ARTICLES

Submitted 02-24-2022 Approved 01-20-2023

Evaluated through a double-blind review process. *ad hoc* Associate Editor: Eduardo de Rezende Francisco

Reviewers: Jonatas Dutra Sallaberry, Universidade Federal do Paraná, Departamento de Ciências Contábeis, Curitiba, PR, Brasil. One of the reviewers did not authorize the disclosure of their identity and peer review report.

The peer review report is available at this URL

Translated version | DOI: http://dx.doi.org/10.1590/S0034-759020230403x

CRYPTOCURRENCY AND FINANCIAL SYSTEM: SYSTEMATIC LITERATURE REVIEW

Criptomoedas e sistema financeiro: revisão sistemática de literatura

Criptomonedas y sistema financiero: revisión sistemática de la literatura

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RESUMO

As criptomoedas são ativos com transações gerenciadas por novos métodos se comparados a transações tradicionais mediadas pelas bolsas de valores. A inserção desses ativos pode modificar o sistema econômico. O objetivo do estudo é analisar um conjunto de artigos publicados em bases de dados internacionais de conteúdo científico sobre criptomoedas e as relações com as bolsas de valores para compreender a evolução da temática ao longo do tempo. A consulta foi realizada nas bases Scopus e Web of Science. Foram analisados 196 artigos que indicaram como evolução temática algoritmos de aprendizagem, negociação eletrônica, mercado financeiro e digital. Os principais estudos focaram a investigação do comportamento das criptomoedas diante de variáveis mercadológicas, criptomoedas como porto seguro ou diversificação, análise dos preços e do impacto do valor emocional nas criptomoedas. Os artigos mais relevantes, a rede de citações e cocitações possibilitaram o conhecimento dos autores Baur et al., 2018; Ji et al., 2020; Peng et al., 2018; Symitsi & Chalvatzis, 2019; Urquhart, 2017.

Palavras-chave: revisão de literatura, criptomoeda, bolsas de valores, sistema financeiro, moeda virtual.

ABSTRACT

Cryptocurrencies are assets with transactions managed by new methods compared to traditional transactions mediated by Stock Exchanges. The insertion of these assets can change the economic system. The objective of the study is to analyze a set of articles published in international databases of scientific content on cryptocurrencies and the relations with the Stock Exchanges to understand the evolution of the theme over time. The consultation was carried out in the Scopus and Web of Science databases, where 196 articles were analyzed, these indicated learning algorithms, electronic trading, financial and digital markets thematic evolution. The main studies focused on investigating the behavior of cryptocurrencies in the face of market variables, cryptocurrencies as a safe haven or diversification, analysis of prices and the impact of emotional value on cryptocurrencies. The most relevant articles, the citations and co-citations network of these, provided insights into not yet known literature, such authors are Baur et al., 2018; Ji et al., 2020; Peng et al., 2018; Symitsi & Chalvatzis, 2019; Urquhart, 2017.

Keywords: *literature review, cryptocurrency, stock exchanges, financial system, virtual currency.*

RESUMEN

Las criptomonedas son activos con transacciones gestionadas por nuevos métodos en comparación con las transacciones tradicionales mediadas por bolsas de valores. La inserción de estos activos puede cambiar el sistema económico. El objetivo del estudio es analizar un conjunto de artículos publicados en bases de datos internacionales de contenido científico sobre las criptomonedas y las relaciones con las bolsas de valores para comprender la evolución del tema a lo largo del tiempo. La consulta se realizó en las bases de datos Scopus y Web of Science, donde se analizaron 196 artículos que señalaron como evolución temática algoritmos de aprendizaje, comercio electrónico, mercados financieros y digitales. Los principales estudios se centraron en investigar el comportamiento de las criptomonedas ante las variables del mercado, las criptomonedas como refugio o diversificación, análisis de precios e impacto del valor emocional en las criptomonedas. Los artículos más relevantes, la red de citas y cocitaciones proporcionaron conocer literatura aún no conocida, los autores Baur et al., 2018; Ji et al., 2020; Peng et al., 2018; Symitsi & Chalvatzis, 2019; Urquhart, 2017.

Palabras clave: *revisión de la literatura, criptomoneda, bolsas de valores, sistema financiero, monedas virtuales*

INTRODUCTION

The systematic literature review is a method of research that can be applied to various fields of study (Thomé et al., 2016). By applying this methodology, one can analyze the existing information on a particular topic and generate new results, as well as identify knowledge gaps to be explored.

The knowledge on economics and markets has theories which are consolidated and important for understanding the dynamic between variables. However, new variables emerge at any time, given markets dynamical nature and globalization, and it is possible to track their influences on the productive chain and the results generated by them through technologies in many areas. At the same pace as the markets, also sciences evolve, thus knowing about new researches, concepts, and perspectives is important to leverage the academic environment, the markets, and society.

In 2009, the first cryptocurrency was created, the Bitcoin, which is an electronic cash system connecting one point to another, and allows direct payments without the intermediation of financial institutions (Nakamoto, 2008). By this definition, cryptocurrency is an alternative currency, still it is a hybridization of commodity money and fiat money, determined by a deterministic automatic rule fulfilled by competitive mining similar to commodity money like gold, but without intrinsic value (Baur et al., 2018). A cryptocurrency can be used as an asset, which gives it a different purpose, such as a store of value.

Cryptocurrencies represent new kinds of assets and new methods of managing transactions having the potential to replace traditional fiat currency in the financial market (Liang et al., 2018). An asset can represent stocks of companies or bonds that people buy or sell, these called investors, or that carry out transactions, those called brokers, with the aim of making a profit (Bhandarkar et al., 2019). Millions of trades are made on the stock market, which are highly computerized to be able to sustain the large amount of trades in a short period of time with security guaranteed by the traditional method.

The behavior of markets may change due to events such as elections, (dis)organization of economic groups, and (de)valuation of strong currencies or a pandemic (Ji et al., 2020). Keeping track on the evolution of variables such as cryptocurrencies is important so that it is possible to interpret and anticipate changes in market behavior, the impacts on the economic system, and for the generation of knowledge in the field. Studying the relationship of a new asset introduced alongside the traditional market is important because it can generate information on how the market behaves in the face of new assets. New kinds of assets can arise at any time; how they will behave in the face of the already established market and what influence this market may undergo are important unknowns to be accompanied for the evolution of the economic theories involved and to improve decision-making by investors. The research problem is: How the research on markets of cryptocurrencies and stock exchanges evolved?

The objective of the study is to analyze a set of articles published in international scientific databases on cryptocurrencies and their relationships with stock exchanges to understand the

evolution of the topic over time. This study is organized into this introduction, the methodology, the results and discussions, the final considerations, and finally, the references used.

METHODOLOGY

Developing a literature review consists of finding all or as many as possible published works on a certain subject. A systematic literature review, on the other hand, is a research modality that aims to understand and generate logic from a *corpus* of documents, according to a context, and through the use of specific protocols for the selection and organization of these documents (Galvão & Ricarte, 2019). Through this kind of review, it is possible to find a solution to conflicting results, as well as to define important questions that remain unanswered or have more reliable results to support practical decision-making (Siddaway et al., 2019).

The interpretations of the results can be generated through the application of meta-analysis, narrative synthesis, and meta-synthesis. Meta-analysis involves summarizing the parameters of the variables studied and the effects generated by the application of tests and/or comparisons (Siddaway et al., 2019). Narrative synthesis of the results is used to connect studies and provide a reinterpretation that develops or evaluates a new theory, or to provide a historical account of research developed on the topic (Baumeister & Leary, 1997). Through meta-synthesis, the results are synthesized on a topic, concept, or key theme that can explain the studied phenomenon (Thorne et al., 2004). The application of these techniques aims to extract new conclusions from the interpretation of the studies already conducted.

