

An Investigation of Fiat Characterization and Evolutionary Dynamics of the Cryptocurrency Market

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Abstract

Recent developments in global financial markets revealed that cryptocurrencies experienced rapid growth due to the popularity of blockchain technology and its evolving position in the digital finance industry. The rise of cryptocurrencies led economists to question generally accepted financial practices. Particularly the interaction between two different types of financial markets arose as a hot research topic to discover specific relationships and differences between major cryptocurrencies and fiat currencies. Therefore, this article aims to examine analyze by attaching importance to the Bitcoin to investigate significant linkages and analyze critical direct and indirect connections. In this research, Bitcoin—which is known as the most prominent cryptocurrency on the market—and 50 different conventional currencies are taken into consideration by applying cross-correlation, HT (hierarchical tree), and MST (minimum spanning tree) methods. The results of this work can be utilized by academicians and economists for further research related to the subject.

Keywords

blockchain, cryptocurrencies, Bitcoin, fiat currencies, cross-correlation, minimum spanning tree, hierarchical tree

Introduction and Literature Review

In today's world, it is essential to keep track of how innovations and technological developments shape our perspectives on life, especially when the subject comes to financial issues. A complex system is commonly defined by the collective approach of its components. Complex behavior is studied in financial markets by many physicists. Their approach was to identify the complexity of the methods and concepts that are originally emerged to promote and evaluate systems of a given physical structure (Amaral et al., 1998, Kertesz & Kondor, 1999; Kwapien & Drozd, 2012; Mantegna & Stanley, 1995, 1999). Complexity financial markets are heavily investigated on the behavior of the group of stocks (i.e., their correlation). This interest has extended its scope from scientific to practical circumstances where investment risk measurement plays a critical role (Bouchaud & Potters, 2000; Campbell et al., 1997; Elton & Gruber, 1995). The key matter on the subject is to observe the correlated behavior of the given financial assets either in terms of their relation to a noise that is driven by the market's dynamic that is structure or the individual interactions. Given the fact that the market has a finite set of historical data and the market is not always predictable with conventional methods, the complex stochastic behavior of the dynamic environment is not enabling an easy approach to address the above matter (Plerou et al.,

1999; Rosso et al., 2007; Wold, 1938). With the impact of digitalization in modern times, the world economy undergoes a transformation as it has been in every field. The latest financial crisis had the largest influence on the perception of financial institutions. It has reintroduced the skeptical perception in terms of the monetary policy for monopolizing the currency. Evidently, it has inflamed the criticisms across the world and ended up with the introduction of new asset mechanism, namely crypto-assets. Along with these developments, a new era has begun with the introduction of Bitcoin. "The technology behind the new era made the state-owned structures challenging with a disruptive paradigm shift for the conventional financial system and its stakeholders" (He, 2018).

In recent years, a substantial rise in the popularity and prevalence of cryptocurrencies in the financial environments

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has emerged due to the role of blockchain system which was considered as an important part of the ongoing worldwide revolution (Corelli, 2018). The high growth rate of blockchain technology acted as a catalyst for change in the finance industry especially after the concept of Bitcoin introduced by Nakamoto (2008). According to the data and calculations gathered from *coinmarketcap.com*, increasing trend of cryptocurrencies can be clearly observed. The cryptocurrency market has reached its peak during the early days of January 2018 with the capitalization of 823 billion dollars where Bitcoin at that time has the value of approximately 284 billion dollars and dominated the market with having around 35% of the total market share. Today, Bitcoin still dominates the cryptocurrency market as a prominent figure with having more than 50% of the total market share (Cryptocurrency Market Capitalizations).

Malović (2014) stated that Bitcoin accepted as an international currency alternative by many authorities. However, still, a considerable amount of the experts does not approve the concept of cryptocurrencies as an appropriate unit of currency, although it has gained widespread acceptance in terms of exchange or payment operations and value storage. For this issue, Glaser et al. (2014) introduced a discussion for Bitcoin's practical use in a community. The argument on the research was standing on the limitations of Bitcoin as a currency considering its position in daily use (Glaser et al., 2014). From another point of view, Baur et al. (2018) also discussed the concerns over the limitations of Bitcoin and introduced an argument over the existing and prospects of the cryptocurrency considering its structure as an asset or as a medium of exchange.

