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INTERCONNECTION AMONG CRYPTOCURRENCIES: USING VECTOR ERROR CORRECTION MODEL

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ABSTRACT

The research paper aimed to investigate the relationship between the major popular cryptocurrencies in terms of market dominance and identify any pattern and/or causality between the short-run and long-run series. Cryptocurrency has received much attention because of media publicity and the financial returns it generates within a short time, with its associated risk level. This innovative financial research investigates for the first time by thoroughly analyzing nine top cryptocurrencies, excluding stablecoins. The study used the Vector Error Correction model to analyse how the various cryptocurrency under investigation are interconnected. The results demonstrated how concentrated the causality effect is on some specific cryptocurrencies. The study uses the top nine cryptocurrencies on the crypto markets, excluding stablecoins that have existed since October 2017. The frequency of the data is 1523 daily closing prices. The choice of the data stemmed from its availability and has existed since October 2017. The primary outcome is clear and possibly explains the dominance of Bitcoin and Ethereum as the main drivers of the prices of related or altcoins. Any movement in the price level of the two dominant cryptos affects all the altcoins on the crypto market. The research further unearths the interconnection or correlation between the major cryptocurrencies. It will assist institutional and retail investors, fund managers, and managers, with the possible mix of assets in their portfolio based on their risk appetite level in making investment decisions.

KEYWORDS: Bitcoin, Altcoins, Cryptocurrency Market, VECM, Cointegration

JEL CLASSIFICATION: G17, L26, K 22.

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INTRODUCTION

Recent financial innovation has given great attention to Cryptocurrency. This decentralized blockchain financial system has no government or central bank interference. The first cryptocurrency (Bitcoin) was issued by Nakamoto Satoshi, which may be a person or group of persons in 2009, that is 13 years ago, after the global financial crisis. Around 14,000 different types of cryptocurrencies have been traded on the cryptocurrency market since November 2021, with a total market capitalization of approximately 2.2 Trillion dollars (CoinMarketCap, 2017). Bitcoin holds market dominance with over 40% in November 2021 compared to 80% in November 2017 (Chan, Chu, Nadarajah & Osterrider, 2017). Ethereum is the second term of dominance, with a market of 16.5% at the end of November 2021 (coinsmarketcap.com).

Much attention has been given to cryptocurrencies and other traditional assets (Shahzad et al. 2019, Corbet et al. 2018, Yi et al. 2018, Ji et al. 2019, Sovbetov 2018). Leung and Ngyugen 2019 researched the co-integration of cryptocurrency. Sovbetov 2018, on the other hand, studied the co-integration of the VAR system of cryptocurrencies. Leung and Ngyugen 2019 also discussed and analyzed the trading strategies of investors and traders regarding the co-integration of cryptocurrency and their portfolio mix.

The decentralized financial tokens have a lot of returns, and their risk level is also high. There is no government supervision and third-party control, and the demand and supply determine the market price. Lee (2018) postulates that changes in news, whether positive or negative, drive the high price cycles due to the attention of crypto investors' behaviors. Deleo and Stull (2014) used ordinary least square weekly data and found a positive relationship between transaction volume and the performance of Bitcoin. Ante et al. 2020 and Krisoufeuk 2021 argue the demand for unstable cryptocurrencies necessitates the demand for Stablecoins, which are usually used to buy or trade other cryptocurrencies. In 2014, for instance, Mt Gox (Bitcoins Exchange experienced a loss of over 850,000 coins to cyber-attacks. Unlike previous studies (Abdakafor, 2018; Möller, 2018), which employ a small sample size, this study broadens it to nine cryptocurrencies with 1523 trading days. The choice of the nine stems from the fact that they are large in market capitalization and have existed since 2017. The study does not include stablecoins.

The following research questions are proposed:

1) Is there co-integration in the cryptocurrency market?
2) What is the interconnection or relationship among the top cryptocurrencies regarding their market dominance?
3) How do the two dominant cryptocurrencies (Bitcoin and Ethereum) affect other cryptocurrencies in the long run?

The research methodology for the investigation is the Vector error correction model (VECM), promulgated by Engle and Granger (1987), which adds to the standard vector autoregressive (VAR) model with an added role for studying deviations from usual long-run equilibria.

The organization for the paper is as follows. Section 1 is the introduction and review of literature related to the research. Section 2 is a detailed description o the steps in modeling and the methodology to be applied to the largest nine cryptocurrencies, excluding stablecoins. Section 4 describes the results, and Section 3 discusses them. Section 4 is followed up by a conclusion. All the results of this paper were generated using GRETL software.

1 LITERATURE REVIEW

This section summarizes prior research on Cryptocurrencies. In addition, this section discusses cryptocurrencies, types of cryptocurrencies, and their interconnectedness concerning empirical and conceptual foundations.

Cryptocurrency

Many governments, scholars, and investors have been paying attention to cryptocurrencies over the past few years because of their rapid development as well as their dramatic peaks and falls (Bank for International Settlement, 2018). As with traditional currencies, cryptocurrencies are designed to serve as a means of exchange, a store of value, and a unit of account. in that, they are not issued by central banks and may be exchanged electronically between users without the need for middlemen or central authority control (Treasury Committee, 2018). As of today, the Internet is the primary means by which cryptocurrency is exchanged, although its survival without the Internet is still viable. Several benefits of electronic money over traditional paper currency account for its widespread acceptance. To the extent that it has a full or near-full value, it performs the tasks of regular money: it may be received, transferred to another person, used to pay for products or services, and so on (Sichinava & Magradze, 2018). In addition, unlike conventional goods and services, cryptocurrencies lack an inherent value that may be used to generate money (Schiller, 2017). The value and legality of traditional currencies are based on

political and legal systems, whereas the integrity of the cryptographic network is all that is needed for cryptocurrencies.

Almost all cryptocurrencies may be purchased in exchange for traditional money (or other cryptocurrencies), both online and at select ATMs. Initially, though, cryptocurrencies are created through various "mining" procedures. Similar to the actual process of obtaining raw materials for bullion,' mining' digital currencies requires an investment of time and/or money. Typically, this implies that a user is compelled to invest time and computational resources in creating a "ledger" of transactions documenting all transactions involving a particular 'altcoin (alternative digital coin). Thus, currency production and payment verification are inextricably intertwined. To combat fraud, all cryptocurrencies require reliable attestation that a certain quantity of value has been moved from one party to another, for example, by the "double-spending" of a single digital currency (Tendermint,2014). For conventional currencies, clearinghouses and banks are resolving this issue for a price. However, in the realm of cryptocurrencies, the verification effort is undertaken by the worldwide community of users. Participants in this evaluation process earn modest sums of newly "minted" digital currencies as a reward or incentive. Additionally, there is debate in the Bitcoin community about whether miners should be able to charge fees for speeding specific transactions. In that instance, miners would behave similarly to traditional middlemen who charge transaction fees. However, even with decentralized mining, this scenario is somewhat different from traditional currencies with a central middleman. (Popper 2016).

