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Review

The Sustainability of Investing in Cryptocurrencies: A Bibliometric Analysis of Research Trends

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Abstract: This paper explores the state of the art in the cryptocurrency literature, with a special emphasis on the links between financial dimensions and ESG features. The study uses bibliometric analysis to illustrate the history of cryptocurrency publication activity, focusing on the most popular subjects and research trends. Between 2014 and 2021, 1442 papers on cryptocurrencies were published in the Web of Science core collection, the most authoritative database, although only a tiny percentage evaluated ESG factors. One of the most common criticisms of cryptocurrencies is the pollution derived from energy consumption in their mining process and their use for illicit purposes due to the absence of effective regulation. The study allows us to suggest future research directions that may be beneficial in illustrating the environmental effect, studying financial behavior, identifying the long-term sustainability of cryptocurrencies, and evaluating their financial success. This study provides an in-depth examination of current research trends in the field of cryptocurrencies, identifying prospective future research directions.

Keywords: cryptocurrencies; ESG; financial behavior; financial performance; sustainability; bibliometric analysis

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1. Introduction

Recent years have been characterized by an unprecedented rise in cryptocurrency demand. Cryptocurrency is defined as a digital currency that is not bound by government laws or external manipulation (Xie 2019). The advantages of cryptocurrencies are plentiful: they do away with the need for a bank or other central figures to take control of monetary transactions (Lipton and Treccani 2021), and the chaining of blocks using cryptographic techniques provides a high level of security to the scheme, making it very difficult to forge or alter (Khan et al. 2019; Conesa 2019). A cryptocurrency's organic nature is a defining feature, and probably it is most appealing beauty; a single authority, making it theoretically impervious to government involvement or manipulation, does not issue it. Nonetheless, the dangers and inadequacies of cryptocurrencies are obvious: they are very volatile, are not based on any physical goods or services like traditional money, encourage financial crime, and have had a terrible impact on the environment (Teichmann and Falker 2020). Bitcoin mining, the most popular cryptocurrency, accounts for about 0.4 percent of total global energy consumption (Küfeoğlu and Özkuran 2019). According to Cambridge University's Bitcoin power consumption index, yearly Bitcoin electricity usage is higher than in Argentina and the Netherlands. As an alternative to mining, "non-mined" Ripple, Stellar, Cardano, EOS, and Neo are examples of cryptocurrencies that need high-energy-consumption processors but whose operations are less expensive to execute. Having a focus on the environmental consequences, they proceed toward proposing viable remedies

in the manner of payment that is almost certain to have a world-changing impact in the next several years (Brennan et al. 2019; Ingram Bogusz and Morisse 2018).

This demand for cryptocurrencies has also increased interest in cryptocurrency-related studies in academic publications (Masciandaro 2018; Hasan et al. 2022). The majority of the business is concerned with topics such as its influence on banking, profitability, blockchain technology, the development of financial bubbles, and its possible connection to illicit activities (Azarenkova et al. 2018). However, few studies have considered an ESG perspective in their analyses. Understanding the environmental, social, and governance (ESG) ramifications of cryptocurrencies such as Bitcoin is a big research need.

Environmental, social, and corporate governance (ESG) is a means of analyzing the extent to which an organization works for societal reasons other than making profits for its owners. The social objectives supported by an ESG strategy frequently entail attempting to achieve a number of environmental goals (Levillain and Segrestin 2019). Investors' confidence in ESG data has also increased significantly. Contracting parties to the United Nations Principles for Responsible Investment (PRI), which were introduced in 2006, pledged to integrate ESG considerations into their investment research as well as management policies and procedures. In 2016, more than 100 rating agencies, including significant data suppliers such as Refinitive and Morgan Stanley Capital International, published ESG data (MSCI) (Majoch et al. 2017; Hoepner et al. 2021).

ESG's primary environmental concerns revolve around mitigating the effects of climate change and guaranteeing long-term growth (Nawaz et al. 2021). The unsettling fact about cryptocurrencies is that the technique of verifying transactions employed by the top cryptocurrencies, such as Bitcoin, Ripple, Stellar, Cardano, and others, is very inefficient in various sectors. Diversity, equal opportunity, consumer rights, and investment are common examples of ESG (Corbet et al. 2019). It is plausible to argue that the complete lack of any character in most cryptocurrencies protects the vulnerable from repressive governments and that the ability of anyone with an internet connection to possess bitcoin promotes financial inclusion (Chuen et al. 2017). From the point of view of corporate governance, the impact of cryptocurrencies is controversial. It has been argued that cryptocurrencies, beginning with Bitcoin, are decentralized, meaning that no central entity controls them. However, many cryptocurrencies are centralized, with a single company acting as their originator, network manager, and primary beneficiary of their sales (Teichmann and Falker 2020).

The contribution of this study lies in its comprehensive exploration of the environmental, social, and governance (ESG) implications of cryptocurrencies, addressing the research gap in the literature. By acknowledging both the advantages and disadvantages of cryptocurrencies and emphasizing the need for more research on their ESG aspects, this study aims to provide valuable insights for responsible growth and investment in the rapidly evolving field of cryptocurrencies. The proposed use of bibliometric analysis and visualization techniques adds an innovative approach to develop a cohesive theoretical framework and provide quantitatively based recommendations for future research. Ultimately, this study seeks to contribute to the understanding of the ESG implications of cryptocurrencies and their potential impact on sustainability and long-term viability while considering the growing importance of ESG considerations for investors.

This study aims to address the gap by providing quantitatively based recommendations for the selection and presentation of papers, authors, and journals most relevant to this study subject, as well as the development of a cohesive theoretical framework and visualization. The literature revision is carried out using bibliometric analysis and VOSviewer software. Furthermore, the research intends to examine the features and evolution of cryptocurrency publications as clusters on the influence on ESG and profitability elements that let us estimate the long-term sustainability of investment in cryptocurrencies.

The rest of the paper is structured as follows. The next section gives context for our research. Section 3 describes the approach and data that we used. Section 4 displays the bibliometric analysis findings to pinpoint the discussion, while Section 5 draws the primary conclusions and summarizes the important outcomes.

2. Background

2.1. Financial and Non-Financial Sustainability of Cryptocurrencies

The term "cryptocurrency" was hardly known ten years ago, but it is now widely accepted. Digital or virtual money is based on cryptography and uses highly sophisticated encryption algorithms. Digital currencies are immune to inflation, easily portable, and built to be extremely secure, with almost no possibility of counterfeiting. Several topics are linked to cryptocurrency.

At first glance, digital currencies may not appear to be a major environmental issue. However, the true consequences of trading with cryptocurrencies are becoming apparent in a number of ways that paint a bleak picture (Corbet and Yarovaya 2020). Elon Musk's decision to discontinue Tesla's use of Bitcoin as payment has reignited debate about the cryptocurrency's impact on the environment. Bitcoin critics have long been concerned about the environmental impact of the currency. Cryptocurrency consumes more energy than the total energy consumption of Sweden and Malaysia (Laboure et al. 2021; Strukov 2021).

Because of the necessity of building a sustainable cryptocurrency, blockchain can alter the world for the better in a variety of ways. Providing digital wallets to customers who do not conduct business with banks can help to reduce fraud and replace inefficient procedures (Vaz and Brown 2020). Although the most popular cryptocurrencies—Bitcoin, Ripple (XRP), and Ethereum—require enormous amounts of energy to function, many mining businesses are resorting to renewable energy sources to aid with their operations, and Bitcoin is now heading toward sustainability based on mining assets (Näf et al. 2021). This metamorphosis of Bitcoin is happening faster than ever, and an increasing number of Bitcoin miners have switched to mining with sustainable energy sources (Arps 2018; Laboure et al. 2021).

The financial behavior of financial cryptocurrencies is characterized by high uncertainty driven by a variety of reasons, such as the technology being extremely technical and opaque to novice traders, and the fundamental value of cryptocurrencies being unclear. Giudici et al. (2020) showed that, in financial markets, pessimism about fundamentals usually leads to zero trading, but this rule does not seem to apply to cryptocurrencies. Even though bitcoin returns are very volatile, trade volumes are enormous. Uncertainty, according to Coskun et al. (2020), leads to "fights for quality" in traditional asset markets, which, if applied appropriately to cryptocurrencies, might explain the recent collapses.

Previous research and technical studies have largely used simple measures like the Sharpe ratio to analyze the performance of cryptocurrencies, which adjusts returns for total (specific and diversifiable) risk. Furthermore, the cryptocurrency market is evaluated using buy-and-hold returns (Momtaz 2020, 2021; Vidal-Tomás 2023a). Because cryptocurrencies are volatile, this statistic may understate outcomes (Wasiuzzaman and Rahman 2021). The currency's low connection with other current assets and currencies offers a huge potential for diversification, which must be accounted for in performance indicators. Furthermore, the global dimension of cryptocurrencies is an important element that should be taken into account when evaluating performance (Alfieri et al. 2019).

2.2. Bibliometric Cryptocurrency Analysis

Bibliometric analysis is a branch of information science and library science that studies bibliographic material quantitatively. Bibliometric analysis has grown in popularity over the years as a method of categorizing bibliographies and creating meaningful summaries of the top findings (Ahmad et al. 2019). As a result, our work might be seen as an enlarged contribution to the literature, offering a comprehensive summary of current and future trends in cryptocurrency research and identifying prominent researchers, institutions, and publications on this subject. A few publications deal with the bibliometric analysis of academic studies in which cryptocurrency is a major topic. Papers from various periods and using various datasets and technologies may be found in the relevant literature. García-Corral et al. (2022) are the most recent authors to have conducted a bibliometric study of cryptocurrency research. They utilized the Web of Science (WoS) and Scopus databases in their work and gathered 771 papers published between 2010 and early 2019.

