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Analysis of Performance and Interdependency of Crypto-Currencies

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Abstract- Crypto-currencies are financial assets that have been created in the virtual world. It is a fully decentralized, secure, digital currency, based on the blockchain technology. A blockchain is a continuously growing list of records, which are linked and secured using cryptography. It is an open, distributed ledger that records transactions between two parties efficiently and in a verifiable and permanent way. Crypto-currency exchanges are online platforms where one can buy, sell or exchange crypto-currencies for another digital currency or fiat money. Crypto-currency is a recent concept and still an unexplored financial asset with a short history. In the recent times, crypto-currencies are viewed more as an alternative investment option rather than as a currency for exchange. Predicting the market price of any crypto-currency is very difficult because of the high volatility of the coins. The market values of crypto-currencies are highly fluctuating, and fluctuations affect the investor's belief. Investing in the highly volatile crypto-currency market is extremely risky.

The present work focuses on analyzing the performance of crypto-currencies and their interdependency in the market. This work aims to identify the crypto-currencies as a viable investment option in the highly volatile crypto-currency market. A set of crypto-currencies is selected based on their market capitalization. Using the closing price, the returns are evaluated and normalized. The correlations between returns of these coins are analyzed. Based on this, a portfolio of crypto-currencies with least correlation is formed. This will ensure sufficient market representation along with diversification to hedge against the market fluctuations.

Keywords – Crypto-currency, Blockchain, Market Capitalization, Correlation.

I. INTRODUCTION

Crypto-currencies are financial assets that have been created in the virtual world. It is a fully decentralized, secure, digital currency, based on the blockchain technology. Digital currencies, especially those which have an embedded decentralized payment mechanism based on the use of a distributed ledger are an innovation that could have a range of impacts on various aspects of financial markets and the wider economy (Chiu et al., 2014). The first digital currency, Bitcoin was invented by Satoshi Nakomoto in 2008 which permanently changed the world's investment universe to include purely virtual assets. Bitcoin is currently the most widespread unregulated digital currency. While many forms of virtual currencies have been circulating for a number of years, and many more have come and gone more recently, only Bitcoin has gained a market share that has made people outside of a small group of technology enthusiasts aware of its existence.

According to David (2015), money is typically defined by economists as having three attributes: it functions as a medium of exchange, a unit of account, and a store of value. Crypto-currencies somewhat meets the first of these criteria, because a growing number of merchants, especially in online markets, appear willing to accept it as a form of payment. However, the worldwide viable use of Bitcoin remains minute, signifying that few people use it as a medium of exchange.

Over a decade later, the original Bitcoin technology has advanced from a technical proof-of-concept to a serious and reliable investment asset. The fundamental blockchain technology has spread and gained recognition with numerous different crypto-currencies being created and actively traded. Virtual assets are now perceived as an entire asset class for alternative investments, with a large number of coins to choose from.

The rapid increase of the blockchain technology owes to the open-source nature of Bitcoin, with its source-code publicly available and a free software license that allows derivative works. Computer programmers worldwide can copy, modify and experiment upon the Bitcoin concept and work on the source-code, thereby creating many alternative crypto-currencies, known as altcoins. According to Elander et al., (2016), there are two types of altcoins, namely crypto-currencies and crypto-assets. Crypto-currencies have their own blockchain and require their own time stamping mechanism. Crypto-assets do not have their own blockchain or time stamping mechanism but instead are created off crypto-currency platforms and rely on the main crypto-currency's blockchain. It requires technical knowledge to create or even to clone an existing crypto-currency. Creating a crypto-asset on the other hand is relatively simple and does not require strong technical expertise.

Crypto-currencies exhibits very high time series volatility and it trades for different prices on different exchanges. Despite the dominance of Bitcoin, investing in the crypto-currency market requires analysis of individual crypto-currencies for their market performance and also the dependency of one crypto-currency on another. The present work focuses on analyzing the performance of crypto-currencies and their interdependency in the market.
The literature related to crypto-currencies is reviewed in section II. Section III illustrates the salient characteristics of crypto-currencies. Analysis of the crypto-currencies and formation of a portfolio based on the correlation of past returns of crypto-currencies is discussed in section IV.

