. The result of this research confirms that Bitcoin is not a safe haven. Yonghyeon (2017) used some risk adjusted return measures such as Sharpe as well as Var and CVAR methods to evaluate the relationship between Bitcoin, Euro, Pound, Japanese yen, Canadian dollar, Australian dollar and gold between 2010 and 2016. The result of their research show that Bitcoin has the potential to improve the portfolio.

Briere et al. (2015) use weekly data from the 2010-2013 period in which the Bitcoin yield and volatility were very high (respectively 404% and 176% annually). An American investor with a diversified portfolio containing traditional assets (international stocks, bonds and powerful currencies) and alternative investments (commodities, hedge funds) considered adding Bitcoin to the portfolio. There is a very low correlation between the return of Bitcoin and other assets. Only two assets (gold and inflation-related bonds) have significant correlations with Bitcoin (about 14%). To measure the amount of interest in investing in Bitcoin, a spanning test is used to check whether adding Bitcoin to a predetermined set could increase investment opportunities. For this evaluation, regression is estimated by the dependent variable of Bitcoin returns and the return of K benchmark assets (as independent variables). If the intercept of this regression is zero and the sum of the return coefficients of the K benchmark assets is equal to one there will be a portfolio of assets with expected returns similar but

with less variance. The Spinning test in this article confirms that investing in Bitcoin comes with a lot of diversification benefits.

In the above research on Bitcoin, mostly correlation has been the focus of consideration and the statistical causal relationship has not been considered. Regression estimation in some of the above studies is considered but not concluded with causal measures inferences as the main theme of evaluation whereas regression should be written on the basis of causal relationship and causal variables must necessarily be placed on the right side of the regression.

3. Research Method

Given the goal of this article being looking into evaluating statistical causal relationships between price changes of Bitcoin and indexes representing US exchange market sectors values, attempts are focused on doing so with econometric techniques provided for this purpose. In this regard, firstly, the two-way relationship between the price of Bitcoin and the stock indexes of S&P500 and Nasdaq composite is evaluated away from predetermined judgments and relying on diagnostic tests and examining VAR model as only the first step.

VAR models extend the one-variable autoregressive model. A VAR model is an n-variable n equation model, in which all of variables are considered endogenous. In this model, each variable is linearly a function of its past values and past values of other variables. These models provide bases for a coherent and valid path for explaining data, prediction, inferences and policy analysis. The length of lag in these models is very important because too many lags reduce degrees of freedom, and the low number of lags makes the model incorrectly diagnosed.

The VAR model form being used in this research is:

$$bitcoin = \beta_0 + \sum_{i=1}^{q} \beta_{1i} bitcoin_{t-i} + \sum_{i=1}^{q} \beta_{2i} sandp_{t-i} + \sum_{i=1}^{q} \beta_{3i} nasdaq_{t-i} + u$$

$$sandp = \beta_4 + \sum_{i=1}^{q} \beta_{5i} bitcoin_{t-i} + \sum_{i=1}^{q} \beta_{6i}\, sandp_{t-i} + \sum_{i=1}^{q} \beta_{7i} nasdaq_{t-i} + u$$

$$nasdaq = \beta_8 + \sum_{i=1}^{q} \beta_{9i} bitcoin_{t-i} + \sum_{i=1}^{q} \beta_{10i} sandp_{t-i} + \sum_{i=1}^{q} \beta_{11i} nasdaq_{t-i} + u \quad (1)$$

Where $bitcoin$ is the price of Bitcoin, $sandp$ is the value of the S&P500 index, $nasdaq$ is the value of the Nasdaq Composite index, and q is the maximum amount of lag.

After estimating the VAR model and since all variable in this model are correlated, the estimated coefficients do not provide much information about the response of the system to the shock. Accordingly, Impulse Response Functions (IRFs) was taken into consideration in order to create a better picture of the dynamic behavior of the model. Then, by considering the results obtained from IRFs and also by doing Granger causality test, a decision is made about the cause and effect of variables statistically. In fact IRFs and also Granger causality test

are used as statistical causality tools to differentiate dependent variable and independent variables. Doing these tests would lead to inferences whether S&P 500 and Nasdaq Composite are statistically causes of variation for the price of Bitcoin or not.