In other words, researches toward identifying the characteristics of virtual currencies regarding the notion of Bitcoin and cryptocurrencies are still in great demand. In this respect, Kubát (2015) focused on the definition of Bitcoin intended for answering the question "What is Bitcoin?" from different aspects as well as technical functions. In any case, to make a proper definition or a clear distinction explicitly for the features of Bitcoin with respect to other currency types accepted as a difficult and complicated issue for the financial analysis. In this matter, as Dyhrberg (2016) pointed out that it is difficult to define Bitcoin; similarly, Klein et al. (2018) emphasized that the difficulty over the analysis of cryptocurrencies with conventional currencies due to its decentralized structure where the link between them does not exist. In this context, it is obvious that understanding the relationship between cryptocurrencies and fiat currencies particularly from monetary approach reveals a significant financial dilemma and investigating connections of the two economical field, currently considered a notable area of research.

The fundamentals of valuation for the cryptocurrencies do not gain a clear understanding and it is still regarded as an unspecified process by some authorities. In general, fiat currencies are usually accepted as government-issued currencies in any country (Islam et al., 2018) that regulated by a trusted central authority. The effect of the central authority as

a ruler and regulator of the economy felt by financial institutions deeply. In contrast, neither governments nor banks are behind the technology of Bitcoin. The main reason for this is the decentralized structure of the cryptocurrencies (Grinberg, 2012). By this reason, the adoption process of Bitcoin in the system by consumers causes several challenges. One of the most important challenges declared as lack of regulation of Bitcoin. It is mainly because of the uncertainties surrounding authorities for the regulatory marks on a global scale (McDougall, 2014) and is also because there is no authority or a federal reserve bank to regulate the system and to impose a monetary policy (Özdemir et al., 2018). In this subject, by analyzing relationships between virtual currencies and national currencies in her paper, Sauer (2016) presented significant results to outline problems that stem from monetary policy framework, related to this issue about monetary status and value of currencies. The paper discussed the value of assets backed by blockchain-based cryptocurrencies heavily relies on the expectation of a community that will utilize the asset. The argument is proposed in opposition to the value of fiat currencies. In the latter, the value is driven by monetary policies and related policymakers (He, 2018).

Since the valuation and pricing mechanism of cryptocurrencies do not have a solid basis according to the defenders of conventional currencies due to the lack of monetary policies, the value or price of cryptocurrencies fluctuates frequently and does not have a stable position on the market. Regarding this issue, many types of research have been conducted to explore how cryptocurrencies can be classified in terms of its valuation mechanism and volatility behavior and the way of its correlation with the well-positioned assets (Klein et al., 2018). Before going into details, it is essential to examine the potential drivers of Bitcoin prices (Kristoufek, 2015) to investigate floating structure and unsteady characteristics of cryptocurrencies in comparison with national currencies in detail.

There is an increase recently in studies analyzing market behavior of virtual currencies based on volatility and stability concepts, and comparison of cryptocurrencies, particularly Bitcoin, against well-known currencies, such as Bitcoin Euro, Dollar, British Pound, and gold (Bhosale and Mavale, 2018; Carrick, 2016; Conrad et al., 2018). Accordingly, Kasper (2017) examined the volatility of the major cryptocurrency Bitcoin compared with different cryptocurrencies and the currencies of least developed countries in their article. It was found that the volatility of Bitcoin is observed higher compared with assets and currencies on a different scale (i.e., gold, stocks, commodities etc.; Kasper, 2017). To reveal a different approach another paper related to the subject involves long-term and short-term cryptocurrency volatility components of cryptocurrencies by applying a special model for the analysis (Conrad et al., 2018).

