Interdependencies Between Cryptocurrency Markets, Precious Metals and Energy Resources

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Abstract. In a rapidly changing world where no market or economy is secure, interconnectivity is becoming a key feature of almost all social and economic systems. As a brand-new digital asset, cryptocurrencies are quickly taking over the world economy. Cryptocurrencies are becoming alternative investments as a store of value compared to precious metals. The purpose of this study is to examine the connections between cryptocurrencies, precious metals, and energy resources using structured numerical data. To achieve this goal, two approaches are employed to create networks that reveal relationships between cryptocurrencies (Bitcoin, Ethereum, Cardano, Chainlink, Litecoin, Stellar, and Ripple), precious metals (Gold, Silver, and Platinum), and energy resources (Oil and Natural Gas) based on their daily prices and returns. The interdependence of the networks is further examined to reveal similarities between the created networks. The proposed methodology facilitates an understanding of the dynamics of cryptocurrency markets, the factors that influence them, and the potential for future research to expand and include additional cryptocurrencies.

Keywords: Cryptocurrencies · Precious metals · Energy resources · Interdependence · Networks

1 Introduction

Globalization has a tremendous impact on the structure of the financial markets and the development of the economy in our interconnected world. The swift

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development of progressive technologies has brought about significant changes in various industries and society as a whole. These technologies have the potential to improve efficiency, productivity, and decision-making, thereby contributing to economic growth. One such advancement is the emergence of digital currencies, particularly cryptocurrencies. Cryptocurrencies are a type of digital currency that utilizes cryptography for security. They are decentralized, meaning they are not under the control of any government or financial institution. The most well-known digital currency is Bitcoin, but there are many others like Ethereum, Litecoin, and Ripple. Cryptocurrencies have gained popularity due to their potential for fast and cheap transactions, as well as their ability to operate outside of traditional financial systems. These days, cryptocurrencies are a crucial component of the world financial system [1].

Interdependencies between cryptocurrencies have been analyzed to understand better the dynamics in the cryptocurrency markets and the different processes that influence their performance [2]. To examine the interconnectivity of cryptocurrencies and potential price shifts due to such influence, centrality measures have been calculated to extract insights from cryptocurrency networks [3]. Researchers investigated the impact of stock market indexes S&P500 and Dow Jones on the prices of eighteen major cryptocurrencies, utilizing the cutting-edge time series prediction library (XGBoost) to develop daily price prediction models for all cryptocurrencies [4]. Another study seeks to explore the relationships between cryptocurrencies and traditional financial markets, analyzing connectivity networks of seven cryptocurrencies and seven conventional economic indicators using an explainable AI model that learns asset dependencies and presents them in a human-understandable format [5]. The relationship between Bitcoin's power consumption and the market is the target of a study that finds a relationship between Bitcoin's power consumption and its daily returns as well as trading volume. Bitcoin's second crash also causes a high correlation with electricity consumption [6]. Investing in Bitcoin compared to gold as a hedge against oil-related uncertainties caused by the COVID-19 pandemic has found gold to act as an increasingly weak diversifier as the pandemic intensifies [7]. Another study researches tail spillover effects between cryptocurrencies and uncertainty in the gold, oil, and stock markets using a cross-quantile approach. They preview that cryptocurrency and traditional markets are inconsiderably connected under normal conditions [8]. The negative consequences of cryptocurrencies' high-power energy consumption on the environment and sustainability have piqued the curiosity of a wide number of regulators and market actors. One study employs a network method to examine the interdependence between clean energy, green markets, and cryptocurrency [9]. Another study will use three machine learning models to investigate the effect of cryptocurrencies and the US dollar in predicting oil prices before and during the COVID-19 outbreak. Support vector machines, Multilayer Perceptron Neural Networks, and Generalized Regression Neural Networks are all examples of neural networks [10].Interdependence about information among multiple commodities such as energy, metals and agricultural commodities, and cryptocurrencies have been

examined using a time-varying entropy-based approach, minimum spanning tree, and various centrality measures [11].