Following the emergence of the cryptocurrency market, a small group of researchers, including Merediz-Solà and Bariviera (2019) and Nasir et al. (2020), performed a traditional literature study of bibliometric cryptocurrency analysis. Jalal et al. (2021) investigated the methods utilized in earlier studies, the contributions of previous researchers, and research opportunities. Furthermore, the studies were divided into subclasses based on five study objectives: bubble processes, effectiveness, cyber-criminality, diversity, and restrictions. In the areas of education, accounting, and computers, their sample included quantitative and qualitative research published in journals or as working papers. Yue et al.'s (2021) study, on the other hand, was largely concerned with the topic of bibliometric cryptocurrency computer analysis. They looked at cryptocurrency transactions, peer-to-peer networks, growth, and financial factors. The few bibliometric studies on cryptocurrencies carried out to date by scholars such as Guo and Donev (2020) and García-Corral et al. (2022) were focused on research in the fields of IEEE, computers, and information technology. They did not address business, finance, or management studies. As a result, there are various gaps in our understanding that our research aims to fill.

3. Methodology

This study used a science mapping technique to perform a thorough analysis and visual depiction of a large collection of scientific materials, with a particular focus on the topic of cryptocurrency. The major goal was to reveal the intellectual structure of this subject by detecting current research trends, identifying research gaps, recognizing key authors, and identifying notable nations in this discipline. The study's technique was divided into two parts: sample size and data collecting, and data analysis. This study contains evaluations that provide short updates on the latest developments, with a special emphasis on following the PRISMA principles for systematic reviews, assuring complete and transparent reporting. This study aims to provide valuable insights into the current landscape of cryptocurrency research by leveraging the science mapping approach and incorporating these requirements while also highlighting notable contributors and countries that have significantly influenced this dynamic field.

3.1. Sample Size and Data Collection

Finding academic gaps and identifying research trends are crucial for shining a light on new studies. Despite the fact that several studies on cryptocurrencies have been performed, a comprehensive study mapping worldwide research on the issue of cryptocurrencies is absent (Sedighi 2016). From 2014 to 2021, the most concentrated study themes and gaps in the literature surrounding the link between bitcoin and ESG, financial performance, and environmental effects were examined using scientometric analysis. The year 2014 was chosen as the starting point since the majority of investigations began this year and then continued. We limited the results to English-language publications only, resulting in 1442 papers that were then reviewed for titles and abstracts. We chose theoretical and empirical approaches.

3.1.1. Choosing a Research Database

Although alternative databases, such as Dimensions Database, Google Scholar, or Scopus, can be used to map bibliographic data, they are not as widely utilized. The scientometric analysis of Bitcoin was performed using the Web of Science Database (specifically, the Science Citation Index Expanded and the Social Sciences Citation Index). WoS was chosen as a query machine since it, is the most commonly used and highly acknowledged database for analyzing scientific papers.

3.1.2. Detection of Keywords

Every publication in WoS has a wealth of information, including the year of publication, authors, author affiliations, title, abstract, source journal, subject categories, and references.

The most relevant keywords were defined in order to acquire scientific documents that are directly connected to cryptocurrencies.

3.1.3. Detection of Relevant Documents

The statements in Table 1 were collected by searching the "Web of Science Core Collection" database using the field tag "(ALL)". The search found 1442 publications published between 2014 and 2021 that were peer-reviewed articles particularly linked to cryptocurrency from a pool of over 4000 sources. The analysis included only publications published in English and classified as an article, book, or proceedings paper, whereas non-scientific sources, such as unreviewed books and white papers, were removed. The focus on performance and behavior is justified since global economic markets are progressively incorporating ESG factors into investing strategies. The ESG Disclosure Score, which assesses a company's voluntary disclosure of its environmental, social, and governance performance and behavior, is regarded as a critical variable because it provides insights into management's performance and behavior and aids in the identification of risks associated with ESG performance and behavior.

Table 1. Detection of keywords in WoS core collection database.

Selected Keywords	Number of Exported Documents
ALL = ("Cryptocurrency" AND "Behavior")	263 documents
ALL = ("Cryptocurrency" AND "Corporate governance")	10 documents
ALL = ("Cryptocurrency" AND "Environment")	160 documents
ALL = ("Cryptocurrency" AND "Environmental impact")	6 documents
ALL = ("Cryptocurrency" AND "Environmental")	45 documents
ALL = ("Cryptocurrency" AND "ESG")	1 document
ALL = ("Cryptocurrency" AND "Financial behavior")	6 documents
ALL = ("Cryptocurrency" AND "Financial performance")	6 documents
ALL = ("Cryptocurrency" AND "Performance")	429 documents
ALL = ("Cryptocurrency" AND "Social")	430 documents
ALL = ("Cryptocurrency" AND "Sustainability")	86 documents

The study looked at the link between cryptocurrencies and a variety of aspects such as behavior, corporate governance, the environment, environmental, social, and governance (ESG), financial behavior, financial performance, performance, social effect, and sustainability. To perform a thorough study, specific keywords relating to each component were searched using the field tag "(ALL)" in the "Web of Science Core Collection" database. The study included papers from 2014 to 2021, a crucial time for the introduction and expansion of cryptocurrency studies. Only English-language peer-reviewed materials classified as an article, book, or proceedings paper were assessed to maintain consistency and comparability, whereas non-scientific sources, such as unreviewed books and white papers, were eliminated. A total of 1442 relevant papers were discovered using these filtering parameters. Following that, these papers were scrutinized further based on their titles and abstracts to establish their relevance to the study.

3.2. Data Analysis

3.2.1. Selection of Science Mapping Tool

This sufficient science mapping technique is required to undertake a full examination of any scientific topic. VOSviewer, Gephi, CiteSpace, Sci2, and HistCite are among the software applications available for this purpose. Gephi is a free tool for graph and network visualization, whereas CiteSpace is free software for visualizing and analyzing patterns and trends in the scientific literature. VOSviewer software, a robust tool for creating and visualizing bibliometric networks, was used in this study. VOSviewer allows you to build networks based on citation, bibliographic coupling, co-citation, or co-authorship links, and you may include journals, authors, or individual articles. VOSviewer also has text-mining

tools for creating co-occurrence networks of important phrases collected from scientific papers (Qudah et al. 2023).

3.2.2. Scientometric Techniques

VOSviewer was used in this study to identify current trends in the field of cryptocurrencies, research gaps, future research subjects, and the most influential nations, sources, and authors. This was carried out by the analysis of co-occurrence patterns in the bibliographic data. Examining the co-occurrences of two terms in a given text to expose the conceptual and thematic structure of a scientific issue is what co-occurrence analysis is all about. Co-occurrence networks are built, and similarity metrics are produced. These similarity metrics are then applied to statistical tests, such as clustering and multidimensional scaling (MDS). These tools can build science maps that display author affiliations, documents, journals, or significant phrases. The frequency of their presence in publications may be calculated by evaluating the co-occurrence of keywords in titles, abstracts, and keywords themselves. Mapping and clustering algorithms give insights into the network structure and are widely employed in bibliometric and scientific research (Li et al. 2016; Radhakrishnan et al. 2017; Qudah et al. 2023).

The authors used VOSviewer to visualize a network of objects with their total number of linkages and link strengths to conduct keyword co-occurrence analysis (Lozano et al. 2019). The relevance of the displayed words is represented by the size of the circles connected with each item. Cluster analysis was used to identify existing domains of cryptocurrency study and forecast future bitcoin research trends. The program examines bibliometric maps thoroughly and may show them in a variety of ways, each stressing distinct characteristics of the map. In the analysis, this study took into account all terms and used a complete counting technique (Qudah et al. 2023).

4. Findings and Discussion

4.1. Publication Output and Growth Trend: Evolution of Cryptocurrency Research

The number of articles published in a certain period by a specific unit (journals, institutions, nations, etc.) is used to calculate publishing activity. Measures of publication activity offer us an overview of the topic's quantitative development and structure, as well as the capacity to identify the greatest number of journals, businesses, and countries publishing in a discipline. Furthermore, we can determine the topics covered during the research period. In this study, Microsoft Excel® spreadsheets were used to analyze qualitative characteristics such as the work sector, study dimensions (cross-sectional or longitudinal), or techniques employed in various examinations (quantitative study, qualitative study, etc.).

This section summarizes the important findings of a bibliometric study undertaken to examine the evolution of cryptocurrency research from 2014 to 2021. The study delves into the most powerful countries, institutions, and writers, as well as their linkages. The findings show that the literature on cryptocurrencies has grown significantly in recent years. Figure 1 depicts the publishing activity throughout the indicated time, revealing that 2014 had a comparatively low number of publications, with just 10 papers. However, since 2016, there has been a continuous increase in publications. Notably, there was a peak in 2019 (n = 854), followed by a minor fall in 2020 (n = 748). There was a revival in 2021, with an increase in the number of publications (n = 866). In terms of citations, the 1442 publications examined received a total of 35,970. Each work obtained an average of 11.60 citations. Figure 1 depicts the exponential growth in the number of citations as the number of published publications has increased.

Secondly, we focused on the most important bibliometric analytic findings to analyze the evolution of the cryptocurrency literature for the same period of 2014–2021 using keyword detection, as seen in Table 1. This paper looks at the most influential and productive cultures, institutes, and writers, as well as their interconnections. As illustrated in Appendix A, at the beginning of the reference period, there was no discussion of publishing activity, with just figures ranging from one to three publications. Meanwhile, among the

chosen terms highlighted, there has been an increase in bitcoin and sustainability papers since 2016. As can be observed, this development experienced many peaks between 2017 and 2019. The publications have garnered multiple citations in fields such as behavior, environment, performance, social, sustainability, and cryptocurrency studies, which increased in 2020 and 2021. On the other hand, the keywords of the least searched topics are ESG, financial behavior, and financial performance, with cryptocurrencies. Therefore, a new research trend for these topics or keywords may be expected to develop.

