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Research Trends from Classical Artificial Intelligence to Deep Learning in Stock Market Prediction: A Scientometric Perspective

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ABSTRACT Artificial intelligence (AI), including machine learning (ML) and deep learning (DL), is a rapidly growing and unexplored field with diverse applications across industries, especially those requiring complex analysis, inference, and prediction from large and diverse datasets. This research paper addresses several key inquiries related to the application of CiteSpace for stock market prediction (SMP). The key objectives include identifying trends and findings in the literature, exploring limitations and future research directions, identifying prominent authors in the field, and determining active countries engaged in cooperative SMP research. The study employs scientometric analysis as the primary methodology, offering a powerful and versatile approach to literature reviews. The analysis encompasses citation analysis, author influence, relevant journals, co-citation patterns, bibliometric coupling, and co-occurrence analysis. The dataset consists of 10,976 articles published between 2013 and 2023, sourced from Scopus-indexed journals, and CiteSpace software tools are used for data analysis. The analysis reveals that Sweden has made outstanding contributions to SMP research, with a total citation count of 2,664, followed by the United States with 2,369 citations. The primary research institutions that have made significant contributions are PLOS ONE, with a citation count of 2,219, and IEEE ACCESS with 2,110 citations. In terms of individual authors, Xiao, Ming and Wang, Lihui are ranked as the top-cited authors, with 53 and 41 citations respectively.

INDEX TERMS Bibliometric Technique, CiteSpace, Research Trends, Scientometric Analysis, Stock Market Prediction, Visualize Research Trends.

I. INTRODUCTION

IN recent years, the integration of artificial intelligence (AI), including machine learning (ML) techniques and deep neural networks (DNNs), into financial markets, has gained significant attention. This convergence has opened up avenues for novel approaches to stock market prediction, potentially revolutionizing trading strategies and risk management practices [4]. The complexity and volatility of the stock market, particularly in futures trading, present a challenging environment for traditional analytical methods [5]. Financial markets consist of a range of market types, such as stock markets, derivatives markets, bond markets, and commodity markets [10]. Thus, the proliferation of financial data sources and advances in computational power have enabled the development of sophisticated AI, ML, and DNN algorithms by uncovering complex patterns [3]. By leveraging these techniques, researchers and practitioners seek to enhance decision-making processes, mitigate risks, and capitalize on market opportunities based on the existing techniques. For example, an analysis of publication patterns in this field over the past two decades reveals a consistent upward trend in the volume of articles focusing on AI derivatives, encompassing ML and DL for stock market prediction are shown in Figure 1. Notably, the number of publications employing AI methodologies nearly doubled over the last two years. According to Capital Markets Fact Book [6], despite the recent and swift progress in developing next-generation AI-based techniques, there remains a notable absence of a comprehensive understanding of how AI, ML, and DL can be fundamentally integrated into the field of stock market prediction.

When it comes to technical analysis, stocks are assessed by analyzing historical data, including volume, prices, and market activity, using statistical methods. Typically, the focus