In brief, studies reflect that the volatility of Bitcoin was observed relatively high compared with international currencies. Because of this situation, the use of Bitcoin and other cryptocurrencies have limited use on the market. For this

matter, it is discussed that high volatility behavior of Bitcoin complicates its use as a means of payment (Bolek & Zelina). Although the technologies have changed the payments industry in recent years (Birch, 2018), in terms of trading framework, Blau (2018) argued whether the unusual level of Bitcoin's volatility is attributable to speculative trading. From an investor's perspective, majority of economists and businessmen who are about to decide about investing money into the blockchain industry start with market research and benchmarking studies to have a solid grasp of facts and the nature of the cryptocurrencies. However, the unstable behavior of the Bitcoin price makes it difficult to assess the real value of this currency, while increasing the risk of investors' losses (Bolek & Zelina). Furthermore, the uncertainty level is enhanced in pricing concerns with its market structure of being unregulated and decentralized by increasing the volatility (Carrick, 2016). Thus, in addition to previously discussed subjects to analyze the structure and working mechanism of cryptocurrencies by examining differences from fiat currencies, some studies provide the background to the genesis of electronic currencies and how these have transformed to the more recent peer-to-peer-based cryptocurrencies in circulation today (Pavlovski, 2015). Moreover, for further information and clearer knowledge, experts review the logic behind the economical elements of the blockchain algorithm and the architectural model of cryptocurrencies (Islam et al., 2018).

In this article, the general principles of currencies will be analyzed comparatively by taking into consideration mainly two main concepts that are cryptocurrencies (specifically Bitcoin) and fiat currencies such as USD, EUR, GBP. As analyzing patterns and correlations between different financial asset classes has a pointed role in identifying similar and distinct characteristics of currencies technically, there has been a growth in research papers related to this topic. As instruments of trade on the financial markets, when it comes to the analysis and the examination of relationships in many aspects, it is observed that comparison studies related to the connections of various financial assets more particularly fiat currencies with cryptocurrencies provide further insights to the literature (Corbet et al., 2018; Corelli, 2018).

In this research, the correlations of cryptocurrencies with financial assets or commodities other than fiat currencies typically contain gold, silver, stocks, and oil crude market (Cryptocurrency Market Capitalizations; Gajardo et al., 2018; Szetela et al., 2016). Dyhrberg (2016) emphasized the comparison of Bitcoin and gold in terms of hedging capabilities, where Klein et al. (2018) analyzed conditional variance properties of Bitcoin and gold to reflect linkages and distinctive properties of these assets. On the contrary, a great majority of researches also concentrate on relationships between cryptocurrencies and globally most traded currencies such as U.S. Dollar (USD) and the European Euro (EUR). Matkovskyy (2018) examined centralized and decentralized Bitcoin cryptocurrency market compared with the EUR, USD, and GBP currencies to find out general patterns.

The process of discovery to find out significant patterns, critical figures, or important connections to identify significant points about the relationship of these two concepts has a key role for the financial analysis in this field. Szetela et al. (2016) identified the correlation among various currencies (i.e., Euro, Chinese Yuan, US Dollar, and the British pound). Similarly, Özdemir et al. (2018) evaluated the price changes of cryptocurrencies and real money in the context of historical value changes in their analysis. In a similar manner, articles that discuss currencies to examine certain aspects of a new evolving algorithmic-based currency known as Bitcoin and analyses toward exchange rate relationship between Bitcoin and conventional currencies are in high demand lately (Bhattacharjee, 2016; Samah et al., 2018; Stosic et al., 2018).

In this context, the goal of this article is to make an analysis of 50 national fiat currencies with respect to the most common cryptocurrency Bitcoin to demonstrate correlations, interconnections, and significant differences between these two currencies. For the analysis, R programming language will be used by applying cross-correlation, MST (minimum spanning tree), and HT (hierarchical tree) methods. In the next section, the methodology and results will be presented and the conclusion part of the research will be covered in the last section.

Method and Results

With respect to the goal of this article, to reveal hierarchical structures and relations between currencies, MST and HT algorithms are proper methods. MST should be the first approach to get minimum spanning trees within the context of currency connections and to create the basis for HT. MST needs distances of the elements which are subject to investigation. By using historical price data of currencies, correlation coefficients could be calculated first. Due to the fact that correlation coefficient is not a metric expression, they cannot be used as a distance. However, Mantegna and Stanley's methodology suggests calculating distances by using correlation coefficients (Mantegna, 1999; Ulusoy et al., 2012).

The approach was designed to analyze over different time horizons and was mainly investigating the complex nature of short- and long-range correlations (Podobnik et al., 2000; Wang et al., 2011).