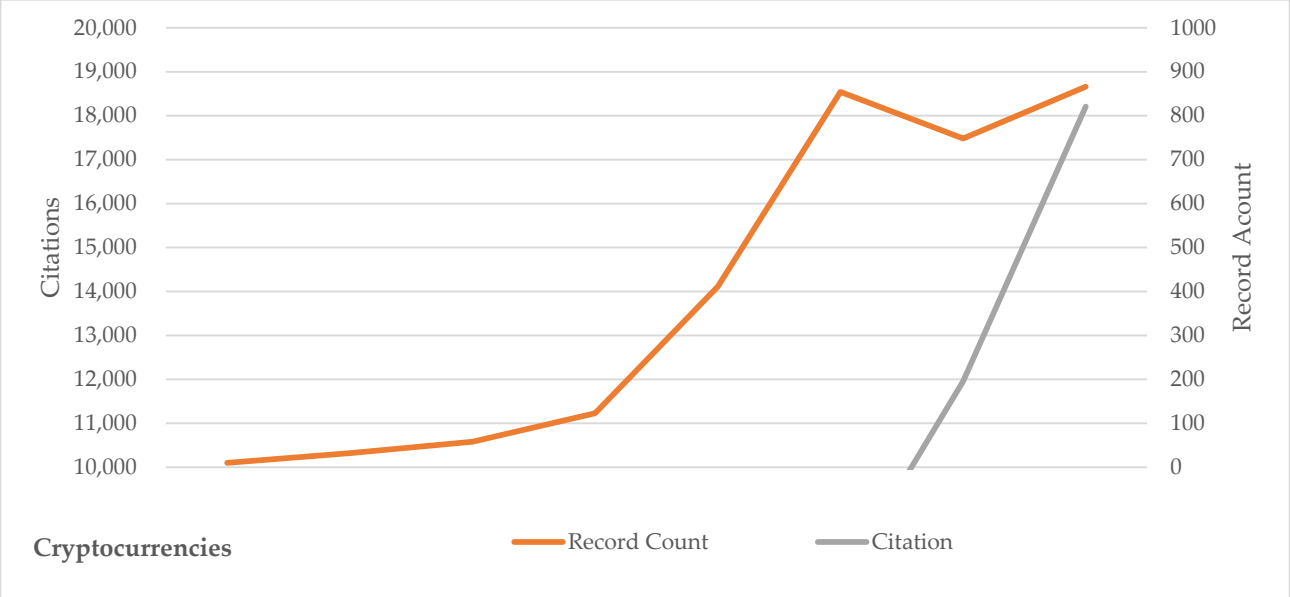

Figure 1. Cryptocurrency publication activity from 2014 to 2021.

4.2. Top Papers, Authors, and Publishers on Cryptocurrency Reporting

This section contains the most relevant publications and authors on the issue. Figure 2 shows the top authors by the number of publications to acquire a clearer view of the most influential individuals. The top 10 authors account for 4.77 per cent of all publications on the subject. Among them, Corbet and Bouri stand out, with 26 papers and 19 publications, respectively. For each author, we identified the authors performing research related to their fields of study and their relationship with cryptocurrencies in the WoS database.

Appendix B identifies the top authors based on the number of publications using keyword detection to obtain a better picture of the most prominent people in the different fields. The top ten writers listed in Appendix B accounted for between 5% and 15% of all publications on the subject. Stolbov is the author who has contributed the most to cryptocurrency and corporate governance papers, accounting for 15% of the total with two papers. Corbet, the author with the most publications on cryptocurrencies, also leads the ranking of contributions related to bitcoin and financial performance. Ante is the author who has contributed the most to cryptocurrency and social publications, accounting for 2% of the total with 9 papers. Nevertheless, Laboure et al. 2021 is the only author who has published about the link between cryptocurrency and ESG.

Figure 3 shows the list of publishers with the highest presence of papers related to cryptocurrencies. The first is IEEE, which has 808 papers, accounting for 26.05 % of the total. Elsevier comes in second, with 569 publications, followed by Springer Nature (359), MDPI (176), Assoc Computing Machinery (161), and Taylor and Francis (136 publications). These six publishers account for 71% of all papers published. As mentioned above, IEEE and Springer Nature are mainly specialized in computer science information systems, electrical engineering electronics, and computer science theory techniques. Therefore, their articles do not particularly emphasize ESG, CSR, and SDG issues, but rather the cryptocurrency mining process. In contrast, Elsevier, MDPI, and Taylor and Francis (almost 60%) are more interested

in studies that approach cryptocurrency research from the point of view of environmental effects, financial behavior, long-term sustainability, or financial performance.

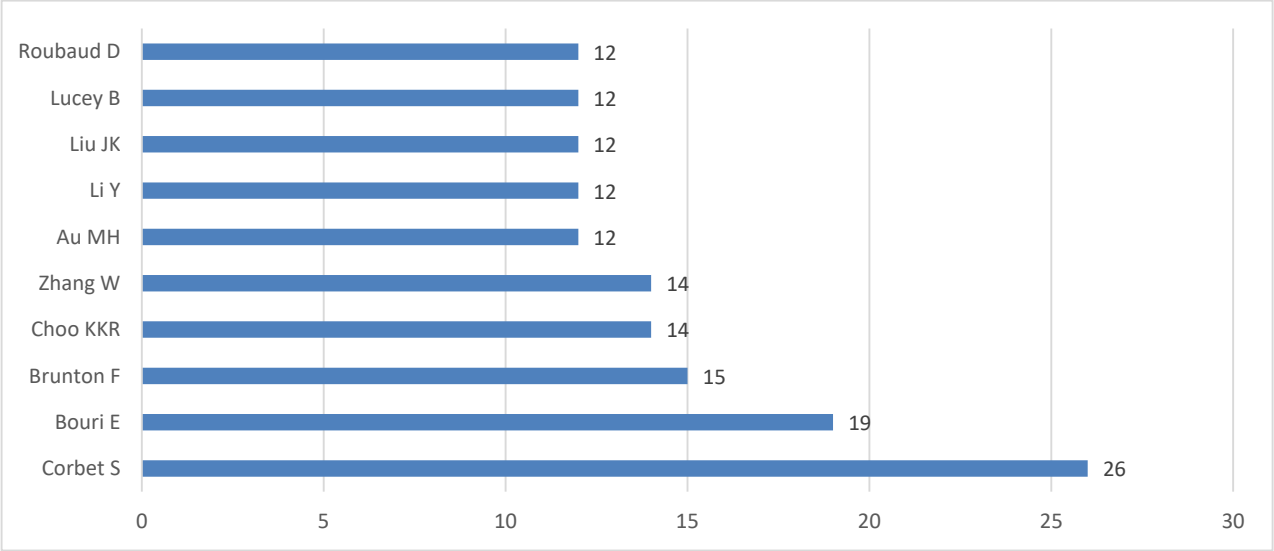

Figure 2. Publications by author.

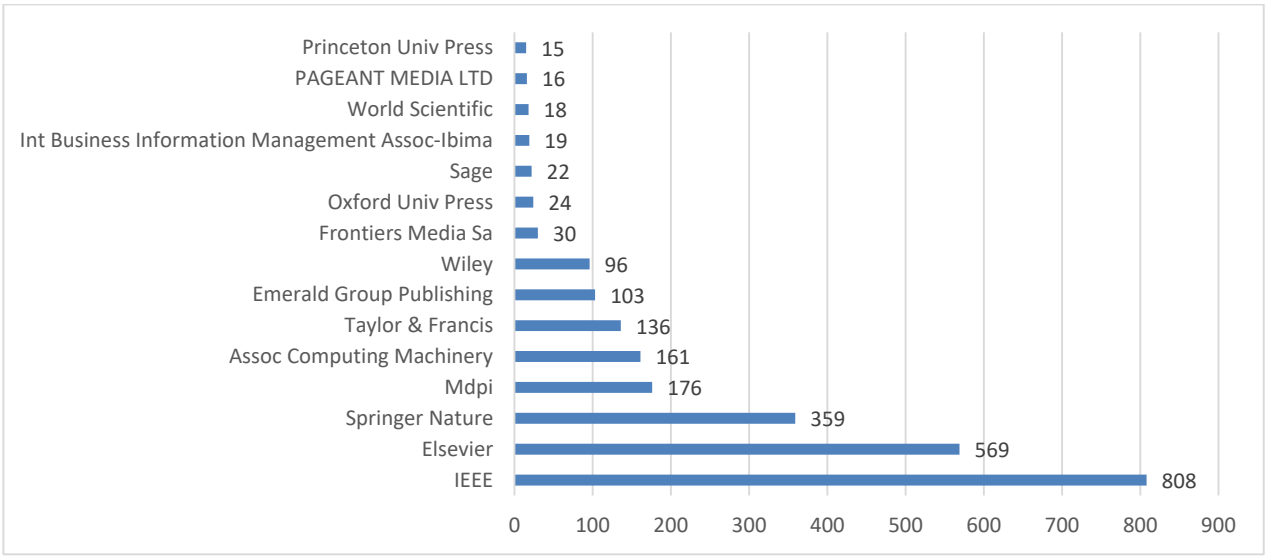

Figure 3. Publications by sources (publishers).

Three sources—Elsevier, MDPI, and IEEE—lead all keyword topics in Appendix C. On the other hand, World Scientific, Emerald Group Publishing, Taylor and Francis, and Saga have recently published on topics such as environment, environmental effects, performance, social components, and financial behavior. Although there are no more concurrences, the basic pattern identified is comparable among these sources, while the other sources have approximate similarities in their published paper counts. Among the sources highlighted, Wiley stands out as a pioneer in researching the link between bitcoin and Environmental, Social, and Governance (ESG) concerns. This is a great start toward integrating ESG principles in the bitcoin sector. While the bulk of publications in these sources focus on economics and computer science, ESG, Corporate Social Responsibility (CSR), and Sustainable Development Goals (SDGs) are recognized as secondary issues (Mora et al. 2020).