This systematic literature review is based on the protocol developed by Thomé et al. (2016). The protocol is based on the Cochrane protocol, widely used in areas such as medicine and technology (Higgins & Green, 2008; The Campbell Collaboration, 2014), but it was adapted to develop systematic reviews in operations management. There are eight steps to be followed with the aim of reducing bias in research and contribute to generate knowledge.

Step 1: Planning and formulation of the problem. In this step, the research planning is carried out, and the problem, justification, and protocol are defined. The *Scopus* (Elsevier) and *Web of Science* databases were selected for the search due to their large amount of publications and the careful selection of journals for indexing, which guarantees the quality of the studies published, given the need for peer review. These scientific databases have the ability to export the search results, as well as a large amount of information on the indexed journals.

Step 2: Literature search. This involves defining the keywords that will create the search string and the databases. The search string includes the words "*Cryptocurrenc** AND "*Stock Exchanges*" OR "*Crypto-asset* AND "*Stock Exchange*" OR ""*Digital Stocks*" AND "*Stock Exchange*"" OR ""*Digital Currenc**" AND "*Stock Exchange*"" OR ""*Virtual currenc**" AND "*Stock Exchange*"", which should appear in the titles, keywords, and abstracts of the documents.

Step 3: Data collection. Data collection is done according to the inclusion and exclusion criteria. The collection was carried out on December 16, 2021, and the inclusion criteria are peer-reviewed scientific articles, with periodicity from 2009, containing research that relates cryptocurrencies and stock exchanges. Documents that are not scientific articles, that deal with only one of the topics, articles not made fully available or without full access by researchers, and duplicates in the collection are excluded.

Step 4: Quality assessment. Schemes and analyses of the collected content are made to reduce possible biases. The collected articles undergo a preliminary reading of the abstract to verify if they meet the selection criteria.

Step 5: Data analysis and synthesis. The data is organized to facilitate interpretation. After selection, the articles will be analyzed with the help of the free software RStudio, (https://www.bibliometrix.org) (Aria & Cuccurullo, 2017).

Step 6: Interpretation. This follows the complete reading of the selected documents. The relevance of the research will be verified through citations and co-citations, and the structure of the research field will be analyzed by co-word analysis (Cobo et al., 2011). That is, it is in this step that meta-analysis, narrative, and meta-synthesis are applied.

Step 7: Presentation of the results. Organization of a report with the evidence found. From this information, steps 6 and 7, interpretation, and presentation of results, are developed.

Step 8: Updating the review. It is important to keep the review up to date, as new articles with advances in research in all areas are constantly being published.

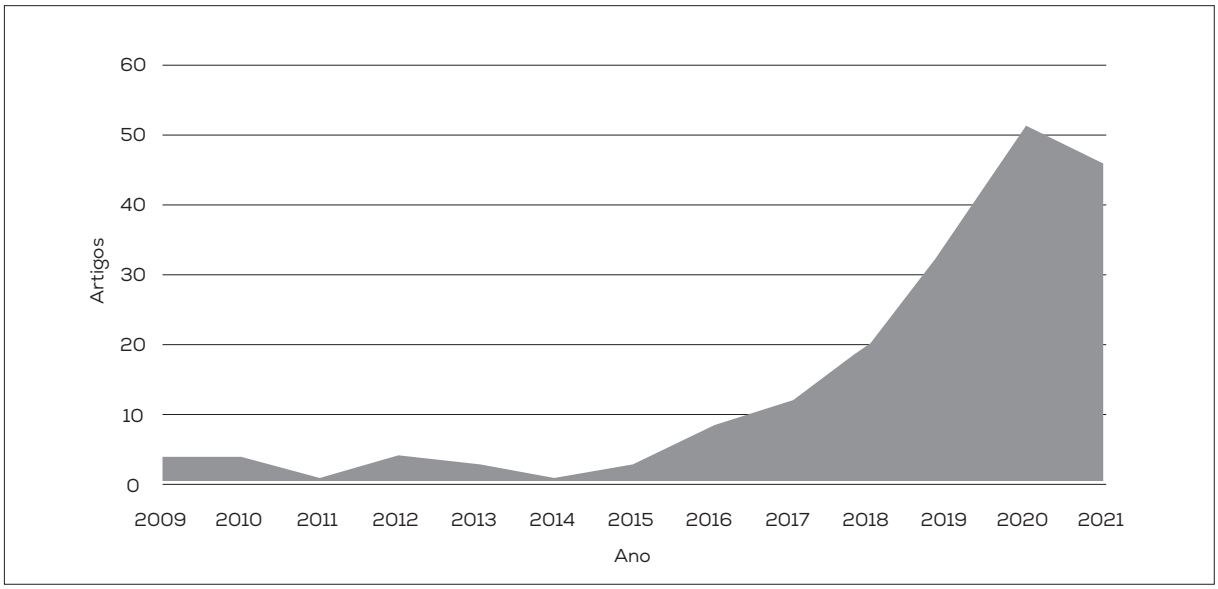
RESULTS AND DISCUSSIONS

The first steps of the systematic review were the definition of the scope in the objective section of the study and the planning of the problem in the methodology. For the literature investigation, *Scopus* and *Web of Science* databases were selected, which, after the search using the keywords, indicated 131 and 141 peer-reviewed articles, respectively; excluding the 76 duplicates, 196 articles remained, according to Step 4.

The 196 selected articles were published in peer-reviewed journals from 2009 to December 2021. The number of keywords is 739, and the number of *Plus* keywords is 924. The *Plus* keywords are those associated with the articles by the scientific database, which may be different from those defined by the authors and represent the general theme of the research. 564 authors were identified, of which 39 were solo authors of articles, and 525 assisted in multiple authorship of articles, with an average of three co-authors per article.

The first four published articles date back to 2009, but most of the publications were made in the year 2020, with 51 articles, as shown in Figure 1.

Figure 1. Annual scientific production from 2009 to December 2021



Source: *software* RStudio.

In Figure 1, the quantity of articles produced on the subject in the years 2020 and 2021 is highlighted, respectively 51 and 49 articles. The periodicity was set from 2009 onwards due to the creation of cryptocurrencies and their start of commercialization in the market.

The researched articles were produced in 53 countries, identified in Figure 2.

Figure 2. Scientific production by countries from 2009 to December 2021

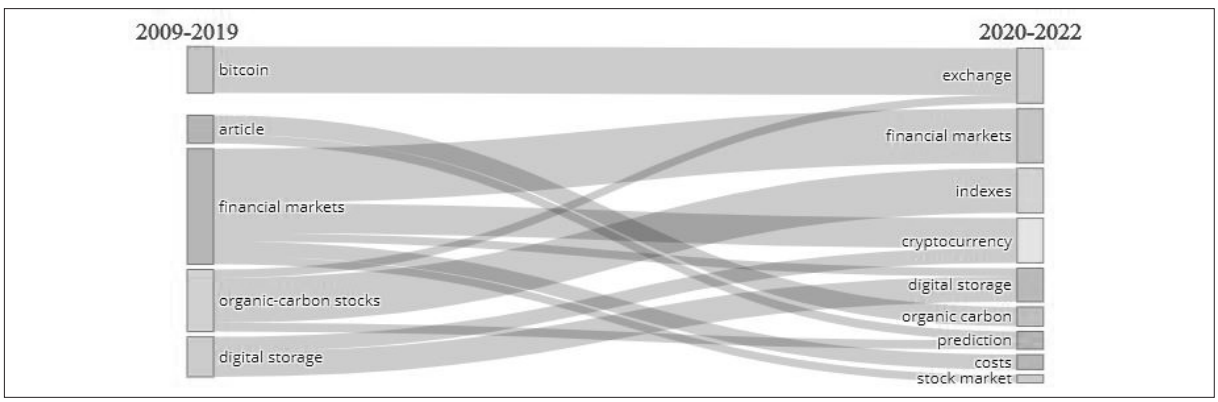
Source: *software* RStudio.