This paper expands on earlier studies by integrating traditional commodities and the growing cryptocurrency market.

2 Data

We have chosen the seven cryptocurrencies with the highest market capitalization from the more than 22,000 listed on Coinmarketcap[1]. Additionally, we select three of the most popular precious metals and two publicly traded energy resources. We then retrieve historical prices for each asset from the resources Yahoo Finance[2] and Investing[3] We gather data for the time period between November 2019 to November 2022, a period of high volatility and price swings.

2.1 Cryptocurrencies

We select seven cryptocurrencies based on relevance and largest market capitalization over the years: Bitcoin, Ethereum, Cardano, Ripple, Litecoin, Chainlink, and Stellar. For every cryptocurrency, the price dataset includes the date, open and close prices, high and low prices, volume and adjusted closing price.

2.2 Precious Metals and Energy Resources

The three most popular and most traded precious metals we select are Gold, Silver, and Platinum. Additionally, we choose to use Crude Oil and Natural Gas, two publicly traded energy resources, due to their significant economic impact. For each precious metal and energy resource, the historical price dataset includes the date, open price, high and low prices, close price, adjusted closing price, and volume.

3 Methodology

Our research models the relationships between cryptocurrencies, precious metals, and energy resources using a correlation-based approach [12].To uncover correlations between cryptocurrencies, precious metals, and energy resources, we employ Pearson's correlation coefficient as a starting point. Pearson's correlation coefficient is a descriptive statistic that summarizes the characteristics of the dataset. It describes the strength and direction of the linear relationship between two quantitative variables.

[1] https://coinmarketcap.com/.
[2] https://finance.yahoo.com/.
[3] https://www.investing.com/.

3.1 Daily Price Correlations

We first use daily prices to obtain time series of daily prices for cryptocurrencies, precious metals, and energy resources by taking the last price at the close of the trading market. As cryptocurrencies are traded 24/7, we take the last price at 11:59 p.m. UTC. However, precious metals and energy resources are not traded on weekends and certain holidays, so we use the previous day's price for days when the market is closed, and no price data is available. This ensures that we have datasets of identical size for all cryptocurrencies, precious metals, and energy resources so that we can accordingly calculate daily correlations. We use these daily correlations to create the first three networks: a network created using cryptocurrency prices, a network created using precious metals and energy resources prices, and a network created using cryptocurrency, precious metals, and energy resources prices.

3.2 Daily Return Correlations

Second, we use daily returns to obtain time series of daily returns correlations for cryptocurrencies, precious metals, and energy resources. The daily return is a measure of the percentage change in the value of an investment or portfolio over the course of a day. It represents the gain or loss in the value of an economic asset as a result of changes in market conditions, economic events, or other factors that may affect the asset's performance. This metric can be calculated if the price of a certain economic asset within a given time period is known. The daily return is calculated as the difference between the current price of the asset and its price on the previous day, divided by the value on the previous day. To obtain the percentage of the daily return, the required result should be multiplied by one hundred as shown in the following Eq. 1.

$$Daily\ Return = \left(\frac{current\ day\ closing\ price - previous\ day\ closing\ price}{prior\ day\ closing\ price}\right) * 100 \tag{1}$$

For example, if an asset has a positive daily return of 1%, it means that its value has increased by 1% from the previous day's closing price. Daily return is used to assess short-term performance and provide insight into the volatility and risk of an investment. To calculate daily returns, we use the daily price time series data. We then calculate the Pearson correlation coefficient using the daily return time series to obtain daily return correlations. Based on these correlations, we create networks for cryptocurrencies, precious metals, and energy resources.

3.3 Centrality Measures

Centrality measures in network theory are quantitative metrics used to assess the importance or influence of nodes within a network. These measures aim to identify nodes that play crucial roles in terms of their position, connectivity, or control within the network. For this research we use the following measures: eigenvector centrality, node strength, and closeness centrality.