Other sources have not considerably contributed to promoting writings about ESG, CSR, and SDGs in the context of cryptocurrencies. MDPI, on the other hand, offers a

distinct viewpoint on bitcoin publication, which may imply potential future advancements in researching new aspects linked with cryptocurrencies. Overall, Wiley's investigation into the relationship between cryptocurrencies and ESG is a significant step in bridging the gap between these two areas and highlights their position as a major influencer in the proliferation of cryptocurrency-related themes. As the bitcoin environment evolves, it is critical for researchers and publishers to examine ESG and sustainability issues, and Wiley's efforts in this regard are noteworthy.

4.3. Bibliometric Analysis: Mapping and Visualizing

The following subsections investigate the different maps obtained by VOSviewer, beginning with a keyword co-occurrence analysis, and then moving on to a bibliographic coupling of countries and authors.

4.3.1. Keyword Co-Occurrence Analysis

Figure 4 depicts the co-occurrence of keyword network visualization in the semantic structure of the bitcoin research issue in this study. VOSviewer, a useful tool, was used to calculate keyword frequency and the strength of the links among them. Clusters of keywords are shown as circles in the graphic, with lines linking these keywords. A distance of 3 was used as the threshold, suggesting that lesser distances between terms imply stronger associations (Fetscherin and Heinrich 2015; Fahimnia et al. 2015; Muhuri et al. 2019; Soliman et al. 2021; Qudah et al. 2023). A cluster analysis was performed to further investigate the co-occurrence of phrases, finding five unique clusters that define major research trends.

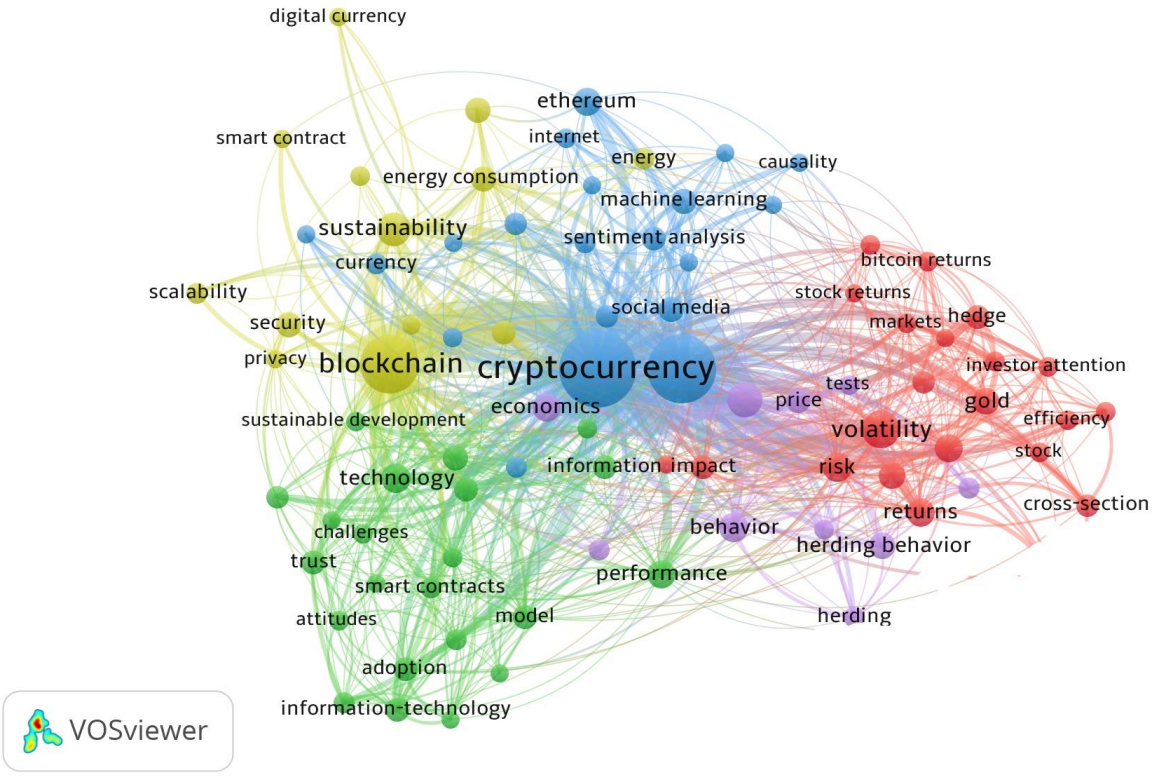

Figure 4. Network representation of term co-occurrence in cryptocurrency research.

The red cluster includes topics related to the financial analysis of cryptocurrencies from the point of view of their profitability or comparing them with other commodities, such as gold. Among the keywords within this cluster, "cryptocurrency market" and "volatility" are some of the words with the highest frequencies and strength. The greatest interrelationships of the red cluster are with the purple cluster, and together, they define a typology of studies focused on the economic and financial behavior of cryptocurrencies.

On the other hand, the yellow and green clusters include keywords such as "sustainability", "energy consumption", "blockchain", "technology", and "information technology", which address topics related to ESG areas and information technologies. Figure 4 shows that the yellow and green clusters are the most distant from the red cluster, evidencing that few studies combine their keywords. In the middle of the map emerges the blue cluster, which is the largest and includes keywords such as "social media", "machine learning", "sentiment analysis", and "internet", mostly related to areas of operation research, management research, and information systems.

4.3.2. Research Trends Related to Cryptocurrency Issues

This study's authors built five co-occurrence networks based on the terms identified in the titles, abstracts, and citation contexts of the articles linked to cryptocurrencies using data from the Web of Science (WoS) and the VOSviewer application (www.vosviewer.com (accessed on 21 June 2023); van Eck and Waltman 2010; Lozano et al. 2019). To extract keywords from these textual components, the VOSviewer application was used, which has text-mining capabilities (van Eck and Waltman 2011). The co-occurrence networks were created by searching for terms that appeared in the same titles, abstracts, or citation contexts. The co-occurrence patterns of terms in the network represent their degree of similarity or relatedness. Keywords that often co-occur are more likely to be identified nearby. A clustering tool is included in the VOSviewer application, which clusters keywords based on their co-occurrence (van Eck and Waltman 2013, 2017; Waltman et al. 2010). The network map for this study was constructed using the same criteria as prior studies, with an emphasis on the most important terms. Unrelated keywords were manually deleted, as were phrases like 'practical implications' and 'originality value' because they indicate abstract structure rather than the actual content. Author names cited in citation contexts were also eliminated.

Cluster 1: "In cryptocurrency marketplaces, there is efficiency and inefficiency, as well as volatility and risk"

The red cluster, titled "In cryptocurrency marketplaces, there is efficiency and inefficiency, as well as volatility and risk", has 20 terms. Table 2 lists the keywords linked with Cluster 1, as well as their frequency of occurrence and relationships with other phrases.

Table 2. Keywords in Cluster 1 related to "In cryptocurrency marketplaces, there is efficiency and inefficiency, as well as volatility and risk".

Keywords (Cluster 1):	Links	Total Link Strength	Occurrences
Volatility	43	122	29
Risk	32	66	15
Inefficiency	32	65	13
Returns	33	62	12
Cryptocurrency market	16	28	11
Gold	23	52	11
Hedge	18	39	8
Impact	29	43	8
COVID-19	18	28	7
Cross-section	14	31	7
Bitcoin returns	19	28	5
Efficiency	14	24	5
Investor attention	20	32	5
Liquidity	13	24	5
Markets	20	25	5
Oil	22	37	5
Stock	12	18	5
Uncertainty	22	28	5
Safe haven	14	23	4
Models	16	19	4

The map illustrates that the red cluster covers the most important occurrences keywords related to cryptocurrency's effect on efficiency, inefficiency, volatility, and risk. The majority of the market efficiency research on cryptocurrencies has applied the weaker form test of the efficient market hypothesis, and the findings are heavily skewed toward exchange cryptocurrencies, as seen in the purple cluster in the map above. As the cryptocurrency business grows, experts are shifting their focus away from gold and toward other large and well-established cryptocurrencies. Urquhart (2016) was the first to analyze bitcoin's weak-form volatility and efficiency, and, via a series of tests, assessed if past return data were dispersed, independent, and did not give the capacity to predict future returns. Therefore, after studying the map in Figure 4, it can be seen that bitcoin has a close relationship with the terms "volatility" and "inefficiency". Some researchers have found correlations in the first red cluster. Shynkevich (2020) expanded on the research on weak-form efficiency. Both researchers have concluded that the bitcoin market is not inefficient (Urquhart 2016; Shynkevich 2020). Kurihara and Fukushima (2017) applied correlation tests to detect price unpredictability and explored daily pricing abnormalities with an emphasis on a regression model. They discovered that bitcoin prices do not fluctuate arbitrarily, resulting in market inefficiencies (Kurihara and Fukushima 2017). All previous cryptocurrency market research on weak-form efficiency has concluded that the current cryptocurrency industry is not inefficient. Nonetheless, they all believe that the facts point to a potential shift in the future as the asset evolves (Mikhaylov et al. 2021; Kang et al. 2021; Fidrmuc et al. 2020). In the end, the red cluster has minor connections with other clusters.

Furthermore, an assessment of the relationships of the red cluster keywords with keywords of other clusters, such as herding behavior, performance, technology, and economics, is displayed. Investigating volatility connections and spillover effects across multiple cryptocurrencies aids in a better understanding of the data communication mechanisms, with cryptocurrency behavior providing significant information on market performance, benefiting investors and miners. There are many different types of theoretical and empirical studies on bitcoin volatility spillovers and related data technology communication mechanisms. The underlying mechanism of cryptocurrency spillover to the rest of the world's economy is a result of its correlation with market fundamentals and international capital distribution (Abakah et al. 2020; Alexander and Dakos 2020; Vidal-Tomás 2021).