The amount of transparency offered by cryptocurrency is unmatched. Bitcoin and other cryptocurrencies have enormous potential to revolutionize society and hold people accountable. Even though cryptocurrency transactions are completely anonymous, they are all recorded in the Blockchain which easily is traced. This implies that anybody may examine all data associated with cryptocurrency transactions at any moment, which is a significant benefit for anyone seeking a more transparent financial system. Indeed, bitcoin has been dubbed "the new gold" because of its openness and transparency. In addition, cryptocurrency provides fast and round-the-clock access to all of its consumers (Sun et al. 2020). Cryptocurrency transactions may be made from any location around the globe, and no computer is required. As long as you have a smartphone or other mobile device, you'll be able to view your accounts and make choices right away. Bitcoin's widespread use is large because it is easier for those who previously had difficulty using the internet to buy and sell goods and services. The complete secrecy provided by cryptocurrencies is yet another big benefit. Because it is not subject to changes in the political atmosphere or alterations in customs, the money is unrestrained. If you're concerned about online privacy and don't want your digital information out in the open, the anonymity that Bitcoin provides is critical. Stocks of large-cap companies in the S&P 500 traded at a 14.5 percent annual interest rate from 2015 to 2020. In addition, bitcoin's price has increased by 131.5 percent on an annualized basis during the same period (Sun et al. 2020).

Diversification is possible because of the wide range of cryptocurrencies. Some have argued that the currency is the best alternative to gold in most people's portfolios. During the 60 months that concluded in December 2020, the S&P 500 and the price of bitcoin both decreased. A five-year compound rate of 26.8% was created by a portfolio with 10% of assets in bitcoin and 90% in the S&P 500 by the end of 2020. Cryptocurrency's value rises due to a lack of available supply. Every time you mine or generate a currency, you are limited to 21 million coins. About 18.5 million bitcoins have been mined, leaving a little over 3 million bitcoins for other miners to work with. In addition, the halving procedure slows down the manufacturing of bitcoins over time. Bitcoin's value has decreased from 50 bitcoins per block produced in 2009 to 6.25 bitcoins per block mined in 2019 (Özyeşil, 2019).

Types of Cryptocurrencies

Cryptocurrency investments have several benefits, but profiting from them is the most essential one. Digital values are extremely volatile, which means that there is a lot of room for profit, but also a lot of room for risk. Many services, like Bitbuy,Gate.io, Coinbase, Bitstamp, Cryptsy, and BitPanda, make it simple for customers to buy, keep, and trade cryptocurrencies (Milutinović, 2018).
There are huge different types of online wallets, some of which only enable you to store one form of digital money, while others let you store many types. There is a wallet available for download on each of these websites, and each wallet has a unique address for accepting digital currency from other users. Going to an exchange website is the most efficient way to acquire or sell these coins. It's as simple as signing up for an account and downloading your wallet. Afterward, you'll be able to purchase whatever currency you like (Gandal & Halaburda, 2014).

Depending on the website, you may see different pricing. According to the price and type of cryptocurrency you desire to purchase, purchasing a cryptocurrency might take a few seconds, minutes, or even hours at times. For every buyer that accepts your offer, you will receive cryptocurrency in your wallet, and he or she will receive money from you. One method of acquiring them is through this method of purchase. On the other hand, you may buy digital money from online communities (Luther, 2013). The cost is comparable to, if not cheaper than, the cost listed on the websites. To obtain the currency, you must exchange your wallet's address with the seller after finding and agreeing to the deal. A dangerous method of purchasing, as the seller may elect not to deliver the cryptocurrency to your wallet.

Decentralized and centralized blockchain cryptocurrencies are the two basic types of cryptocurrencies. This implies that each computer is a functional unit on its own, and there is no governing body to approve it. Everyone can operate this system, yet no one has authority over it, which is one of its most distinguishing features (Fernandez-Villaverde & Sanches,2016). In a centralized system, a small number of individuals are in charge of overseeing the currency and making sure it is a success. Rule number one: know your consumer. So, they are attempting to prevent money laundering by allowing people to examine the currency and pay taxes on it (Investopedia, 2017). It is impossible to determine whether the system is improving or deteriorating. The market dictates the fate of an investor's investment. Finally, when purchasing a cryptocurrency, the most critical factors to take into account are the number of coins in circulation, the market price, the price stability over time, the security of the cryptocurrency, the users and traders who have said yes to the cryptocurrency, public support, and legal regulations in countries that accept it. (2017) (Investopedia). Although there are hundreds of more cryptocurrencies available for purchase, the following are some of the most valuable and well-capitalized.

Ethereum

As of the middle of 2015, it was a new decentralized platform. It has a valuation of €28,6 billion on the stock market. Vitalik Buterin, a young crypto-genius, is the inventor of this cryptocurrency. Both Bitcoin and Ethereum make use of blockchain technology, which keeps a public ledger of all transactions. However, when it comes to design and usage, they are radically different. In contrast to Bitcoin, which is primarily used as a form of payment money, the Ethereum blockchain is meant to support a wide range of business-related applications. For this reason, many businesses were eager to acquire this coin. Algorithms included in smart contracts ensure that obligations are honored as soon as criteria are met. Because of its decentralized nature, Ethereum may end up becoming the Internet's next big thing. However, the hack of the DAO, an Ethereum-based smart contract, means it can't be considered a single currency. As a result of their hard effort and lack of agreement, the Ethereum team created Ethereum Classic. Additionally, Ethereum is home to a slew of other Tokens, like DigixDAO and Augur, further solidifying its status as a crypto-family (Milutinović, 2018).

Bitcoin

When it first hit the market in 2008, it didn't get much notice. In a scientific article titled Bitcoin: A Peer-to-Peer Electronic Cash System, the pseudonym Satoshi Nakamoto was used to symbolize a person or group of persons whose identity is currently unknown. In 2013, there was a lot of interest in this platform. In the future, many organizations from all over the world will consider Bitcoin as a reserve currency as well as an alternative monetary and financial system. These countries include South Korea, India, Australia, and Japan. They believe that if it continues to expand at this rate, it might replace the American dollar as the world's reserve currency. When everyone started putting their money in Bitcoin, the perception of it as a strong asset used by criminals to launder money began to alter. Everybody wants a piece of it since the transactions are untraceable and anonymous. Japan has emerged as the global leader in this new kind of commerce. Bitcoin, digital money, may be used to pay for some services and buy some commodities (Milutinović, 2018; Urquhart, 2016).