Eigenvector centrality takes into account both the number and quality of a node's connections. It assigns higher centrality to nodes that are connected to other highly central nodes. This measure captures the idea that the importance of a node is determined by the importance of its neighbors.

In network theory, node strength refers to a measure of the total strength or importance of a node in a weighted network. Node strength is calculated by summing the weights of all the edges connected to a specific node. It provides a quantitative measure of the overall influence or significance of a node in the network based on the total weight of its connections.

Closeness centrality measures how close a node is to all other nodes in the network. It calculates the average shortest path length between a node and all other nodes in the network. Nodes with higher closeness centrality are more central as they can reach other nodes more quickly.

4 Results

In our research, we study the intra and inter-dependencies of cryptocurrencies and precious metals, and energy resources, however, we pay special attention to the links between different types of economic assets. We use the strongest 1/2 of all links to create networks based on correlations between assets of the same type, however, we use the strongest 1/3 of all links when creating networks based on correlations between assets of different types.

4.1 Networks Created Using Daily Price Correlations

First, we study the cryptocurrency network generated using daily price correlations, shown in Fig. 1. This network shows the interdependence between cryptocurrencies with respect to their price.

We observe that Bitcoin is the most influential cryptocurrency, with four strong links, followed by Ethereum, Litecoin, Chainlink, and Stellar, which have three strong links each. The strongest connection in this network is between Litecoin and Stellar, with a value of 0.96.

Next, we observe the network of precious metals and energy resources generated using daily price correlations, shown in Fig. 2. This network only shows the interdependence between precious metals and energy resources with respect to this data.

We see that Platinum is the most influential among precious metals and energy resources, with the highest number of strong links, 3 in total, followed by Gold and Silver, with two strong links each. The strongest relationship is between Oil and Gas, with a value of 0.84.

Figure 3 shows the network of cryptocurrencies, precious metals, and energy resources created using daily price correlations. This network shows the interdependence between cryptocurrencies and precious metals, and energy resources in terms of their price.

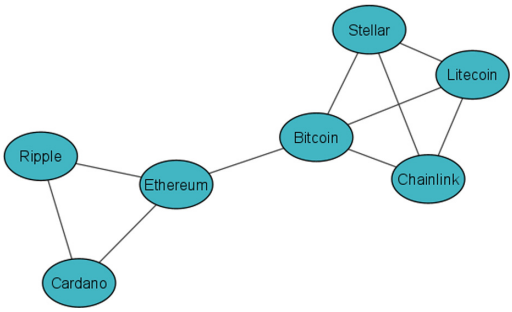

Fig. 1. Network showing one-half of the strongest network links based on cryptocurrency daily price correlations.

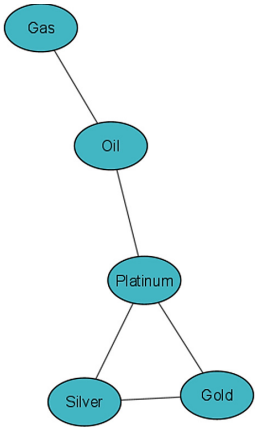

Fig. 2. Network showing one-half of the strongest network links based on precious metals and energy resources daily price correlations.

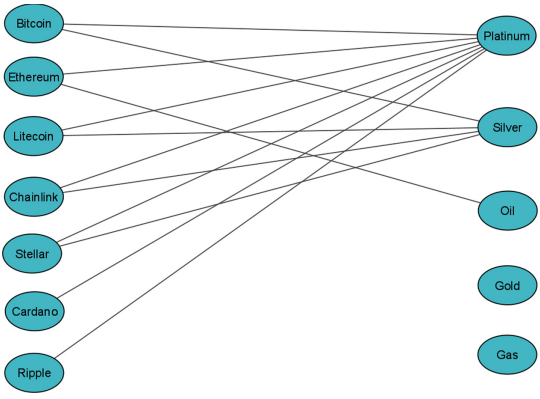

Fig. 3. Network showing one-third of the strongest network links based on cryptocurrency, precious metals and energy resources daily price correlations.

