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Bibliometric Analysis of Green Finance and Climate Change in Post-Paris Agreement Era

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Abstract: Climate change is undeniably one of the long-term challenges confronting humanity across the globe. Various nations have taken initiatives that help reduce greenhouse gas emissions to the environment as well as accelerate financial flows to clean and sustainable projects. The paper provides an overview of green finance after the Paris Agreement by adopting a bibliometric analysis of the selected literature. The study reviewed the literature from the Web of Science database between 2015 and 2022. Data cleaning, formatting, and analysis was performed using VOSviewer and R-studio. Our study indicates increased scholarly interest on the issue of green financing. Most scientific research has been published in climate policy and sustainability journals but lacks mainstream interest in economic and finance journals. Based on our results, it is recommended that further studies on green financing be carried out from the economic and financial perspective using quantitative approaches to supplement the existing literature and provide a wider view to policy makers and regulators.

Keywords: green financing; green investments; climate change; Paris Agreement; VOSviewer; R-studio; plot analysis; co-citation; co-occurrence

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1. Introduction

Climate change is undeniably one of the long-term challenges confronting humanity across the globe. Climate change is a unique challenge and perhaps the biggest market failure the world economy has experienced over decades (Adom and Amoani 2021). The continued increase in human activities resulting from massive industrialization and the burning of fossil fuels has been responsible for accelerating greenhouse gas emissions into the atmosphere (Ngwenya and Simatele 2020). The rising concerns for environmental protection and climate change mitigation have propelled many international organizations and economies toward sustainable growth and development approaches (Nordhaus and Yang 1996; Easterling et al. 2000; Alley et al. 2003; Hayhoe et al. 2004; Matthews et al. 2017; He and Liu 2018; Abbasi et al. 2021).

The United Nations is focused on reducing global warming temperatures to below 2 degrees Celsius by the end of this century so as to protect humankind and the environment from the adverse effects of global warming (Adekoya et al. 2021). As a result, various nations in both developed and developing economies have taken initiatives that help reduce greenhouse emissions to the environment as well as accelerate financial flows to clean and sustainable projects (Tudo et al. 2021). In the case of finance 4.0, East African economies and societies have an improved access to international financial markets (Vida et al. 2020).

The transition to lower carbon and more resilient economies requires the investment of significant resources from both the private and public sectors (Long and Blok 2021). The G20 green financing study defined green finance as financial investments that aim at providing

environmental benefits in the wider context of achieving environmentally sustainable development (Long and Blok 2021). Other terms used interchangeably with green finance include environmental finance, climate finance, sustainable finance, and carbon finance (Arezki 2021). Based on the UNEP definitions, climate finance is part of green finance because the latter focuses on the financing of mitigation and adaptation investments (Managi et al. 2022). Green financing is considered the intersection between economic growth and environmental protection. According to Azad et al. (2022) it is important to revisit the current status of green finance and sustainable finance disbursement.

Since the Paris Agreement of 2015, green financing has gained popularity as a key enabler in countering threats resulting from environmental damages and climate change. A study by Pham et al. (2019) revealed that the Paris Agreement global initiative has increased the risk of return for stocks in the polluting industries. Green financing also forms a strong background for sustainable development and long-term growth (Frydrych 2021). More than 200 countries have publicly outlined their intentions to participate in reducing the impact of climate change as detailed in the Intended Nationally Determined Contributions (INDCs) (Arezki 2021). Numerous scientific publications discuss the European and worldwide companies' and markets response to the Paris Agreement (Birindelli and Chiappini 2021; Christoff 2016; Sen and von Schickfus 2020; Mukanjari and Sterner 2018; Diaz-Rainey et al. 2021). A study by Dutta et al. (2021a) notes that green investments, especially green infrastructure and projects, have gained international and national attention in India as a solution for reducing the level of CO_2 emissions. A study by Xu et al. (2020), which adopted the meta-analytic approach and utilized comprehensive meta-analysis software, revealed that green financing positively correlates with an enterprise's green performance.

As agreed in the Paris Agreement, countries have begun to implement laws that influence financial actors in this direction. The focus for these countries has been on adopting adaptation and mitigation strategies against climate change.