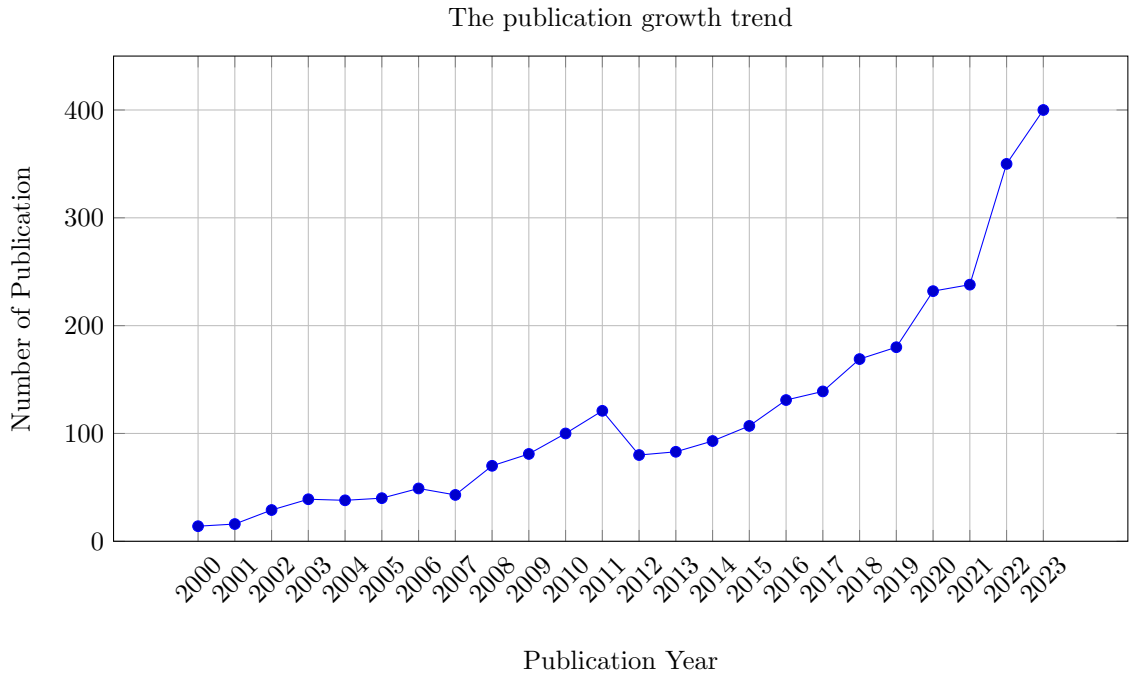

FIGURE 1. Number of publications adopting AI derivatives in the stock market (2000–2023) on Scopus database

is on examining the overall trend to determine the potential performance of a specific stock in the upcoming period [11]. Earlier studies have published vast literature on various methods developed to predict the trend of the stocks [12]. Conducting a technical analysis with a literature review on stock market prediction (SMP) is an essential initial task before conducting a study or making decisions in this field. This review delves into the progression of SMP techniques, encompassing both conventional approaches and cutting-edge deep learning (DL) methods. This paper provides a scientometric review of stock market prediction methods, spanning AI approaches from conventional machine learning algorithms to deep learning architectures [7]. We aim at identifying key trends, prominent methodologies, influential works, and emerging research directions within this financial markets domain through a scientometric analysis. By synthesizing insights from a diverse range of studies, we seek to offer valuable perspectives on the efficacy, limitations, and prospects of employing AI techniques for stock market forecasting.

In this study, to achieve a wider picture of bibliometric data, tools, and methods, scientometric research has been conducted to review the progress and trends in SMP and to complement and add to the existing knowledge on stock market prediction. Utilizing one of the best academic databases, i.e. Scopus, we retrieved all the related academic articles published over 20 years. Scopus is a well-recognized academic database enriched with data that links scholarly articles across all disciplines. The selected data bank retrieves data for mapping and analyzing the network of various occurrences and collaborations in SMP. The reason for this mapping is to systematically and critically scrutinize previous studies and identify the impacts made so far in the years under coverage. This will enable us to spot the targeted areas in the earlier studies.

A. RESEARCH QUESTIONS AS PURPOSE OF STUDY

With the advancement of technology, various tools and techniques have been developed to aid in this process, including the use of CiteSpace [8]. CiteSpace is a software tool that allows researchers to analyze and visualize the literature in a particular field. In this paper, we conduct a bibliometric literature review of stock market prediction using CiteSpace. Specifically, we aim to answer the following research questions:

- RQ1 How has Citespace been used in the field of stock market prediction?
- RQ2 What are the key findings and trends in the literature regarding the application of Citespace in stock market prediction?
- RQ3 What are limitations and future research directions in emerging application areas of SMP ?
- RQ4 Which are the prominent authors in the field of SMP?
- RQ5 Which active countries are mostly involved in cooperative research in SMP?

By addressing these questions, we hope to provide a comprehensive overview of the current state of research in this field, and identify potential areas for further investigation. In summary, this scientometric review offers a comprehensive

synthesis of research efforts aimed at harnessing the power of ML, particularly DNNs, for predicting stock market behavior.

B. CONTRIBUTIONS

By shedding light on the current state of knowledge and identifying areas for further exploration, this paper aims to contribute to the ongoing discourse on enhancing predictive capabilities in financial markets through advanced computational techniques. This study explores the ten-year scientometric patterns in the domain of the stock market for discussing and defining future research agendas. The significant contributions of this quantitative research are as follows.

1) This article introduces a bidimensional approach to scientometric analysis.
2) This article contributes an approach to analyzing the technological trends in a research domain using keyword co-occurrence analysis.
3) This article contributes an approach to identifying the significant categories and research areas, from the perspective of the scope of research in those areas.

C. PAPER ORGANIZATION

The remainder of this paper is organized in five Sections: Section II presents a review of relevant literature, categorizing studies based on the types of ML techniques employed and highlighting their respective contributions. In Section III, we conduct a scientometric analysis to examine the quantitative and qualitative characteristics of the identified research corpus. Section IV discusses the the findings, addressing the strengths and limitations of existing approaches and outlining potential avenues for future research. Section V provide the future research direction and implications. Finally, Section VI concludes the paper with a summary of key insights and recommendations for advancing the field of ML-driven stock market prediction.