According to the legend of Figure 2, the darker shade of gray represents a higher quantity of produced articles. China has the highest production with 28 articles, followed by the United

Kingdom with 24, the United States with 22, France with 19, and Poland and Switzerland have 18 publications each. During the timeframe set to the data for the study, 9 articles were produced in Brazil.

The research theme underwent modifications over time, with the inclusion of cryptocurrencies and digital storage following the evolution of society and the market. To identify the conceptual structure of the theme, the co-word analysis was applied, which allows discovering the main concepts and interactions among different fields of scientific research and describing them (Cobo et al., 2011). Through this analysis, the keywords that identify the articles are divided into subgroups for consecutive periods. In each subgroup, themes are identified, and if they are associated, it indicates the evolution of a theme "A" to a theme "B," meaning the keywords that appear in different subgroups are considered a thematic or conceptual nexus. The evolution of the researched themes is represented by Figure 3, which shows in a network form the most used terms in each period.

Figure 3. Evolution of research themes conducted between 2009 and December 2021

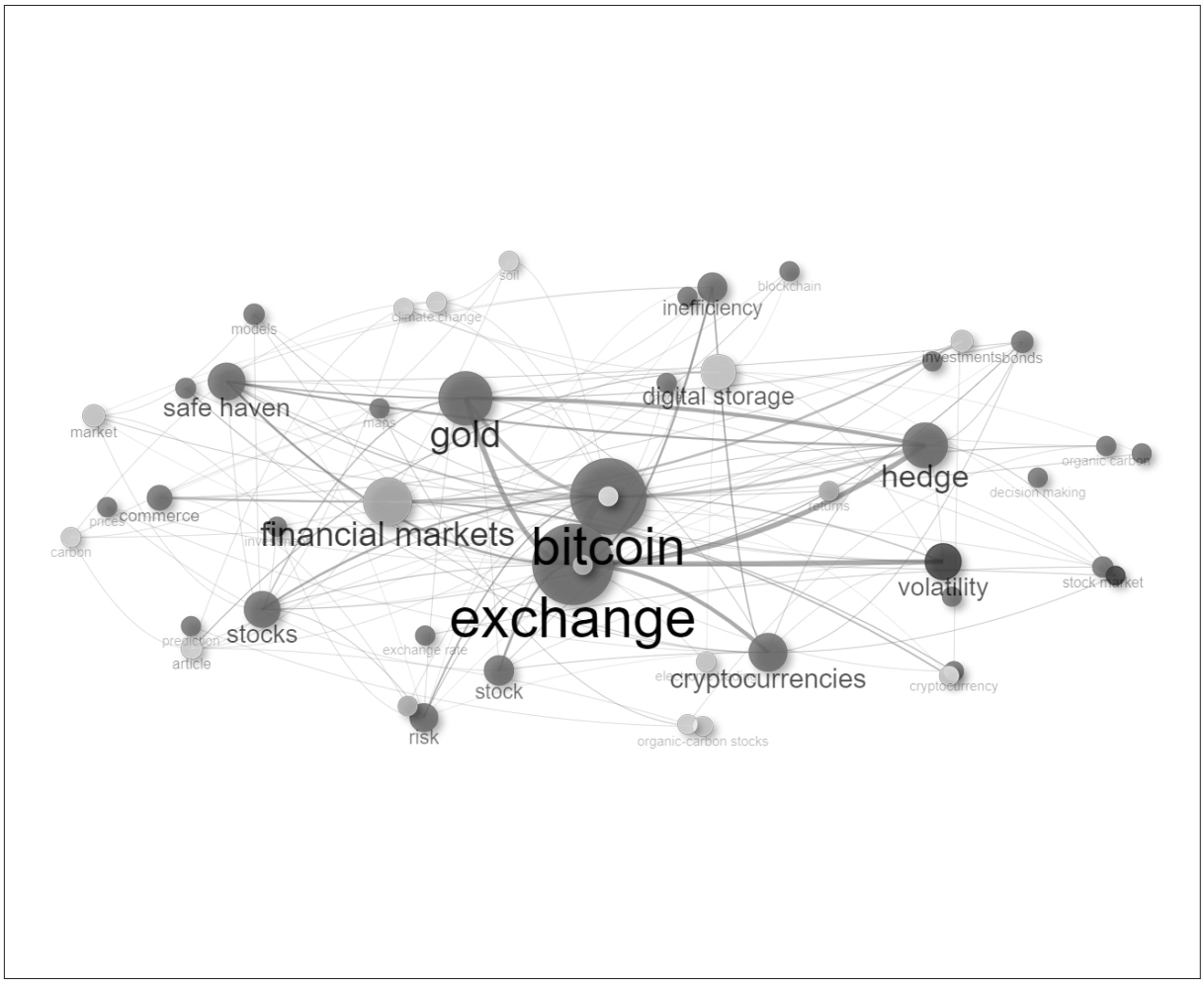


Source: *software* RStudio.

Figure 3 was generated by verifying 5,000 words with a minimum grouping frequency of 5 per 1,000 documents (0.005 rate) by the index of inclusion weighted by word occurrence. The *Plus* keywords were used because they indicated greater thematic variation than the keywords indicated by the authors. Other cutoff timeframes were tested but did not indicate thematic variation, which is why Figure 3 shows the cutoff in 2019, as 2020 is characterized by the highest number of articles produced. The most indicated theme until 2019 was the financial market, which from 2020 on, was divided into financial market, cryptocurrencies, costs, stock market, and digital storage. The theme of organic carbon stocks evolved into themes involving indices, exchange rates, and forecasting. Another highlight is the diversification of themes indicated by the cutoff in Figure 3, which increased from 5 to 9 main themes.

To expand the evaluation of the themes, the co-occurrence network was developed, which is designed by the keywords and their interconnections. The network is identified by the most important keyword, central with respect to the associated theme, which is linked to words represented by spheres proportional to the equivalence index of the central word. Figure 4 shows the co-occurrence network of this study.

Figure 4. Network of co-occurrence of research topics carried out between 2009 and December 2021