The implementation of these projects, however, is faced with a myriad of challenges including a wide green financing gap (Adekoya et al. 2021). Financial resources are critical in achieving the United Nation's sustainable goals and are a pressing issue for global economies, especially the developed nations (Lewis 2018). Developing economies such as Africa are most likely to be adversely affected by climate change (Filho et al. 2022). These observations align with the observations of the Intergovernmental Panel on Climate Change (IPCC) special report, which also iterates that a further increase in temperatures would become even more disastrous for Africa especially because of her weak institutions that can effectively deal with climate change impacts (Edenhofer et al. 2011). Developing economies are still heavily reliant on the developed nations to finance them with the 100 Billion annual pledge to invest in their mitigation and adaptation projects (Adekoya et al. 2021). This paper aims at providing a review of green finance after the Paris Agreement by adopting a bibliometric analysis of the selected literature.

The paper seeks to find answers to the following research questions.

RQ1: What are the Post-Paris Agreement academic trends on matters of green financing considering annual scientific production, trend evolutions, mainstream journals and co-citations, and co-occurrence?

RQ2: What are the main issues of interest by the researchers regarding green financing?

This paper adds to the existing literature on the growing concept of green financing. The enablers identified in the literature also provide a great guidance opportunity for policy makers both in the developed and developing economies on how they can accelerate financial innovations to bridge the existing green financing gap. The paper also provides a wide in-depth knowledge of green financing instruments to practitioners and academicians that can be utilized to transition to greener economies.

The paper structure will be organized into various sections. Section 2 will provide an overview on the research methodology adopted in this paper. Section 3 will present the study results. Section 4 will entail a discussion of the research findings while Section 5

will capture the conclusions drawn from the study key findings and include the scope for future research recommendations.

2. Materials and Methods

The study adopted a bibliometric approach with the aim of understanding the academic productivity of green financing after the Paris Agreement of 2015. Bibliometric analysis involves analyzing and investigating selected literature using mathematical and statistical methods (Gutiérrez-Salcedo et al. 2018). The approach has gained much popularity since the establishment of the Science Citation Index (SCI) in 1963 as a strong approach for conducting meta-analytical review on the literature (Gallegos et al. 2020).

The study reviewed the literature from the Web of Science. The Web of Science is characterized with a narrow scope but high quality papers (Lakner et al. 2021). Based on some heuristic trials informed by review of the related literature, the researcher settled on the following optimal words combinations to search for relevant documents from the database.

TS = (((“Green Finance*”)OR (“Climate Finance*”)OR (“Carbon Finance*”)OR (“Environmental Finance*”))AND ((“Climate Change*”)))

The above keywords were used to derive the corpus from the web of science database upon which the results of this study were based on. The review was conducted in four major steps, including data collection, data cleaning, data formatting, and data analysis. Data collection was implemented by searching relevant key words. Data cleaning, formatting, and analysis were performed using VOSviewer and R-studio. The VOS software and bibliometric packages available in R-studio are strong statistical tools for carrying out bibliometric analysis (Komiyama and Yamada 2018). The analysis was performed based on the dataset for the published articles collected after rigorous and systematic inclusion and exclusion criteria.

The exclusion criteria were based on three major factors, which included language (English), if the articles were peer reviewed papers or journal articles and if their publication timeframe was within 2015–2022. The selected articles were also reviewed manually one by one by examining their titles and abstract to identify those that were relevant to the subject matter. Those whose scope was not focused on green financing were deemed irrelevant and retracted. The articles included for final analysis were those that were highly related to the subject matter, i.e., those that explored various aspects of green finance, were published within the time frame of (2015–2022 April), and were written in the English language.

The VOS software helps with retrieving bibliometric information regarding top authors, keyword analysis, citations, and top countries’ production (Cobo et al. 2011). The time span for this study was from (2015–April 2022). This time-span helped us to see how various economies have reacted to the Paris Agreement Appeal of 2015, as well as show academic scholarly interest on green financing after the agreement. VOSviewer and Bibliometric R-Studio software assist in representing the dataset graphically for easier interpretation as it has a robust interface for interpreting and examining bibliometric maps (Komiyama and Yamada 2018; Cobo et al. 2011).

Figure 1 below shows the research process adopted for the study.

