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Bibliometric Analysis Studies of Published in the Field of Volatility

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ABSTRACT

Volatility, used to determine the risk structure of financial markets or instruments, is one of the most used methods by researchers. In this study which is conducted to reveal the tag of volatility studies, 15,132 articles related to volatility between 1980 and 2023, scanned in the Web of Science database, were subjected to bibliometric analysis. As a consequence of the investigation, the details of the subject, such as the country with the highest number of publications, institutions, the most cited authors, articles, leading journals and keywords in the field, were revealed. As a consequence, it was determined that the authors worked on three basic subjects such as "stocks and stock markets", "exchange rates" and "macroeconomic indicators" on volatility. It has been observed that the main objectives of the studies are either to compare the performance of existing volatility estimation models or to develop new models by adding new variables.

Keywords: Bibliometric Analysis, Volatility, Web of Science, Finance, Risk.

JEL Classification Codes: C01, C38, G17

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INTRODUCTION

Volatility is a critical aspect frequently investigated by financial market analysts to discern whether fluctuations in investment instrument or market prices are random or driven by specific factors. Determining the scope, direction and degree of volatility as a result of the analysis is of great importance in guiding investors in their decision-making processes. Thus, the concept of risk is an important issue that financial investors consider and study. Risk emerges as an important issue when conducting research on volatility. Han (2011) seeks to address the puzzle inherent in the relationship between risk and return by acknowledging the stochastic nature of volatility. It emphasizes that volatility is very important for financial markets, arguing that the systematic risk in markets should be defined as volatility risk. Consequently, investors require a risk premium not only for assuming systematic risk but also for shouldering the volatility risk inherent in the investment.

Risk (risque), which is a French word, is defined as "*The Probability of Occurrence of An Event That May Lead to A Loss, A Damage or A Danger*" (Emhan 2009: 210). In other words, risk can also be defined as the difference between actual and expected situations. Financial risk can be divided into two main categories. The first of these is the non-systematic risk that can be minimized by the diversification of the investment portfolio and the systematic risk that the investor does not have any disposition on and arises from the current economy or the sector. Especially with the impact of globalization on financial markets, volatility has increased and this has increased the risk rate. However, at the same time, due to the increase in financial derivatives, the opportunities to minimize risk have increased with the opportunity of portfolio diversification. Although the most fundamental element in portfolio diversification is the measurement of risk, volatility modeling is one of the areas where new methods and techniques for risk measurement methods are researched.

Investors who analyze financial time series encounter many problems such as instability of price series, asymmetric effects on asset prices and returns, and volatility clusters (Akel, 2011: 22). Many models have been developed over time to address these problems on financial series. Volatility prediction models,

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including the Random Walk Model, Historical Average Model, Moving Average Model, and Weighted Average Model, assume constant returns over time and that the distribution of returns is independent of time. However, Engle (1982) introduced the AutoRegressive Conditionally Heteroscedastic (Arch) model, challenging the assumption of constant variance by proposing that variance changes with time. In this model, Engle formulates error terms in financial series as a function of the previous period's error terms. Bollerslev's (1986) development of the Expanded Arch (Garch 1.1) model itakes volatility estimation to a higher level by considering the variance changes over time based on past period variance. Although Garch models address some limitations, such as the symmetric reaction to market shocks, other models (Agarch, Arch-M, Augmented Arch, Egarch, Gjr-garch, Qgarch, Tarch, Ngarch, Igarch) have been developed to compensate for these shortcomings.

This study delves into the key issues for investors and academics analyzing financial markets through bibliometric analysis. The research consists of four main parts: an introductory section emphasizing the importance of the subject, a literature review presenting relevant studies that used bibliometric analysis, description of the methodology applied for the analysis of the data, and a concluding section summarizing findings such as the number of citations, keywords, leading institutions, journals, The conclusion section provides a comprehensive evaluation of the results of the study.

LITERATURE REVIEW

Although bibliometric analysis is a method used to understand many fields in depth, it is also used occasionally in the field of volatility. In this context, studies dealing with bibliometric analysis of volatility studies conducted for financial instruments or financial markets in the literature are briefly reviewed and presented below.

Depren, Kartal, and Depren (2018) conducted a bibliometric analysis on stock market volatility articles from 1975 to 2017 using the Web of Knowledge database and VOSViewer program. Analyzing 7,568 publications, the study explored the social network structure of authors, co-authorship patterns, keywords, and prominent institutions. The co-authorship analysis revealed a network centered in the USA and China. The authors determined the most frequently used keywords as "volatility", "stock market", "stock returns", "economy", "GARCH" and "financial crisis", and Jiqian Wang as the most mentioned author. On the other hand, they found that the network structure was wider.

Merediz-Solà and Bariviera (2019) conducted a bibliometric analysis of 1,162 articles published on Bitcoin and scanned in the WoS database. The authors determined the clustering of studies on Bitcoin, the topics covered and the leading authors in their studies. As a consequence, they determined that the studies conducted for Bitcoin showed an annual increase of 124%, and the citations between other publications occurred around a few articles.

Chen and Yang (2019) conducted a bibliometric analysis on volatility spread studies across financial markets using the WoS database and Citespace software. Their analysis involved citation analysis, information mapping, and cluster visualization. The authors determined that studies on volatility spread utilized clusters creating VAR models with diverse volatility indexes and multi-variable GARCH models. Most publications on the subject originated from the USA. Collaboration mapping indicated academic cooperation among European academics or institutions, while the authors observed a growing interest from Chinese academics and institutions in exploring volatility spillovers in financial markets.

Vianez, Martínez and Román (2020) conducted a bibliometric analysis of publications scanned in WoS and Scopus in the field of behavioral finance using SciMAT software. As a consequence, Malcom Baker and Jeffrey Wurgler, who conducted research on the impact of investor sentiment on stocks by the most prolific and cited authors in this field, determined "Journal of Banking & Finance" as the leading journal, the USA as the leading country and the National Bureau of Economic Research as the leading institution.

Sosa, Ochoa and Merigó (2020) conducted a bibliometric analysis of the articles scanned in WoS and Scopus on exchange rate volatility. In their analysis, prominent authors have mapped their reviews through VOSViewer software, examining institutions and countries. As a result, regarding exchange rate volatility; they determined that the leading author was Bahmani-Oskee, the university was the University of Wisconsin-Milwaukee, the institution was the National Bureau of Economic Research, and the region was the European continent.

METHODOLOGY

The purpose, scope, data set, and method used in this study, which was carried out in the field of volatility by

examining the publications scanned in the WoS database, are explained under the methodology title of the study.

The Aim of the Study

This study, which conducts a bibliometric analysis of publications on volatility, has two main purposes. The first aim of the study is to reveal the development and change of volatility, which has an important place in the academic literature, from past to present, to identify leading publications, journals, institutions, authors and countries and to compile the subject. The second most fundamental goal is to compile and present the most important resources that will help investors investing in financial markets understand the basic dynamics of volatility and to show new techniques that they can use to determine risk while investing. Thus, it will be ensured that the resources to be applied by researchers who want to work in the field of volatility are presented to researchers in a single study.

Method and Data Set

The term bibliometrics, first used by Alan Pritchard in 1969 in his article titled "Statistical Bibliography or Bibliometrics?" (Gaberli, 2023; 30), has become increasingly widespread in recent years. Bibliometric analysis is an analysis method that determines the profile of researchers and publications published in a particular field and determines details such as the progress of scientific knowledge over time and the point of focus (Hussain, Fatima, & Kumar, 2011).

Academics utilize bibliometric analysis for various purposes, such as revealing trends in article and journal performance, collaboration models and research components within a specific field (Donthu et al., 2021; Verma and Gustafsson, 2020). This method is valuable for providing researchers with rigorous interpretation of large volumes of unstructured data to decode and map accumulated scientific knowledge and the evolutionary nuances of established domains.