Then the ARDL model is estimated based upon statistical causality tests in the previous step. In ARDL model, the dependent variable is a function of its past values (autoregression) and current and past values of other variables. The main advantage of these models is that the variables in them should be first examined to be in the forms of dependent and independent.

The form of the ARDL model in the present research will be as follows:

$$bitcoin = \beta_0 + \sum_{j=1}^{s} \beta_{1j} bitcoin_{t-j} + \sum_{i=0}^{q} \beta_{2i} sandp_{t-i} + \sum_{i=0}^{k} \beta_{3i} nasdaq_{t-i} \quad (2)$$

Where s, q and k are the maximum lags for each variable.

Considering that strong least squares methods are not sensitive to the presence of observations outside the usual norm of the model (unlike the usual least squares method, where the existence of outlier data caused the estimated coefficients of the underlying statistical relationships to be inaccurate), the regression form of the ARDL model is estimated using Robust method. Robust models are generally estimated in three ways:

1) M estimation

This method of estimation relates to when the outlier data is present in the dependent variable.

2) S estimation

This method of estimation relates to when outlier data exists in independent variables.

3) MM Estimation

This method is a combination of two methods M and S.

4. Analysis of data and findings

The data were collected daily data for 1/3/2012 to 6/11/2024 from www.investing.com site. The software used is Eviews13.

Data analysis process is started by stationary test of the variables involved with using Dickey Fuller unit root test. All variables are not stationary at the level and are stationary in the first order difference. In fact, all variables are I (1) considering that all variables are stationary in the first order difference and also the existence of cointegration between variables working with level data cause any statistical concern (Sims, 1990).

Based upon Schwartz index and also the necessity of non-autocorrelation in the selective lag, the lag one for the model was selected and then the VAR model

was estimated. Cointegration is evaluated by Johansen test and the existence of cointegration is inferred (table1).

Table1. Unrestricted cointegration Rank Test (Max-eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.** Critical Value
None *	0.007034	22.04563	21.13162	0.0371
At most 1	0.003853	12.05587	14.26460	0.1086
At most 2	2.22E-06	0.006931	3.841465	0.9331

Source: *Research finding*

Max-eigenvalue test indicates 1 cointegrating equation(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

There is a long-term equilibrium relationship between variables. The dynamic stability of the model was evaluated by testing that all inverted roots are inside the unit circle (AR root graph) and the stability of the model is the result. Also based upon the impulse response functions (IRFs) in Figure 1, one standard deviation shock on the value of the Nasdaq Composite has a gradual incremental effect on the price of Bitcoin and the system is divergent according to the information available so far, as well as the structure used in this paper. Also, one standard deviation shock on the value of S&P 500 has a negative downward effect on the price of Bitcoin and system is also divergent in this case. While Bitcoin's standard deviation shock is ineffective on the S&P500 and Nasdaq Composite.

To infer the result of statistical causality more strongly, the Granger causality tests for prediction of price changes was run and conclution was that at the significance level of 5%, S&P 500 and Nasdaq Composite are Granger causaliforthepredictionprediction

Bitcoin price changes, while Bitcoin price was not the Granger causality for changes of other two indexes.