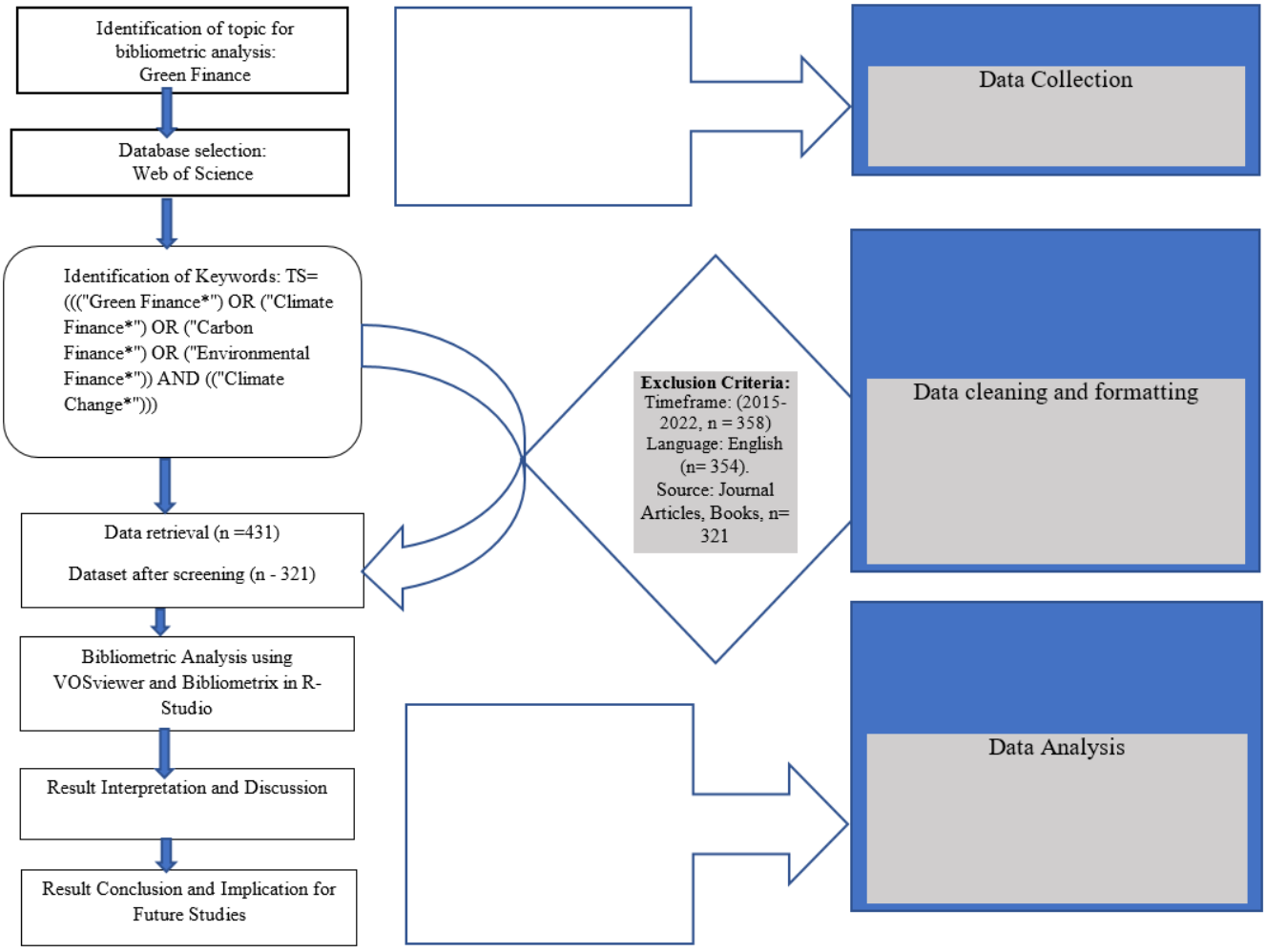

Figure 1. Summary of the research process adopted. Source: Authors' own compilation on the research process adopted.

3. Results

3.1. General Characteristics of Corpus

Table 1 summarizes the general characteristics of the corpus used in the paper. The timeline used for the paper was 2015 to 2022. The research was interested in the scientific research production after the Paris Agreement of 2015. After rigorous selection criteria, a total of 321 documents were selected.

The average citation per document is 10.02 implying that the selected documents were averagely highly cited and of high quality. Reviewed articles accounted for the highest number in the corpus (n = 264), followed by review papers (n = 25) and early access articles (n = 19). Author's appearances were 1004 while the collaboration Index was 3.21, showing that there has been a high rise in collaborations between countries and among authors. The basic details of the corpus are summarized in Table 1 below.

Table 1. General characteristics of Corpus.

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2015:2022
Sources (Journals, Books, etc.)	160
Documents	321
Average years from publication	2.63
Average citations per documents	10.02
Average citations per year per doc	2.704
References	16,367
DOCUMENT TYPES	
Article	264
article; book chapter	5
article; data paper	1
article; early access	19
article; proceedings paper	5
Review	25
review; book chapter	1
review; early access	1
DOCUMENT CONTENTS	
Keywords Plus (ID)	629
Author's Keywords (DE)	914
AUTHORS	
Authors	823
Author Appearances	938
Authors of single-authored documents	76
Authors of multi-authored documents	747
AUTHORS COLLABORATION	
Single-authored documents	88
Documents per Author	0.39
Authors per Document	2.56
Co-Authors per Documents	2.92
Collaboration Index	3.21

Source: Authors' own compilation using Bibliometric R-package.