Bibliometric analyses fall into two categories: traditional bibliometric effects and modern visual and recorded mapping techniques (Kurutkan and Orhan, 2018; 2). Modern bibliometric techniques include performance analysis, which considers the contributions of the components studied, and science mapping, which focuses on the relationships between research components. Performance analysis commonly involves calculating annual or per-component publication and citation counts, where the number of publications indicates productivity, and citations measure impact. Science mapping techniques include citation analysis, co-citation analysis, bibliographic matching, co-word analysis, and co-authorship analysis (Baker et al., 2019; Tunger and Eulerich, 2018; Donthu et al., 2021; 287).

An additional method, the enrichment technique, enhances bibliometric results through network measurements, clustering, and visualization (Donthu et al., 2021; 290). The typical bibliometric analysis method comprises five steps: determining the study's purpose and scope, data collection, data screening and filtering, analysis, and interpretation (Radu et al., 2021; 3).

The data to be used in the study were obtained from the Web of Science (WoS) Core Collection database. The journal archive of the WoS Core Collection database dates back to the 1800s and includes 211 million records, more than 13 million data sets, and more than 115 million patents. Studies in the WoS Core Collection database covers a wide range of data, including biomedical sciences, natural sciences, engineering, social sciences, arts and humanities ("Clarivate", 2015). Another reason for selecting the WoS database is its more detailed coverage of social, arts, and humanities topics compared to the Scopus database (Karasözen et al., 2011: 244; Gaberli, 2023: 31).

To achieve the study's objectives, the scope was limited to publications in the WoS database. Searching for "volatility" yielded 81,260 sources, filtered to define the study's scope. The filters applied are as follows;

Table 1: Applied Filters and Statistics

Filter Option	Query	Number of Publications
Search	Volatility	81,260
Fields	Title	17.700
Publication Year	1980 - 2023	17,684
Documents Type	Article	15,346
Language	English	15,132

As a consequence, a total of 15,132 publications were obtained. All of the data obtained was used in scientific mapping and performance analysis, which are one of the bibliometric analysis techniques. When selecting data to undergo clustering analyses, there are various criteria. The most rominent measures are the number of publications and citations per year or per research constituent, wherein publication is a proxy for productivity, whereas citation is a measure of impact and influence (Donthu et al., 2021). Another factor that is effective in data selection is the Pareto Analysis technique. Pareto analysis, introduced by the Italian economist Vilfredo Pareto in the 19th century, suggests that some inputs contribute more significantly to the outcome of the study than others. In this context, including the most effective articles in the analysis will be sufficient to provide general information on the subject. The most effective articles in the field were determined as the most cited articles. As part of the bibliometric enrichment technique, the number of publications to undergo clustering analysis has been determined as the top 100 most-cited articles.

Two techniques, bibliometric and document analysis, were used to analyze the obtained publications. Utilizing bibliometric and document analysis techniques, software like CiteSpace and Wosviewer was employed to create network maps based on citations, covering authors, journals, institutions, countries, and keywords. The enrichment analysis focused on the three largest clusters, with the cluster coverage rate influencing the number of articles examined. When the cluster coverage rate reached around 50%, other articles in the cluster were not reviewed.

FINDINGS

15,132 publications on volatility have been handled by different disciplines such as economics, business finance, finance, mathematical methods, management, statistics, and environment. Economics is at the top of these fields, with 6,432 publications. The field of economics is followed by business finance with 4,885 publications, social sciences mathematical methods with 1,260 publications, mathematics interdisciplinary applications with 1,233 publications, statistics probability with 1,079 publications, management with 667 publications, environmental science with 545 publications, and business with 540 publications. When the number of

Table 2: 10 Most Cited Articles

Title	Authors	Source Title	Publication Year/ Volume/Issue	Tot. Cit.	Avg. per Year
On the relation between the expected value and the volatility of the nominal excess return on stocks	Glosten,LR; Jagannathan,R; Runkle,DE	Journal of Finance	1993/48/5	4,010	129,35
A closed-form solution for options with stochastic volatility with applications to bond and currency options	Heston, SL	Review of Financial Studies	2.06.1993	3,982	128,45
Better to give than to receive: predictive directional measurement of volatility spillovers	Diebold, FX.; Yilmaz,Kamil	International Journal of Forecasting	2012/28/1	2,285	190,42
The cross-section of volatility and expected returns	Ang,A;Hodrick,RJ;Xing,Y; Zhang, XY	Journal of Finance	2006/61/1	1,860	103,33
Modeling and forecasting realized volatility	Andersen,TG; Bollerslev,T; Diebold,FX; Labys, P	Econometrica	2003/71/2	1,763	83,95
Expected stock returns and volatility	French,KR; Schwert,GW; Stambaugh,RF	Journal of Financial Economics	1987/19/1	1,715	46,35
Measuring and testing the impact of news on volatility	Engle,RF; NG,VK	Journal of Finance	1993/48/5	1,639	52,87
Answering the skeptics: yes, standard volatility models do provide accurate forecasts	Andersen, TG; Bollerslev, T	International Economic Review	1998/39/4	1,612	62
The pricing of options on assets with stochastic volatilities	Hull, J; White, A	Journal of Finance	1987/42/2	1,608	43,46

Table 3: 10 Most Cited Journals

Source Name	Documents	Citations
Journal of Finance	87	24,179
Review of Financial Studies	66	16,246
Energy Economics	273	15,207
Journal of Econometrics	197	14,138
Journal of Financial Economics	84	12,530
Journal of Banking & Finance	213	8,545
Finance Research Letters	280	6,473
Journal of Futures Markets	335	6,438
Journal of International Money and Finance	115	5,305
Journal of Business & Economic Statistics	103	5,141

examined in the disciplines is added up, the total number of examined sources is less due to the fact that some papers appear in more than one fields.

When the publications were examined, it was determined that the first publication year was 1980. The article titled "*Estimation of Security Price Volatilities From Historical Data*" published by Garman, M. B. and Klass, M. J. in the Journal of Business today ranks 41th with 689 citations among the publications. During this period, the most publications were made in 1993, 1998, and 2003, with eight publications each.

The 10 most cited articles regarding studies in the field of volatility were examined in detail and presented in table 2. According to the analysis, it was determined that the most cited study was the article titled "*On The Relation Between the Expected Value and The Volatility of The Face Excess Return on Stocks*" by Glosten, L. R., Jagannathan, R. and Runkle, D. E. It was featured in the Journal of Finance in 1993 with 4,010 citations. The second most cited article is the article of Heston S. L.'s published in the Review of Financial Studies in 1993, with 3,982 citations, titled "*A Closed-Form Solution for Options with Stochastic Volatility with Applications to Bond and Currency Options*". Heston offers a closed-form volatility estimation model for estimating the price of European Call Options on financial assets with stochastic volatility. As a consequence, the model has shown that the volatility arising from option prices is not related to the future volatility forecast. It has been determined that the constructed model can be applied to other volatility-related problems (Heston, 1993). The third most cited article is Diebold, Francis X. and Yılmaz, Kamil's "*Better to Give Than to Receive: Predictive Directional Measurement of Volatility Spillovers*" article published in International Journal of Forecasting, with 2,285 citations.