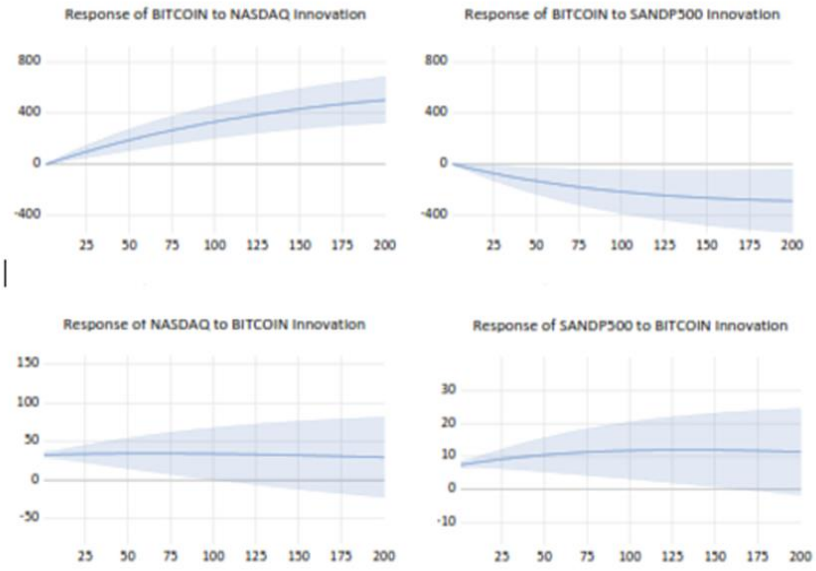

Figure1. Impulse response function
Source: *Research finding*

Based upon Granger test and Impulse Response Functions, inferences are made that S&p500 and Nasdaq Composite should be considered as independent variables and the price of Bitcoin as dependent variable. These statistical inferences would lead to appropriateness of ARDL model. Since in the ARDL model, right hand side variables are independent ones and the left hand side are dependent variable, according to the Akaike index, the appropriate lag becomes 4 for Bitcoin, 2 for the S&P500 and 1 for Nasdaq Composite. After estimating ARDL model, due to the contradiction of the results of CUSUM and CUSUMSQ tests, the stability of the structure of the model became questionable and as a consequence, structural break of the model using Chow's Breakpoint was tested. The test results show that there is break in the structure. In order to improve the structure of model, we looked at the curve of price of Bitcoin versus time. The following observations were made:

1) There are extremum points within the period 2020 to 2024;
2) Halving (a Bitcoin halving event occurs about every 4 years when the reward for mining is cut in half) occurred in 2020 and halving would lead to drastic increase in the price of Bitcoin;

3) Even though China as a big player of financial market from 2017 started to put restrictions on using Bitcoin, in 2021 it devised very limited laws and punishment for citizen getting involved in bitcoin trading (Satsuk, 2023).

Due to the above reasons, subsamples were determined and for each subsample, a dummy variable was assigned. Three dummy variables were added to the original model (also with multiple breakpoint test these periods are checked and would include such changes of structure). Then, using these dummy variables as intercept, the model was re-estimated and the results can be seen in Table 3. The added current dummy variables were significant at the level of 5%.

Since the estimators in large samples tend to normal distribution and the sample used in this study is large enough, Wald estimators could be used for hypothesis testing if needed. Then with respect to bound test, cointegration (long-term relationship between dependent and independent variables) is inferred (Table2).

Table2. Result from Bound test

Lower Bound value	Upper Bound Value	Critical Value
3.06	4.15	1% significance level
2.39	3.38	5% significance level
2.80	3	10% significance level

Source: *Research finding*
Note F-statistics = 7.122479

Therefore, in order to separate short-term effects from the overall effects, the ECM was estimated.

$$D(Bitcoin) = -0.009484\ CointeQ^{*} - 0.052043\ D\big(Bitcoin(-1)\big)^{**} + 0.015957\ D\big(Bitcoin\ (-2)\big) + 0.076248\ D\big(Bitcoin(-3)\big)^{*} + 3.431492\ D(Nasdaq)^{*} - 5.310644\ D(Sandp500)^{*} + 0.946000D\big(Sandp500(-1)\big)^{**} + 1918.664D(D_2)^{*} - 1821.041D(D_3)^{*} + 891.82250\ D\big(D_3(-1)\big) \quad (3)$$

Note: *, **, *** indicates significance at the 1%, 5% and 10% respectively. Also CointeQ is Error Correction term.