A timeline may be used to visualize the progression of examined issues, with major milestones and critical events linked to bitcoin efficiency, volatility, and risk noted using color-coded markers. Beginning with Urquhart's 2016 study on bitcoin's weak-form volatility and efficiency, succeeding markers highlight significant research discoveries, such as Shynkevich's work on weak-form efficiency and Kurihara and Fukushima's study on price irregularities. Connections and effects among efficiency, volatility, and other elements, such as herding behavior, performance, technology, and economics, are illustrated by lines linking markers in the red cluster to those in other clusters. This graphic depiction provides a quick summary of how research and advances have led to our understanding of bitcoin markets and their influence on many areas of interest.

Cluster 2: "A review of cryptocurrency acceptability, financial performance, and market characteristics"

The green cluster, titled "A review of cryptocurrency acceptability, financial performance, and market characteristics", has 22 terms in total. Table 3 lists the keywords connected with Cluster 2, as well as their frequency of occurrence and relationships with other terms. The keywords in this cluster indicate essential subjects within the field of research, such as technology, performance, acceptability, and management, which are thought to be important factors to evaluate.

Table 3. Keywords in Cluster 2 related to "A review of cryptocurrency acceptability, financial performance, and market characteristics".

Keywords (Cluster 2):	Links	Total Link Strength	Occurrences
Technology	34	70	14
Performance	39	70	12
Management	30	62	10
Adoption	21	48	8
Information	35	26	8
Information technology	21	45	8
Innovation	26	48	8
Model	30	49	8
Trust	22	35	8
Blockchain technology	13	21	7
Acceptance	17	30	6
Smart contracts	21	36	6
User acceptance	16	33	6
Attitudes	14	33	5
Business	19	32	5
Challenges	23	31	5
Framework	24	36	5
Sustainable development	16	21	5
Neural network	10	15	4
Perceived risk	15	18	4
Supply chain	17	25	4
Systems	18	28	4

The graphic shows that the green cluster is highly related to the majority of the other clusters, demonstrating its importance in discussing present and future developments. Numerous studies have been conducted to investigate the impact of these qualities on financial technology adoption or financial performance. However, no agreement has been reached on their influence on the desire to deploy smart contracts. Surprisingly, considerable differences have been found depending on the technology employed and the target population being investigated. Many keywords inside the green cluster, including technology and performance, are strongly related to other concepts, such as blockchain, sustainability, and energy investment assumption, in this context. Scholars in the second green cluster have observed several connections among these phrases, suggesting their interconnection and possible significance for the discipline. Kasri and Yuniar (2021) performed research and discovered evidence that effort expectation and social influence had a good impact on the likelihood of using crowdfunding. They did not, however, discover any evidence that performance expectations and enabling factors had a similar effect. Kim (2021) revealed, on the other hand, that performance expectation, behavioral intention, and social pressure all had a favorable impact on the desire to utilize a digital payment authentication mechanism. Makanyeza and Mutambayashata (2018) discovered that while the link between effort and performance favorably influenced behavioral intention to use cryptocurrency, social pressure and enabling environments had no impact. However, when examined from the standpoint of applied technology adoption, it became clear that psychological variables had considerable influence on the acceptance of cryptocurrencies. These findings emphasize the complexities of the elements that influence people's intentions to use various technologies or platforms, such as crowdsourcing, digital payment authentication, and cryptocurrency. The research shows that, depending on the environment and technology being studied, characteristics such as effort expectation, social influence, performance expectation, behavioral intention, and social pressure can have various degrees of impact. Expectations of performance and effort, according to Ebizie et al. (2022), have a beneficial impact on the worldwide acceptability of cryptocurrencies. However, Ferri et al. (2020) found no evidence to support the influence of performance expectations or social pressures on such intentions. Interestingly, despite their study's lack of effect, performance expectations and

enabling conditions were nevertheless recognized as major determinants of behavioral intention to use cryptocurrencies.

A visualization of the evolution of the examined issues is shown using linked nodes, where each node represents a key idea or term such as technology, performance, blockchain, sustainability, and investment in energy assumption. The relationships are highlighted by color-coding the nodes based on clusters, with the green cluster as the central emphasis. Lines or arrows connecting the nodes represent the links between the ideas, illustrating the effect of the green cluster on the other clusters and highlighting correlations within the green cluster. This graphic depiction depicts the developing knowledge of how these ideas influence financial technology adoption, financial performance, and the intention to employ smart contracts.

Cluster 3: "A look into cryptocurrencies and why bitcoin has such a large market share"

The blue cluster, labeled "A look into cryptocurrencies and why bitcoin has such a large market share", includes 20 terms in total. Table 4 lists the keywords connected with Cluster 3, as well as their frequency of occurrence and relationships to other phrases. This cluster's keywords emphasize important subjects in the field of research, such as cryptocurrencies, Bitcoin, Ethereum, and sentiment analysis. These keywords show a concentration on understanding the causes underlying Bitcoin's large market share and examining the broader cryptocurrency environment.

Table 4. Keywords in Cluster 3 related to "A look into cryptocurrencies and why bitcoin has such a large market share".

Keywords (Cluster 3):	Links	Total Link Strength	Occurrences
Cryptocurrency	85	537	187
Bitcoin	84	484	140
Ethereum	15	32	12
Machine learning	14	22	10
Social media	20	33	10
Sentiment analysis	19	30	8
Finance	14	23	7
Investment	15	27	7
Currency	13	22	6
Deep learning	11	19	6
Fintech	15	23	6
Internet	14	22	5
Money	11	14	5
Causality	12	16	4
Cryptography	9	15	4
Mining	7	15	4
Networks	12	14	4
Price prediction	10	16	4
Time-series	13	17	4
Twitter	16	23	4

The map demonstrates that the blue cluster has a higher number of occurrences for some keywords and it is related to all other clusters. We begin with the most important keywords in the map, where the cryptocurrencies, including bitcoin, are located. Cryptocurrencies have grown to be a significant type of digital currency (Chuen et al. 2017), in particular, Bitcoin. Bitcoin is unique from other digital currencies, which may include centralized issuance, community-based distribution, or ties to fiat money or producing organizations (Chatterjee et al. 2020). As important phrases used throughout diverse frameworks, concepts, and the literature on this subject, cryptocurrencies and Bitcoin are related among all clusters of different colors in Figure 3. Bitcoin, which was founded in 2008, seeks to simplify electronic payments by eliminating the need for banking institutions or third parties. While Bitcoin remains the most popular cryptocurrency, new cryptocurrencies,

such as Ethereum, Litecoin, and Ripple, have arisen. However, the concentration on Bitcoin has led to broad generalizations, ignoring the presence of several cryptocurrencies that are actively traded in the market (Corbet and Yarovaya 2020). Academics argue whether Bitcoin should be considered a currency or merely a speculative asset (Gronwald 2019). The emergence of cryptocurrencies has also sparked debates regarding private money and currency rivalry, pushing numerous central banks to investigate the possibility of adopting decentralized digital currencies (Latifa et al. 2017).

A timeline that emphasizes major milestones and significant events linked to the topics addressed is used to depict the progression of the studied concerns. Each milestone is represented by a marker on the timeline, which is color-coded to coincide with the various clusters, with the green cluster serving as the focal point. The following markers represent major results and trends in the discipline, beginning with early studies such as those by Kasri and Yuniar (2021) and Kim (2021). Connections between the markers, represented by lines or arrows, show the linkages and interconnections between concepts across time. This graphic clearly depicts how research and advances have influenced our knowledge of the challenges, particularly their impact on financial technology adoption, financial performance, and intent to employ smart contracts.

Cluster 4: "Cryptocurrencies and sustainability"

The yellow cluster, titled "Cryptocurrencies and Sustainability", has 12 terms in total. Table 5 shows the keywords connected with Cluster 4, as well as their frequency of occurrence and relationships with other phrases. This cluster focuses on the link between cryptocurrencies and sustainability, emphasizing the significance of investigating environmental, social, and governance issues in the context of digital currencies.

Table 5. Keywords in Cluster 4 related to "Cryptocurrencies and sustainability".

Keywords (Cluster 4):	Links	Total Link Strength	Occurrences
Blockchain	60	282	89
Sustainability	28	70	20
Energy consumption	17	37	10
Cryptocurrency mining	9	16	9
Security	12	23	9
Energy	14	17	6
Scalability	6	13	6
Internet of things	8	9	5
Digital currency	5	9	4
Distributed ledger technology	15	22	4
Privacy	15	19	4
Smart contract	4	9	4

The map shows that the yellow cluster is tightly linked to the bulk of the keywords, specifically notably famous terms like blockchain and sustainability. Therefore, various linkages between the blue and green clusters may be seen. The scientific investigation of cryptocurrencies' long-term viability is still in its early phases (Giudici et al. 2020). Blockchain technology has shown promise in fostering sustainability in a variety of cultural, regional, and industrial contexts. While much research has been conducted on Bitcoin's energy usage, other cryptocurrencies have rarely been discussed. Some studies have compared consensus algorithms qualitatively without using quantitative criteria or sustainability metrics. Non-scientific assessments have typically focused on financial performance and offer investment advice (Vaz and Brown 2020). There is currently no universally accepted definition of cryptocurrency sustainability, nor is there a widely recognized methodology for examining its sustainability in terms of factors such as investigation, security, privacy, and scalability, as indicated by the keywords within the yellow cluster. With the lack of a scientifically defined strategy with quantifiable criteria for evaluating and comparing the sustainability of differ-

ent cryptocurrencies, there is a substantial research gap. This provides an opportunity to promote academic research on the relationship between sustainability and the characteristics of cryptocurrencies and blockchain (Fry and Serbera 2020). Assessing the long-term viability of numerous cryptocurrencies can serve as a starting point for talks on how to improve the long-term viability of existing or emerging digital currencies, particularly those based on blockchain technology (Giudici et al. 2020).