The 10 most journals regarding studies in the field of volatility were examined in detail and presented in table 3. When the journals were published are examined, Journal of Finance is the journal with the most cited journal, with 24,179 citations. Journal of Finance magazine contains the article named "*On The Relation Between The Expected Value and The Volatility of The Nominal Excess Return on Stocks*" by Glosten, L. R., Jagannathan, R. and Runkle, D. E., which is ranked first among the most cited authors with 4,010 citations. The magazine also shows the feature of being the magazine that includes writers such as Andersen, one of the most published writers. The second most cited journal is Review of Financial Studies with 16,246 citations. The journal also includes the second most cited article, Heston S. L.'s "A Closed-Form Solution for Options with Stochastic Volatility with Applications to Bond and Currency Options". The third most cited journal is the Energy Economics, with 15,207 citations. Journal of Econometrics ranks fourth in the list of journals with the highest number of citation, with 14,138 citations. Journal of Financial Economics ranks fifth in the list of journal with the highest number of citation, with 12,530 citations.

Within the scope of the study, analyses were also conducted on which institutions or organizations own printed sources with publications in the field of volatility and from which country they originate. According to this; National Bureau of Economic Research ranked first with 16,254 citations to its 97 articles in the field of volatility. The average number of citations of articles was calculated as 167 citations per article. Duke University ranks second with 13,729 citations to its 83 articles. The average number of citations of articles was calculated as 165 citations per article. The institution in third place is determined as the University of Pennsylvania. The University of Pennsylvania received a total of 12,697

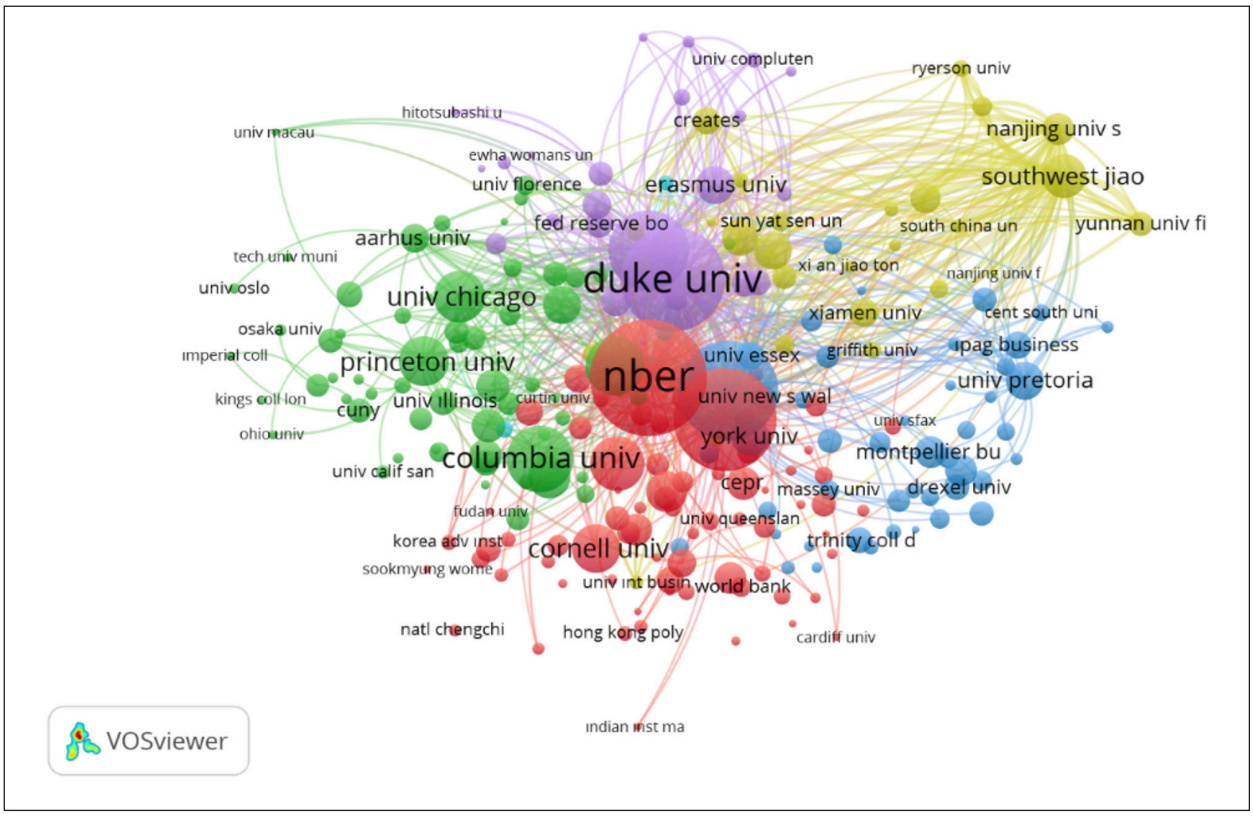

Figure 1: Network Map of Institutions

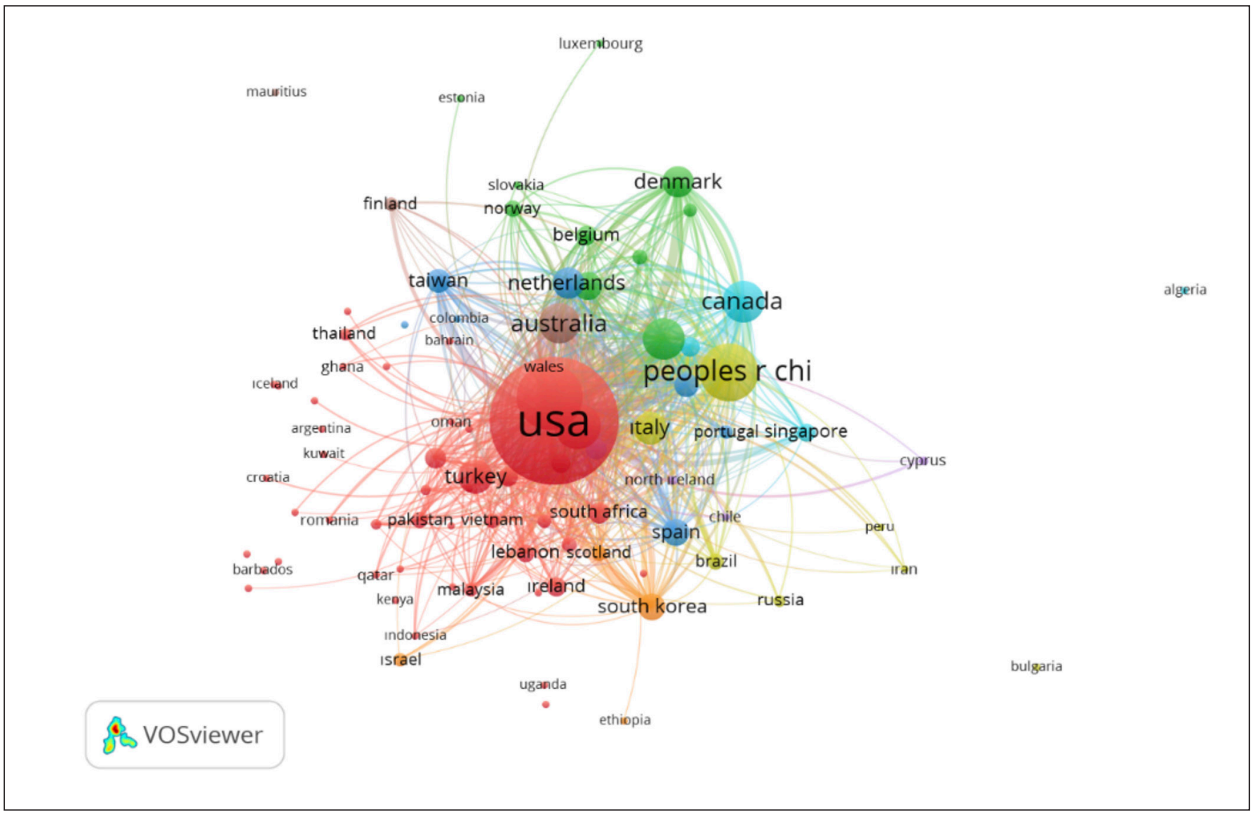

Figure 2: Network Map of Countries

citations from 32 publications on volatility. The average number of citations of publications was determined as 396. It has been determined that the organizations that broadcast the most in the institutions are in the USA. Figure 1 shows the network map that includes the links between the institutions of origin of the studies.