3.2. Annual Scientific Production

The scientific production on green financing has increased continuously from 2015. This trend shows that scientific researchers have continued to gain more interest in the matter of green financing. This growth is also a reflection of increased interests by researchers to explore more knowledge on green financing as a solution to combating climate change. This rise can be attributed to the increased international activities towards sustainability. These results aligns with the findings of a similar study by Akomea-Frimpong et al. (2022), which found a rising trend in academic scientific production of green finance articles from the year 2017. The establishment of the global climate finance fund in 2010 has also attracted scientific research focused on the inclusion of the financial sector and innovation of financial instruments to control climate change and support mitigation and adaptation investments (Akomea-Frimpong et al. 2022). This growth trend is illustrated in Figure 2.

Notably, the evolution of green financing seems to transition from "green bonds to climate finance" to "sustainable finance" and now "green finance". Among the top terms as revealed by the trend topic analysis, "green bonds" and "sustainable finance" were not part of our initial search pattern. It is, therefore, noteworthy that despite this exclusion, "sustainable finance" still ranked 2nd place. This implies that the inclusion of these terms into the search pattern would have probably resulted in a larger corpus. Rashid and Uddin (2018) argues that green finance is a sub-aspect of sustainable finance. This explains why the prevalence of the word sustainable finance was conspicuously high even though it was not included in the keyword patter used in developing the corpus used for this study.

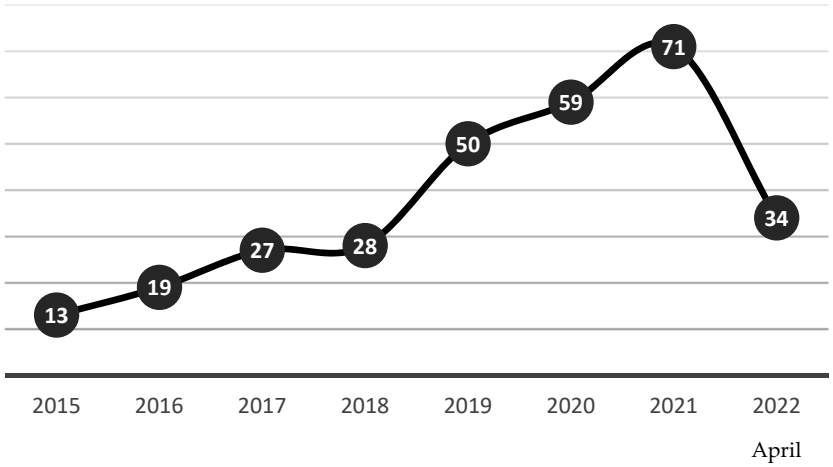

Figure 2. Annual scientific production on the green financing domain (articles). Source: Authors' own compilation.

This trend topic transition is illustrated in Figure 3, as shown below. The trend topic analysis was based on author's keywords in R-studio.

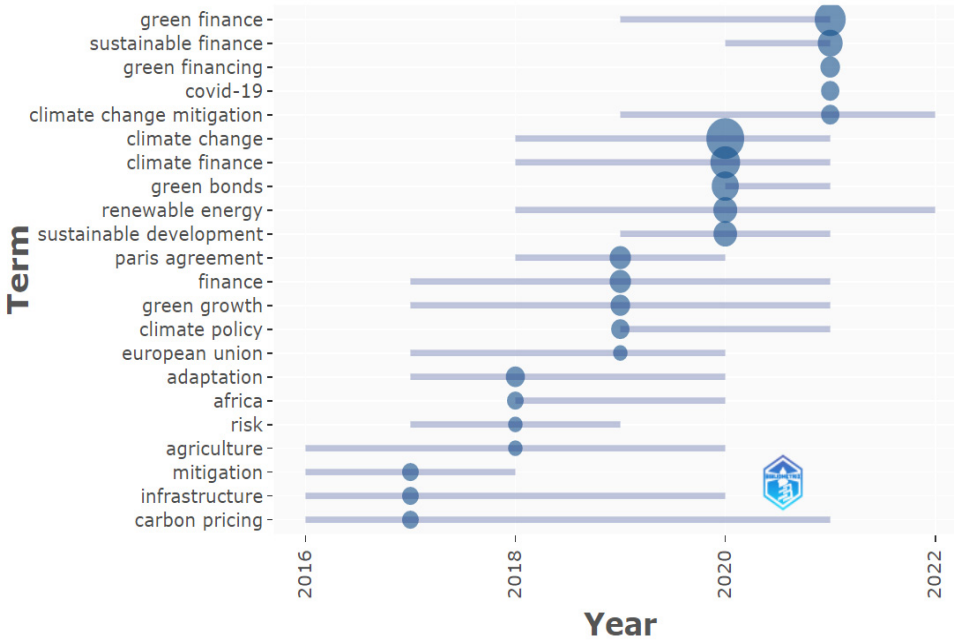

Figure 3. Trend topic based on author's keywords. Source: Authors' own compilation using Bibliometric R-package.