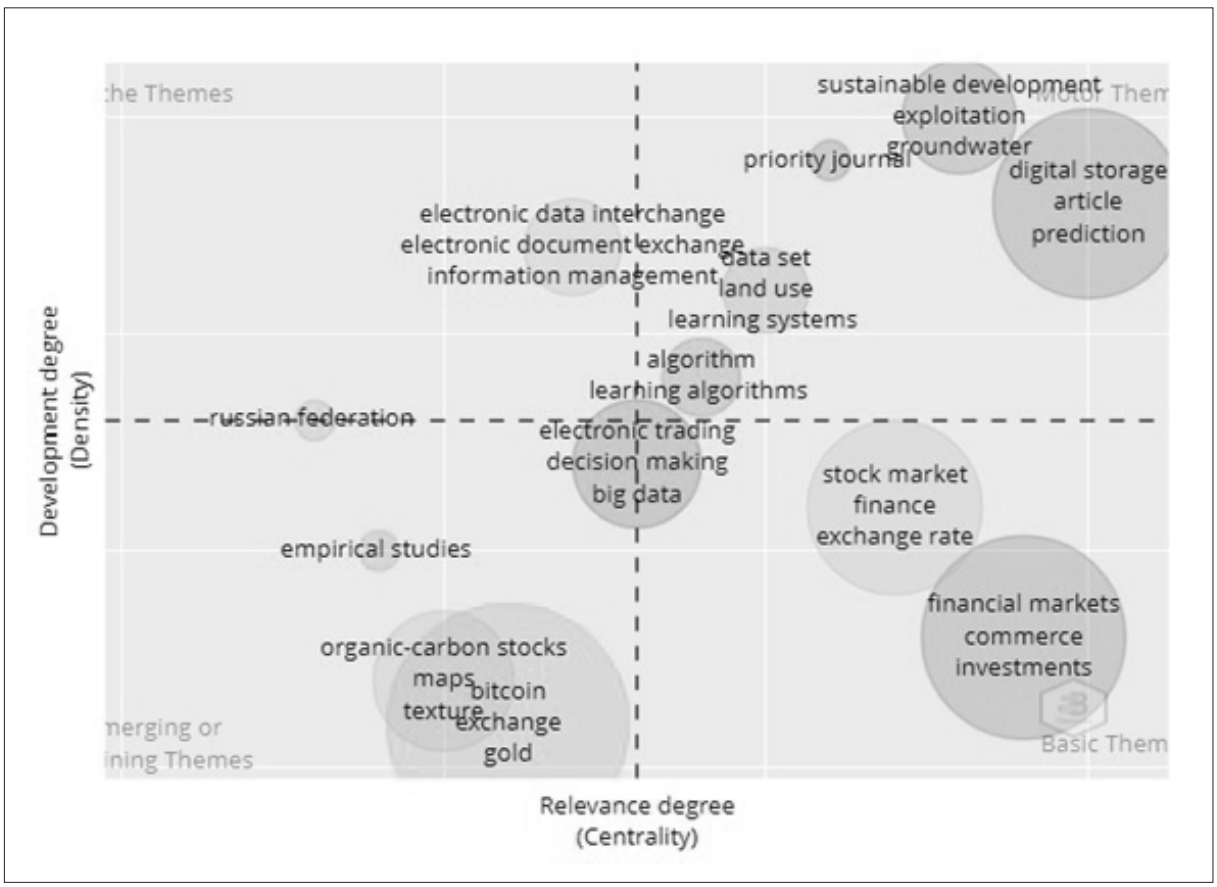
Source: *software* RStudio.

The network was configured using the Plus keywords, grouped by the principal eigenvalues of the 50 main nodes. As a result, 4 groups were generated, indicated in Figure 4, the central keywords obtained from the research collection were "*bitcoin*," "*exchange*," and "*gold*," which are interconnected to the main network represented in Figure 4 by the darker color.

The terms related to "*financial markets*" are interconnected to words related to the economic area, such as "*commerce*," "*investments*," "*stock market*," and "*cryptocurrency*." This network is indicated in Figure 4 by the second darkest. The light gray color network, indicated by the words "*digital storage*," contains words such as "*climate change*," "*organic carbon*," "*carbon*," "*soil*," and "*environmental monitoring*." This network relates to topics related to climate change, carbon, and environmental monitoring. The lighter gray color network has lower equivalence indices to the main themes of the study. The keywords presented are "*organic-carbon stocks*," "*prediction*," and "*maps*," which support research and system functioning.

The co-word analysis, which examines the most frequent terms in the articles, is used to map thematic groups, interconnections, and the degree of proximity, characterized by density and centrality. The average values of these parameters can be used to classify themes into 4 groups (Cobo et al., 2011). The thematic map in Figure 5 is a two-dimensional space constructed according to the centrality and density classification of the themes that form a set of research themes.

Figure 5. Thematic map of research topics carried out between 2009 and December 2021



Source: *software* RStudio.

To generate Figure 5, were used 5,000 *Plus* words mentioned in the articles with a minimum frequency of 5 per 1,000 documents were selected (0.005 rate). The upper right quadrant indicates the driving themes, as it presents high density and strong centrality. The main driving themes identified were "*digital storage*," "*prediction*," "*sustainable development*," "*exploitation*," "*groundwater*," "*data set*," "*land use*," and "*learning systems*." Based on the related themes, it can be presumed that future studies in the spotlight will be related to the creation or use of information systems, models, and algorithms that can predict and support sustainable development and environmental preservation.

The upper left quadrant has marginal importance, with very specialized topics, but of peripheral concern, such as "*electronic data interchange*," "*electronic document exchange*," and

"*information management*." Information management and data access are fundamental to create models and algorithms because without data, it is not possible to advance studies based on natural phenomena. However, these topics are used as a methodological foundation for the advancement of motor themes. Despite a multiple range of possibilities for advancing knowledge, reliable and established forms of data exchange and management are already available.

The lower left quadrant is composed of low-density and low-centrality themes, which makes them emerging or disappearing themes. Among the themes in this quadrant, "*empirical studies*," "*organic-carbon stocks*," "*maps*," "*bitcoin*," "*exchange*," and "*gold*" are highly explored themes. Highly explored themes tend to become exhausted due to the knowledge already generated about them. However, since they are close to the centrality axis, they can be considered emerging in terms of following this research. Empirical studies are a widely disseminated source of knowledge in the academic community, and studies involving gold and Bitcoin prices can be highly explored in the face of other market variables.

The lower right quadrant indicates important research topics that are not extensively developed, *i.e.*, they are cross-cutting and general themes. This quadrant includes the topics of "*stock market*," "*finance*," "*exchange rate*," "*financial markets*," "*commerce*," and "*investments*." All of these topics are relevant to the main research theme and are necessary for understanding the context they belong to.

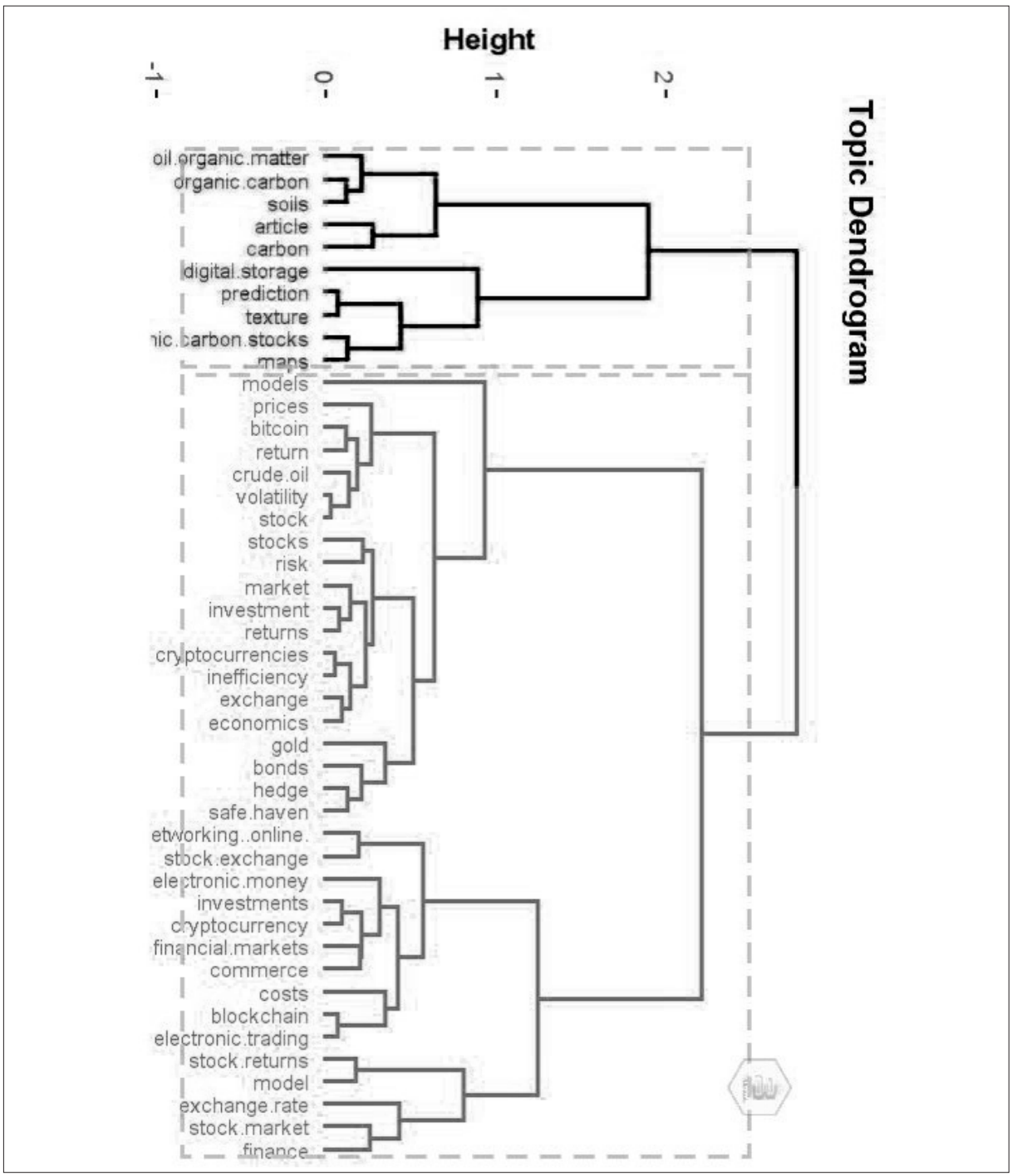
At the center of the thematic map are the terms "*learning algorithms*," "*electronic trading*," "*decision making*," and "*big data*." These terms have the potential to indicate the advancement of models that assist in decision-making and knowledge generation, incorporating all of the topics mentioned in the study and adaptable to other subjects.