Through woven nodes, the overlay graphic depicts the progression of the investigated concerns. The yellow cluster, which is fundamental to the picture, is associated with phrases such as blockchain and sustainability. Other nodes, connected by lines or arrows, reflect crucial ideas such as energy usage, consensus methods, security, privacy, scalability, and quantitative sustainability standards. These links extend to the blue and green clusters, demonstrating the impact of blockchain applications on sustainability in a variety of scenarios. The graphic also emphasizes the research gap in cryptocurrency sustainability criteria and approaches, underlining the importance of scientific exploration. This overlay visualization depicts the increasing knowledge of the links among blockchain, sustainability, and cryptocurrencies, casting light on the research gaps and allowing for additional academic inquiry.

Cluster 5: "An examination of the financial behavior of cryptocurrencies"

The purple cluster, labeled "An examination of the financial behavior of cryptocurrencies", has ten terms in total. Table 6 lists the keywords connected with Cluster 5, as well as their frequency of occurrence and relationships with other phrases. This cluster's keywords emphasize major subjects in the discipline, such as behavior, economies, and pricing. These keywords suggest an emphasis on the financial features and dynamics of cryptocurrencies, such as their behavioral patterns, economic ramifications, and price changes.

Table 6. Keywords in Cluster 5 related to "An examination of the financial behavior of cryptocurrencies".

Keywords (Cluster 5):	Links	Total Link Strength	Occurrences
Cryptocurrencies	29	61	23
Behavior	30	58	14
Economics	31	60	12
Herding behavior	14	30	11
Price	21	35	8
Corporate governance	14	25	6
Exchange	16	23	6
Herding	12	23	6
Market	13	19	5
Tests	11	16	5

The map shows that the purple cluster has a low presence, but it has moderate correlations with other clusters, as seen in Figure 3. This cluster focuses on the financial behavior of cryptocurrencies, which is critical for understanding the present and future trends in the industry. The fifth purple cluster's principal connections are with terms from the first red cluster. Herding behavior has received a lot of attention in the behavioral finance literature, especially when it comes to alternative investments and portfolio selection decisions. Herding is a behavioral phenomenon in which investors copy the activities of others in the same market, taking into account their knowledge or fundamental analysis, notably in the bitcoin market. Herding can be natural or manufactured, with investors reaching identical conclusions based on company fundamentals (Stavroyiannis and Babalos 2019). ESG investments, also known as socially responsible investments, have grown in favor due to their perceived performance and durability during market downturns (Rubbaniy et al. 2021). According to some recent research, ESG investing may act as a safe haven during market downturns. However, in comparison to the considerable research accessible in the stock market environment, there is a scarcity in the literature on investor behavior patterns explicitly connected to ESG metrics (Geuder et al. 2019; Pedini and Severini 2022).

The overlay graphic depicts the progression of the topics under consideration. The purple cluster, which depicts bitcoin financial activity, is linked to other clusters and concepts. The lines linking the purple and red clusters show the links between herding behavior and ideas such as alternative investments and portfolio selection. Furthermore, links are drawn between notions such as ESG investing and their position as a safe haven. The relevance of herding behavior in the cryptocurrency industry, as well as the research gap in understanding investor behavior in ESG metrics, are highlighted in this image, adding to a better understanding of the emerging environment in this subject.

4.3.3. Bibliographic Coupling of Countries

Figure 5 depicts the research collaboration network across nations and territories. The findings are based on a minimum of one document, and up to fifty of the most important bibliographic relationships are shown. A label and a circle, the size of which indicates the item's weight or significance, represent each item. The item with the greatest label and circle represents the most relevant entity. The lines connecting the items indicate country ties or linkages, and the distance between distinct items shows the degree of relatedness in this study subject. The map allows you to see nations or regions that have comparable features. Notably, nations on the same continent have comparable profiles and are clustered together on the map.

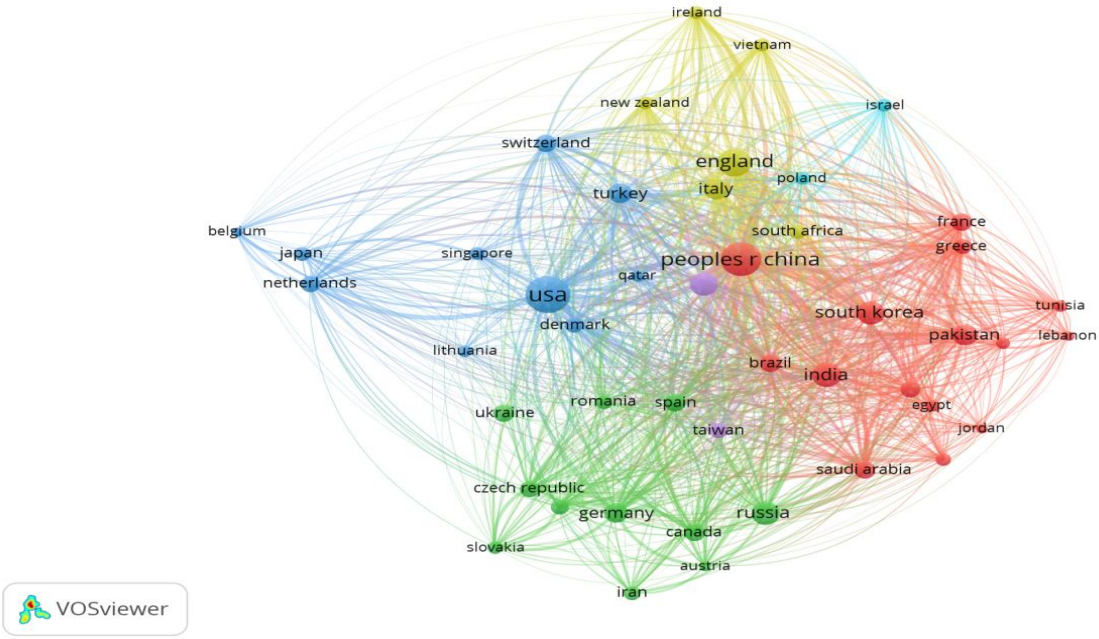

Figure 5. Network visualization of countries' bibliographic coupling in cryptocurrency research.

Figure 5 shows that China has the biggest circle in the network, demonstrating its considerable presence and impact in the research sector. China has strong ties with other nations such as Indonesia, Jordan, Korea, Brazil, and France, implying partnerships and common interests in cryptocurrency research. The United States is represented as the second biggest circle, reflecting its major interest in this area of research as well. The United States has tight ties with nations such as Switzerland, the Netherlands, Turkey, Denmark, and Japan, implying cooperation connections and common research objectives. It is worth mentioning that cryptocurrencies are cited in around 14.7% of published studies in the United States. The majority of these publications are about bitcoin mining and electronic processing, showing that these are important areas of the subject. Simultaneously, other publications on topics like performance, behavior, sustainability, and environmental effects account for an estimated 8.5 percent of published research on cryptocurrencies and their

links. The formulation of economic and environmental repercussions has been published, as well as social ties relating to currency in particular. There has also been interest in the construction of a digital currency, which has already begun in China, and speculation about its expansion into other nations. Figure 5 shows that the six clusters are strongly tied to the discussion of themes relating to mining, converting cryptocurrencies, and developing a worldwide digital currency (Voge 2018).

4.3.4. Bibliographic Coupling of Authors

The idea of author bibliographic coupling (ABC) is an extension of the concept of bibliographic coupling, which refers to two writers quoting the same article(s) in their separately published works. ABC expands on this concept by claiming that the more references two writers have across their body of work, the more comparable their study is seen to be. The ABC notion suggests that the common references show a resemblance in the two writers' study emphasis or interests. It is feasible to analyze the level of their research similarities and uncover future partnerships or common study fields by evaluating the bibliographic coupling between authors. The utility of document bibliographic linking for research front mining and science mapping has been studied. This method entails examining the bibliographic coupling patterns among articles in order to discover upcoming research topics or to illustrate the landscape of a scientific field. Researchers can obtain insights into the linkages and similarities among authors' research works by using ABC, providing better knowledge of the scientific community and its research patterns.

Figure 6 shows the top 48 contributing authors ordered by the number of papers cited. Ludermir, and Teresa are the most cited authors in cryptocurrency papers, with 84 citations. Then there is Giungato, Pasquale, who has 77 publication citations. Each of the top 48 writers has an average of 28 publications citations connected to cryptocurrencies. Bouri, Elie is the author with the most citations among these top authors and has written three papers on cryptocurrencies, which have received 99 citations. Figure 6 shows that the clusters with red, green, and purple hues correspond to authors' names who have research interests centered on the keywords displayed in Figure 3. Furthermore, the yellow cluster in Figure 6 is remote, representing both the authors' involvement and interest with other authors in the other clusters. As illustrated in Figure 3, there is no substantial correlation between the keywords of the yellow cluster and the other clusters. This was one of the publications that compared bitcoin's hedging and safe-haven properties to the major global stock indexes, bonds, oil, gold, the public goods index, and the US dollar index. As a result, it is critical to adopt and have access to studies linked to environmental knowledge and the long-term viability of all cryptocurrencies in terms of behavior and performance.