3.3. Three Field Plot Analysis on Green Financing

A Sankey 3-plot diagram helps in visualizing the flow of the scientific literature based on three selected fields. The diagram helps in visualizing the important contributions of each of the selected fields to the flow system. The 3-plot diagram is constructed based on the top 10 countries where the authors are affiliated, keywords, and journals in which their research work is published.

As seen in Figure 4, the scientific research on green financing is dominated in China, United Kingdom, USA, Italy, Australia, France, Germany, Spain, Sweden, and Netherlands, respectively. The top ten keywords used include, climate change, green finance, climate finance, green bond, green climate funds, sustainable finance, renewable energy, finance, sustainable development, and sustainability. The top journals where most of these articles

are published include sustainability, climate policy, journal of sustainable finance and investment, journal of cleaner production, environmental research letters, environmental science and pollution research, international journal of environmental research and public health, and climate change. The inter-links between countries and keywords show that most authors have focused their research on climate finance, climate change, and green finance. Most authors publish their literature about green finance in climate policy journal, sustainability, and international environment agreements—politics law and economics.

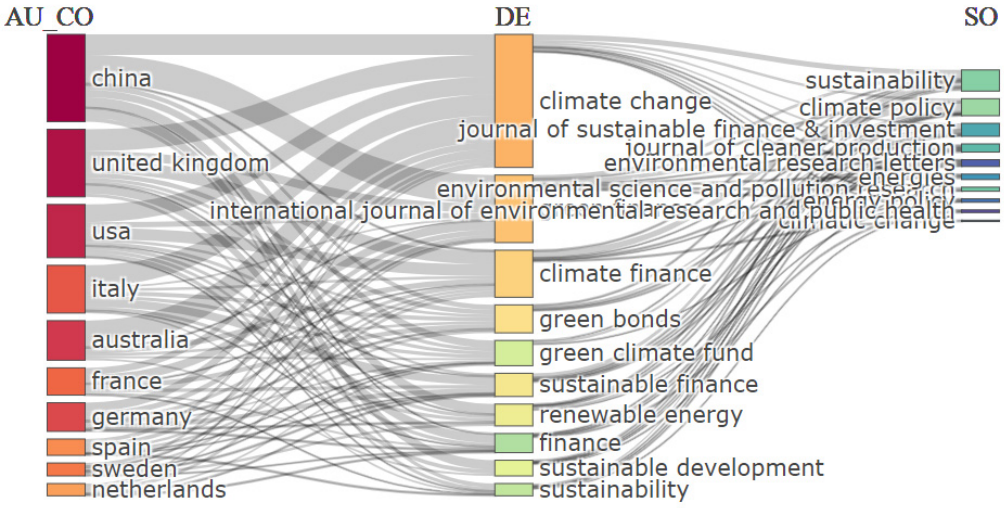

Figure 4. 3-field plot analysis on green financing. Source: Authors' own compilation using bibliometric R-package.

3.4. Co-Citation Analysis

Co-citation analysis provides insight into the research contributions made for the purpose of developing a given concept. It is a popular approach in understanding the intellectual structure of a certain field. Co-citation analysis was performed using network visualization by VOSviewer.

A network visualization is a set of items that are connected through links. Items are represented in circles and labels. The co-citation network diagram was developed based on cited sources using the counting method. The threshold was a minimum of 20 citations. Out of the 13,673 sources, only 151 met the threshold. Sources with the highest total strength for the co-citation links were selected in developing the co-citation network visualization.

The size of the circle and the labels depends on the weight of the items. The larger the size of the circles or labels, the more the weight, and vice versa. An item with a high weight is considered more important than an item with a lower weight. The connection between the two items is expressed in the form of links. The links in Figure 5 show the relationship between the authors and their countries of origin. The links have different values that determine their strength. Links with higher values are stronger than those with lower values. A set of items form a cluster, which is labeled in numbers. An item can only belong to one cluster. All the items must not belong to a cluster. Only items with closely related nodes are classified in one cluster. The co-citation network was based on four clusters, shown in Figure 5.