Cryptocurrencies in Practice

Cryptocurrencies (such as Bitcoin) have developed into something completely different from the vision Nakamoto envisaged in 2008. When it comes to cryptocurrency, Bitcoin and other prominent cryptocurrencies have struggled to maintain their value and hence their level of trust or acceptability, despite intense competition (Hayek money). There are certain issues when comparing cryptocurrencies in concept to cryptocurrencies in practice. Since 2013, the number of cryptocurrencies has increased exponentially. According to research published by the Institute and Faculty of Actuaries, there were 66 crypto assets in 2013, 644 in 2016, 1,335 at the end of 2017, and 2,116 in January 2019. Similarly, according to Ward and Rochemont, the market value of crypto assets has risen dramatically from around USD 10 billion at the end of 2013 to USD 572.9 billion at the end of 2017. (2019). As of April 2018, there were over 10,000 cryptocurrency trading sites (Ward and Rochemont, 2019).

There are almost 2,000 cryptocurrencies, and their market capitalizations are distributed evenly. Daily averages for active unique addresses, daily averages for blocks generated, daily averages for adjusted transaction volume, and finally, daily averages for fees paid to miners are all derived using data from coin metrics for 18 distinct cryptocurrencies. Throughout the data, which ranges from 438 days (Tezos) to 3903 days (Ethereum), averages are derived (for Bitcoin). While Bitcoin is the most well-recognized cryptocurrency, other cryptocurrencies such as NEO have a higher daily transaction volume (Aiden & Mason, 2021).

Counting the number of people who use a service is tough. As of July 2014, there were nearly 41 million Bitcoin addresses on the Bitcoin blockchain, although only 1.6 million of them held more than 0.001 bitcoins (about £0.35) in their balances. There is still an overestimation in this much lower amount since each user can have any number of wallets and each wallet can have any number of addresses. Fewer than 30% of cryptocurrency owners send any funds to a third-party or intermediary or alternative account at least once a month, according to a 2018 poll by the Foundation for Interwallet Operability [FIO] (Aiden & Mason, 2021).

One year later, 43% of those polled said they had sent or purchased cryptocurrency only a few times, while 27% said they had transferred none at all. As a result, we may infer that around two-thirds of all cryptocurrency owners have never or only sometimes utilized their coins to make payments. The number of places that take Bitcoin may also be used to get an idea of how widespread its use is right now. With reference from coinmap.org, there are more than 15,000 locations where Bitcoin is accepted. Bitcoin payments are accepted by Microsoft and other leading software corporations. However, digital banks like Revolut let customers create accounts with Bitcoin and make payments using that currency (Aiden & Mason, 2021).

Interconnection between Cryptocurrencies

Schinckus, Duy, and Canh (2021) studied the connections between all of the current cryptocurrencies using a data-driven approach known as network analysis. Starting in 2013, researchers examined the interdependencies between 1636 cryptocurrencies, which they continued until July 2018 after completing their initial research. Even though Bitcoin is the oldest and most well-known cryptocurrency, the research found that it does not influence the virtual currency market. It was found that the links between virtual currencies have become denser, indicating that one coin's alteration will have a ripple effect on other coins as well. We've also seen that the most popular cryptocurrencies one year don't appear to be popular the next year, which is interesting. Finally, the effect of cryptocurrencies shifts with time, which suggests a short-term relationship between them.

Andrada-Félix, Fernandez-Perez, and Sosvilla-Rivero (2020) studied the volatility interconnection between the most important cryptocurrencies and traditional currencies between February 2014 and September 2018, using both the framework proposed by Diebold and Yilmaz (2014) and Antonakakis and Gabauer's modified approach (2020). As a result of the study's findings, only 34.43 percent of the total variance in forecast errors was explained by the eight investigated cryptocurrencies, while the rest of the 65.57 percent was due to the idiosyncratic shock. The researchers found that when economic and financial instability is on the rise, there is a noticeable increase in volatility connection. Based on their research, traditional currency and cryptocurrency markets are largely independent although volatile times of net volatility occasionally cross over into one another. Traditional currency total connectedness is driven by financial market variables, while cryptocurrency-specific variables are the primary determinant of total connectedness within traditional currencies, and a combination of both business cycles and cryptocurrency-specific variables explain directional volatility connectedness between both blocks of currencies.

Furthermore, Yi, Xu, and Wang (2018) used the spillover index and its revisions to examine the static and dynamic volatility connectivity of eight major cryptocurrencies. There was a definite rising trend since the end of last year in their connectedness, according to these findings. VARs were estimated using the LASSO-VAR in a variance decomposition framework to establish a volatility connectedness network of 52 cryptocurrencies. Volatility is more likely to spread among "mega-cap" cryptocurrencies analyzed in the study, according to the researchers. However, certain lesser-known cryptocurrencies (such as Maidsafe Coin) are important net transmitters of volatility connectivity and even have a greater impact on volatility spillovers than other cryptocurrencies.

Additionally, Corbet, Meegan, Larkin, Lucey, and Yarovaya (2018) examined the correlations between three major cryptocurrencies and several other financial assets in the temporal and frequency domains. In the study, it was discovered that these assets were relatively isolated from financial and economic assets. Cryptocurrencies may provide investors with short-term investment horizons with diversification benefits, according to the study results. External economic and financial shocks are reflected in the time variation in the links.

Finally, the Diebold and Yilmaz (2012, 2014) generalized spillover metrics have been used in developing literature to quantify the market integration or connectivity of cryptocurrencies. To be sure, this technique is beneficial, but it fails to account for the cross-correlations among the cryptocurrencies when calculating the aggregate spillovers from all other cryptocurrencies to a single cryptocurrency. The innovative multivariate conditioning sets used by the joint spillover approach were further explained by Wiesen and Bharadwaj (2021). In comparing the two methods, the researchers found that accounting for cross-correlations in cryptocurrencies is important for estimating aggregate spillovers and the market's overall interconnectedness. The generalized spillover index overestimates overall connectivity by nearly nine percentage points when compared to the new joint spillover measure, according to the authors, who used data on ten of the most traded cryptocurrencies. Over time, this disparity shifts and isn't consistent across all cryptocurrencies.