The correlation coefficient of a pair of currency could be calculated by using daily price change rates of currencies. Price change rate $\xi_i(t)$ is calculated as follows where i denotes currency index ranging from 1 to n , $S_i(t)$ is the closing price of the currency i at the day t , $S_i(t-1)$ is the closing price of the currency i at the previous day, and $\Delta S_i(t)$ is the difference between them.

$$\Delta S_i(t) = S_i(t) - S_i(t-1) \quad (1)$$

$$\xi_i(t) = \frac{\Delta S_i(t)}{S_i(t)} \quad (2)$$

Using the daily rate of changes, the correlation coefficient, known as Pearson's correlation or Pearson's r , of a pair of currency prices can be calculated as follows:

$$r_{ij} = \frac{C(\xi_i, \xi_j)}{\sigma_i \sigma_j} \quad (3)$$

For time interval $1, \dots, t$ the formula is given in more detail as follows:

$$r_{ij} = \frac{\sum_1^t (\xi_i(t) - \bar{\xi}_i)(\xi_j(t) - \bar{\xi}_j)}{\sqrt{\sum_1^t (\xi_i(t) - \bar{\xi}_i)^2 (\xi_j(t) - \bar{\xi}_j)^2}} \quad (4)$$

where

$$\bar{\xi}_i = \frac{1}{N} \sum_t \xi_i(t), \bar{\xi}_j = \frac{1}{N} \sum_t \xi_j(t) \quad (5)$$

where σ_i and σ_j are variance of closing currency prices S_i and S_j and $C(\xi_i, \xi_j)$ is the covariance of prices, respectively. $r_{ij} = 1$ means prices of currency i and j are perfectly correlated and $r_{ij} = -1$ corresponds to currency i and j are completely oppositely correlated. Currencies are uncorrelated if $r_{ij} = 0$.

MST is based on minimizing the sum of edges among all spanning trees in the complex network. To get MST, it is required to convert the correlation matrix provided above to a metric distance matrix. The Euclidean distance between two vectors, namely $\bar{v}_i$ and $\bar{v}_j$, is calculated by using the Pythagorean relation stated below:

$$d_{ij}^2 = \|\bar{v}_i - \bar{v}_j\|^2 = \bar{v}_i^2 - \bar{v}_j^2 - \bar{v}_i \bar{v}_j \quad (6)$$

Accordingly,

$$d_{ij} = \sqrt{2(1 - \xi_i \xi_j)} \quad (7)$$

$$d_{ij} = \sqrt{2(1 - r_{ij})} \quad (8)$$

An MST algorithm is capable of detecting clusters between connections of data patterns. By detection of clusters, it is possible to construct an HT using shortest paths obtained from MST. In this study, Kruskal's algorithm is used to construct MST, and algorithms are generated on R statistical programming software.

For the implementation of the methodology explained above, selection of the currency list that will be studied on and their historical price information is required. Within the scope of the study, Bitcoin is the first currency that gets involved in the list. With respect to the gross domestic product (GDP) growth rate of countries, it is decided to select the top 50 countries having their own currency along with the Bitcoin. Selected currencies can be seen in Table 1.

All data have been derived from Yahoo Finance data source (Yahoo Finance API) using R packages. Price data for last 1 year are filtered and daily price change percentages are calculated. All currencies have prices in USD except for

Table 1. Selected Crypto and Fiat Currencies.

AED	COP	ILS	NGN	SAR
ARS	CZK	INR	NOK	SDG
AUD	DKK	IQD	NZD	SEK
BDT	DZD	IRR	PEN	SGD
BRL	EGP	JPY	PHP	THB
BTC	EUR	KRW	PKR	TRY
CAD	GBP	KWD	PLN	TWD
CHF	HKD	KZT	QAR	USD
CLP	HUF	MXN	RON	VEF
CNY	IDR	MYR	RUB	VND

Table 2. Top 10 Daily Prices of EUR in Yahoo Finance.