VOSviewer only classifies an item to one cluster to avoid overlapping. In the events where the links between two items has a value of one, VOSviewer does not show the link strength. The color of the item depends on the cluster in which the items belong. Total strength indicates the number of citations two items share.

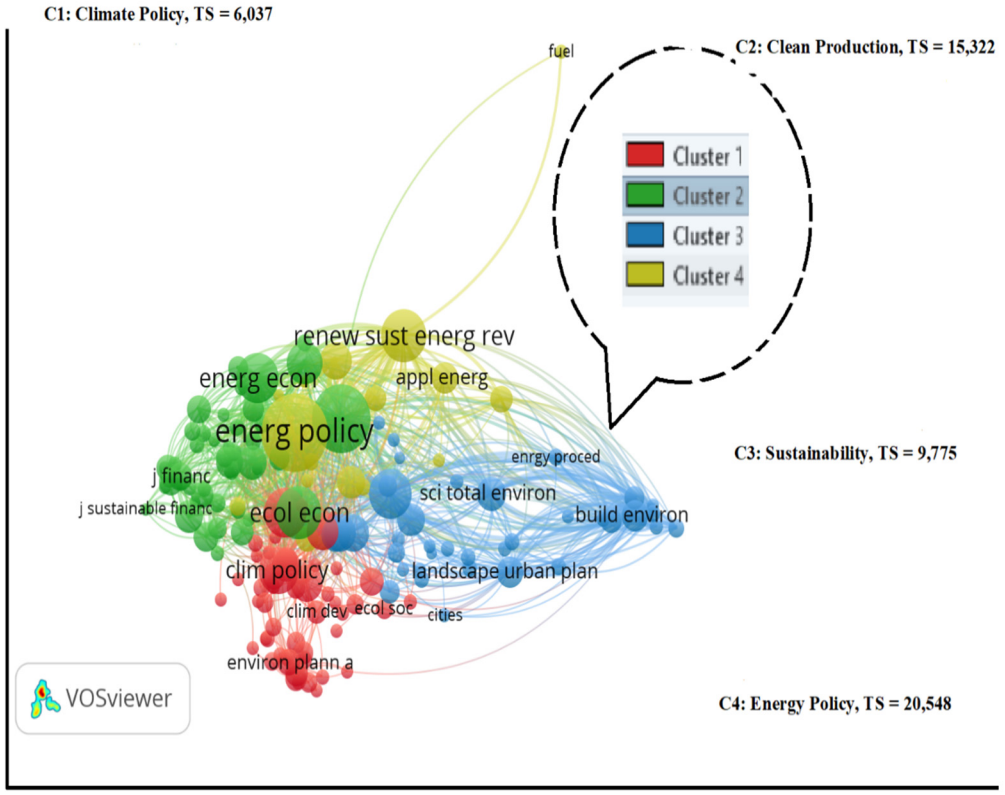

Figure 5. Co-citation analysis. Source: Authors' own compilation using VOSviewer.

The degree of co-citation is indicated by the size of the cluster, while the strength of the co-citation relations is shown by the width of connecting lines. The bigger the size of the circle, the higher the frequency of citations. The co-citation network was based on four clusters. The green financing research was highly co-cited along with the research work published in energy policy journals (Cluster 4, TS = 20,548), followed by studies published in clean production journals (TS = 15,322), sustainability journals (TS = 9775), and climate policy journal (TS = 6037). Authors in the same cluster are more likely to be cited jointly in a given publication.

In cluster 1, there was high co-citation on scientific research published in climate policy and environmental planning. High co-citation is also evident on research studies published in energy economies, ecological economics, sustainable finance, and energy policy in cluster 2. High citations were also shared among documents published in building environment journals, landscape urban planning and scientific total environment journals, as shown in cluster 3. Cluster 4 shows high co-citation connection for research work published in energy policy and renewable and sustainable energy journals. Figure 5 provides a detailed visual analysis of the co-citations, as shown below.

3.5. Co-Occurrence Analysis

Co-occurrence network visualization shows the collective interconnections of key texts based on their paired presence. In this case, the co-occurrence network map was developed based on author's keywords. The weight was calculated based on total link strengths. As indicated in the figure, network visualization included six clusters. The clusters were developed based on the collective interconnections identified by the VOSviewer software. The total weights of the keywords were measured in terms of total strength. High total strength indicated a high frequency of occurrences of the keywords in at least five documents. Keywords that recorded highest occurrences for each cluster included climate change, green finance, climate finance, sustainable development, green bonds, and carbon emissions, respectively. As revealed by the co-occurrence network diagram, there is high

connection in research studies relating to green finance with research work on the climate Paris Agreement, climate finance, climate change, mitigation, green climate fund, European Union, and sustainability, among others. The co-occurrence visual network can be seen in Figure 6 below.