2 METHODOLOGY AND DATA

As stated, the main aim of this research is to investigate the interconnection among cryptocurrencies using the top 9 cryptocurrencies' closing prices that have existed since October 2017 excluding stable coins. The data was downloaded from coingecko. The data of the cryptocurrency forms about 70 percent of the market dominance. The data is secondary data. In analyzing the data, various descriptive statistics of the data were computed with GRETL. These include the mean, median, maximum, minimum, standard deviation, skewness, and excess kurtosis for all nine cryptocurrencies. A correlation matrix was also adopted to fully explain the relationship between them. An Augmented Dickey-Fuller test is adopted to test the stationarity of the data. On the other hand, when the returns series are not stationary, it is appropriate to test a first difference to establish the stationarity of the returns.

The Engle and Granger approach-Cointegration steps.

According to Engle and Granger (1987, Econometrica), the following steps should be taken

(i) First, we have to estimate the long-run (equilibrium) by equation: $y=\delta_0 + \delta_1 x_t + u_t$ (1)

While the OLS residuals from (1) can be determined of disequilibrium: $u_t=y_t - \delta_0 - \delta_1 x_1$ The next step is to compute Cointegration to see whether u_t is stationary. This is done by ADF tests on the residuals, with the MacKinnon (1991) critical values adjusted when necessary for the number of variables (which MacKinnon denotes as n).

When the assumption of Cointegration holds, the OLS estimator of (1) is classified as super-consistent. The implication is that when: as $T \to \infty$ (i) it is not necessary to include I(0) variables when defining the cointegrating equation.

Data Collection

Secondary data was obtained from coingecko.com. These are nine (9) essential cryptocurrencies with high trading volume except for stable coins. From 1st October 2017 to 1st November 2021, closing price transactions statistics of the top nine(9) cryptocurrencies excluding stable coins for a complete 1523 trading days is the primary focus. The transaction volume of the nine (9) varieties of cryptocurrencies, which includes Bitcoin, turned into showed that they've been traded available in the marketplace for an exceedingly long term since 2017. Thus, such long-time period transactions statistics series had a strong robust benefit in determining the accuracy of the assessment results. Table 1. shows the details of the cryptocurrencies understudy and the precise descriptive statistics.

The table above shows detailed statistics of the crypto assets understudies. Bitcoin has the highest maximum price and ADA has the lowest maximum price among all the assets. In the crypto market Bitcoin is dominating the market, followed by Ethereum.

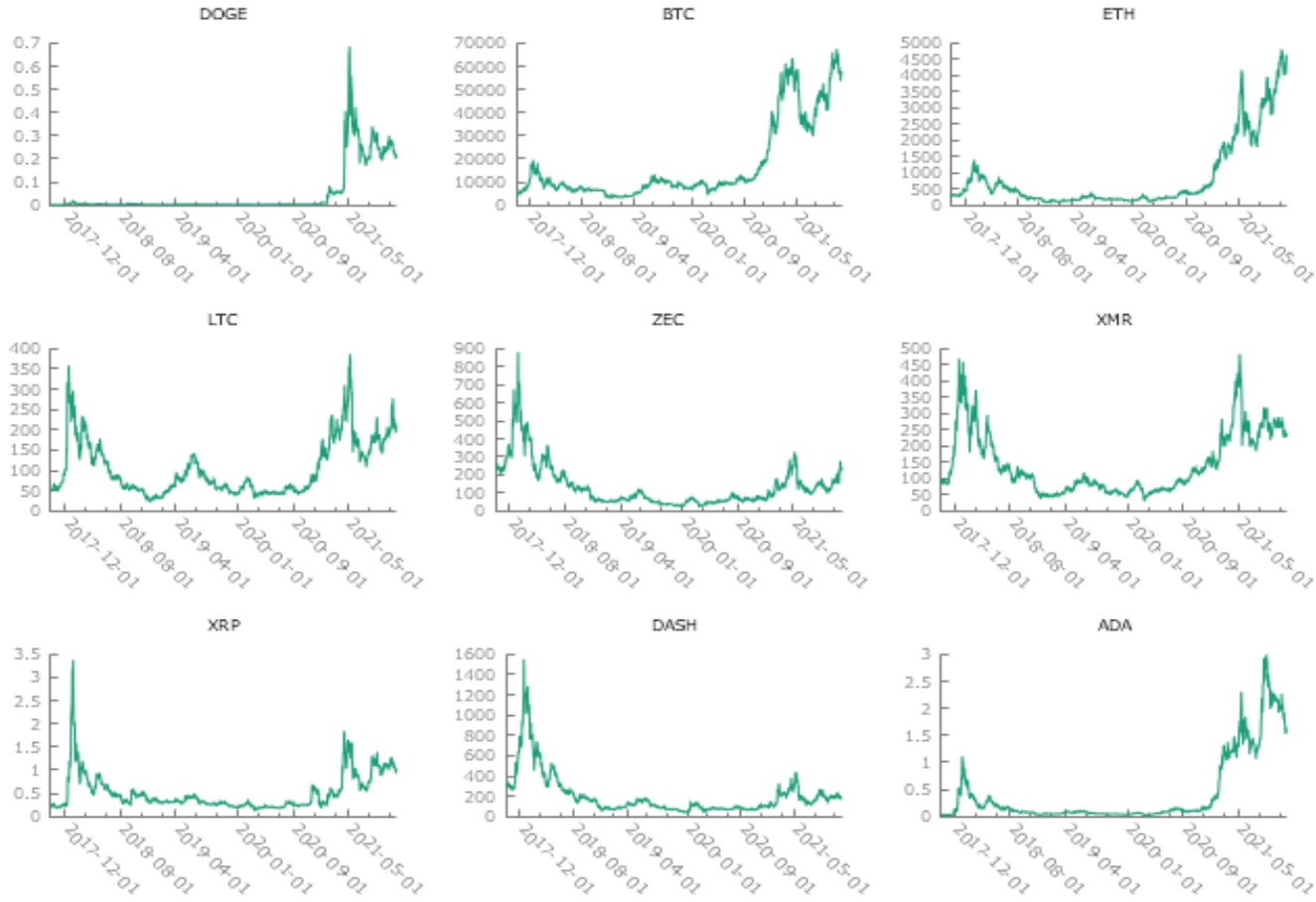
3 RESULTS

Table 1 **Descriptive Statistics of selected CC: 1/10/2017–01/11/2021**

	MEAN	MEDIAN	MAXIMUM	MINIMUM	STD DEVIATION	SKEWNESS	EX KURTOSIS
DOGE	0.048041	0.003043	0.68478	0.000991	0.10473	2.4779	6.0059
BITCOIN	17235	9328.2	67567	3236.8	16990	1.4982	0.78223
ETHER	846.16	333.36	4812.1	84.308	1091.7	1.8675	2.49
LITECOIN	104.19	75.536	386.45	23.464	68.292	1.1762	0.85711
ZEC CASH	134.69	89.749	880.76	24.504	118.7	2.1561	5.6688
XMR	142.93	105.11	483.58	33.01	95.302	1.0861	0.3511
XRP	0.51272	0.33321	3.3778	0.13964	0.39494	2.3457	8.3835
DASH	202.62	131.79	1550.8	39.874	205.88	2.8682	9.611
ADA	0.42471	0.096357	2.9682	0.018539	0.66243	1.8859	2.4878