We find that Platinum has the highest degree of the node (7), followed by Silver which has the degree of the node (3). Cryptocurrencies in this network all have low node degrees. The strongest link in this network is between Stellar and Platinum, with a value of 0.72.

Table 1 shows the centrality measures for the network of cryptocurrencies, precious metals, and energy resources created using daily price correlations. The eigenvector centrality is highest for Platinum with a value of 0.46, followed by Silver with a value of 0.41, and Bitcoin with a value of 0.3. All other cryptocurrencies have similar values for this measure ranging between 0.24–0.27, while Gold and Gas have the lowest with 0.18 and 0.16. The node strength measure is highest for Platinum with a value of 4.33, Silver with a value of 3.82,2, and Oil with a value of 2.48. Among cryptocurrencies, the values are similar and range between 1.75–1.9, with the exception of Bitcoin and Ethereum, which have values of 2.3 and 2.26, respectively. The closeness centrality measure is highest for Platinum with a value of 4.83, for Stellar cryptocurrencies with a value of 4.55, followed by Chainlink, Litecoin, and Bitcoin with values of 4.32, 4.28, and 4.23, respectively. From the data, we can notice that Platinum has the strongest influence. Cryptocurrencies are not as influential, with the exception of Stellar, which exhibits high closeness centrality.

4.2 Networks Created Using Daily Return Correlations

Figure 4 shows the cryptocurrency network created using daily return correlations. This network shows the interdependence between cryptocurrencies in terms of this variable. We see that Ethereum, Cardano, and Litecoin are the most influential cryptocurrencies, with four strong links each, followed by Chainlink, with three strong links. The strongest connection in this network is between Ethereum and Litecoin, with a value of 0.82.

The network of precious metals and energy resources created using daily return correlations is shown in Fig. 5. This network only shows the interdependence between precious metals and energy resources with respect to this variable. From this network, we can conclude that Platinum is the most influential among precious metals and energy resources, with a total of 4 strong links, followed by Gold and Silver, with two strong links each. In this network, the closest connection is between Silver and Gold, with a value of 0.77.

Figure 6 shows the network of cryptocurrencies, precious metals, and energy resources created using daily return correlations. The network displays the interdependence between cryptocurrencies and precious metals, and energy resources in terms of this variable. We can notice that Platinum has the highest node degree (5), followed by Silver and Bitcoin, which has the node degree (4). The strongest link in this network is between Litecoin and Silver, with a value of 0.1.

Table 2 shows the details of centrality measures for the nodes of this network. The eigenvector centrality is highest for Silver with a value of 0.45, followed by Platinum with a value of 0.41, and Bitcoin with a value of 0.37, and Litecoin with a value of 0.34. All other cryptocurrencies have values for this measure ranging between 0.15–0.3. The measure for node strength is highest for Silver

Table 1. Centrality measures for the network based on cryptocurrency, precious metals and energy resources daily prices.

Asset	eigenvector centrality	node strength	closeness centrality
Bitcoin	0.3	2.3	4.23
Cardano	0.25	1.9	3.07
Stellar	0.27	1.87	4.55
Ripple	0.24	1.84	3
Chainlink	0.27	1.87	4.32
Litecoin	0.26	1.75	4.28
Ethereum	0.27	2.26	3.14
Gas	0.16	1.46	2.01
Oil	0.26	2.48	2.75
Gold	0.18	1.69	1.91
Silver	0.41	3.82	3.72
Platinum	0.46	4.33	4.83