II. LITERATURE REVIEW

According to Elendner et al., (2016), crypto-currencies display high expected returns with large volatilities, have low correlations with each other and other financial asset classes. Hence, the crypto-currency market provides valuable contributions to portfolio allocation. They observed that the deepening liquidity of crypto-currencies is complemented by the rise in market value, and the growing number of altcoins is contributing larger amounts to aggregate crypto-currency market capitalization. They evaluated pure portfolios of crypto-currencies, and found that portfolio based on market index CRIX displays lower risk than any individual of the crypto-currencies.
Investing in Bitcoin shows highly distinctive features, including exceptionally high average return and volatility (Briere et al., 2015). Their analysis on investing in Bitcoin with a diversified portfolio including both traditional assets and alternative investments shows that Bitcoin has safe-haven characteristics. Its correlation with other traditional and alternative assets was remarkably low. They clearly state that this early-stage behavior does not ensure its future performance.
Bitcoin platform's design principles and the underlying blockchain technology and processes are described (Bohme et al., 2015). Bitcoin's approach to transaction flow, centralization and decentralization in the Bitcoin ecosystem is analyzed. They point out the operational and privacy risks and regulatory issues associated with Bitcoin. They discuss the possible future payment modes and its technology, and discuss the difficulties and complexities of virtual currency interacting with the conventional financial system and the real economy. Moreover, virtual currency regulatory options and consumer protection are explained.

III. SALIENT CHARACTERISTICS OF CRYPTO-CURRENCIES

Crypto-currency is a recent concept and still an unexplored financial asset with a short history. In the recent times, crypto-currencies are viewed more as an alternative investment option rather than as a currency for exchange. The salient characteristics of crypto-currencies are discussed below:

3.1. Volatility –

Trading in Bitcoin is driven by uninformed investors. It has been theoretically proven that uninformed traders cause a high level of volatility. Thus one would expect a high volatility in Bitcoin trades. Various studies have shown that in crypto-currency market the average volatility increases with the time interval. According to Catania et al., (2018), from an econometric viewpoint, the process underlying the evolution of the crypto-currencies' volatility has been found to exhibit at the same time differences and similarities with other financial time–series. Moreover, the volatility of any crypto-currency varies from exchange to exchange across the market based on the events and news in each region. Overall, the Bitcoin price experienced high returns combined with periods of high volatility.

3.2. Returns –

Crypto-currencies, unlike most fiat currencies, exhibit sizable fluctuations in their market value even over short time horizons, and how this affects the risk inherent in an altcoin position and the related expected returns evolve over time. According to Elander et al., (2016), crypto-currencies' risk and return properties fluctuates over time, like Bitcoin have a lower mean when the standard deviation is higher, while Litecoin exhibit the opposite pattern. Apparently, the higher standard deviations result from opposing reasons: for some crypto-currencies from higher positive and for others from higher negative returns. Even simple properties of the return process as means and standard deviations are unstable over time.

3.3. Liquidity –

Liquidity is defined as the ability of an asset to be converted into cash, on demand, without any difficulty [5]. In the case of crypto-currency, liquidity translates into how easily it can be bought or sold for exactly the worth it has, i.e., without any need for discounts. A low liquidity level means the market is volatile, which causes large spikes in prices of crypto-currency. In contrast, high liquidity represents a stable market, where price fluctuations are minimal.

Crypto-currency liquidity is primarily dependent on how widely virtual currency is embraced by various networks. Bitcoin and other crypto-currencies are rapidly gaining acceptance as a mode of payment, particularly by the online stores. As of mid-September 2017, acceptance and use have risen almost 800%. Today, more than 370,000 vendors across 182 different countries accept crypto-currency, including U.S. giants like Amazon, Dell, IBM, Microsoft, Apple's app store, PayPal, eBay, Home Depot, Zappos, Target, Gap, Kmart, Sears, Netflix, Expedia.com, Overstock, and many others [5].