Table 4: 10 Most Cited Authors

Authors	Documents	Total Citations
Bollerslev, T.	37	9,663
Andersen, T. G.	27	8,839
Diebold, F. X.	13	9.330
Schwert, G. W.	7	4,309
Yılmaz, K.	4	4,147
Glosten, L.	1	4,010
Jagannathan, R.	1	4,010
Runkle, D.E.	1	4,010
Heston, L. S.	1	3,982
Engle, R. F.	8	3,083

When the publications in the field of volatility are analyzed on a country basis, it is seen that most broadcasts are made in the USA. 3,047 publications in this field were published in the USA. A total of 133,484 citations were made to 3,047 articles published in the USA, and the total ling strength is 53,403. The USA is also the only country with the feature of being a citation link with all other countries. The second country is England, with 33,550 citations to its 1,101 publications. And the total link strength is 21,612. The third country is China, with 27,326 citations to its 1,825 publications. And the total link strength is 24,460. France ranked fourth place with 16,578 citations to its 649 publications. And fifth place is Canada with 13,712 citations for its 505 publications. Figure 2 shows the network map that includes the links between the countries of origin of the studies.

When the publications in the field of volatility were examined on the basis of authors, it was determined that the author with the most citations is Bollerslev, T. with 9,663 citations. The author has 21 publications in the field of Volatility. Secondly, most cited author is Diebold, Francis X., who received 9,330 citations for their 13 publications. The third author with the highest number of citations is Andersen, T. G. with 8,839 citations and 27 publications. Table 4 presents the number of publications and citations of the top 10 authors in the field of volatility.

Figure 3 shows the network map that includes the links between the authors of the studies.

Keywords in publications are another subject analyzed. The keywords presented in the publications are extremely important in terms of providing basic information about the publication. While examining the keywords of the publications in the volatility field, the minimum number of occurrences was determined to be five. The keywords most commonly used were volatility, stochastic volatility, realized volatility, garch, volatility forecasting, option pricing, forecasting, implied volatility, volatility spillover and long memory. Figure 4 shows the network map that includes the links between the keyword of the studies.

When the studies conducted in the field of volatility are examined through bibliometric analysis, it has been determined that studies within the field of volatility encompass a broad spectrum, spanning from economic disciplines to finance, mathematics, and environmental science, thereby reflecting an interdisciplinary approach. Throughout the period from 1980 to the present day, there has been a noteworthy surge in publication activity, especially in the years 1993, 1998, and 2003.

The most cited article is identified as "*On The Relation Between The Expected Value and The Volatility of The Nominal Excess Return on Stocks*." This article has exerted a significant influence on volatility studies. Furthermore, noteworthy contributions are found in the works of Diebold and Nerlov on exchange rate volatility, along with Schwert's comparative analysis of macroeconomic variables and stock volatility. The Journal of Finance stands out as the most cited journal, encompassing important researchers and articles in the field.

As a result of the analysis of institutions, the National Bureau of Economic Research has been identified as the institution making the most significant corporate contributions in the field of volatility. The predominance of institutions contributing the most being typically based in the United States is noteworthy. On a country basis, the leading position of the United States demonstrates the influence of American institutions in global research on volatility. Additionally, notable academic contributions are observed from the United Kingdom, China, France, and Canada.