Day rank	Currency	Date	Closing price	Previous price
1	EUR	1/11/2018	\$0.8364	NA
2	EUR	1/12/2018	\$0.8304	\$0.8364
3	EUR	1/13/2018	\$0.8202	\$0.8304
4	EUR	1/14/2018	\$0.8151	\$0.8202
5	EUR	1/15/2018	\$0.8149	\$0.8151
6	EUR	1/16/2018	\$0.8208	\$0.8149
7	EUR	1/17/2018	\$0.8172	\$0.8208
8	EUR	1/18/2018	\$0.8160	\$0.8172
9	EUR	1/19/2018	\$0.8159	\$0.8160
10	EUR	1/20/2018	\$0.8123	\$0.8159

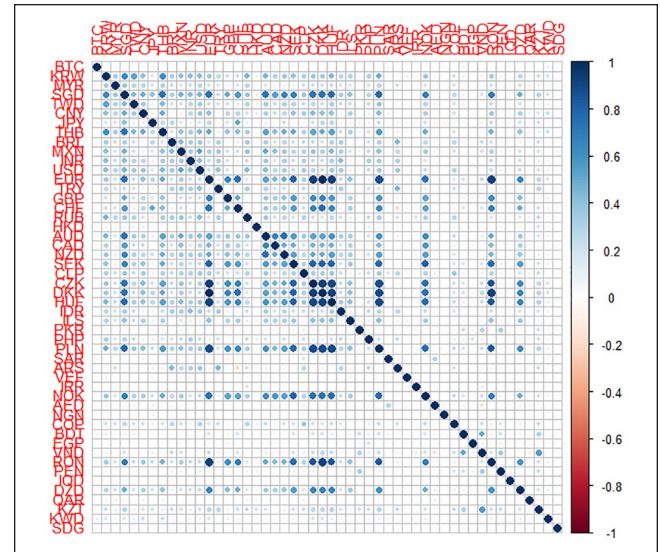


Figure 1. Cross-correlations calculated between currencies.

USD, USD is calculated with respect to the average prices of a group of countries with a high amount of trade with the United States. For instance, EUR prices against USD can be seen in Table 2 for the first 10 observations.

Correlations between currencies are calculated by using last year's daily closure prices and daily changes in percentage. Cross-correlation matrix is demonstrated in Figure 1. In the figure, positive correlations are pointed by blue circles