Considering the negative and significant short-term to long-term adjustment coefficient (-0.009), adjustments of uniformity towards long-term equilibrium occur. The explanatory power of ECM is 10%. Godfrey test for non-correlation test does not reject the null hypothesis at a significance level of 5%. The CUSUM test show that the cumulative sum of residual statements in the region is placed between two critical lines and the CUSUMSQ test results are higher than previous model (not dummy variables being added to the structure).

However, to support conclusions based upon stronger statistical bases, considering the ability of Robust least square estimation to adjust for heteroscedasticity and the absence of normal distribution, as well as the existence of outlier data regarding the Bitcoin market and Figure 2, the estimation method

of MM was used to estimate the ARDL model (Table 3). According to the statistics of Rn-squared and p-value, the null hypothesis of coefficients being zero is rejected at a significance level of 5%. The model's explanatory power is between 64% and 99%.

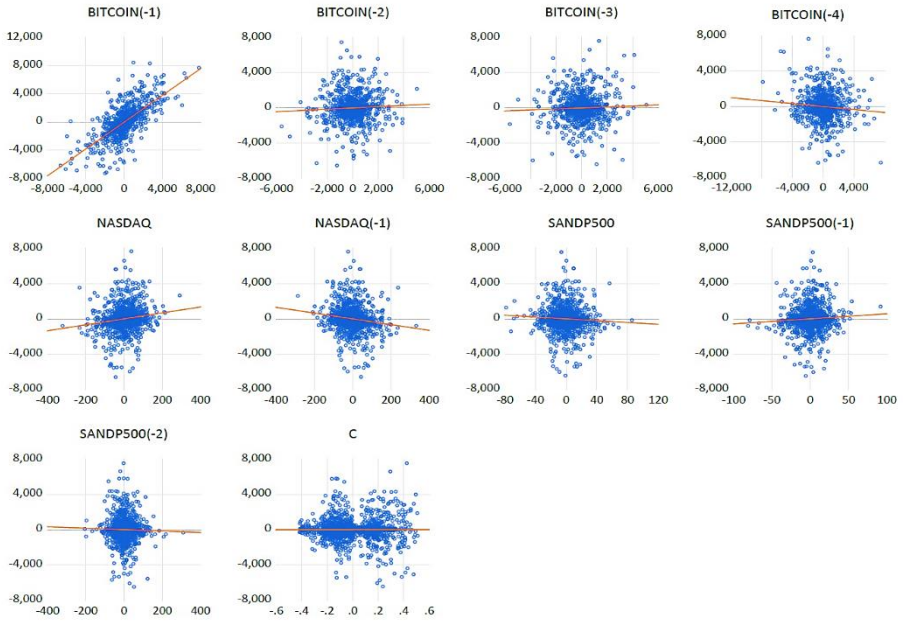

Fig2. Existence of outlier data (BITCOIN vs. Variables (Partialled on Regressors))
Source: *Research finding*

Table 3. The result of estimating ARDL and ROBUST model

	ARDL		MM-Estimation	
Bitcoin(-1)	0.938473	0.0000	0.869124	0.0000
Bitcoin(-2)	0.068000	0.0043	0.083232	0.0000
Bitcoin(-3)	0.060291	0.0103	0.068700	0.0000
Bitcoin(-4)	-0.076248	0.0000	-0.024185	0.0000
Nasdaq	3.431492	0.0000	0.167102	0.0000
Nasdaq (-1)	-3.277764	0.0000	-0.134156	0.0005
Sandp	-5.310644	0.0001	0.157675	0.2663
Sandp(-1)	5.847828	0.0000	-0.447274	0.0030
Sandp(-2)	-0.946000	0.0525	0.195677	0.0002
D1	-269.4543	0.0112		
D2	1918.664	0.0064		
D2(-1)	-1577.456	0.0250		