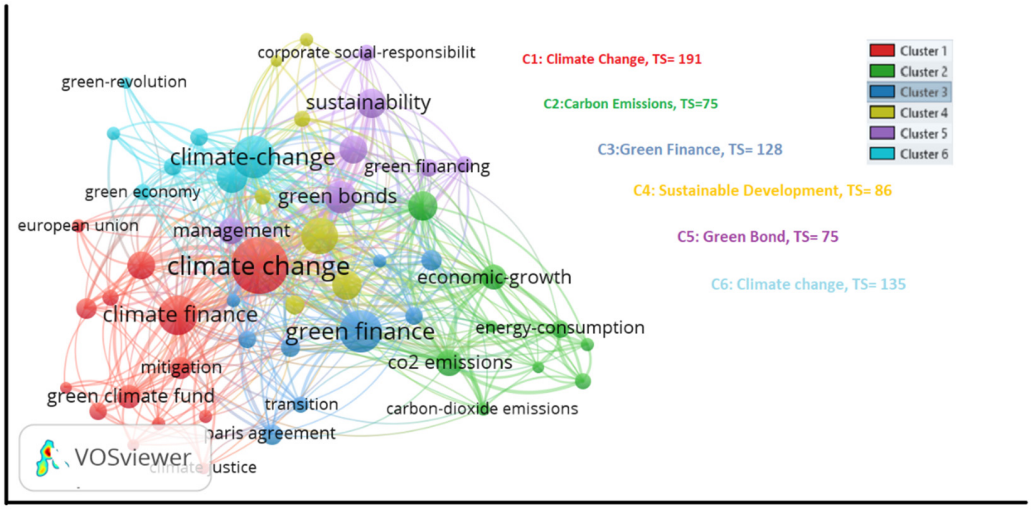

Figure 6. Co-occurrence analysis. Source: Authors' own compilation using VOSviewer software.

4. Discussion

Green financing has become a paramount enabler in countering threats of environmental damage and climate change while still creating a strong foundation for long-term and sustainable growth and development (Afridi et al. 2021). The paper adopted a basic bibliometric method in analyzing the trend and current status of green financing research after the Paris Agreement of 2015. Based on a visualization analysis of 321 relevant publications, we found important results that provide insight into the current status and trend of the subject matter.

Based on the scientific production analysis, we find that the interest to study green financing has increased seven fold after the Paris Agreement and the topic has continued to gain scholarly interest over the years. In addition to the Paris Agreement of 2015, a study by Bhatnagar et al. (2021) also established that the implementation of Industry 4.0 has been a great enabler of green financing, also explaining the rising trend of scholarly interest in this subject matter. A study by Yang et al. (2021) found that fintech promotes the impact of green finance on economic and ecological efficiency. Another study by Bhatnagar et al. (2021) also found that the financial innovations brought about by industry 4.0 supports green financing practices that promote the concepts of the circular and green economy. Chiarvesio and Romanello (2018), in their study, observe that the prevalence of research studies on industry 4.0 has also been high in the previous years. The interconnectedness of green finance and industry 4.0, therefore, might also have attracted more scholarly interests in the field of green financing.

It is, however, notable that this growth is only observed in developed economies and not visible in developing economies, as shown by the 3-point plot analysis, Figure 3. The author's country of origin clearly indicates that research relating to green finance is dominated by the developed economies and especially the G20 countries, and the absence of similar research publications from developing economies, especially in Africa, is very conspicuous. This trend justifies the need for more scholarly insight from African countries. Africa is the most vulnerable continent to the consequences of climate change due to her weak institutions and limited resources to deal with such consequences. More research in green finance for African would, therefore, be more helpful in providing relevant insight to policy makers and regulators. More collaborations among African and international scholars are, therefore, highly advised.

It is notable that although green finance has been acknowledged as an important solution in the fight against climate change and attention was raised to influence policies and regulatory tools to optimize the utilization of green financing, scientific green finance is yet to become a notable interest in mainstream finance and economic journals. The number of investments in green finance are growing worldwide after the Paris Agreement of 2015, and that demands more academic research in this field (Akaev and Davydova 2020). The finance industry is yet very paramount in helping the world to bridge the green financing gap, which is one of the biggest obstacles to achieving the UN sustainable climate change goal of reducing global temperature to the desired level of 1.5 °C (Kissinger et al. 2019). In light of the increased level of green investments by the global economies, the growing financial innovations and the introduction of new financial instruments, we are confident to claim that an opportunity for further research in green financing exists, especially from the finance and economics perspectives.