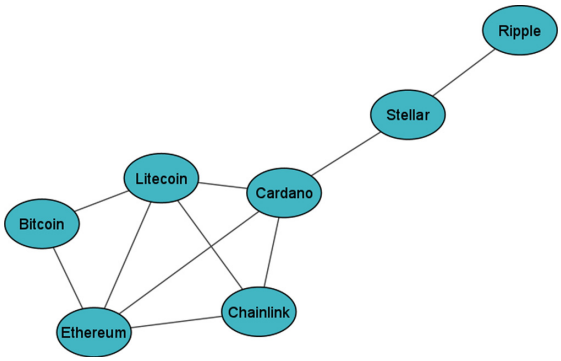

Fig. 4. Network showing one-half of the strongest network links based on cryptocurrency daily price correlations.

with a value of 0.47, Platinum with a value of 0.45, and Oil with a value of 0.31. Among cryptocurrencies, the values range between 0.11–0.28, with the exception of Bitcoin, which has a value of 0.34. The measure of closeness centrality is highest for Silver, with a value of 21.29, and Platinum, with a value of 19.1, among cryptocurrencies Bitcoin, with a value of 20.43, followed by Litecoin, with a value of 20.21. The other cryptocurrencies have a value between 11.22–15.9. From the data, we can notice that Silver has the strongest influence. Cryptocurrencies are not as influential, with the exception of Bitcoin, which exhibits high closeness centrality.

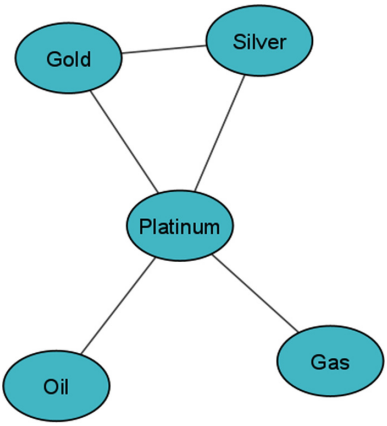

Fig. 5. Network showing one-half of the strongest network links based on precious metals and energy resources daily return correlations.

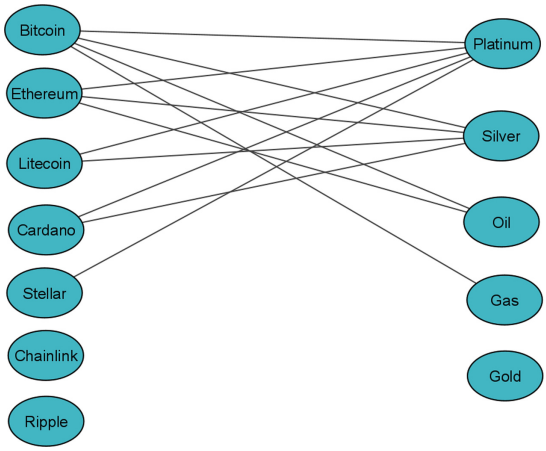

Fig. 6. Network showing one-third of the strongest network links based on cryptocurrency, precious metals and energy resources daily return correlations.

5 Discussion

Our research provides an analysis approach for dependencies between cryptocurrencies and some precious metals and energy resources. The methodology we apply is based on organized numerical data that is freely available to the public collected on a daily basis. We calculate correlations based on daily prices and daily returns using this data. Then we investigate the relationships between seven cryptocurrencies (Bitcoin, Stellar, Cardano, Litecoin, Chainlink, Ethereum, and Ripple), three precious metals (Gold, Silver, and Platinum), and two energy resources (Gas and Oil), both based on their daily prices and daily returns. We

Table 2. Centrality measures for the network based on cryptocurrency, precious metals and energy resources daily returns.