(*Sources*: Authors' computation)

Figure 1 **Plot of price movement of the nine cryptocurrency understudy**



(*Sources*: Authors' computation)

The plot above shows the price movement of the nine cryptocurrencies. Bitcoin and Ethereum show a similar increasing trend, DASH, ZEC, and XRP depict a downward swing in their price. Ada and Dogecoin saw a sudden increase in 2020 during the pandemic covid period. LTC and XMR show plummet and upward swing. DASH tumbled from 2017 and rise a little in 2021.

Vector Error Correction Model(VECM)

Most econometrics data are typically stochastic or have a nonstationary trend, implying that the data has a root unit. So if the unstable time series have a co-integration relationship, VECM is suitable to verify the long-run equilibrium relationship between the time-series variables and the short-run dynamic structural relationship; because the model can gradually correct the part where the long-run equilibrium deviates through a short-run adjustment process. To validate the method, Vector Error Correction Model allows us to distinguish long-term and short-term causal relationships between variables. Vector Error Correction Model is different from the VAR model, which usually depicts short-term dynamics. Vector Error Correction Model is very useful to dynamically analyze the interrelationship of unstable time series variables.

For more than one variable, the Vector Error Correction Model equation is define below:

$$yt = \alpha 1 yt-1 + \cdots + \alpha pyt-p + \beta xt + et$$

Test of Unit root

First, we have to use a procedure of a time series analysis to perform a unit root test to determine whether time series data have a nonstationary trend. The variables used by most time-series data are known to be nonstationary time series with a unit root. Moreover, If an unstable time series that does not assume data stability is used in the analysis, the value of R2 increases exponentially due to the apparent regression phenomenon. Above all, a test of the uni root t is typically performed to determine the stationarity of the analyzed time-series data. From the study, a traditional method, Augmented DickeyFuller's unit root t-test is performed. As shown, Table 4. has a unit root in the level variable. It is also confirmed that the time series has no normality. When we apply the first difference for the variables shows that the time series have normality because there is no root of unity. That is, it is confirmed that the time series is stable.

Augmented Dickey-Fuller Test

The problem of autocorrelation often occurs in the Dickey-Fuller stationarity test. To resolve this problem a test called the Augmented DickeyFuller Test was conducted. As shown below, this must be true for stationarity to exist:

Table 2 presents the ADF unit root test of all nine cryptocurrencies. It is established that all nine cryptocurrencies except (Ethereum) are nonstationary (have unit roots) in the levels. On the other hand, they exhibit stationary behavior at the first difference, since the critical values are all smaller than the ADF test statistics at the 1% significance level.

The hypothesis tested was that:
H0: the variable has a unit root.
H1: the variable has no unit root.

Decision

If the statistical value t > critical value ADF no, then we should reject Ho and otherwise

We can see from the results that all nine cryptocurrencies exhibit stationary after the first difference.

Table 2 **Augmented Dickey-Fuller Test at First Difference**

TEST WITH CONSTANT AND TREND	LEVEL		FIRST DIFFERENCE	
VARIABLES	ADF TEST STAT	CRITICAL VALUES	ADF TEST STAT	CRITICAL VALUES
DOGE	-0.0108406	-2.75935	-0.899487	-20.4358
BITCOIN	-0.00314728	-1.42225	-0.885104	-11.3322
ETHER	0.00102599	0.452024	-0.908586	-11.6794
LITECOIN	-0.00814313	-2.31477	-0.899635	-14.6148
ZEC CASH	-0.00818906	-2.32528	-1.068	-13.8822
XMR	-0.00781266	-2.37236	-1.15309	-45.4587
XRP	-0.0151124	-3.54912	-0.775838	-8.2676
DASH	-0.0110679	-3.36724	-0.953801	-18.0865
ADA	-0.00525993	-2.13607	-0.534753	-5.86055

(*Sources*: Authors' computation)

Analysis of the Cointegration procedure

Anytime unit root test yields no stationary returns time series, it is usually analyzed using stabilized data obtained through the data first difference process to establish stationarity. The simple application of this process, on the other hand, may result in errors in the modeling of the long-term equilibrium relationship between variables, as well as information loss in the time series. As a result, a co-integration test is also performed to investigate the possibility of a long-term equilibrium relationship between the variables, which investigates the possibility of a long-term equilibrium relationship between the individual level variables diagnosed with unstable time series by a unit root test. We employ in this study, Engle Granger's co-integration test method, which is an expanded multivariate analysis. The VECM (Vector Error Correction models) is used in multivariate analysis; once the co-integration relationship is established, the linear combination is stable and long-term equilibrium can be analyzed. The results confirm that all nine (9) variables established a co-integration relationship and a long-term equilibrium was considered to have a co-integration relationship. The results show that when the time series is unstable due to the unit root, the error is caused by the VAR (Vector Autoregressive Model), and co-integration exists and represents a long-term equilibrium relationship. This study focuses on the Vector Error Correction Models instead of the Vector Autoregressive Model.We use the Johansen co-integration test after determining the optimal lag order of the VAR model.This is to determine whether there is a long-term and stable relationship between the price of Bitcoin, Ethereum, Dogecoin, Litecoin, ZEC Cash, DASH, Ada(Cardano), XRP (Ripple), and XMR (Stellar). The Cointegration test of the Vector is shown in the results with the formula $Yt = (= \alpha 1yt-1 + \cdots + \alpha pyt-p + \beta xt + et)$.