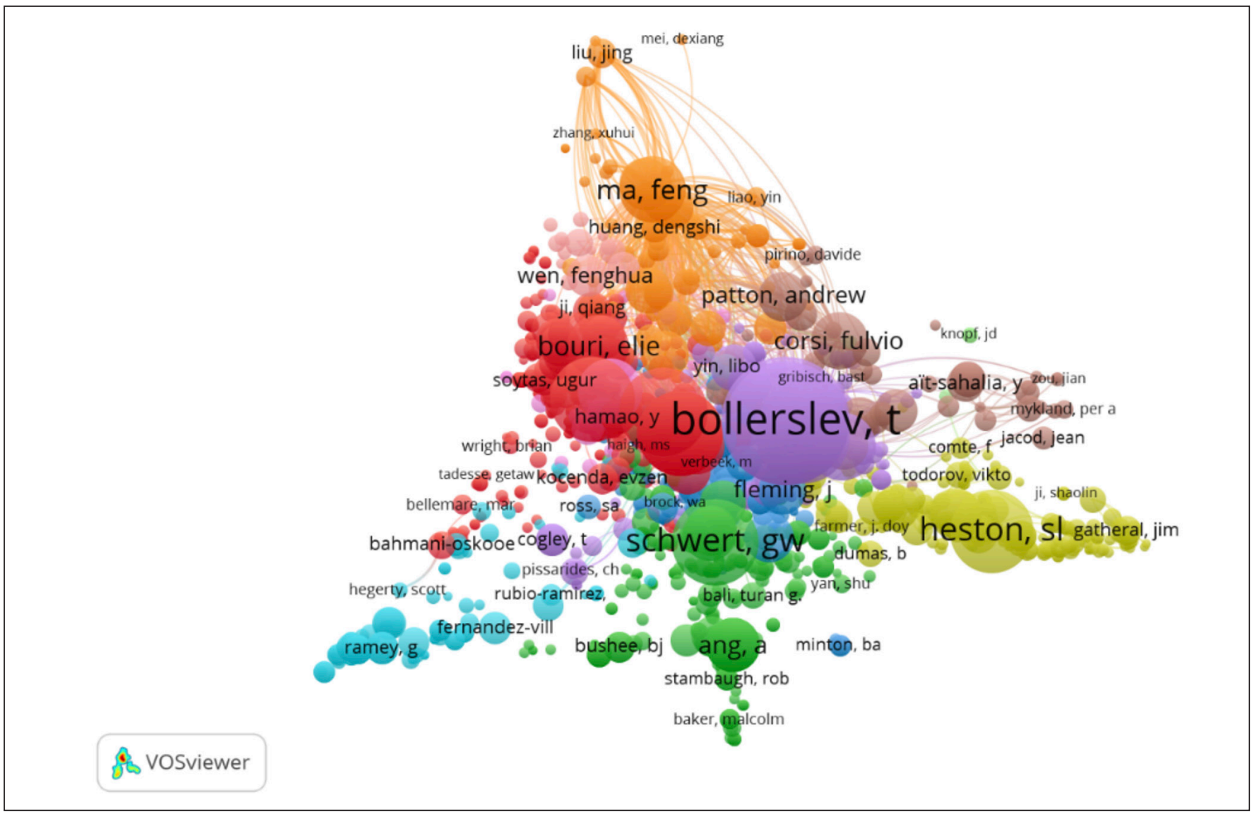

Figure 3: Network Map of Authors

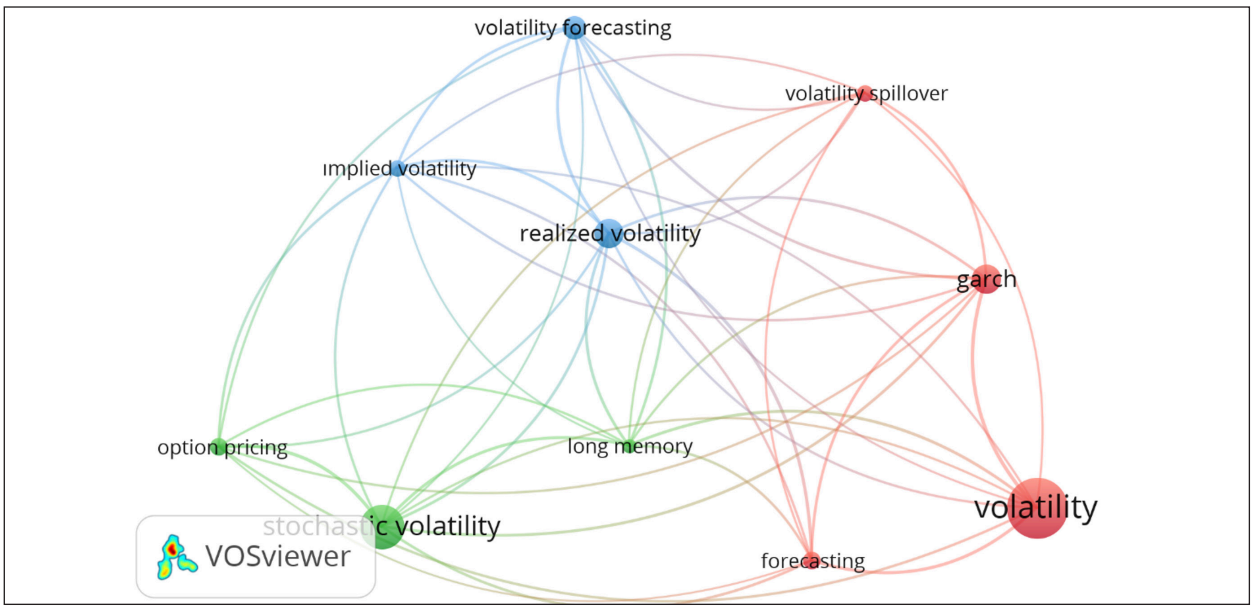

Figure 4: Network Map of Most Repeated Keywords

Finally, the analysis of keywords sheds light on the focal points of researchers. Terms such as volatility, stochastic volatility, option pricing, among others, reflect fundamental concepts in the literature. These findings emphasize that research in the field of volatility is diverse and underscore the impact of specific articles, journals, authors, and institutions in this domain.

The issue of clusters is extremely important in determining how the field is handled academically. For this reason, clusters in the volatility area have been analyzed in detail and presented in the next section.

Cluster Analysis

From 1980 to the end of 2023, 15,132 articles addressed the topic of volatility from various dimensions, that it shows clusters around certain main issues. These main

Table 5: Clustering of Volatility Publications

Cluster	Number of Authors	Silhouette	Label (TFIDF)	Label (LLR)	Label (MI)	Mean (Citation Year)
1	77	0.895	volatility	volatility forecast comparison	global macroeconomic causes (0.37); low-frequency volatility (0.37); spline-garch model (0.37)	2003
2	61	0,831	volatility	stock return volatility	global macroeconomic causes (0.42); emerging equity market volatility (0.42); low-frequency volatility (0.42)	1996
3	52	0,874	stochastic volatility	multivariate latent factor arch model	stochastic volatilities (0.41); global macroeconomic causes (0.41); emerging equity market volatility (0.41)	1985

clusters underwent detailed analysis through cluster analysis.

Silhouette analysis, assessing the separation distance between resulting clusters, was employed to determine the appropriate clustering algorithm for the dataset.

The Silhouette value, ranging from -1 to +1, helps evaluate the effectiveness of the clusters. A value close to +1 indicates that a data point is correctly clustered, close to 0 suggests potential misplacement, and close to -1 implies incorrect clustering (Ogbuabor and Ugwoke, 2018; Shahapure and Nicholas, 2020).

The tables resulting from the cluster analysis provide information on cluster coverage values, citation frequency based on the total count in the Web of Science (GCS), and citation frequency within the collection (LCS).

Table 5 summarizes the sizes, silhouette values, cluster labels, and average citation year values of the first three clusters formed by studies in the field of volatility.

The three largest clusters in table 5 have been analyzed in detail and presented below. By examining all authors' studies in the clusters, a wide range of information about clusters can be obtained. However, scientific knowledge

Table 5: First Largest Cluster The Most Fundemental Authors Table

Coverage	GCS	LCS	Bibliography
16	305	1	Patton, A. J. (2011). Volatility Forecast Comparison Using Imperfect Volatility Proxies. Journal of Econometrıcs, 160(1), 246-256
15	1230	1	Andersen, T. G., Bollerslev, T., Diebold, F. X. and Labys, P. (2003). Modeling and Forecasting Realized Volatility. Econometrica, 71(2), 579-625
11	554	1	Andersen, T. G., Bollerslev, T. and Diebold, F.X. (2007). Roughing It Up: Including Jump Components in The Measurement, Modeling and Forecasting of Return Volatility. Review of Economics And Statistics, 89(4), 701-720
9	668	1	Poon, S. H. and Granger, C. W. J. (2003). Forecasting Volatility in Financial Markets: A Review. Journal of Economıc Lıterature, 41(2), 478-539
8	235	1	Blair, B. J., Poon, S. H. and Taylor S. J. (2001). Forecasting S&P 100 Volatility: The Incremental Information Content of Implied Volatilities and High-Frequency Index Returns. Journal of Econometrics, 105(1), 5-26
6	595	1	Eraker, B., Johannes, M. and Polson, N. (2003). The Impact of Jumps In Volatility and Returns. Journal of Finance, 58(3), 1269-1300
6	253	1	Bandi, F. M. and Russell, J. R. (2006). Separating Microstructure Noise From Volatility. Journal of Financial Economics, 79(3), 655-692.
5	590	1	Corsi, F. (2009). A Simple Approximate Long-Memory Model of Realized Volatility. Journal of Financial Econometrics, 7(2), 174-196.
5	266	1	Ghysels, E., Clara, P. S. and Valkanov, R. (2006). Predicting Volatility: Getting The Most Out of Return Data Sampled At Different Frequencies. Journal of Econometrics, 133(1-2), 59-95.
5	267	1	Engle, R. F. and Rangel, J. G. (2008). The Spline-Garch Model For Low-Frequency Volatility And İts Global Macroeconomic Causes. Review of Financial Studies, 21(3), 1187-1222.

progresses rapidly thanks to today's increasing communication technologies. To efficiently gather pertinent information about the cluster, the Pareto analysis technique was employed, excluding authors with a coverage value below 5% from the cluster. This approach allows for the identification of clusters shaped by authors, their perspectives on volatility, developments in global literature on volatility, and the current state of the field.

First Largest Cluster (# 1): Volatility Prediction and Comparison

The largest cluster in the volatility analysis, Cluster #1, comprises 77 members with a silhouette value of 0.895. Three key criteria, TFIDF, LLR, and MI, guide the evaluation of works within this cluster. According to these criteria, the cluster is named "Volatility" under TFIDF, "Volatility Estimation and Comparison" under LLR, and "Global Macroeconomic Causes", "Low Frequency Volatility" and "Spline-Garch Model" under MI. While the Citespace program suggests the LLR panel for cluster naming, we will adopt the name "Volatility Estimation and Comparison" in alignment with the first cluster's predominant themes.

The articles of the authors in the first cluster were examined to create a 51% coverage rate. Patton, which has a high coverage rate of the first cluster; in 2011, he tried to take the work of Andersen and Bollerslev's (1998), Meddahi's (2001) and Hansen and Lunde's (2006) one step further with his article titled "Comparison of Volatility Forecast Using Imperfect Volatility Proxies". Firstly, he examined the effect of invisible variables in volatility calculations on volatility results. In particular, he used variables such as end-of-day return, intraday return, and actual variance to estimate volatility. Consequently, he determined that the choice of variables used in volatility estimation effectively calculated volatility accurately. In addition, the increase in data frequency increases the probability of giving accurate results in volatility estimation. Patton states that while defining a new variable set to be used in volatility models, it would be more useful to use new variables in the estimation of macroeconomic indicators.