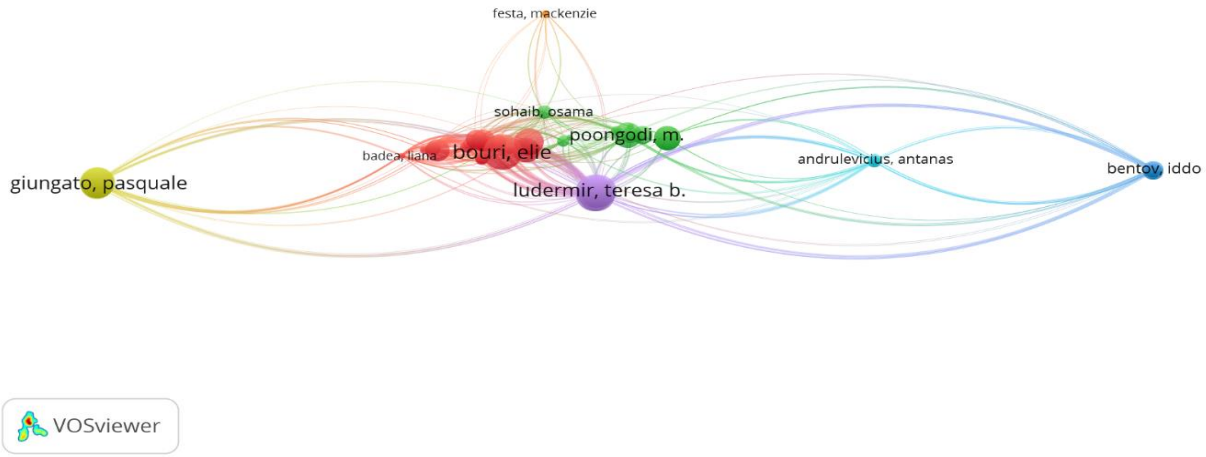

Figure 6. Network visualization of authors' bibliographic coupling in cryptocurrency research.

5. Conclusions, Future Research Directions, and Limitations

This study contributes to the understanding of the literature on cryptocurrencies through a systematic revision and clustering of papers published in the WoS core collection. It identifies the most significant authors, topics, publishers, and nations related to cryptocurrency research. In addition, it explores new streams of research that may be useful in reflecting on environmental impact, analyzing financial behavior, determining the long-term sustainability of cryptocurrencies, and assessing their financial performance. The notable increase in the number of publications in recent years reflects the growing interest in the cryptocurrency phenomenon, the study of which is still at an early stage, with a small number of quantitative studies undertaken. Consequently, many of the results obtained are inconclusive, and there are issues that remain underexplored in the literature.

The keyword analysis identified five exceptional areas of study that are being developed, with a few studies connecting the different areas. Research on the sustainability of cryptocurrency investing shows the following general trends: useful in reflecting the environmental impact, analyzing financial behavior, determining the long-term sustainability of cryptocurrencies, and evaluating the financial performance of cryptocurrencies. Therefore, it is possible to deduce that cryptocurrency research should concentrate on elements that impact cryptocurrencies, the most significant of which would be ESG, efficiency, inefficiency, volatility, risk, acceptability, financial performance, and sustainability, but also risks and monitoring financial behavior. Other academics may seek to develop a scale to statistically quantify cryptocurrency characteristics and examine their links with value co-creation and other new challenges in markets, although research in this area is limited.

Another sign suggesting that cryptocurrency research is at a nascent stage is the high concentration of papers in the hands of a few countries and authors that is gradually spreading. The majority of the 1442 papers studied have been published in American and Chinese journals and are well-cited, demonstrating considerable interest in writing on this topic. Other papers on the sustainability of investing in cryptocurrencies have often been issued in publications in the USA, Indonesia, Jordan, Korea, Brazil, France, Australia, Canada, and Spain. Ludermir, Teresa B. et al. and Giungato, Pasquale are the most prominent authors who have produced publication citations for publications debating the sustainability of investing in cryptocurrencies. This study detected that the number of academic papers has increased because of unexpected issues and global bubbles. This, again, evidences that the concern about the sustainability of investing in cryptocurrencies remains an intriguing problem both conceptually and empirically.

5.1. Future Research Directions

Research trends in the sustainability of investing in cryptocurrencies are organized around the five identified clusters. The first trend shows the efficiency and inefficiency of cryptocurrency marketplaces, as well as the volatility and risk. This helps investors and miners comprehend the data transfer methods, with cryptocurrency efficiency and volatility offering important information on market performance and risk. The second trend focuses on the assessment of cryptocurrency acceptability, financial performance, and market features, showing that performance expectations, behavioral intention, and social pressure all influence the decision to utilize cryptocurrency authentication techniques.

The third trend is an analysis of cryptocurrencies and the reasons why bitcoin has such a large market share. Due to the obvious emphasis on Bitcoin, there has been a generalization that ignores the reality of many other cryptocurrencies already traded on the market. The fourth trend is related to the connection between sustainability and its characteristics and cryptocurrency and blockchain. The evaluation of the sustainability of numerous cryptocurrencies can serve as a starting point for a discussion on how to make existing or new digital currencies more sustainable, and it is widely employed in the blockchain network. Finally, the fifth trend is an assessment of cryptocurrency financial behavior, where investors replicate the conduct of other investors in the same

market while taking their knowledge or fundamental analysis into consideration in the cryptocurrency marketplace.

When compared to prior studies, the found study patterns in the sustainability of investing in cryptocurrencies indicate substantial progress. Unlike previous research, which has frequently focused on certain features of cryptocurrencies, the current analysis is comprehensive and multifaceted. The first trend investigates market efficiency, volatility, and risk, offering vital information about bitcoin market performance. The second trend considers bitcoin acceptance, financial performance, and market characteristics, as well as critical aspects such as performance expectations and behavioral intention. The third trend threatens Bitcoin's current supremacy by recognizing the presence of various cryptocurrencies in the market. The fourth trend looks at the relationships among sustainability, cryptocurrency features, and blockchain technology. Finally, the fifth trend delves into bitcoin financial behavior, specifically the problem of investor herding. These study findings, taken together, lead to a more comprehensive view of the long-term viability of investing in cryptocurrencies, increasing our knowledge in this quickly changing industry.

Future research on the sustainability of investing in cryptocurrencies has substantial potential for advancing knowledge and understanding in this domain. To enhance the comprehensiveness and impact of this review, it is crucial to explore several avenues of investigation. These avenues include examining the influence of different consensus algorithms on sustainability (Vaz and Brown 2020), developing standardized criteria and frameworks for assessing sustainability (Giudici et al. 2020), investigating the role of regulatory frameworks and policy interventions (Corbet and Yarovaya 2020), exploring the interplay between sustainability and financial performance (Makanyeza and Mutambayashata 2018), asset tokenization (OECD Blockchain Policy Series 2020), the development of the metaverse in Web 3 (Vidal-Tomás 2023b), the improvement of decentralized finance (Dos Santos et al. 2022), understanding the behavioral aspects of sustainable investing (Stavroyiannis and Babalos 2019), and evaluating the scalability and environmental impact of blockchain technology (Chuen et al. 2017). Resolving these research gaps will allow scholars to contribute to a more thorough and educated understanding of the long-term viability of cryptocurrency investing, which will benefit both academia and industry.

The study's conclusions have both theoretical and practical consequences. Theoretical implications include presenting a thorough overview of major authors, subjects, publishers, and countries in bitcoin research, highlighting key research trends, and recommending options for future cryptocurrency study and development. Insights for investors and miners on cryptocurrency efficiency, volatility, and risk, understanding performance expectations and behavioral intentions for businesses and individuals using cryptocurrencies, guiding discussions on sustainability for policymakers and industry stakeholders, and providing insights into financial behavior for market participants and regulators are all practical implications. Overall, this study has practical consequences for bitcoin ecosystem decision-making, policy-making, and future research.

Further research into the environmental effect of cryptocurrencies, particularly in terms of energy usage and carbon footprint, might be one of the next research paths in the subject of bitcoin sustainability. Furthermore, studying cryptocurrency investors' financial behavior, including behavioral biases and herd behavior, might reveal insights into market dynamics and investor decision-making. Further research on the long-term viability of cryptocurrencies, including their economic, social, and environmental viability, might help to design more sustainable cryptocurrency models. In addition, research on the relationship between sustainability qualities and cryptocurrencies, as well as the potential of blockchain technology in promoting sustainability, may give useful insights for policymakers, industry practitioners, and investors. Finally, investigating the performance and dangers of various cryptocurrencies, as well as creating statistical techniques for assessing cryptocurrency features, might contribute to a better understanding of cryptocurrency markets and their influence on the larger financial ecosystem.

This study improves upon prior objective and assessment studies in the literature on the long-term sustainability of cryptocurrency investing and increases the efficacy of interdependent links and how they influence the long-term viability of cryptocurrency ESG. Furthermore, it focuses on risk management in cryptocurrency investing as a strategy for long-term sustainability with diverse mining methods. The most relevant keywords discovered by the bibliometric study might be used as explanatory factors in an econometric approach, with the assessment carried to a macroeconomic level, and the variable of interest as the response variable to consolidate recommendations for future research. Insights into the connection between the keywords and macroeconomic parameters may be gained from this method, which might help guide future studies in this field.

5.2. Limitations

This study has various limitations that should be noted. For starters, the data source was confined to the WoS core collection, which may not include all important papers on the subject. Furthermore, the study concentrated on certain fields and geographies, potentially omitting significant findings from other areas. In certain areas, the findings were unclear; indicating that more research is needed. The absence of quantitative investigations hinders the capacity to reach clear findings. Furthermore, concentration was found among the authors and nations, which may alter the representativeness of the findings. This study was also constrained by a set era and currency, which may have missed the most recent events. Language bias may exist because of the constraint to a single language. Finally, this study was limited by the limits of keyword-based techniques. Given these limits, further research is required to overcome these constraints and gain a more thorough grasp of the subject of bitcoin research.