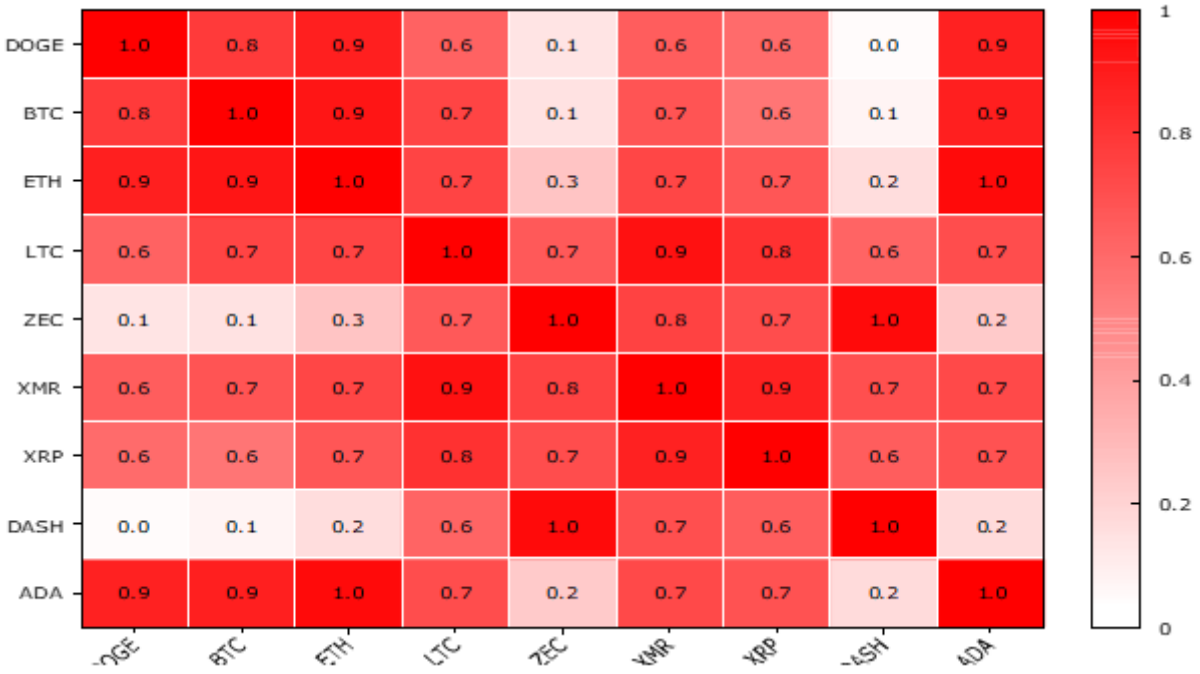
The results above at a p-value of less than 1% establish that there is a long-term relationship between the nine cryptocurrencies. The process starts with testing for zero cointegrating vectors and then accepts the first null hypothesis that is not rejected. From the results in Table 3, at the level of 10% significance, the results show that we should reject the null hypothesis of no co-integration but fail to reject the null hypothesis of at most one cointegrating vector.

Table 3 **Cointegrating regression**

OLS, using observations 2017-10-01:2021-12-01 (T = 1523)				
Dependent variable: BTC				
	coefficient	std. error	t-ratio	p-value
Const	1061.25	249.471	4.254	2.23e-05 ***
ETH	10.2253	0.448663	22.79	4.33e-099 ***
DOGE	−48819.8	2503.32	−19.50	9.57e-076 ***
LTC	100.596	4.89614	20.55	6.12e-083 ***
ZEC	−42.2808	4.08727	−10.34	2.79e-024 ***
XMR	70.9628	4.89609	14.49	1.12e-044 ***
XRP	−7137.76	638.774	−11.17	6.52e-028 ***
DASH	−15.4373	2.32764	−6.632	4.59e-011 ***
ADA	4062.4	686.197	5.92	3.97e-09 ***
Mean dependent var		17235.04	S.D dependent var	16989.61
Sum squared resid		2.85E+10	S.E. of regression	4341.033
R-squared		0.935057	Adjusted R-squared	0.934714
Log-likelihood		−14912.98	Akaike criterion	29843.95
Schwarz criterion		29891.91	Hannan-Quinn	29861.8
Rho		0.964756	Durbin-Watson	0.070094
Testing for a unit root in uhat Augmented Dickey-Fuller test for uhat including 7 lags of (1-L)uhat				

(*Sources*: Authors' computation)