In second place is the article "*Modeling and Forecasting Realized Volatility*" published in 2003 in Econometrica by Andersen, Bollerslev, Diebold, and Labys with a coverage rate of 15%. The article of Andersen et al., they are also the most cited article of the cluster, with a total of 1,763 citations to their articles, as mentioned above. In their studies, Andersen et al. worked on integrating high-frequency intraday data and volatility prediction models into a formation that will be used to predict low-frequency data. They carried out their studies with the help of Garch family models with data on the German mark, US Dollar and Japanese Yen between 1986-1999. They used the first 10 years of the considered period as the within-sample forecast interval and the remaining period as the out-of-sample forecast interval. Consequently, the developed model was determined as an easily applicable model even in multivariate situations. As a result, they stated that the determination of open volatility factors and the market-wide variables that underlie and are related to systematic volatility movements could help provide an important step towards a better understanding of the volatility economy.

In the third place, there is the article by Andersen, Bollerslev and Diebold published in 2007 titled "*Roughing It Up: Including Jump Components in The Measurement, Modeling, and Forecasting of Return Volatility*" with 11% coverage rate and 554 citations in total. Andersen et al. developed a nonparametric method to measure the jump in the volatility of return on assets in their work on volatility modeling based on the theoretical results they obtained from the literature. They concluded by using the Arch family models in their application with 30 years of data on Mark/Dollar exchange rate, S&P 500, and US Treasury Bill returns. As a consequence, they determined that most of the jumps in volatility were directly related to important news in the markets. They also found that the predictability of the volatility jump is more predictable in daily, weekly, and monthly return volatility than volatility non-jump.

Among the articles in the first cluster, the article ranked in fourth place according to the ranking of the highest coverage rate, with a rate of 9% and 736 citations total; it was published in the Journal of Economic Literature by Poon and Granger in 2003 and titled "*Forecasting Volatility in Financial Markets: A Review*". In their studies, Poon and Granger analyzed which volatility model was the best estimate based on 93 articles made in the last 20 years in the volatility field. At the point of estimation, they focused on the factors affecting the estimation result, such as the time interval and the markets considered. As a result, the studies comparing the Hisvol and Garch models determined that the Hisvol model gave results one step ahead of the Garch model. In addition, it was determined that Egarch and Gjr-garch, which are alternative Garch models, give more meaningful results in certain studies compared to the Garch model. Consequently, volatility in financial markets has been determined as a predictable phenomenon.

The analysis of the first cluster, comprising 51% of reviewed articles, revealed a focus on predictive performance in volatility estimation models. Especially, studies in which models in previous studies are re-analyzed and tried to be developed have a large place in the cluster. The cluster predominantly covers exchange rates and stock markets, with a total of 5,198 citations. In addition, the article "Modeling and Forecasting Realized Volatility" published in Econometrica in 2003 by Andersen, T.G, Bollerslev, T., Diebold, F.C and Labys, P. which is at the top of the general citation ranking with 1,763 citations, is included in the first cluster.

Second Largest Cluster (# 2): Stock Return Volatility

The second cluster in the volatility analysis, Cluster #2, comprises 61 members with a silhouette value of 0.831. Three key criteria, TFIDF, LLR, and MI, guide the evaluation of works within this cluster. According to these criteria, the cluster is named "Volatility" under TFIDF, "Stock Return Volatility" under LLR, and "Global Macroeconomic Reasons", "Growing Stock Market Volatility" and "Low Frequency Volatility" under MI. While the Citespace program suggests the LLR panel for cluster naming, we will adopt the name "Stock Market Volatility" in alignment with the first cluster's predominant themes.

The articles of the authors in the second cluster were analyzed to create a coverage rate of 46%. Andersen et al, which has a high coverage rate of the first cluster; in 2001, analyzed the correlation between the exchange rate volatility in the presence of high-frequency data with the help of the daily five-minute returns of the German Mark and the Japanese Yen with their article titled "The Distribution of Realized Exchange Rate Volatility". In addition, they used the squares of intraday returns as a simpler and new parameter that can be used in volatility calculations. As a result, they concluded that the relationship between exchange rates increases volatility. Another study result is that the persistence of volatility in the markets is high, and volatilities have no unit roots. The most specific part of the study is the first modeling that provides a nonparametric characterization of both unconditional and conditional distributions of bilateral exchange rate volatility.

Barndorff-Nielsen and Shephard (2002), in their article titled "Econometric Analysis of Realized Volatility and Its Use in Estimating Stochastic Volatility Models" with a coverage rate of 13%, focused on the asymptotic distribution of volatility errors in estimating stochastic volatility, using intraday five-minute data for the German Mark and the US Dollar. Nielsen and Shephard (2002) developed a more accurate model for estimating high-frequency data volatility by determining the difference between actual and integrated volatility, without resorting to simulation-intensive methods.

Andersen and Bollerslev (1998), in their article titled "Answering The Skeptics: Yes, Standard Volatility Models do Provide Accurate Forecasts" with a coverage rate of 9%, examined the validity and consistency of volatility estimates using high-frequency data, employing Arch and stochastic volatility models with spot market rates for

Table 6: Second Largest Cluster The Most Fundemental Authors Table

Coverage	GCS	LCS	Bibliography
15	842	1	Andersen, T. G., Bollerslev, T., Diebold, F. X. and Labys, P. (2001). The Distribution of Realized Exchange Rate Volatility . Journal of The American Statistical Association, 96(453), 42-55
13	762	1	Barndorff-Nielsen, O. E. and Shephard, N. (2002) Econometric Analysis of Realized Volatility and Its Use In Estimating Stochastic Volatility Models. Journal of The Royal Statistical Society, 64(2), 253-280
9	1062	1	Andersen, T. G. and Bollerslev, T. (1998) Answering The Skeptics: Yes, Standard Volatility Models Do Provide Accurate Forecasts, International Economic Review, 39(4), 885-905
9	510	1	Bekaert, G (2000) Asymmetric Volatility and Risk in Equity Markets, Review of Financial Studies, 13(1):1-42
9	439	1	Andersen, T. G. and Bollerslev, T. (1998) Deutsche Mark Dollar Volatility: Intraday Activity Patterns, Macroeconomic Announcements, and Longer Run Dependencies. Journal of Finance, 53(1), 219-265
7	282	1	Andersen, T. G. and Bollerslev, T. (1997) Heterogeneous Information Arrivals and Return Volatility Dynamics: Uncovering The Long-Run in High Frequency Returns. Journal of Finance, 52(3), 975-1005
2	361	1	Christensen, B. J. and Prabhala, N. R. (1998) The Relation Between Implied and Realized Volatility. Journal of Financial Economics, 50(2), 125-150

the US Dollar-German Mark and US Dollar-Japanese Yen. Contrary to prevailing literature beliefs that using high-frequency data is inconvenient for volatility estimation, Andersen and Bollerslev concluded that it is feasible with appropriate modeling. They emphasized the importance of correctly defining models for successful volatility predictions and proposed volatility assessment criteria, highlighting that structural methods for estimating volatility allow for more meaningful comparisons.

Bekaert and Wu (2000), in their article titled "Asymmetric Volatility and Risk in Equity Markets" with a coverage rate of 9%, examined the leverage effect on asymmetric volatility and risk premium explanations. Testing their reviews on different portfolios, the authors found that the leverage effect on volatility is small compared to the asymmetry caused by shocks in the Garch specification. However, their analysis found that negative shocks significantly increased conditional covariance, while positive shocks had a mixed effect on conditional covariance. They also state that although their results seem consistent, there may be other factors affecting these results.