II. LITERATURE REVIEW AND STOCK MARKET

The present valuation of a publicly traded company's stock reflects its historical performance, current market conditions, and future prospects for profitability [6]. To obtain a more precise prediction of the stock price, various types of studies have already been conducted. The traditional approaches [9]–[14] primarily concentrate on analyzing the financial data in different ways, including techniques, databases, companies, etc., but we incorporate external factors, such as document co-citation analysis (DCA), author co-citation analysis (ACA), country co-citation analysis (CCA), journal co-citation analysis (JCA), author-keyword-country (AKC), and keyword analysis (KA). This technical analysis, depicted in Figure 2, illustrates the common approaches to SMP that are outlined in the need of this study.

Within this section, we present a comprehensive review of different methodologies that have been employed in previous studies to analyze the aforementioned factors in stock market prediction (SMP). Despite their differences, these studies share the common objective of analyzing trends in SMP. They have utilized diverse search strings across various databases and analysis tools to examine SMP documents. Table 1 lists some of the search strings employed in prior research. These search string limits the earlier studies as less number of results found for SMP.

These different search strings highlight the varied approaches taken by researchers in selecting relevant articles for their studies [15] [16]. Each study focused on specific aspects of stock market prediction, such as machine learning techniques, specific algorithms, or the intersection of AI and finance. The utilization of different search strings demonstrates the diverse research interests and methodologies employed to explore the field of AI-based stock market prediction [17]. Following the aforementioned approach, these studies applied document filtering based on document types such as Journal Article (JA), Review Article (RA), Early Access (EA), and Data documents (DD), as well as language, predominantly English (EN). Subsequently, the analysis was conducted, as depicted in Figure 2 including document co-citation analysis (DCA), author co-citation analysis (ACA), country co-citation analysis (CCA), journal co-citation analysis (JCA), author-keyword-country (AKC), keyword analysis (KA) and statical analysis (SA). Some studies have relied on traditional bibliometric techniques, which may not fully capture the evolving and dynamic nature of the SMP.

The comparative study of the existing literature on the SMP are illustrated in the Table 2. Many existing studies are limited to specific markets, sectors, or time periods, limited number of publications, making it challenging to generalize the findings and apply them to different contexts. There is a lack of research on the transferability of tools like CiteSpace-based insights and methodologies across different stock markets and asset classes. The existing literature in the field of AI-based stock market prediction shares a common objective but exhibits a research gap in terms of not encompassing all the factors mentioned to identify emerging trends. A significant research gap exists in understanding how the insights derived from CiteSpace-based studies can be effectively integrated into real-world stock market decision-making and investment strategies. Addressing this gap could enhance the practical impact and utility of the research.

Furthermore, the previous studies do not utilize the CiteSpace tool for bibliometric analysis, which presents an opportunity for this study to offer a distinctive approach. By leveraging the CiteSpace tool, this study aims to address these gaps and provide a novel method for conducting a comprehensive bibliometric analysis. The utilization of CiteSpace allows for a more extensive exploration of the literature, enabling the identification of hidden patterns, influential publications, and emerging research areas within the field of AI-based stock market prediction.

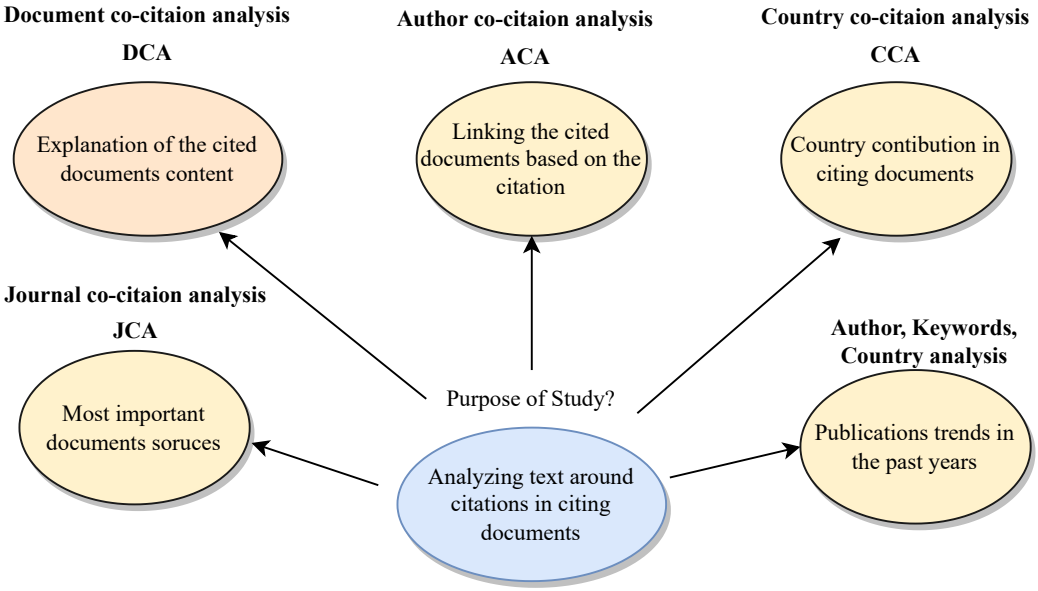

FIGURE 2. Needs of the study definition and components of citation content analysis, citation.