The problem of climate change has been persistent over a long period and requires continuous management as the world economies seek to engage in activities that foster their economic growth (Ahmad et al. 2020). The previous literature reveals the conflicting nature of economic and ecological goals and, therefore, the need for a sustainable green financing mechanism so that the world can deal with the problem of climate change in a sustainable manner (Baniya et al. 2021). Based on the previous literature, some studies have provided more insights, especially relating to green stocks, from the financial and economic perspectives. A study by Andersson et al. (2016) revealed that long-term investors can hedge against climate risk by investing in decarbonized indexes. Another study by Saeed et al. (2020) concluded that clean energy stocks are particularly effective in hedging for crude oil. Antoniuk and Leirvik (2021) in their study revealed that events related to climate change policies significantly affect the stock returns. A similar study by Saeed et al. (2021) found that there exists a high return connectedness across crude oil, green bonds, and energy stocks. Dutta et al. (2021b) concluded that the inclusion of climate bonds in the investment portfolio is a good hedging option, although the hedging effectiveness was affected during the pandemic. Another study by Zhang (2022) revealed that equity prices for firms in the emerging markets are less sensitive to climate risks when compared to equity prices for companies' headquartered in the advanced economies. A study by Sarker et al. (2022) on US stocks also concluded that increases in climate policy uncertainties have a positive effect on the prices of clean energies.

While these studies provide important insights, we are confident to claim that more scientific research from the financial and economic perspective is needed to expand and supplement the existing knowledge base on green finance. More research from the economic and financial perspectives is likely to build up the aspect of sustainability on green financing. Furthermore, green financing is essentially a matter of finance, and future research on this matter using financial techniques can add great value to the existing literature.

Research Limitations

This study is faced with a few limitations that we would like to outline. First, the size of the corpus analyzed in this study depends on the list of keywords selected at the time this research was performed. After the analysis, however, we noted that the prevalence of some keywords such as sustainable finance and green bonds was significantly high, yet these terms were not included in the initial keyword pattern. The selection of keywords is based on heuristic trials, implying that a researcher may fail to include an important keyword, which, consequently, affects the size of the corpus. Second, the metrics of analysis that this method uses are much more useful to other authors interested in related research and may have limited impact on other readers.

5. Conclusions

In regard to the study research questions, the study indicates increased scholarly interest in the issue of green financing. Most scientific research has been published in

climate policy and sustainability journals but lacks mainstream interest in economic and finance journals. The evolution of the concept is also evident over the years. Based on trend topic analysis, the concepts have transitioned from "green bonds" to "climate finance" to "sustainable finance" and now "green finance", but the basic theme is the same; "financing investments that aim at protecting environment damage and reducing the consequences of climate change". Similarly, the major current issues of interest among scholars include green bonds, climate finance, climate change, climate adaptation and mitigation, COVID-19, sustainable development, and green finance.

Based on these findings, it is recommended that further studies on green financing be carried out from the economic and financial perspective using quantitative approaches to supplement the existing literature and provide a wider view to policy makers and regulators.

Green investments are growing across economies and it would be very important to publish scientific research that measures the green investments quantitatively. We expect that such further studies will play a crucial role in enhancing the harmonization of the financial system in a manner that supports the fight against climate change sustainably. A recent similar study by Kumar et al. (2022) recommended that future studies on green finance may focus on carrying out empirical analysis of financial instruments and systems that can enhance the growth of the green financing market.

This study used documents derived from the Web of Science database. The results, however, agree with similar studies published in other databases, including a study by Desalegn and Tangl (2022) published in the Scopus database that established that more publications on green financing originate from the global north than the global south. Future studies may use multiple databases such as Science direct, Scopus, and Google scholar, among others. To increase more coverage and identify the academic transition, other related keywords combinations may be adopted as well.

Finally, the study reveals that scientific studies relating to green finance are dominated in developed economies with high absence in developing economies. Further research on green financing focusing on Africa needs to be performed to fill the big geographic gap identified in this study. Furthermore, more international research collaborations between developing and developed economies are also recommended. To drive the green financing field forward, it is necessary that future research may explore important aspects of green financing, including managing returns of green financing, making green finance more sustainable, and leveraging on the use of new technologies, such as block-chain, artificial intelligence, and machine learning, for green finance.

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