3.4 Trading Platforms –

Innovation and the ease of building on the Bitcoin have thus led to the creation of various altcoins available for investment and as media of exchange. Their online trades have huge differences in liquidity. Trading activity of common altcoins is conducted through online crypto-currency exchanges which commonly operate continuously, i.e., 24 hours per day, 7 days every week. The complete arrangement of trading hours throughout the year provides an aspect of liquidity that even the world's largest stock exchanges do not provide. According to David et al., (2017), most altcoins are traded against Bitcoin, effectively making it the virtual reserve currency. Only the most popular altcoins have trading pairs with fiat currencies such as the US Dollar, the Euro, the Chinese Yuan, or the Russian Ruble.

3.5. Information Platforms –

There are different sources of information that can be used to study the crypto-currency ecosystem. One of the primary sources of information is to use blockchain data. Various platforms like blockchain.info provides online Bitcoin wallets and also data such as price, mined blocks, number of transactions and other statistics. Since each crypto-currency has its own blockchain, the information for each altcoin needs to be obtained from each individual altcoin's block explorer, (Elander et al., 2016). While block-explorer services are suitable for the average user to obtain information related to the blockchain, application developers prefer more flexibility in interacting with the blockchain and choose for Application Program Interface (API) services such as BlockCypher.com and BitGo.com. Traditionally, developers need to host a Bitcoin node in order to obtain the latest transactions and blocks. With these services, the barriers to entry for developers to build apps on top of the Bitcoin blockchain are reduced. To get information on the latest price for Bitcoin, it needs to be obtained from the dozens of exchanges operating worldwide. According to Elander et al., (2016), each of these exchanges has their own market and orderbook and due to the differences in transaction volume, each Bitcoin exchange will quote different bid/ask prices. So far, there has not been a global standard in determining the Bitcoin "spot price." There are several initiatives to identify the true spot price of Bitcoin such as the Coindesk Bitcoin Price Index (BPI) and the Winkdex.

3.6. Crypto-Currency In India –

Bitcoin and other crypto-currencies have been operating within the country for a number of years now. As early as 2012, small scale Bitcoin trades were already taking place within the country, when only crypto hobbyists were involved in Bitcoin. By 2013, Bitcoin began gaining a level of popularity that was spreading across many countries. That year, a few businesses began to accept Bitcoin payment. In a short span of time, crypto-currency exchanges began to spring up within the country. Apart from the online exchanges, there are also a number of over-the-counter crypto shops in the country and see the beginning of a crypto economic hub. The move by the government to demonetize country's paper currency on November 2016, led many Indians to take up Bitcoin and other crypto-currency investments. This meant that they were successfully evading what would have been significant taxes if they circulate their wealth through the banking system [4]. Despite its vast population, India only contributes 2 percent of the total global crypto-currency market capitalization.

The Reserve Bank of India (RBI) has been consistent in warning citizens of the risk associated with crypto-currencies [4]. The bank has also issued statements detailing the potential negative security, financial, and legal ramifications of crypto investments. The Finance Ministry in the country has labeled crypto-currencies as not being legal tender during the Union Budget 2018 speech. While the government of the country hasn't banned crypto-currencies, they haven't exactly been endorsing it. In recent times, a debate has begun as to whether profits from crypto transactions must be taxed or not. The coming months will reveal the direction in which the crypto market will move as far as India is concerned.

The number of crypto-currencies in the market is large and analyzing all of them for investment is non-viable. Shortlisting a few currencies based on their return characteristics can help create a portfolio for investment. The portfolio can be further analyzed for their risk-return characteristics. In order to achieve this, the market is scanned for identifying the various types of crypto-currencies which have been under trading for at least a year. The identified crypto-currencies are further shortlisted based on their market capitalization. The highest capitalized

crypto-currencies are analyzed based on their return. These are also subjected to correlation analysis to identify the least correlated crypto-currencies to form a portfolio, thus providing a viable investment option. These procedures are detailed in the forthcoming section.