The conceptual structure of the Plus keywords can be identified through the analysis of the *Plus* keyword dendrogram, as shown in Figure 6.

The parameters that define the dendrogram are the 50 *Plus* keywords representing the articles resulting from the research, based on their frequency of occurrence. The analysis generated two clusters indicated in Figure 6 by the dotted line that defines the cut of the dendrogram. The upper cluster indicates the words with the strongest connection, meaning the shortest distance between the words and the zero axis are "*prediction*" and "*texture*." This axis gathers themes related to organic carbon and data processing, as the words "*soil organic matter*" and "*digital storage*" appear. The articles related to these words describe ways in which carbon can interfere in the market, and it can be considered themes capable of affecting the research objective, indirectly nonetheless.

The lower cluster contains more words than the upper and has a direct relation to the research objective. This cluster has a clear subdivision, where in the central part of Figure 6, there are common elements to the traditional financial market; the strongest connections are to the words "*volatility*" and "*stock*," "*cryptocurrencies*" and "*inefficiency*," "investment" and "*returns*," respectively. The union of these terms refers to the traditional stock market, which is volatile and initially considered new assets as an inefficient promise in the face of the previously established market.

Figure 6. Plus keywords dendrogram of articles searched between 2009 and December 2021



Source: *software* RStudio.

In the lower part, the characteristics are closer to the new financial assets, represented by cryptocurrencies. The connections between the words "*block chain*" and "*electronic trading*," "*investment*" and "*cryptocurrencies*," "*stock returns*" and "*model*" are stronger. These thematic groupings indicate an affinity between the technologies that involve the registration of cryptocurrency transactions and electronic trading, as well as investments and stock returns related to models. The use of information technology and new models is part of the essence of cryptocurrencies.

The subdivision of the lower cluster indicates that, although it is a single group and there is a connection between these themes, the two subgroups have characteristics that differentiate them. Cryptocurrencies are a new form of available assets, while stock exchanges are traditionally formed by traditional assets. What connects them, according to Figure 6, is that they are types of assets present in the same financial market.

Analyzing Figures 3 to 6, it can be seen that, in Figure 3, the study of the financial market theme, which stood out until 2019, has been subdividing itself: cryptocurrencies, cost, and prediction. These themes are mainly part of the second network contained in Figure 4, which has secondary importance, and the fourth quadrant of Figure 5, which are important themes but not the focus of the study. For the definition of the object of this study, these words are part of the scenario in which the terms that organize the *String* are inserted. They are the basis for understanding the economic system, present in various forms in research, but not the main theme. To understand what cryptocurrencies are and the influences their emergence has caused on the economy, prior knowledge of the traditional financial market is necessary.

The studies on cryptocurrencies commonly cite Bitcoin, as it was the pioneer and is consolidated in the market. In Figure 3, the term is replaced, from 2019 onwards, by "*exchange*;" both compose the main network, in Figures 4 and 6, and are situated in the lower quadrants in Figure 5. It is understood that, due to this composition of results, these are themes with great potential for exploration in studies, as the interferences that Bitcoin can cause in the market stem from its commercialization and use as a virtual currency of exchange. Although it is not the only existing cryptocurrency researched and capable of modifying the market, it is the most commonly found in studies.

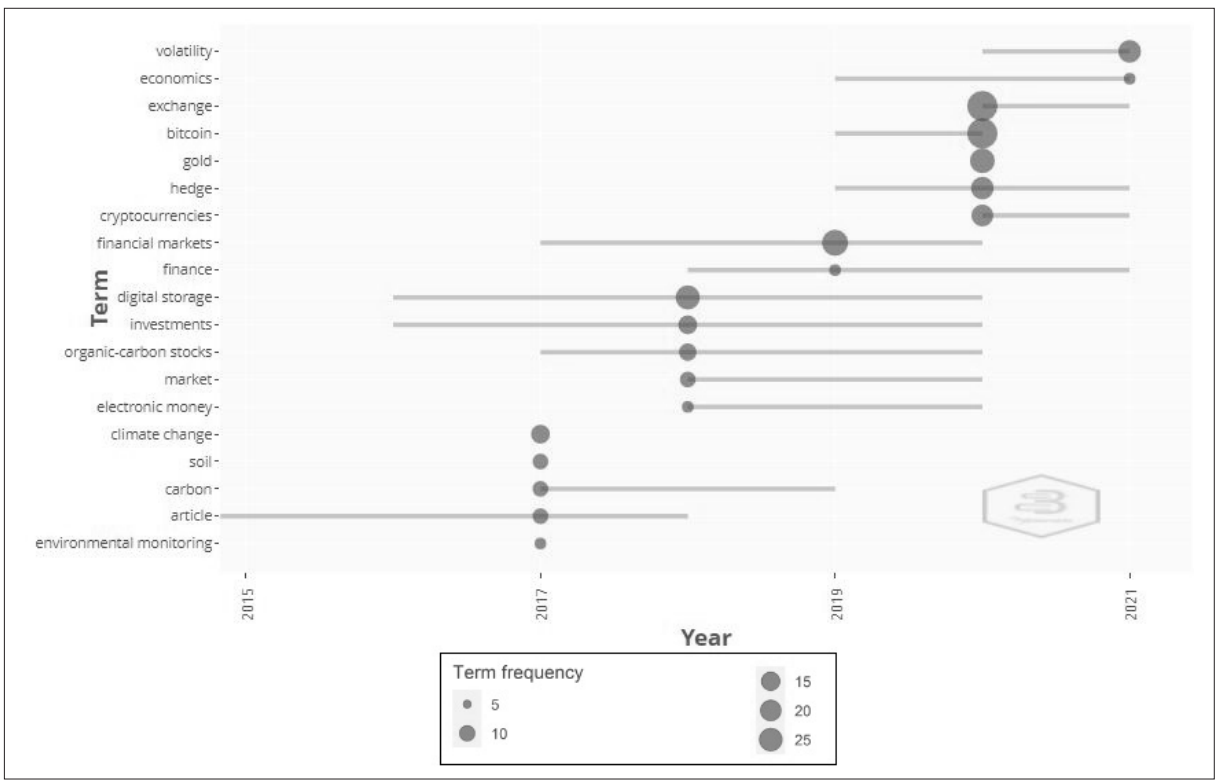
The "*organic carbon stocks*" migrate, from 2019 onwards, according to Figure 3, to terms such as rates and prediction. These terms appear in the secondary networkof Figures 4 and 6, with lower representativeness among the others, and in the third quadrant of Figure 5. Carbon reserves are important for themes related to the economy and global sustainability, but with less relevance to the scope of the *String* of this study, thus they are viewed in positions with less prominence. The relevance of the emergence of these terms is due to the possibility of developing other studies that contemplate themes of market relevance together with cryptocurrencies.