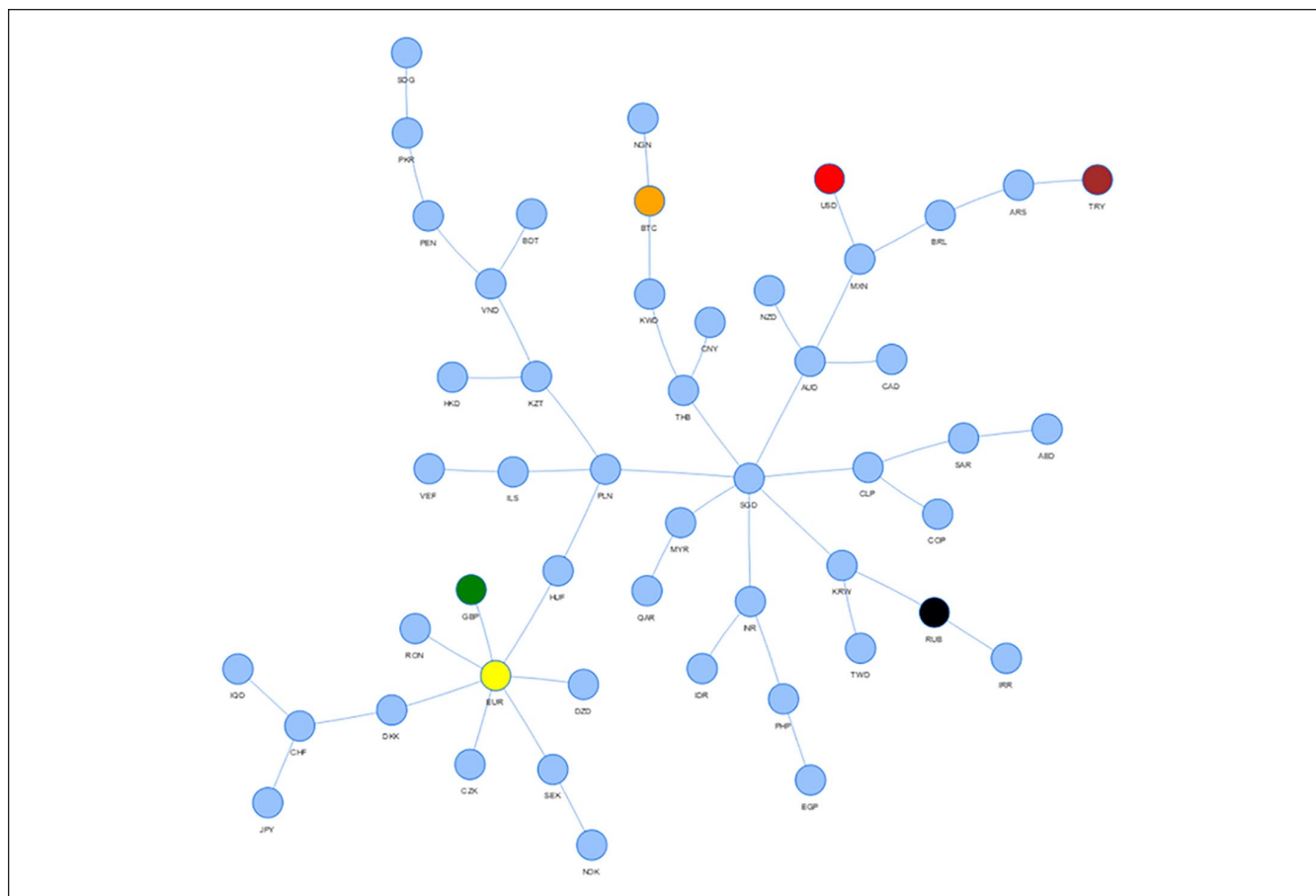


Figure 2. Minimum spanning tree obtained from distance matrix.

and red circles are used for negative correlations. Bigger and darker circle means the correlation is higher. From the correlation matrix, most apparent relations are between European currencies. EUR has a high positive correlation with DKK, CZK, HUF, PLN, and RON. In fact, the correlation between EUR and DKK is almost 1.

As seen in the above figure, the matrix is full of blue points, which shows that almost all currencies have only positive correlations. This is because all fiat currencies are affected by global sequences in a similar way. There is an only one salient red point in the matrix, which is between CHF and ARS. This point indicates Argentina economy and the Swiss economy have some slightly opposite dynamics.

By using cross-correlations which are already calculated before, MST is generated. In Figure 2, an overview of MST is demonstrated. Some critical currencies are shown with different colors, such as BTC is orange, USD is red, EUR is yellow, GBP is green, RUB is black, and TRY is brown.

Examining the tree, it is seen that there are some relationships between currencies that can be analyzed. The most basic relationship is between EUR and several European currencies such as GBP, RON, DKK, CZK, HUF, and SEK. This observation indicates that although European countries such as Great Britain, Denmark, Czech Republic, Hungary,

Romania, and Sweden used their own fiat currency, their economies are highly connected with the eurozone.

Singapore's fiat currency has a relationship with two different blocks. One of them is Asian block which includes THB, CNY, and KWD and the second one is dollar using countries including AUD, CAD, and NZD.

BTC is located next to some Asian currencies such as KWD, THB, and CNY. It has neither a positive nor negative correlation between most of the currencies. This relationship can also be explained by frequent price changes of BTC in last year. It has an only slight positive correlation with KWD. This causes BTC to be located next to KWD.

USD is mainly related to countries of South America (Brazil, Argentina), North America (Canada, Mexico), and Pacific countries (Australia, New Zealand). This is because of geographical location and economic relations of the United States.

When the location of RUB is investigated, it is seen that KRW, IRR, and TWD are linked to RUB. Russia's political and economic relationship could be effective on the occurrence of this block.

Another significant relationship is between TRY, ARS, and BRL. This could be explained by the similarity between Turkey, Argentina, and Brazil in terms of high inflation rates.