Figure 2 **Correlation Matrix**

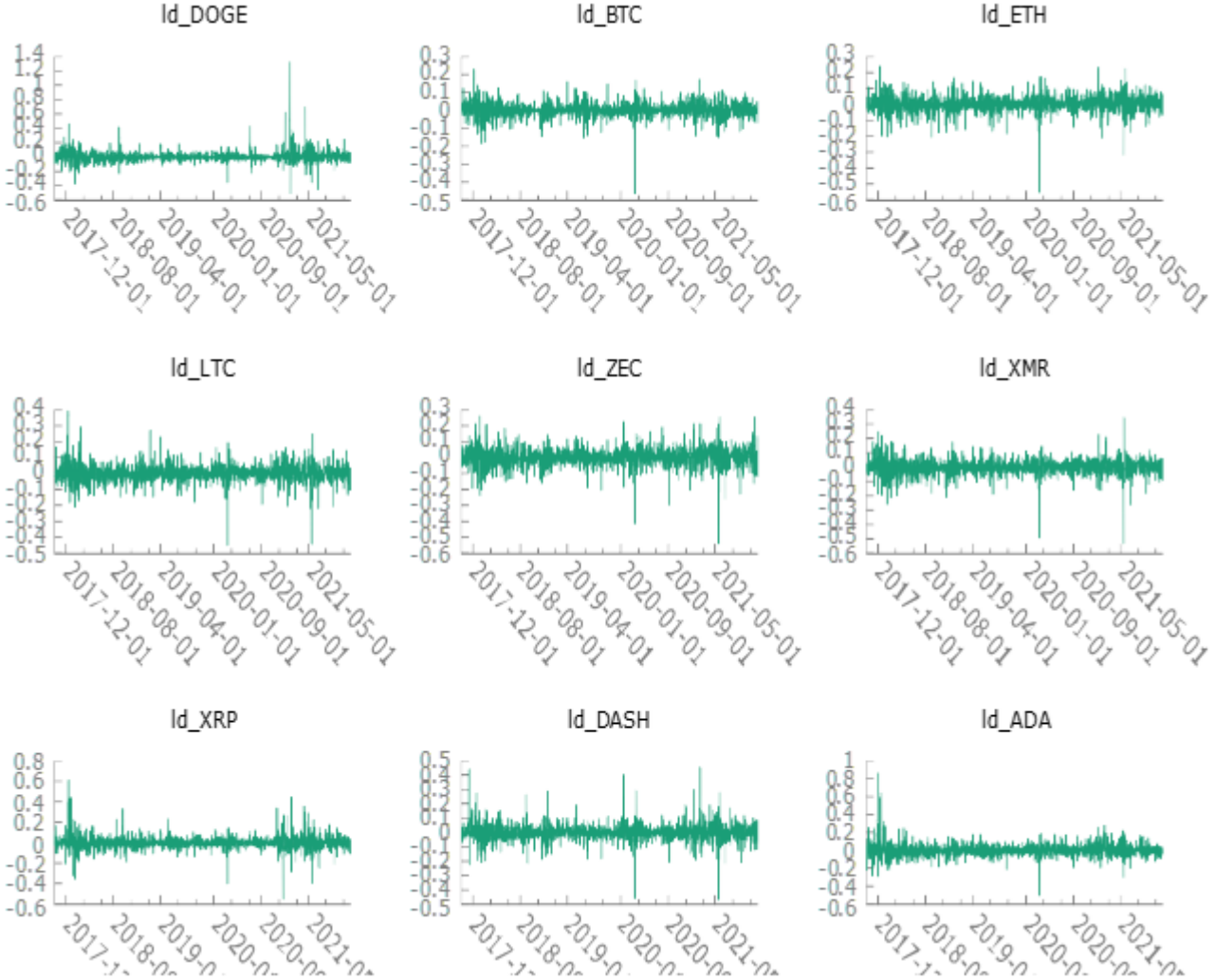


We present the estimated correlation returns among the nine cryptocurrencies using their closing prices. Sources: Authors' computation

The above pictorial diagram shows the correlation between the nine cryptocurrencies under study. There is a strong positive correlation between Bitcoin and Ethereum, followed by a strong positive correlation between Etherum and Dogecoin, Dogecoin and Ada, followed by Dogecoin and Bitcoin. On the other hand, there is less correlation between Dash and Dogecoin, followed by a less correlation between Dogecoin and ZEC. Again there is less correlation between Dash and Bitcoin, and Zec and Bitcoin.

From the daily closing price transaction, we calculated the log returns for each period, presented with an associated graph in the Figure above. The graph above shows the log returns of the nine cryptocurrencies. It is found that Bitcoin and Ethereum have a similar movement to Dogecoin that significantly departs from the two dominant crypto movements. Litecoin, ZEC Cash, XMR, and XRP also move together.

Figure 3 **Plot of Daily closing log returns**



(*Source*: Authors' computation)

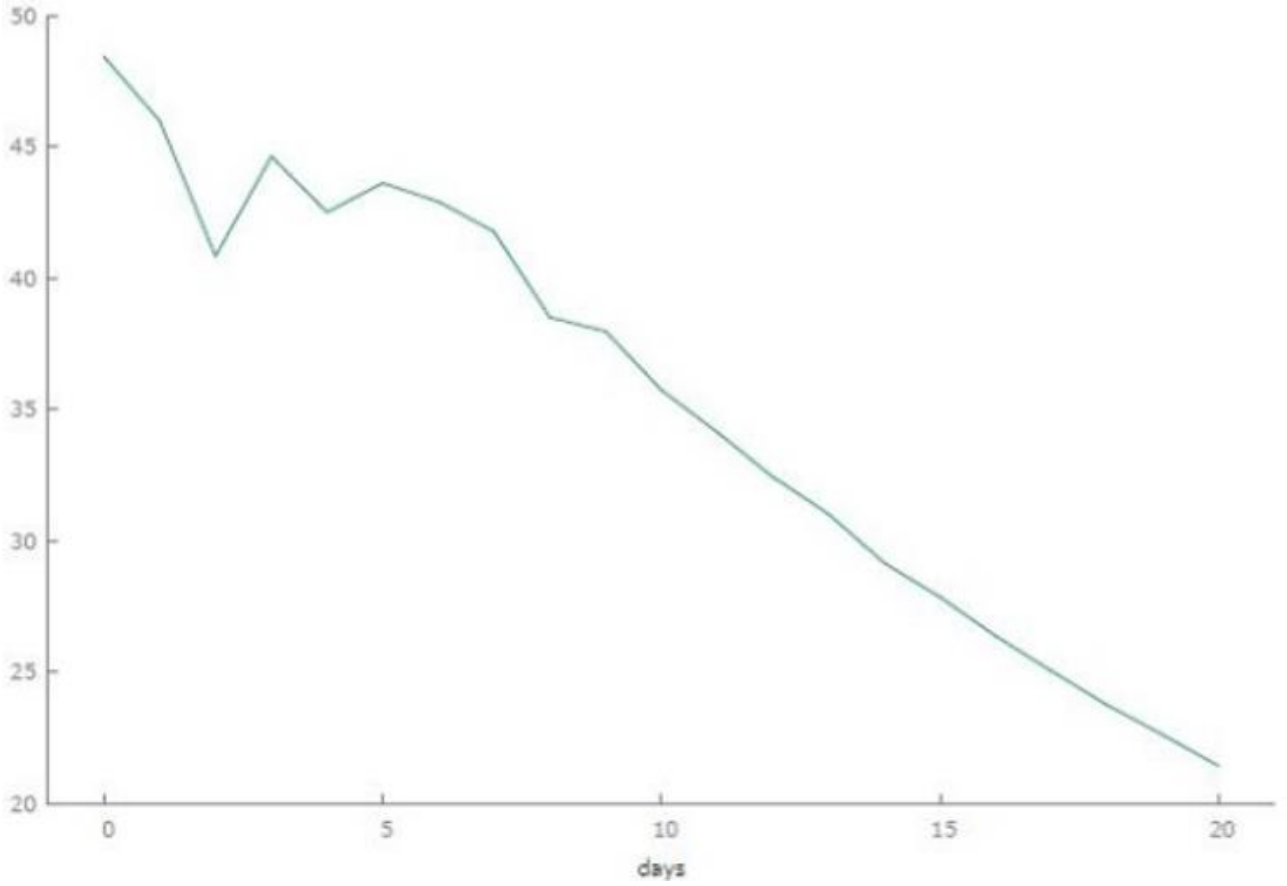
Engle and Granger were performed with GRETL. From the results generated using Engle and Granger, Bitcoin and Ethereum are used at an exogenous dependent value at optimal lag 7 . It can be seen that at a level of significance of 5 %, both Bitcoin and Ethereum are cointegrated with the other altcoins except for order difference BTC 4 and ETH3. Both Bitcoin and Ethereum generated a p-value of 0.1460 and 0.1413 respectively.