The theme "*digital storage*" can be considered the means for the commercialization of cryptocurrencies. In Figure 3, there is a subdivision for studies related to cryptocurrencies; in Figure 4, it appears in the network, third in relevance, but with terms such as "*commerce*" and "*electronic money*," and in Figures 5 and 6, with "*prediction*." However, in Figure 5, it is in the

first quadrant, which makes the theme visible and important for the development of studies. Regarding digital storage, there is a vast field to be explored, as data is the basis for generating knowledge, and how to store it securely is a challenge.

"*Cryptocurrency*," according to Figure 3, is a theme that can be further explored; Bitcoin and Gold are part of the same network, along with volatility and exchange, in Figure 4. The same terms appear in Figure 5 in the third quadrant, indicating highly explored topics. The themes in the first quadrant suggest studies focused on digital storage, prediction, and sustainable development, serving as a basis for the development of the central themes, which are learning algorithms, electronic trading, and decision-making. In Figure 7, the trend line of the topics covered in the articles selected for the study was generated.

Figure 7. Trend of topics researched by studies collected from 2009 to December 2021

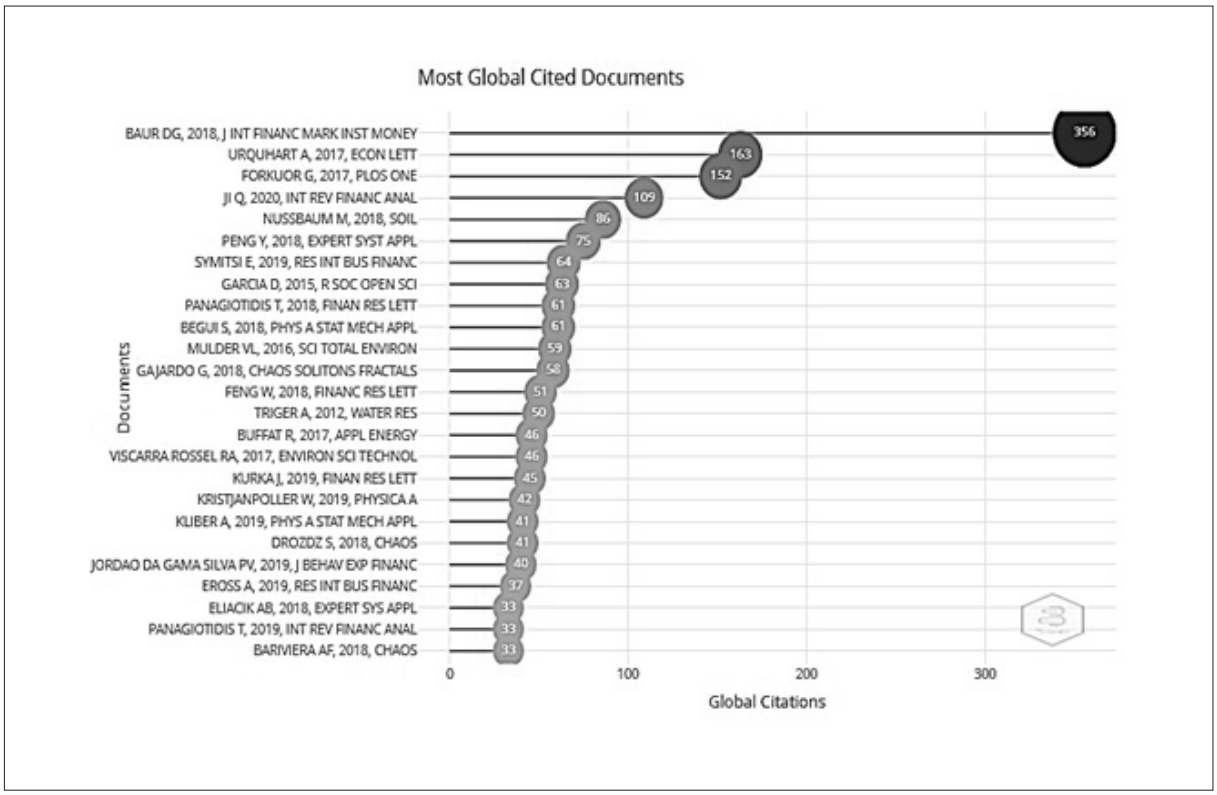


Source: *software* RStudio.

The terms considered as trends in the selected studies, shown in Figure 7, indicate a higher frequency for "*exchange*" and Bitcoin, followed by "*gold*," "*financial markets*," and "*digital storage*." The result obtained from the trend of researched topics corroborates the analysis from Figures 3 to 6 regarding the themes.

The main authors were examined by the quantity of citations, also from the citation and co-citation network. The number of citations indicates the influence of the article in the scientific research field, and the co-citation is used to analyze the structure of this (Cobo et al., 2011). The most cited articles are presented in Figure 8 among those collected by the *String* of the study.

Figure 8. The most cited articles among those collected by the study's String from 2009 to December 2021



Source: *software* RStudio.

The Figure 8 shows the most cited articles by relevance, which is given by the number of citations each article receives. This ranking can be modified according to the date of data collection and the periodicity defined for the collection. In the first row, the most cited article, Baur et al. (2018) is presented, which analyzes whether Bitcoin is a means of exchange or an asset, what its current use is and what use will prevail in the future. The main finding was that Bitcoin is not correlated with traditional asset classes, it is used as a speculative investment, and not as an alternative currency or means of exchange.

The second most cited article is by Urquhart (2017), which verified the behavior of Bitcoin prices by clustering, commercial benefit, and the determinants of clustering. Evidence of clustering around integers with more than 10% of prices ending in decimal digits of 00 compared to other variations was found, but there is no significant pattern of returns after the round number. The results indicate that when prices and volume increase, the *cluster* also increases (Harris, 1991; Ikenberry & Weston, 2007).

In the two most cited articles, behavioral characteristics of the cryptocurrency and the behavior of its prices were examined, two distinct categories from the objectives of the collected articles. The objectives of the most relevant articles, focusing on the relationship between cryptocurrencies and stock markets, were organized and indicated in Table 1.

Table 1. Objectives of the most relevant articles on the subject from 2009 to December 2021

Objectives of the articles	Number of articles	Total of citations	Authors
Behavior/properties of cryptocurrencies.	17	982	(Begušić et al., 2018; Drożdż et al., 2018; Eross et al., 2019; Feng et al., 2018; Gajardo et al., 2018; Ji et al., 2020; Kristjanpoller & Bouri, 2019; Kurka, 2019; Mensi et al., 2019; Panagiotidis et al., 2019; Peng et al., 2018; Silva et al., 2018; Silva et al., 2019; Stosic et al., 2019; Symitsi & Chalvatzis, 2019; Tiwari et al., 2019)
Cryptocurrency as a safe haven or diversification	3	429	(Baur et al., 2018; Bouri et al., 2020; Kliber et al., 2019)
Price of cryptocurrency.	3	62	(Bariviera et al., 2018; Poyser, 2019; Urquhart, 2017)
Emotional value (tweets) and cryptocurrencies	2	96	(Eliacik & Erdogan, 2018; Garcia & Schweitzer, 2015)
Overall total	25	1569	

Source: *software* RStudio.