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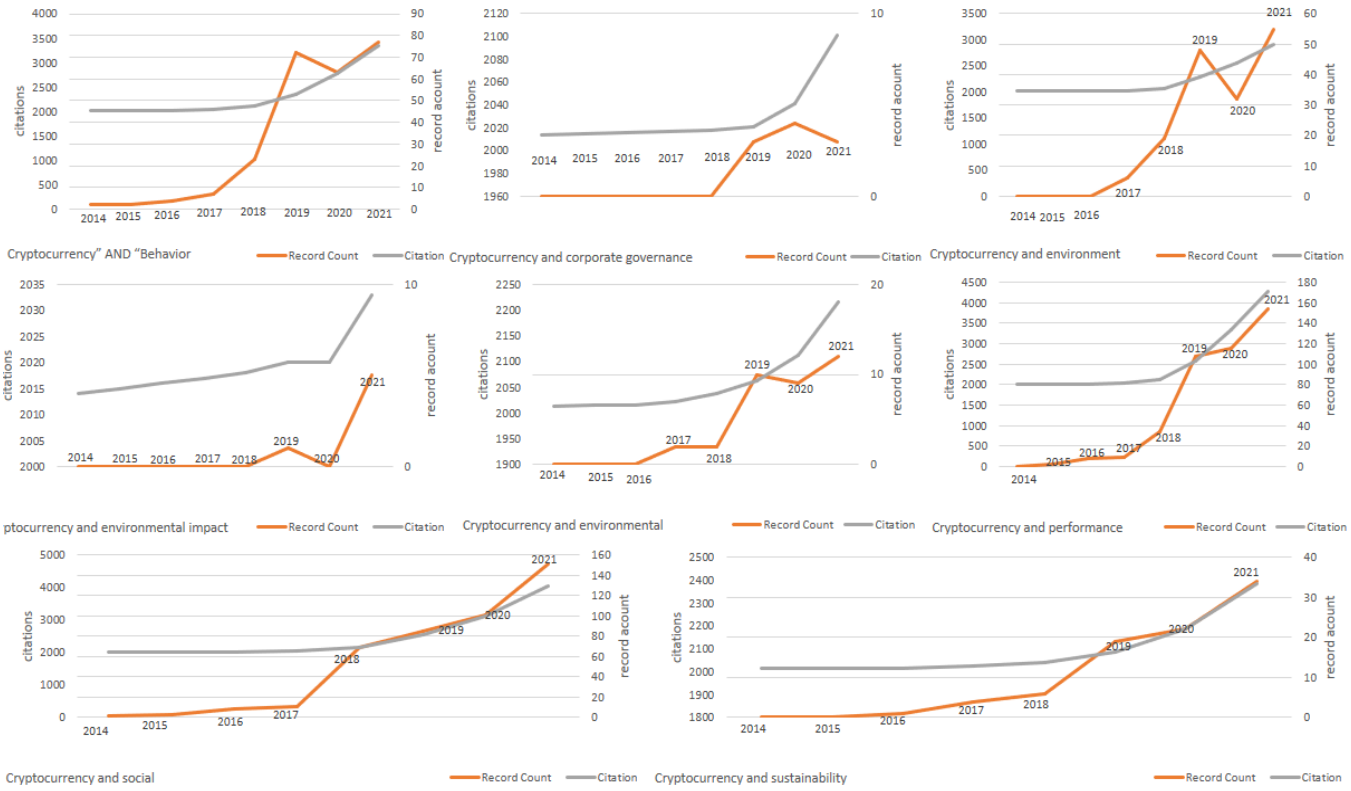
Conflicts of Interest: The authors declare no conflict of interest.

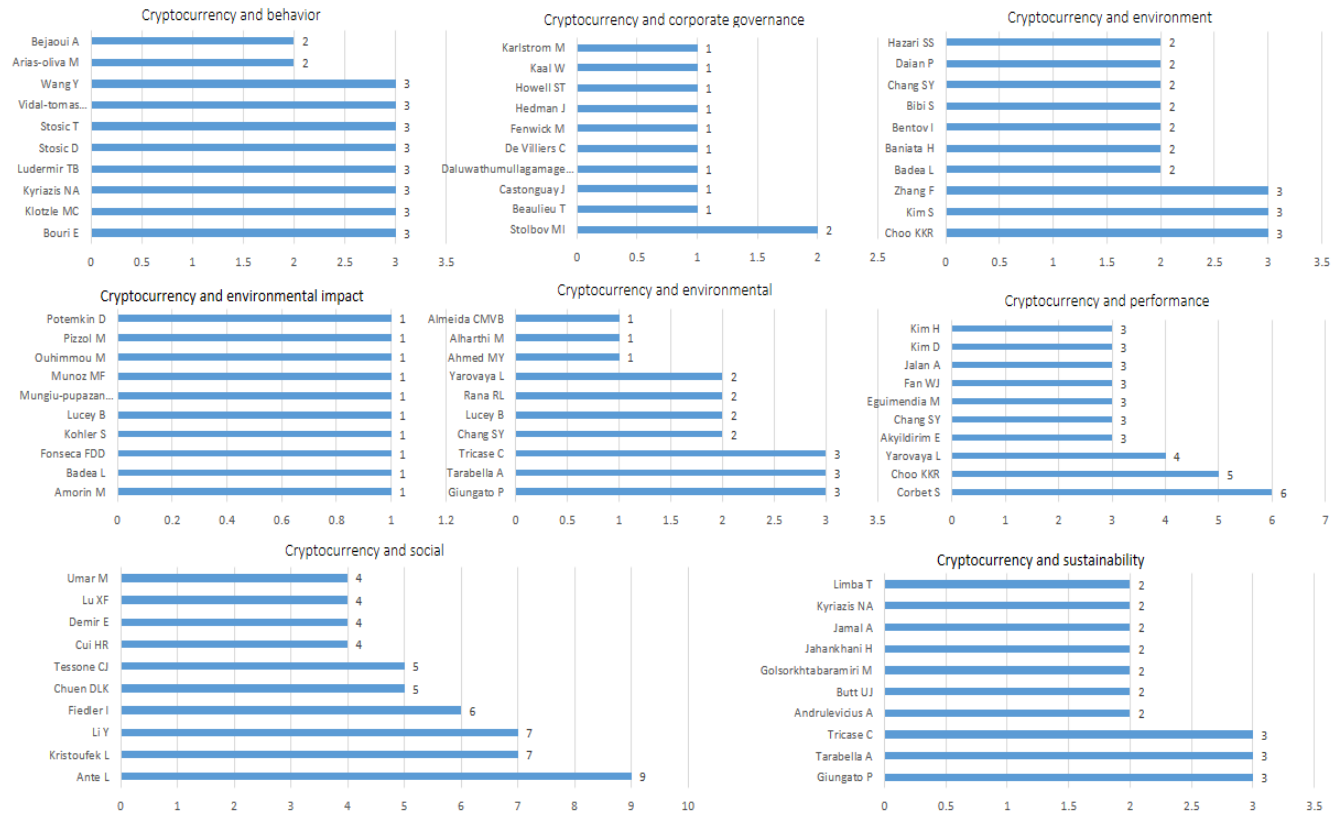
Appendix A

List of figures using the detection of keywords and cryptocurrency publication activity from 2014 to 2021.



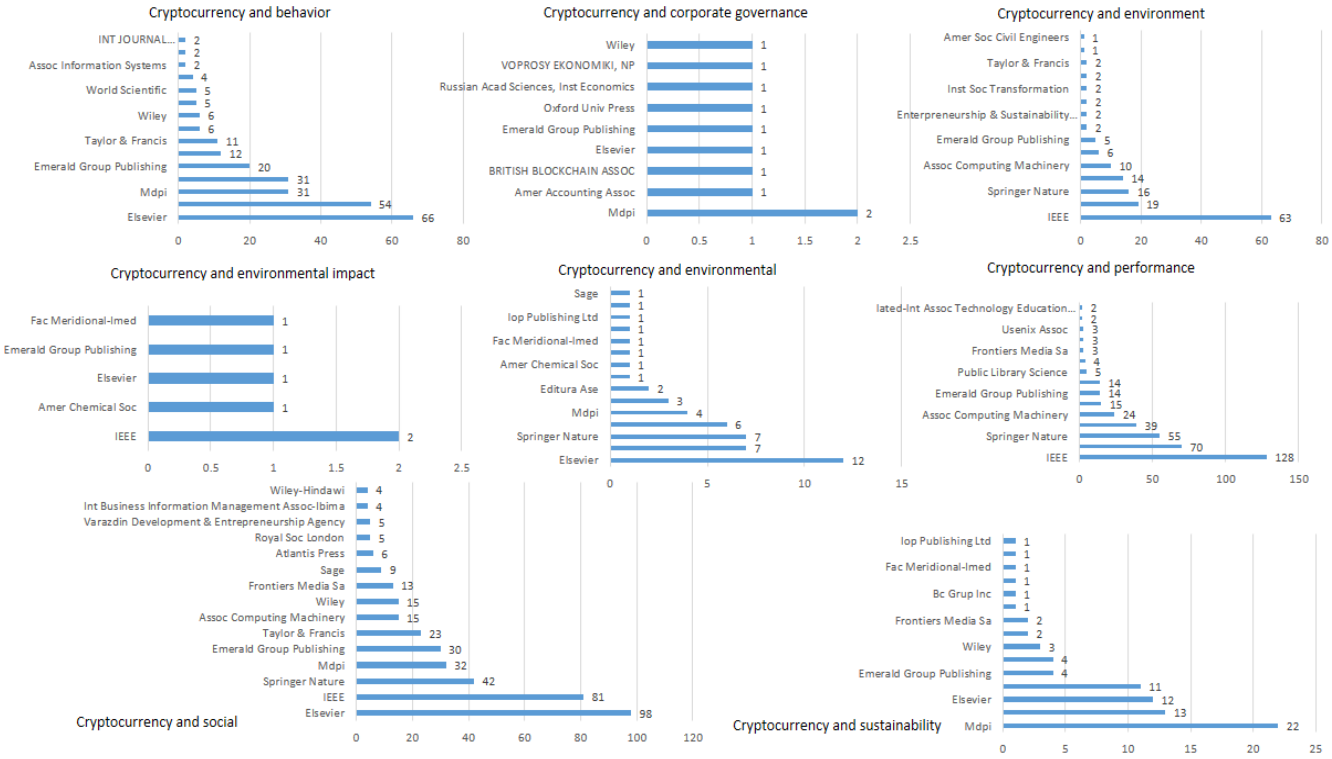
Appendix B

List of figures using the detection of keywords and publications by author.



Appendix C

List of figures using the detection of keywords and publications by publisher.



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