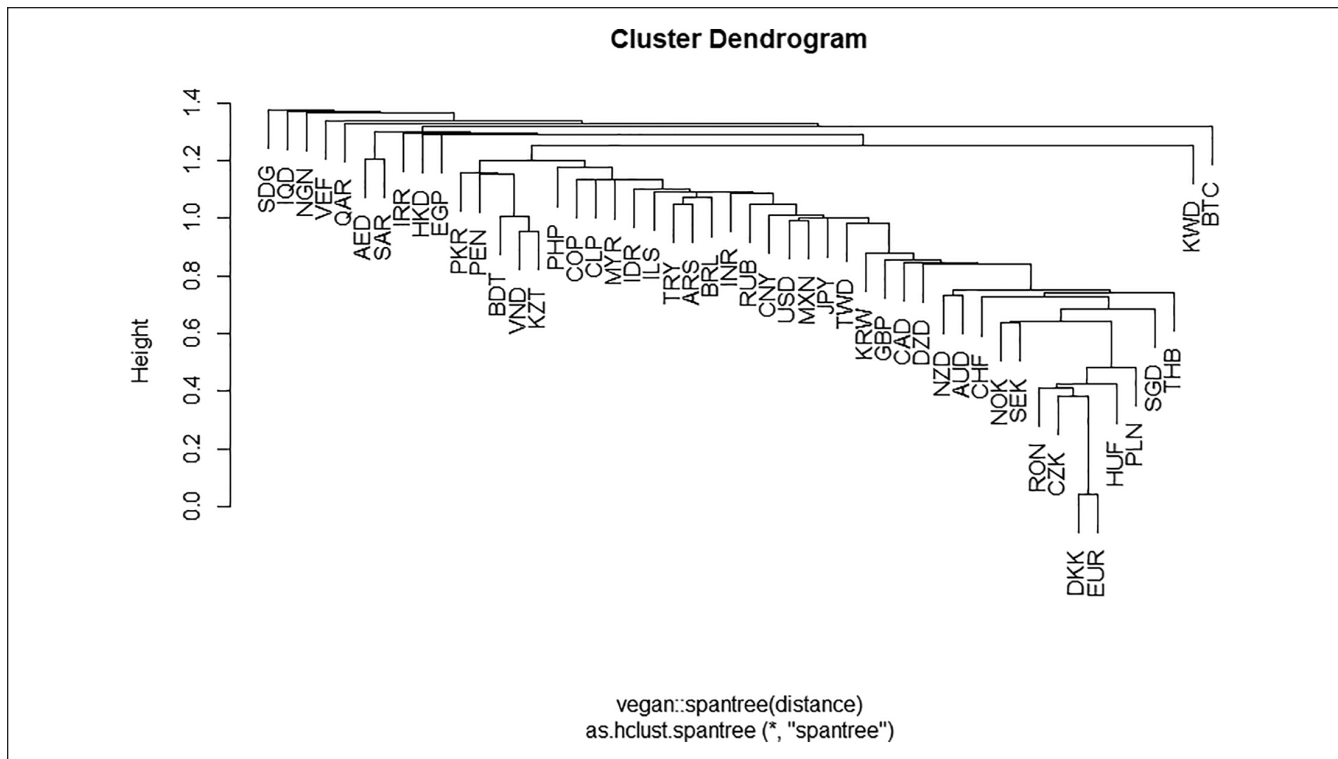


Figure 3. Hierarchical tree obtained from the MST graph.

Note. MST = Minimum spanning tree.

MST presents meaningful information to understand the connections between the currencies. In addition, it helps to divide currencies according to their closeness and get clusters. In Figure 3, the HT clustering dendrogram is given.

Having created HT from MST graph, a further step is to create clusters with respect to hierarchies in the tree. After some inspections, it is decided to create nine clusters which are represented with distinct colors in Figure 4.

As the number of clusters increases, outer leaves of the biggest cluster are separated as another cluster. For example, SDG is the outermost leaf of the HT and it is to the first cluster generated from the tree. However, sometimes some currencies such as AED and SAR are subtrees of upper leaves and they are together a cluster when they were to be separated from tree. DKK and EUR are the lowest levels of hierarchy; therefore, they are center of the biggest cluster in the HT.

Conclusion

This research analyzes the relationship between Bitcoin and a range of selected monetary units to find meaningful patterns, correlations, and causalities among the currencies. This work has a unique feature in terms of combining a cryptocurrency and fiat currencies.

Within the scope of this research, 50 fiat currencies together with Bitcoin have been investigated. First, correlation of

currencies is calculated based on the closing prices of 50 selected currencies. In the next step, using correlation coefficient distances is calculated for pairs of currencies. Then, the MST is generated by taking distances into consideration, as it can be seen in Figure 2. Together with MST, HT structures and clusters are generated and examined which can be seen in Figure 3 and 4. With the help of these approaches, meaningful relations between currencies are obtained.

There are some subtrees of MST which can be explained by economic, political, and geographical similarities and interactions. For example, European and Asian region currencies are mostly correlated and separated by geographical relations. Another example is between RUB and IRR, countries of which are political allies. Relationship between TRY and ARS can be seen as an example of economic similarities due to the high inflation rate.