As a result of detailed examinations of these four articles, it was determined that the authors in the cluster focused especially on the covering various aspects of exchange rates, volatility estimation, and risk premium disclosures, revealed a cluster focus on the estimation of exchange rates and factors affecting volatility in stock markets. The cluster garnered a total of 5,795 citations, featuring influential articles such as "Modeling and Forecasting Realized Volatility" (1,763 citations) and "Answering The Skeptics: Yes, Standard Volatility Models do Provide Accurate Forecasts" (1,612 citations), thereby comprising a significant body of work by notable authors.

Third Largest Cluster (# 3): Stock Return Volatility

The third largest cluster in the volatility analysis, Cluster #3, comprises 52 members with a silhouette value of 0.874. Three key criteria, TFIDF, LLR, and MI, guide the evaluation of works within this cluster. According to these criteria, the cluster is named "Volatility" under TFIDF, "Stock Return Volatility" under LLR, and "Global Macroeconomic Reasons", "Growing Stock Market Volatility", "Growing Stock Market Volatility" and "Low Frequency Volatility" under MI. While the Citespace program suggests the LLR panel for cluster naming, we will adopt the name "Stock Market Volatility" in alignment with the first cluster's predominant themes.

The third cluster's authors, with a 51% coverage rate, aimed to enhance forecast performance. Diebold and Nerlov, which has a high coverage rate of the first cluster; in 1989, analyzed the need for multivariate specification due to univariate limitations with their article titled "The Dynamics of Exchange-rate Volatility - A Multivariate Latent Factor ARCH Model". They proposed using latent variables to overcome the challenges posed by a large number of variables in Arch modeling. The study revealed a robust link between information quality, market volatility, and it is easier to interpret volatility when the markets are relatively calm. Among the authors in the third cluster, Diebold and Nerlov, authors of the article with the highest coverage rate, focused on improving forecasting performance, as an example in their article titled The Dynamics of Exchange-Rate Volatility - A Multivariate Latent Factor Arch Model.

Schwert's article, "Stock Volatility and The Crash of '87" (1990), with 424 citations, covered 14% of the second cluster. Analyzing stock return volatility from 1885 to the 1987 market crash, Schwert focuses on the impact of the 20% stock price drop during the crisis on market returns volatility. Conclusively, he notes that stock volatility peaked before the crisis, gradually returning to normal afterward. Schwert observes higher stock volatility during the 19th and early 20th-century banking panics and he determined that negative shocks have more effects on volatility than positive shocks.

Thirdly Schwert's article, "Why Does Stock-Market Volatility Change Over Time" (1989), with 1,437 citations, comprises 11% of the third cluster. In his study, Schwert examined the correlation between macroeconomic variables (inflation, money emission, industrial production) and stock market volatility from 1857 to 1987. He noted the unusually high volatility during the Great Depression (1929-1939), but also stated that macroeconomic variables alone were not sufficient to explain the volume of financial assets. Schwert identifies a link between interest rates, corporate bond yield volatility, and stock return volatility. Overall, he observes higher stock volatility and increased operating leverage during economic recessions. None of the analyzed variables dominate in explaining stock volatility, concluding a relationship between Schwert's operational activities and stock volatility.

The publication with the highest coverage, with 427 citations, in the fourth place is Wiggins's article titled "Option Values Under Stochastic Volatility-Theory and Empirical Estimates" published in the Journal of Financial Economics in 1987. Wiggins assessed stock volatility by focusing on stochastic processes using numerical

Table 7: Third Largest Cluster The Most Fundemental Authors Table

Coverage	GCS	LCS	Bibliography
18	259	1	Diebold, F. X. and Nerlove, M. (1989) The Dynamics of Exchange-Rate Volatility – A Multivariate Latent Factor Arch Model. Journal of Applied Econometrics, 4(1), 1-21
14	344	1	Schwert, G. W. (1990) Stock Volatility and The Crash of 87. Review of Financial Studies, 3(1), 77-102
11	1080	1	Schwert, G. W. (1989) Why Does Stock-Market Volatility Change Over Time. Journal of Finance, 44(5), 1115-1153
8	370	1	Wiggins, J. B. (1987) Option Values Under Stochastic Volatility - Theory and Empirical Estimates. Journal of Financial Economics, 19(2), 351-372
7	1353	1	French, K. R., Schwert, G. W. and Stambaugh, R. F. (1987) Expected Stock Returns and Volatility. Journal of Financial Economics, 19(1), 3-29
7	567	1	Stein, E. M and Stein, J. C. (1991) Stock-Price Distributions With Stochastic Volatility - An Analytic Approach. Review of Financial Studies, 4(4), 727-752
6	470	1	Pagan, A. R. and Schwert, G. W. (1990) Alternative Models For Conditional Stock Volatility. Journal of Econometrics, 45(1-2), 267-290
6	277	1	Melino, A and Turnbull, S. M. (1990) Pricing Foreign-Currency Options With Stochastic Volatility. Journal of Econometrics, 45(1-2), 239-265
5	388	1	Ross, S. A. (1989) Information And Volatility - The No-Arbitrage Martingale Approach To Timing and Resolution Irrelevancy. Journal of Finance, 44(1), 1-17
2	1243	1	Hull, J and White, A. (1987) The Pricing of Options on Assets with Stochastic Volatilities. Journal of Finance, 42(2), 281-300

methods. It derives statistical estimators for the volatility process parameters and estimates the index parameters using these derived statistical estimators. Estimated option values deviate significantly from Black-Scholes values in most cases; this emphasizes that Black-Scholes dominates out-of-the-money options in long-term index options.

When four articles covering 51% of the articles in the third largest cluster were examined, it was revealed that the cluster focused on the development of new model proposals. The authors in this cluster strive to create new volatility estimators using long-term stock market data. They analyze the relationships between macroeconomic variables and stock market volatility, comparing the estimation performances of univariate and multivariate volatility models. In the exploration of new statistical methods, efforts are made to determine fundamental effects like asymmetric impact and leverage ratio. The total number of citations in this cluster amounts to 7,973, featuring notable works such as French, K. R., Schwert G. W., and Stambaugh R. F.'s "Expected Stock Returns and Volatility" (1,716 citations), Hull, J. and White, A.'s "The Pricing of Options on Assets With Stochastic Volatilities" (1,607 citations), and Schwert G. W.'s "Why Does Stock-Market Volatility Change Over Time" (1,437 citations).

In summary, the cluster analyzes performed; it has revealed the different approaches and basic issues that the authors focus on regarding volatility. The first cluster focused on comparing volatility forecasting models using different parameters and developing new models. Researchers who want to analyze the performance of volatility forecasting models under different conditions can benefit from the information in the first cluster. The second cluster identified focuses on the stock and foreign exchange markets, the determination of the volatility of exchange rates, especially the US Dollar, the German Mark, and the Japanese Yen, and their relations with other financial instruments. For those interested in researching exchange rates and stocks, exploring publications in the second cluster is recommended. The third cluster investigates the volatility of macroeconomic indicators by addressing the relationship between stock markets and macroeconomic indicators. Authors in this group strive to enhance volatility forecast performance by incorporating new variables. Researchers approaching volatility from a macro perspective may find valuable contributions from authors in the third cluster. One of the most common points in all clusters is the studies to improve the volatility forecast performance or compare the performance of existing volatility prediction models. In general, researchers have tested which volatility forecasting models perform best under different market conditions or have carried out studies on incorporating new variables into statistical models to improve existing models.