Table 4 **Engle and Granger results**

	coefficient	std. error	t-ratio	p-value	
const	−10.9904	4.0864	−2.690	0.0072	***
d_BTC_1	0.00544616	0.002664	2.045	0.0411	**
d_BTC_2	−0.00805265	0.002672	−3.014	0.0026	***
d_BTC_3	0.00816798	0.002677	3.051	0.0023	***
d_BTC_4	−0.00390954	0.002688	−1.454	0.146	
d_BTC_5	0.0104673	0.002684	3.899	0.0001	***
d_BTC_6	−0.00702915	0.002696	−2.607	0.0092	***
d_ETH_1	−0.109575	0.036095	−3.036	0.0024	***
d_ETH_2	0.095309	0.036118	2.639	0.0084	***
d_ETH_3	−0.0534320	0.036302	−1.472	0.1413	
d_ETH_4	0.0949338	0.036295	2.616	0.009	***
d_ETH_5	−0.152646	0.036306	−4.204	2.77E-05	***
d_ETH_6	0.184552	0.036616	5.04	5.22E-07	***
ZEC	0.0961086	0.06869	1.399	0.162	
XMR	0.130736	0.079586	1.643	0.1007	
XRP	4.24996	10.4075	0.4084	0.6831	
DASH	−0.104822	0.037004	−2.833	0.0047	***
ADA	51.0123	11.1103	4.591	4.77E-06	***
LTC	0.14942	0.076137	1.963	0.0499	**
DOGE	58.7446	42.6586	1.377	0.1687	
EC1	0.000465303	6.51E-05	7.145	1.40E-12	**
Mean dependent var		2.820492	S.D. dependent var		73.1132
Sum squared resid		7220429	S.E. of regression		69.4962
R-squared		0.108422	Adjusted R-squared		0.0965
rho		0.049963	Durbin-Watson		1.89981
Cross-equation covariance matrix:					
	BTC	ETH			
BTC	8.88E+05	45606			
ETH	45606	4762.8			
determinant = 2.14721e+009					

S

Figure 4 **Impulse response Function of ETH to a shock in BTC**



(*Sources*: Authors' computation)

30 days time horizon of Impulse Response function between Bitcoin and Ethereum based on VECM(Vector Error Correction models) with order lags 7.

Impulse Response Function

Compared with VAR, impulse response functions of VECM with order lag 7 help us establish that the series are cointegrated in the long run. The dynamic effects of the model response to shocks by using the two most dominant cryptocurrencies, Bitcoin and Ethereum to certain shocks were analyzed. As shown in the Figure above, it is found that Bitcoin shocks the price of Ethereum. This suggests that any positive shocks in Bitcoins prices have a large influence on the prices of Ethereum. Hence, the long-run movement is sustained over the 20 days under study.

4 DISCUSSION

Figures 1 and 3 also report the price and log returns for the nine-coins sample, respectively. The results are similar to those obtained for the returns. Volatility linkages increase considerably over time, especially towards the end of the sample, showing a strong level of interdependence. A closer look at the plot depicts that Bitcoin and Ethereum move in the same direction. This confirms the long-held view that any movement in the top dominant cryptocurrency, Bitcoin and Ethereum, leads to a shift in the corresponding altcoins.

Figure 2 also reports the correlation matrix. Dash and Dogecoin show a zero correlation between them. On the other hand, Bitcoin, Ethereum, and Ada are relatively less correlated with Dash. The results also show a similar pattern of Bitcoin and Ethereum exhibited in Figure 1 and Figure 3, the plot of the prices and returns of the cryptocurrency understudies. It can be referenced from the Correlation Matrix that there is a strong positive correlation between Bitcoin and Ethereum and a less strong positive correlation between Dogecoin and Ethereum, Dogecoin and Ada, followed by Dogecoin and Bitcoin.

On the other hand, there is less correlation between Dash and Dogecoin, followed by less correlation between Dogecoin and ZEC. The analysis above confirms that the current cryptocurrencies are highly interconnected in both returns and volatility over the sample period, making it an integrated market. This is also similar to the results of Ji et al. (2019), which show a strong shock transmission over the whole cryptocurrency market. Furthermore, the results are partly consistent with the results of Frances et al. (2018), who postulate that Ripple and Ethereum have contagious effects on other cryptocurrencies based on their analysis of the market interconnection. The study, on the other hand, contrasts with Schinkus, Duy, and Canh(2021), using a network analysis model to investigate 1636 cryptocurrencies until 2008. They concluded that Bitcoin does not influence the virtual currency market.

From the technical perspective, the market will be watching the movement of bitcoin and Ethereum to react. When Bitcoin and Ethereum fall, the over altcoins will also fall and vice versa. New crypto assets may continue to be coming to the market, but in reality, there is a great likelihood for them to follow the price movement of Bitcoin and Ethereum, which dominate the overall crypto market except for stablecoins. As shown in Table 2, which displays the results of ADF unit roots tests, it is further reviewed that all the nine cryptocurrencies exhibit a nonstationary unit root at every level except for Ethereum. A further ADF test at a significance level of 1% also at first differencing establish a stationary level for all the cryptocurrency since the tests statistics are greater than the critical values.
Moreover, the results generated using Engle and Granger, Bitcoin, and Ethereum are used at the exogenous dependent value at optimal lag 7. It can be seen that at a level of significance of 5 %, both Bitcoin and Ethereum are cointegrated with the other altcoins except for order differences between BTC 4 and ETH3. Both Bitcoin and Ethereum generated a p-value of 0.1460 and 0.1413, respectively.

CONCLUSION

An analysis of both the short-run and long-run interconnection and co-integration dynamics among the top 9 cryptocurrencies that have existed from October 2017 to November 2021 was conducted. It is established both in the short-run co-integration except for Ethereum, which in the long run also exhibits a co-integration. The choice was based on the cryptocurrency's market capitalization, market attractiveness, and features. The evidence generated shows there is a long-run relationship among the cryptos. Any price movement in Bitcoin and Ethereum, which dominates the market share at 41 % and 17%, respectively, leads to a change in the price or returns of the remaining altcoins. There may be possible drivers of the prices of the cryptos, but these studies concentrated on the interconnection or co-integration among cryptocurrencies with Bitcoin and Ethereum as dependent variables. Further studies can be conducted to analyze the possible price drivers or co-integration into the cryptocurrency market. The cryptocurrency market dominated by Bitcoin and Ethereum has an important impact on cryptocurrency prices in the long run; however, the evidence does not support the prediction in the short run since some of the altcoins are in the various stages of growth as compared with Bitcoin and Ethereum which has existed since 2008 and 2013 respectively.

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