IV. CRYPTO-CURRENCY PERFORMANCE AND INTERDEPENDENCY ANALYSIS

This section serves as a description to the crypto-currency data procured and sorted for analysis. The various steps for data analysis of the crypto-currencies are explained in detail. In this section, the data structure and its component parameters are observed. This data analysis aims to identifying the movement of the crypto-coins relative to the other coins. The various steps followed for analyzing the data and identifying the least correlated crypto-currencies is discussed below.

4.1. List of Crypto-Currencies –

Initially the various types of crypto-currencies existing in the market are identified. Various coins are created day by day and many of them easily disappear from the market. Hence, the first step is to procure the list of existing coins in the market by streaming the data available in the public domain.

To procure the data, a code is developed in Python 3.2.4. This helps in extracting the list of crypto-currencies in market with ease. The data obtained from the site contains various information namely - ID, Url, ImageUrl, Name, Symbol, CoinName, FullName, Algorithm, ProofType, FullyPremined, TotalCoinSupply, PreMinedValue, TotalCoinsFreeFloat, SortOrder, Sponsored.

This data of existing crypto-currency coins in the market identified 1610 coins (as of 1st June 2018) that are currently being traded through online platforms or digital currency exchanges. From this data, the names of the coins are extracted from the list, and then sorted.

4.2. Crypto-Currency Selection –

To select the most outstanding crypto-currencies among all currently traded coins, they are sorted according to their market capitalization. In this second step, the market capitalization for the past one year is used and the time series data is merged to store the coin tickers and its market capitalization into an empty data frame in Python. This dataframe is converted to the same numeric data type, because online streaming causes possible difference in the data type and the existence of many 'Not a Number' (NaN) data type values representing the undefined values in the data. Then the annual average market capitalization of each coin is evaluated. To use the highly capitalized crypto-currencies, in the third step, those crypto-currencies of market capitalization greater than the mean of the annual average market capitalization of all the crypto-currencies are selected.

The list of crypto-currencies analyzed for its market-capitalization based on the availability of trading data for past 1 year from 1st June 2017 to 1st June 2018 is shown in Table 1. Table 1 contains the coin's ticket name along with their annual average market capitalization based on data for 1st June 2017 to 1st June 2018.

Table - 1 Annual Average Market Capitalization (AMC) for Selected Crypto-Currencies

Crypto-currency (Ticker)	A M C (in billions $)	Crypto-currency (Ticker)	A M C (in billions $)
Bitcoin (BTC)	157.3500	DigixDAO (DGD)	0.5392
Ethereum (ETH)	157.3500	Waves (WAVES)	0.5392
Dash (DASH)	66.4772	Steem (STEEM)	0.6718
Ripple (XRP)	3.8040	Lisk (LSK)	0.9908
Litecoin (LTC)	32.8184	Zcash (ZEC)	1.4039
Monero (XMR)	8.3556	E-Dinar Coin (EDC)	1.0896
NEM (XEM)	3.8755	VeChain (VEN)	0.0176
GameCredits (GAME)	3.6794	Verge (XVG)	2.3851
Factom (FCT)	0.1180	BitConnect (BCC)	1.1454
Bytecoin (BCN)	0.2546	Stratis (STRAT)	0.0094
Ethereum Classic (ETC)	1.0136	Tether (USDT)	0.6696
Dogecoin (DOGE)	2.2177	Aeternity (AE)	2.4177
Stellar (XLM)	0.6023	Siacoin (SC)	1.0521
MaidSafeCoin	7.9087	ReddCoin (RDD)	0.9316

(MAID)			
BitShares (BTS)	0.1722	Monaco (MCO)	0.2607
Iconomi (ICN)	0.9423	Groestlcoin (GRS)	0.1852
Ardor (ARDR)	0.1573	Median M C	0.9908

The median of the annual market capitalization of all the crypto-currencies traded during 1st June 2017 to 1st June 2018 is computed. Thereafter the market capitalizations of individual crypto-currencies are compared with this computed value and those crypto-currencies are shortlisted whose market capitalization values were higher than the computed value. The tickers of the shortlisted crypto-currencies are listed below:
['BTC', 'ETH', 'DASH', 'XRP', 'LTC', 'XMR', 'XEM', 'ETC', 'XLM', 'LSK', 'ZEC', 'VEN', 'XVG', 'BCC', 'STRAT', 'USDT']
These shortlisted crypto-currencies are further analyzed for their dependencies based on the return values which are explained as follows (Step 4 to Step 8).