Asset	eigenvector centrality	node strength	closeness centrality
Bitcoin	0.37	0.34	20.43
Cardano	0.26	0.22	14.02
Stellar	0.15	0.11	11.33
Ripple	0.17	0.14	11.22
Chainlink	0.2	0.16	12.01
Litecoin	0.34	0.28	20.21
Ethereum	0.3	0.27	15.9
Gas	0.15	0.14	11.6
Oil	0.29	0.31	14.04
Gold	0.17	0.16	11.11
Silver	0.45	0.47	21.29
Platinum	0.41	0.45	19.1

create networks using the correlations to gain insight into the interdependencies between cryptocurrencies, precious metals, and energy resources. Our results show that when daily price correlations are used, Platinum stands out with the strongest measures of centrality out of the precious metals, followed by Silver which has higher degrees compared to cryptocurrencies, which do not appear to be as central, except for Stellar, showing a strong closeness centrality. When we analyze the correlations of daily returns, our results show that Silver has the strongest measures of centrality, followed by Platinum which has higher degrees compared to cryptocurrencies, with the exception of Bitcoin, which stands out with the strongest measures of centrality among cryptocurrencies. In addition, energy resources, oil, and gas, show a very low correlation with cryptocurrencies and precious metals, with the exception of Bitcoin and Ethereum, with which they have a medium correlation, which may be due to different market dynamics and influence.

Based on the results we obtained, it is evident that there is a strong correlation between precious metals and cryptocurrencies. This can be attributed to the strategy adopted by both individual and corporate investors to diversify their investment portfolios by including speculative and risky investments in cryptocurrencies, which have the potential for significant returns. Cryptocurrencies are often considered an alternative investment opportunity and are compared to precious metals in this context. In contrast, precious metals have a long history as a store of value and a hedge against inflation and economic uncertainty. They are frequently utilized as a safe haven asset during periods of market volatility and geopolitical instability.

Both cryptocurrencies and precious metals have limitations of use, although these limitations differ in nature. While cryptocurrencies can be used to buy

goods and services from merchants who accept them as payment, their acceptance is still limited compared to traditional forms of payment like cash or credit cards. Precious metals have been traditionally used as a store of value and a means of exchange, but they have limited use in day-to-day transactions. They are not easily divisible, and their physical nature makes them difficult to transport and store securely. Overall, depending on the specific needs and circumstances of the users, both cryptocurrencies and precious metals have their limitations and benefits.

6 Conclusion

In this paper, we present a methodology for analyzing the connections between cryptocurrencies, precious metals, and energy resources based on publicly available datasets of structured data. We create and analyze networks of seven cryptocurrencies (Bitcoin, Cardano, Ripple, Stellar, Chainlink, Ethereum, and Litecoin), three precious metals (Gold, Silver, and Platinum), and two energy resources (Oil and Gas) using a correlation of their prices and daily returns data.

The results of this paper show that by looking only at the cryptocurrency market, we can not pick a single main driver that moves the market. However, when we look at precious metals and energy resources alone, the main driver is definitely Platinum. In addition, when we cross-reference the cryptocurrency, precious metal, and energy resource markets, it is interesting to note that Platinum is highly correlated with all cryptocurrencies.

While cryptocurrency markets are new and unpredictable, they are positioned to integrate into the traditional financial system through growing usage of blockchain technology or by providing alternative payment methods in order to create a unified global currency. The relationship between cryptocurrency markets and precious metals, oil, and gas markets is not direct and can be considered to be not significant.

While all of these markets can be affected by global economic and geopolitical factors, they have different underlying drivers and face different challenges. For instance, the value of precious metals can be influenced by factors such as central bank policy, while the price of oil and gas is largely driven by supply and demand dynamics. The value of cryptocurrencies, on the other hand, is driven by factors such as investor sentiment and adoption. However, in some cases, changes in the value of cryptocurrencies, precious metals, oil, and gas can have an impact on the other market, but this is not always the case. It is important to keep in mind that markets are very dynamic, and correlations can change over time.

The methodology we show in this paper is a basis for understanding the complex world of cryptocurrencies and traditional markets, including precious metals and energy resources, as well as a stimulus for further research in this area. Our methodology is scalable and may be developed to incorporate a greater number of cryptocurrencies and other traditional economic indicators, as well as to cover a larger time period. We hope that our research will contribute to greater understanding of various financial markets and the influence of major events, taking into consideration both traditional and innovative emerging markets.

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