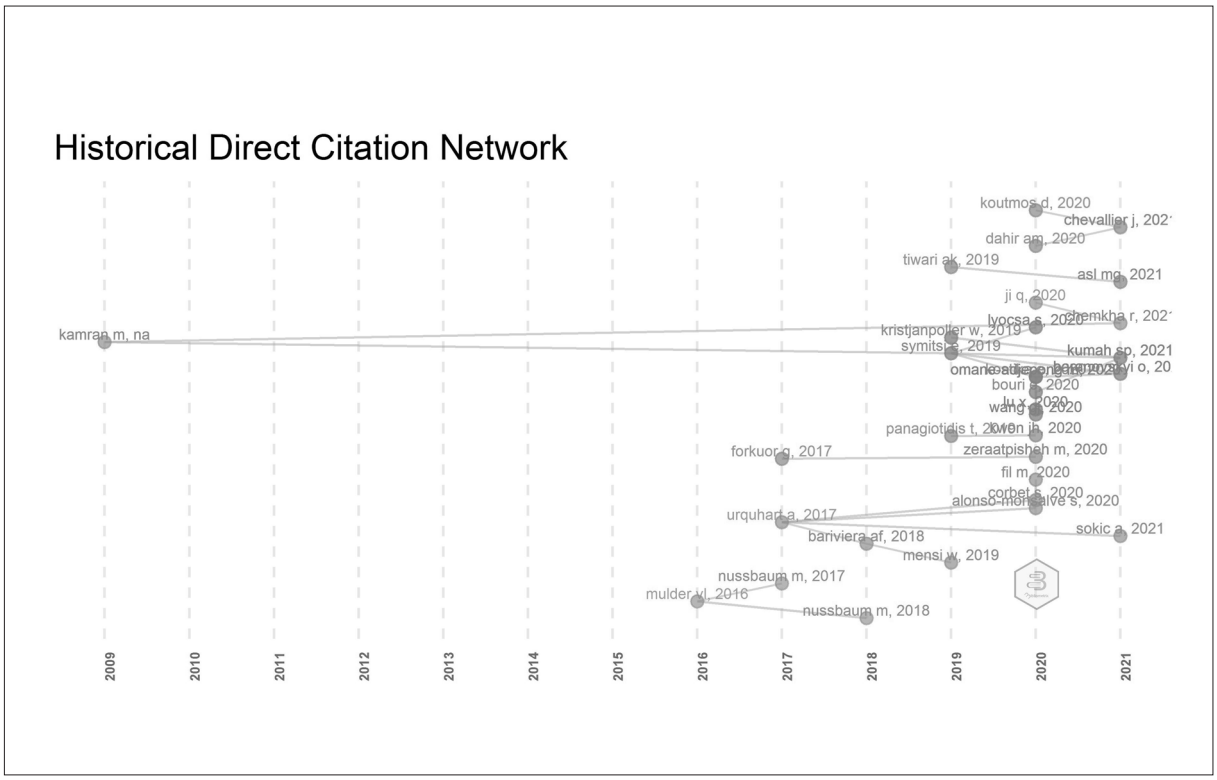
Table 1 is composed of four columns, with the first defining the objectives, which were generally indicated as "*Behavior/properties of cryptocurrencies*." In this row, articles were selected in which authors chose a set of variables and a statistical method to analyze the behavior of these variables and cryptocurrencies according to the generated results. It is noteworthy that as the acceptance and use of cryptocurrencies increase, their performance and movement in relation to other assets will likely change (Gajardo et al., 2018). The lack of supervision of cryptocurrency markets, such as the lack of regulatory laws and supervision by regulatory authorities, is a potential reason for the existence of informed trading, which may be relevant to global regulators (Feng et al., 2018). The behavior of variables can change, and investors cannot ignore driving forces of market turbulence, such as Brexit and US election periods, for example (Ji et al., 2020; Mensi et al., 2019).

The second row lists articles that verified "*cryptocurrency as a safe haven or diversification*," that is, the possibility of using this type of asset as security for moments of market instability. According to Baur et al. (2018), if the acceptance of virtual currencies increased significantly on a global level, it could affect the value of major fiat currencies and alter the relevance of monetary policy.

In the third row, there are articles that focused on the "*price of cryptocurrency*." The objectives are the association between the market price of Bitcoin and a set of internal and external factors (Poyser, 2019), the dynamics of intraday cryptocurrency prices (Bariviera et al., 2018), and price clustering (Urquhart, 2017). The last row of Table 1 indicates the articles that investigated "*emotional value* (*tweets*) *and cryptocurrencies*," in which data from Twitter were collected to examine how the mood of users in the social finance community can interfere with the variation of Bitcoin in the market.

The citations made by the collected articles generated subgroups or citation networks, and Figure 9 presents this network.

Figure 9. Historiographer – historical direct quotes network from 2009 to December 2021



Source: *software* RStudio.

The network of historical direct citations, or the flow of citation of the articles, or the resulting intellectual structure of the research, began in 2016. This network, identified in Figure 9, consists of a chronological map of relevant citations resulting from the collected bibliographic set. The point of interest in these cases is the opening of a debate in the scientific field regarding the topic of interest.

Figure 9 indicates at least eight intellectual structures, the largest cites Urquhart (2017), who studies the behavior of Bitcoin prices through clustering, commercial benefit, and determinants of clustering.

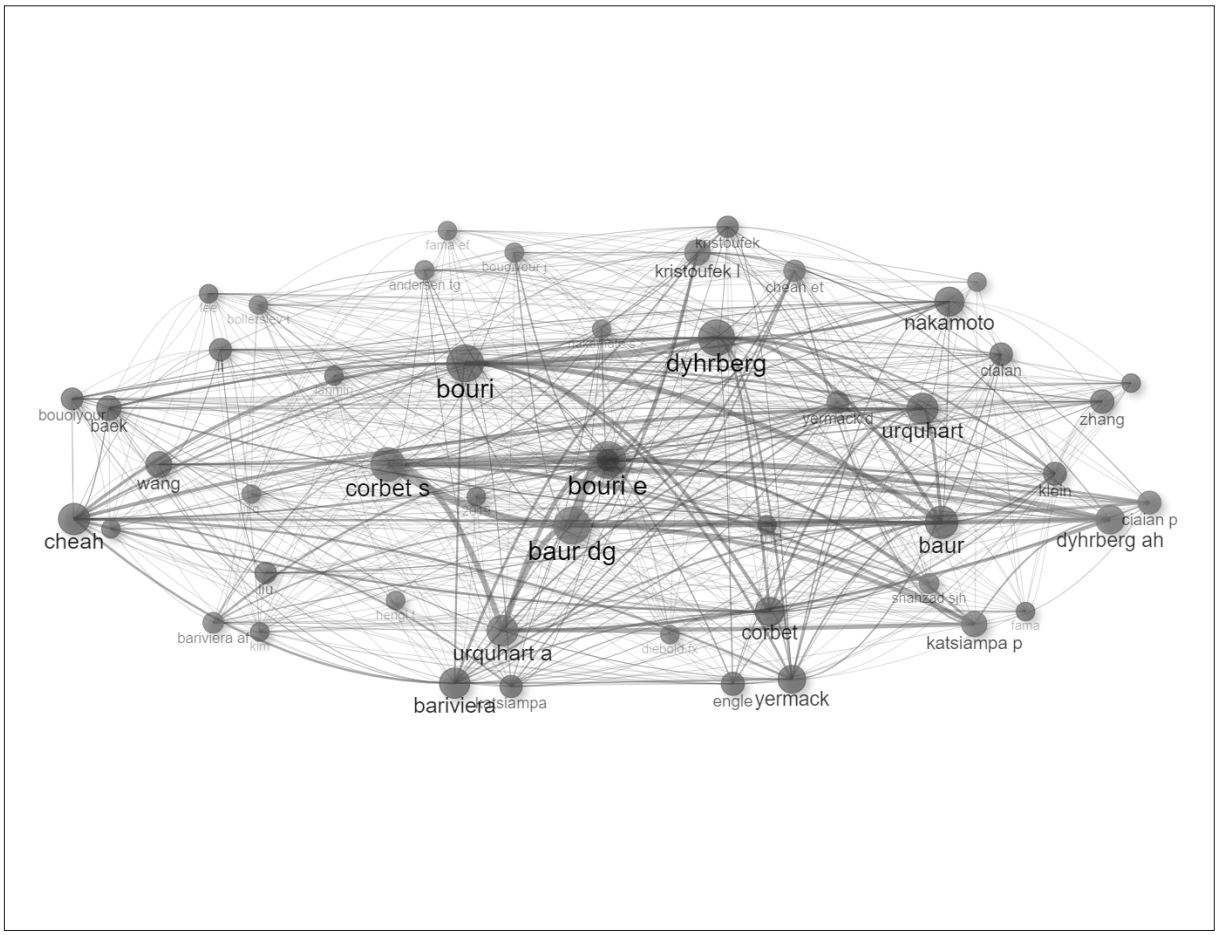
In the other network, the cited authors performed an analysis of asset portfolio diversification with the inclusion of Bitcoin (Symitsi & Chalvatzis, 2019), the behavior of major cryptocurrencies (Bitcoin, Litecoin, Ripple, Monero, and Dash) and major conventional currencies (Swiss franc, euro, sterling pound, yen, and Australian dollar), and the safe-haven property of Bitcoin in relation to major Australian stock indices during the first two waves of the COVID-19 pandemic (Kamran et al., 2022).