D3	-1821.041	0.0096		
D3(-1)	2323.872	0.0122		
D3(-2)	-891.8225	0.1429		
C	83.9019	0.4731	36.15449	0.0003
Adjusted R Ssquared	.997			
Rw-squared			0.641332	
Adjusted Rw-Squared			0.99	

Source: *Research finding*

As can be seen in Table 3, in the ARDL model, the first lag of Nasdaq Composite and S&P500 variables have a negative and positive effect on the price of Bitcoin, respectively, and the coefficients of these two variables are effective at the maximum error level of 1%. Nasdaq Composite and S&P500 variables also have a positive and negative effect on the price of Bitcoin, respectively, and their coefficients are also significant at the level of maximum error of 1%. Also, the first to third lags in the price of Bitcoin have a positive effect on the price of Bitcoin and the corresponding coefficients are effective at the error level of 5%. The fourth lag of the Bitcoin price variable has a negative effect on the price of Bitcoin, and the coefficient of this variable is effective at a significance level of up to 1%. D1, D2 and D3 have negative, positive and negative effect on the price of Bitcoin respectively and coefficients of these are effective at the error level of 5%. The first lags of D2 and D3 have negative and positive effect on the price of Bitcoin respectively and coefficients of these are effective at the error level 5%.

In the MM estimation method, the first to third lags in the price of Bitcoin have a positive effect on the price of Bitcoin, while the fourth lag has a negative effect. All these coefficients are also significant at the maximum error level of 1%. The Nasdaq Composite variable has a positive impact on the price of Bitcoin and the corresponding coefficient is effective at the error level of 1%. The S&P500 variable is insignificant at the 5% error level. The first and two lags of the S&P 500 variable also have a negative and positive impact, respectively on the price of Bitcoin, and the coefficient of this variable is also effective at the level of error of up to 1%.

5. Conclusions

Bitcoin now being in the portfolio of individuals makes it important to evaluate changes in its valuation more fully and if possible from different angles. Each additional aspect added to pervious knowledge such as the one considered in this paper could help investors or the agents to improve the optimality of their portfolio chosen.

This article focuses on evaluating the relationship between Bitcoin price changes and two other groups of assets that fall into investors' portfolios. In this regard, by using the VAR model, it was concluded that if bitcoin is considered to be interacting with two other group assets represented by Nasdaq Composite and S&P 500 in the US financial market, the statistical conclusion in this regard would

be unsuccessful. In fact, there is no two-way causality relationship between Bitcoin and the S&P500 and Nasdaq Composite indexes, and the S&P 500 and Nasdaq Composite Granger causality are unilateral.

Having made the above inferences, by focusing on the one-way statistical causality relationship of the financial market indexes on the price changes of Bitcoin, ARDL model was estimated. Conclusion was made that the S&P 500 and Nasdaq Composite indexes as representatives of main financial assets not only cause Bitcoin price changes but also create a highly detection coefficient. Short-term effects also cause 10% of the level of Bitcoin price changes estimated. Considering the ability of the strong least squares method (Robust least square) to adjust for the absence of normal distribution and also the existence of variance heterogeneity, the regression form of the ARDL model is estimated using this method. The success of the model in explaining the changes price of bitcoin is estimated to be between 64 and 99 percent.

It should be noted that in this research, the aim has not been to predict the changes price of Bitcoin; rather, the focus is evaluating statistical causal relationship and its strength (explanatory power).

Author Contributions

Providing manuscript as well as software work , as part of her PhD dissertation, are done by M.S. Proposing the frame work for this research and also directing different steps for completing the research was done by R.KH who is the supervisor of the dissertation of M.S. Collaborating for improvement of econometric technics being applied and in particular suggestion of doing Impulse response function evaluation is being done by S.S. M.V has made constructive finance point and editing comments for improvements of the manuscript. S.S and M.V both also are advisors for dissertation of M.S. The text of the manuscript has been read by all authors.

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Conflicts of Interest:

The authors declare no conflict of interest.

Data Availability Statement:

The data were collected daily data for 1/3/2012 to 6/11/2024 from www.investing.com site.

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