4.3. Time Series Data Documentation –
The fourth step is to stream the online time series data. A Python code is built to execute the task of procuring the time-series Open-High-Low-Close (OHLC) data from the site. The entire OHLC data of the coin is extracted from the date of its creation and later a time period is set for analysis of the crypto-currencies. For this, the timestamp of the time-series data is converted into Greenwich Mean Time. While downloading the data, the maximal number of data rows that the online service allows us to download is limited to 2000 data points. The daily price-series is downloaded for 4000 dates back, which dates back to the year of 2010. Then the code for streaming the crypto-currency data versus a fiat currency is created wherein the list of tickers is specified for expressing the crypto-currencies versus the fiat currency. Here all the crypto-currency closing price data is expressed in USD to form the base data.

4.4. Pre-Processing Crypto-Currency Data –
The base dataframe contains significant amount of missing values. These NaN values can be distracting, but replacing them with a fixed value (like zero) will introduce invalid data. Interpolation can also create invalid data. An ideal way to sort out the issue is to filter all the data on a chosen date, forcing all the time series to start on the same date where data becomes available for all crypto-currencies. So in the fifth step, we create time series dataframes with time based filtering, to start and end on the same date so that the data will be continuous.

4.5. Time Series Returns –
The analysis of crypto-currencies is based on the returns stream. For this, the returns of each coin are evaluated from the time series data of the closing price of each coin. The time series data of the closing price of the crypto-currency is highly fluctuating, and so will the returns of the crypto-currency, which is evaluated as the difference of the closing price of present day to that of the previous day. In order to avoid the highly fluctuating data, the log returns of data are evaluated as the returns time series in the sixth step. The time series returns Ri(t) as described by Ruey (2010) is calculated as –

$$Ri(t) = (Pi(t) + Pi(t+1)) / Pi(t) \quad (1)$$

Where,
Pi(t) – Closing Price of crypto-currency 'i' on day t
Pi(t+1)) – Closing Price of crypto-currency 'i' on day t+1

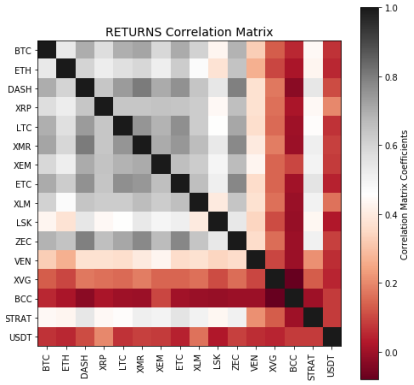
4.6. Normalization –
The mean and standard deviation of returns of each coin is estimated in the seventh step, and then normalized for each data point of the respective coin.

4.7. Correlaion Detection –
In order to analyze the dependency of a coin's movement on any other coin, the correlation matrix is obtained in the eighth step, which is shown in Table 2. The correlation coefficients between the various coins are obtained from the correlation matrix. This helps to analyze the relative movement between crypto-currencies. Table 2 shows the correlation coefficient between the crypto-currencies, and highlights the coins with least correlation.