CONCLUSION

This study, which conducts a bibliometric analysis of articles in the field of volatility, aims to contribute to financial research by delving into trends and significant findings in the literature. With the bibliometric analysis performed, knowledge gaps in the literature were identified, different perspectives in the literature were revealed in order to understand the inherently complex structure of the financial world, and the literature was enriched by identifying possible opportunities for researchers. The conducted studies indicate a growing focus on research related to exchange rates and macroeconomic factors, particularly those influenced by global economic uncertainties and technological developments. According to the findings obtained as a result of the bibliometric analysis study, studies carried out in the field of volatility are mostly aimed at determining how stocks, exchange rates and macroeconomic factors are affected by global economic uncertainty and technological developments. In particular, Heston's (1993) study and Glosten, Jagannathan and Runkle's (1993) study stand out as the most cited publications. In their work, the authors contribute to the understanding of uncertainties in financial markets by addressing fundamental questions in the field of volatility. The articles in question are highly cited; this can be attributed to reasons such as addressing current issues according to their periods, developing advanced mathematical models and using unique data sets. The topics covered by new researchers in these articles are; conducting interdisciplinary studies to analyze the impact of new parameters on volatility in more detail, by adapting them to current market conditions and by taking advantage of new technological approaches, especially big data analytics, artificial intelligence and deep learning, will contribute to the literature. Results from journal analysis highlight the Journal of Finance as the most cited journal, it is possible to attribute this to the effective publishing policy, quality editorial process and selectivity of the journal. Although the National Bureau of Economic Research (NBER) is one of the leading institutions publishing on volatility, the majority of publishing institutions are universities. In the publications, it has been determined that while universities address the issue of volatility from an academic perspective, institutions outside universities, such as NBER, use the issue of volatility as a strategic tool to achieve their goals. NBER's prominence in volatility research also strengthens the leadership of the United States on a country basis. This leadership, attributed to the country's comprehensive and dynamic financial markets, is further enhanced by NBER's expertise and pioneering contributions. Therefore, participating in volatility research at US-based institutions offers the opportunity to collaborate with global researchers and thus develop volatility studies worldwide. In addition, researchers focusing on journals that stand out with their effective research, such as the Journal of Finance, can increase the visibility of their studies and the recognition of authors. In future studies, researchers will be able to conduct joint volatility studies with experts from different disciplines such as economics, finance, statistics and engineering, which will allow them to look at the complex structure of volatility from different perspectives and develop more creative solutions. Volatility forecast models developed by taking advantage of the opportunities of developing technologies, especially big data analytics, artificial intelligence and deep learning, will contribute to the creation of more accurate models in the dynamic market structure.

The use of cluster analysis in understanding the development and major themes of volatility literature allows future researchers to efficiently navigate and synthesize existing knowledge. Studies on issues such as the development of volatility forecasting models, exchange rate volatility, and the effect of macroeconomic indicators on volatility, identified as the main focus points through cluster analyses, help determine the primary research areas for scholars and develop strategies to mitigate market volatility. When the articles in the clusters were examined in detail, it was determined that the articles on volatility underscores their substantial contributions to financial literature by challenging established assumptions in traditional financial theory. Specifically, critiques of the normal distribution assumption reveal volatility's tendency to deviate from this norm, especially in certain periods. Revisiting assumptions of data independence and constant variance highlights the inadequacy of traditional notions in capturing the intricacies of financial market dynamics. Criticisms toward the Rational Expectations Hypothesis emphasize the need for reassessment, emphasizing the impact of irrationality and emotional reactions on price formation. The analysis emphasizes the importance of adapting volatility models to specific market conditions and asset classes. In high volatility periods, Garch family models, stochastic volatility models, and regime-switching models excel, capturing sudden market changes and nonlinear responses to price fluctuations. Conversely, simplicity takes precedence in low volatility environments, with stochastic volatility models, constant volatility models, and Garch (1,1)

performing better. The research suggests that asset class differences influence model effectiveness, with Garch family models recommended for stocks, bonds, and exchange rates, Gacrh derivatives and stochastic volatility models for cryptocurrencies, and stochastic volatility and regime-switching models for commodities. Long-term analyses benefit from constant volatility and econometric models, while short-term analyses favor quickly updated variance estimates from stochastic volatility and Garch derivatives. Novel approaches like Data Mining and Machine Learning Integration, Adaptive Models and Artificial Intelligence, Time Series Analysis and Parameter Optimization, Sensitivity and Risk Management, Alternative Financial Models, and Multiple Model Integration offer more accurate and comprehensive volatility forecasts, compensating for traditional model's limitations. The analysis advocates for a reconsideration of data frequencies and modeling approaches, suggesting that high-frequency data and alternative techniques may enhance accuracy in volatility predictions. This critical perspective deepens our understanding of financial markets and opens avenues for refining traditional financial theory. Based on both the clusters identified around fundamental topics in the volatility literature and the detailed analyses of articles within these clusters, future researchers in volatility studies are encouraged to integrate insights from studies on volatility prediction models, exchange rates, and macroeconomic indicators into new research. Exploring the psychological aspects of investor behavior, utilizing alternative modeling techniques, including high-frequency data, and adopting an interdisciplinary approach will enhance our understanding of market dynamics and pave the way for more comprehensive and nuanced research, addressing the complexities of financial markets and volatility.

As a result of the examination of volatility studies, future study topics that could contribute to the literature were determined and presented below. For future studies in this context;

* Strengthening volatility modeling through the integration of new data sets, advanced statistical methods, machine learning techniques, and a more detailed examination of socioeconomic factors.

* Exploring the impact of emerging financial instruments, particularly digital assets, on volatility to guide investors in understanding and evaluating the volatility of digital assets.

* Investigating the capacity of social media to predict volatility in financial markets through news and sentiment analysis, along with assessing the impact of social media on investor behavior.

* Expanding bibliometric analysis using different databases and alternative methodologies in future studies to address the limitations.

* Examining the relationship between volatility and social and environmental factors, such as climate change, global events, and pandemics, to help investors create sustainable investment strategies.

* Understanding the effects of investor behavior and emotional reactions on volatility in financial markets in more detail, exploring how stock trading decisions influence volatility, and minimizing these effects.

* Conducting a comparative analysis of regional and global factors to understand how volatility differs on a regional or country basis, particularly focusing on the effects of regional economic factors and policies on volatility.

* Exploring volatility factors in developing economies and evaluating forecasting models specific to these economies to contribute to the literature on volatility.

* Investigating how new methodologies like machine learning, artificial intelligence, and big data analytics can be applied in volatility forecasting, providing future researchers with innovative perspectives.

* Promoting interdisciplinary research collaboration across economics, finance, statistics, and engineering to better understand the complexity of volatility and evaluate it from various perspectives.

As a result, the in-depth bibliometric analysis study comprehensively evaluates the trends and important findings in the literature in the field of volatility and offers researchers new study opportunities that will fill existing knowledge gaps and close gaps in the literature. It is important to foster collaboration between experts from various disciplines to increase knowledge in this field, strengthen financial decision-making processes and respond more effectively to future uncertainties. Investors' risk perception and sensitivity to market conditions should also be examined in detail. In this

context, future research could be expanded to include individual and institutional investors to understand the effects of investor behavior on volatility in more detail. In addition, research evaluating the effects on the general stability of the financial system, taking into account the risk management strategies of financial institutions and the compliance of regulators with these strategies, can also make a significant contribution. In this way, knowledge gaps on volatility can be filled more quickly and a more resilient economic environment against fluctuations in financial markets can be created. Considering the limitations of bibliometric analysis, it is important to note that future studies could extend a similar analysis by using different databases and applying alternative methodologies. It is also necessary to update the literature on volatility and conduct more specific research focusing on new trends, especially considering evolving technology and market conditions. At this point, advanced analyzes and applications on volatility have the potential to place industry practice on more solid foundations. In conclusion, this study provides a basis for in-depth understanding of the current situation in the field of volatility and direction for future research. Understanding and effectively managing fluctuations in financial markets is of critical importance for global economic stability. Therefore, constantly updating and expanding research on volatility requires the joint efforts of professionals in the financial sector, regulators and academics.

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