In the network, the topics that generate debate are the testing of multifractality, the efficiency of the Bitcoin price index, and the temporal variations in market efficiency level, where the efficiency of Bitcoin changes over time and is marked by a persistent long memory phenomenon (Tiwari et al., 2018). The other authors did not indicate any follow-up studies in

the area; however, it is possible that other publications have been made but are not indexed in the consulted databases.

In Figure 10, the co-citation network is shown, where the relationship of citations of the 50 most frequently cited references among the research articles is represented. This type of network indicates the number of times two articles are cited together by another article, the size of the node indicates the number of citations, and the lines relate to the occurrences.

Figure 10. Network of co-citations on the topic from 2009 to December 2021



Source: *software* RStudio.

Figure 10 shows two groups identified by the light and dark gray colors. The highlight is the participation of authors Baur, Bouri, Corbet, Dyhrberg, Urquhart, among others, in both groups. This result indicates the importance of these authors to the topic, as they are indicated in both groups and, consequently, are the most cited. The parameter defined for the selection of the base references used for the creation of the resulting articles from this collection was 50 authors with at least more than one repetition. For this assumption, 39 references were returned that described their theories in the period between 2002 (Engle, 2002) and 2020 (Bouri, 2020); for these two specific dates, only one author/work was indicated.

The most expressive amount of indicated authors was 25.6% in the year 2017, followed by 17.95% in 2015, 15.3% in 2016, and 12.8% in 2019. According to Figure 3, the year 2019 can be considered the cut-off period for the thematic evolution of the collected articles, although the references used to construct them are from the period 2009-2019, with the exception of author Bouri (2020). This characteristic indicates that, despite the use of references, with a higher concentration in the period from 2015 to 2019, there was a thematic evolution of research from 2020 onwards, as well as an increase in the number of studies.

The analyses of the most cited articles, the citation network, and co-citation network enable the understanding of the most influential works and what has been studied about the relationship between cryptocurrencies, stock markets, and the financial market in which they are inserted. By understanding the existing knowledge, it is possible to evolve in the theme and add more scientific knowledge to the academic community and to aid the development of the market.

The trending topics obtained as a result of this collection, highlighted in Figure 7, are *exchange*, *Bitcoin*, *gold*, *cryptocurrencies*, and *financial markets*. The relationships that these themes have with each other, based on the studied articles, are of coexistence in the same environment, and as a result, interference and possible causality.

The financial market has, as its main structure for business development, stock exchanges, which mainly involve traditional assets such as gold. Cryptocurrencies, especially Bitcoin, are considered new assets, with recent negotiations that may or may not use traditional means for their development and negotiation. This distinct and innovative characteristic makes this asset a source of interest for understanding its behavior in the consolidated market and, consequently, the market's response properties to variations in the market. This argument can be justified by Table 1, which indicates the search for most of the collected studies.

The second highlighted theme in Table 1 is the verification of whether cryptocurrencies can be used as a capital diversification asset or a safe haven asset. In this case, the focus is on investors attempting to detach from the traditional asset market by investing in an asset that is not regulated by financial systems. This strategy is being studied to determine if it can be an alternative to the traditional market, a new path to an independent market that can become a guarantee or a way to dilute risk.

The analysis of cryptocurrency pricing and emotional response, which appear less frequently in Table 1, are related to the traditional market, as this market serves as a basis for valuing or comparing the prices and volatility of cryptocurrencies. *Volatility* was one of the intermediate highlighted terms indicated in Figure 7, as well as "*digital storage*," which serves as a way to record these characteristics of cryptocurrencies.

In summary, research linking the traditional financial market, represented by stock exchanges, and cryptocurrencies has evolved from studies of the financial market with interferences from organic carbon stocks and the Bitcoin cryptocurrency to the same themes mentioned, along with other topics such as cryptocurrencies in general, including others beyond Bitcoin, costs, indices, forecasting, and digital storage. The research has become more complex in analysis and variable selection, as well as methodological robustness in developing results. The topic

is still in its infancy and has potential for development, especially regarding the digital storage technology that involves cryptocurrencies and their relationships with the traditional market.

FINAL CONSIDERATIONS

Cryptocurrencies are recent in the financial market compared to other assets or currencies, so there is still potential to explore their behavior and the influences they may undergo and impose on assets. Although it is a virtual currency, it has a speculative investment character and, in some cases, it could be considered a safe haven for consolidated economies, even in times of crisis.

Through a systematic literature review on the relationship between cryptocurrencies and stock markets in the *Scopus* and *Web of Science* databases, it was possible to identify the evolution of studies on the topic. Until 2019, the most addressed topic was the financial market, but from 2020 onwards, it was subdivided into financial market, cryptocurrencies, costs, stock market, and digital storage.

Studies on digital storage, prediction, and sustainable development have the potential to serve as a basis for the development of central themes such as learning algorithms, electronic trading linked to cryptocurrencies and stock markets since these themes are identified by the articles as new types of assets and traditional assets, respectively. The identified trend terms were "*exchange*," Bitcoin, "*gold*," "*financial markets*," and "*digital storage*." Bitcoin is the most cited cryptocurrency; however, it is not the only one applied in studies such as those that verify correlation or volatility. Ethereum, Ripple, Binance Coin, Cardano, Litecoin, Monero, and Dash were also mentioned.

The main studies focused on verifying the behavior of cryptocurrencies in the face of a set of market variables such as assets traded on stock exchanges, rates, and indices. Cryptocurrencies were also verified as a safe haven or diversification asset for investment portfolios. Studies on cryptocurrency prices and the impact of tweets, as emotional value, in groups that deal with economic-related issues, were also identified.

The limitation of this study was the application of the *String* only in two scientific databases; more databases would indicate other studies. The study carried out, as provided by the research methodology, will need updating due to the constant publication of articles on the topic since the aim is not to exhaust the discussion but to understand the generated knowledge and opportunities for studies to be developed.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

AUTHORS' CONTRIBUTIONS

Viviane de Senna: Conceptualization, data curation, formal analysis; Investigation; Methodology; Software; Visualization; Writing – original draft; Writing – proofreading and editing.
Adriano Mendonça Souza: Project management; Resources; Supervision; Validation.