Table - 2 Correlation Coefficient between Crypto-Currencies

	BTC	ETH	DASH	XRP	LTC	XMR	XEM	ETC	XLM	LSK	ZEC	VEN	XVG	BCC	STRAT	USDT
BTC	1	0.53	0.70	0.57	0.70	0.72	0.59	0.71	0.60	0.43	0.69	0.33	0.13	0.05	0.44	0.07
ETH	0.53	1	0.60	0.52	0.57	0.59	0.52	0.62	0.47	0.38	0.65	0.27	0.10	0.02	0.43	0.05
DASH	0.70	0.60	1	0.64	0.74	0.80	0.71	0.76	0.64	0.54	0.80	0.37	0.17	-0.03	0.54	0.11
XRP	0.57	0.52	0.64	1	0.64	0.64	0.65	0.64	0.62	0.44	0.66	0.37	0.16	0.02	0.44	0.20
LTC	0.70	0.57	0.74	0.64	1	0.75	0.69	0.77	0.62	0.46	0.71	0.37	0.15	0.00	0.45	0.07
XMR	0.72	0.59	0.80	0.64	0.75	1	0.71	0.75	0.66	0.53	0.78	0.40	0.18	0.00	0.51	0.09
XEM	0.59	0.52	0.71	0.65	0.69	0.71	1	0.66	0.62	0.49	0.67	0.43	0.14	0.10	0.50	0.08
ETC	0.71	0.62	0.76	0.64	0.77	0.75	0.66	1.00	0.66	0.51	0.78	0.36	0.15	0.00	0.55	0.04
XLM	0.60	0.47	0.64	0.62	0.62	0.66	0.62	0.66	1	0.40	0.64	0.37	0.16	-0.01	0.50	0.17
LSK	0.43	0.38	0.54	0.44	0.46	0.53	0.49	0.51	0.40	1	0.54	0.34	0.11	-0.01	0.44	0.03
ZEC	0.69	0.65	0.80	0.66	0.71	0.78	0.67	0.78	0.64	0.54	1	0.36	0.16	0.00	0.51	0.09
VEN	0.33	0.27	0.37	0.37	0.37	0.40	0.43	0.36	0.37	0.34	0.36	1	0.10	0.00	0.21	0.06
XVG	0.13	0.10	0.17	0.16	0.15	0.18	0.14	0.15	0.16	0.11	0.16	0.10	1	-0.08	0.13	0.05
BCC	0.05	0.02	-0.03	0.02	0.00	0.00	0.10	0.00	-0.01	-0.01	0.00	0.00	-0.08	1	0.00	0.08
STRAT	0.44	0.43	0.54	0.44	0.45	0.51	0.50	0.55	0.50	0.44	0.51	0.21	0.13	0.00	1	0.08
USDT	0.07	0.05	0.11	0.20	0.07	0.09	0.08	0.04	0.17	0.03	0.09	0.06	0.05	0.08	0.08	1

Analyzing the correlation matrix ensures that differences in measurement scales are accounted for. Coins with maximum correlation coefficient show that the coins have higher dependency with each other, whereas coins with low or zero correlation coefficient shows that their movements have low dependency or no dependency with each other.



Crypto-Currency Correlation Plot

4.8. Formation of Portfolio –

The pictorial representation of the correlation coefficients is depicted in Figure 1, which helps to visualize the coins with lower correlation (given in red). Since Bitcoin has the highest market capitalization and is the most traded, this forms a candidate in the portfolio. The correlation matrix is further analyzed for identifying the least correlated currencies with the Bitcoin. Here two crypto-currencies are identified namely, BitConnect and Tether, which has least correlation with the Bitcoin and hence has the possibility of being incorporated into an investment portfolio along with Bitcoin. This will ensure sufficient market representation along with diversification to hedge against the market fluctuations.

V. CONCLUSION

This work focused on the analysis of crypto-currencies based on their market performance and identification of dependencies between them. From the major crypto-currencies, the coins with higher market capitalization over the past one year are selected for the analysis. Using the closing price, the returns are evaluated and normalized for analysis. The correlations between returns of these coins are analyzed. Based on their correlation, it is observed that coins like BitConnect (BCC) and Tether (USDT) have least correlation, and hence can be considered for investment along with market dominator, Bitcoin (BTC). This analysis helped to identify possible crypto-currencies for investment based on the concept that assets with low positive or negative correlation must be used in a portfolio to ensure diversification, to hedge against market fluctuations. The reason for including assets that have low correlations or even negative correlations is that they will eliminate some risk known as idiosyncratic or diversifiable risk.

Since the crypto-currency market is highly fluctuating, and coins emerge and disappear in the market quite often, correlation analysis alone cannot be held as a criterion for selecting a crypto-currency into an investment portfolio. Further research to evaluate the probability of a crypto-currency to continue trading in the market can be explored as a future work, which can help validate the coin's selection into an investment portfolio. These portfolios can be analyzed further for their risk – return trade-offs.

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