In this research, Bitcoin is also taken into consideration as a major cryptocurrency in addition to fiat currencies. Due to the high variance in prices of Bitcoin, it is observed that Bitcoin could not have a central role in MST. However, as the number of cryptocurrencies involved in this work increases, cryptocurrencies could have a central role among fiat currencies.

By investigating these relationships in more detail, insight about price changes and currency network could be obtained. As the cryptocurrencies are involved in economic environment further, they would become more correlated and linked fiat currencies and they can even become a replacement for

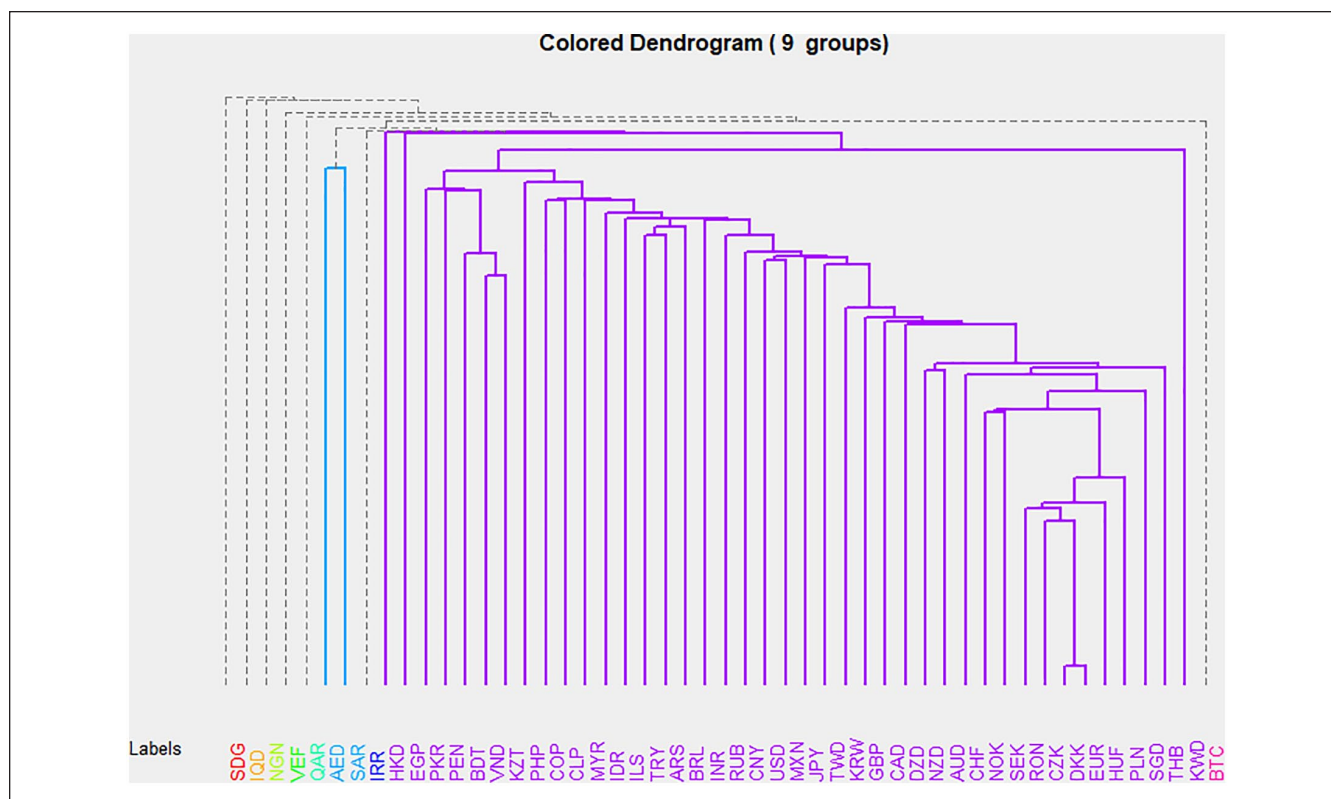


Figure 4. Hierarchical tree clusters obtained from the MST method.

them. This study would help people to extract these relationships for future researches.

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