TABLE 1. Diverse search string utilized for analyzing trends of stock market prediction (SMP).

Literature	Year	Search String
Tupe-Waghmare [14]	2021	"Prediction" AND "Stock" AND "Stock Price" OR "Machine Learning" OR "Artificial Intelligence"
Vuong PH [18]	2024	"stock price forecasting," "stock price prediction," "stock price forecasting using ARIMA," "machine learning in stock prediction," "deep learning model in stock forecasting," "CNN, LSTM in stock price forecasting," "GAN in stock price forecasting," "transformer for stock price forecasting," "graph-CNN in stock price forecasting," and "hybrid models in stock price forecasting."
Farman AL [20]	2022	artificial AND intelligence + stock + market
Fantin CO [21]	2022	"stock* market*" and "LSTM" or "stock* market*" and "long short-term memory" or "forecas* stock*" and "LSTM" or "forecas* stock*" and "long short-term memory" or "predictive regression*" and "LSTM" or "predictive regression*" and "long short-term memory" or "supervision *learning*" and "long short-term memory" and "backpropagation".
Nazareth N [22]	2023	"Machine learning" OR "Deep learning" OR "Neural networks" OR "Support vector machine" OR "LSTM" OR "Decision tree" OR "Random Forest" in combination with the Boolean operator AND "Finance" OR "Banking" OR "Investment" OR "Stock market" OR "Cryptocurrency" OR "Insolvency" OR "Bankruptcy" OR "Forex" OR "Foreign exchange" OR "Financial crisis" OR "Financial Distress" OR "Market crash" OR "Currency crisis" OR "Sovereign debt".
Henrique BM [24]	2019	stock market prediction/ forecasting, neural networks, data mining, stock price, classifiers, support vector machine, k-nearest neighbors, and random forest.
Duong QH [25]	2022	"core acquisition", "buyback core", "product return", "return behavior", "return policy", "consumer return" and "customer return".

III. RESEARCH METHODOLOGY

The current study employs a scientometric approach to explore the evolutionary paradigms and future directions of SMP. It identifies research collaborators, facilitating a comprehensive understanding of the research gap to explore. This section focuses on the tools and methods utilized for mapping analysis. The flowchart presented in Figure 3 provides a holistic overview and concise outline of the elements discussed. This research focuses on providing the response to the research questions addresed in the Section I. Researchers have utilized CiteSpace to analyze keyword co-occurrence, author co-citation, and other bibliometric indicators to uncover trends, influential works, and research themes in this domain. This is used to identification of influential authors, articles, and journals in the field. Here are the detailed steps for the citation, co-citation, and keyword analysis conducted using CiteSpace.

1) Fist step is data acquisition, accessed the Scopus database to retrieve the relevant literature on stock market prediction (SMP) research.
2) Second step is selection of the tool for the analysis, adopt the CiteSpace as most popular and based on the usability.
3) Filter the exported the bibliographic data, including titles, abstracts, author information, citations, and keywords, for the selected set of publications.
4) Imported the Scopus data into CiteSpace.
5) Utilized CiteSpace's citation analysis function to con-

TABLE 2. A comparison table provides a comparative analysis of different studies conducted in the field of AI-based stock market prediction.

Literature	Year	Literature Database	Period	Limitation	Analysis approach	No. of papers	Tool used
Tupe-Waghmare et.al., [14]	2021	Scopus	1998 to 2021	EN, JA, RA,	DA, AKJ, JCA, ACA, KA	136	VOSviewe l
Vuong PH et.al., [18]	2024	Scopus and Google Scholar	2014 to 2023	NA	SA	73	MS Excel
Balasubra -manian P et.al, [19]	2024	Scopus, Google Scholar, Science Direct, IEEE, and WoS	NA	NA	SA	300	MS Excel
Farman AL et.al., [20]	2022	Scopus	2002 to 2022	EN, JA	ACA, DCA	183	VOSviewer
Fantin CO and Hadad E [21]	2022	WoS	2000 to 2022	EN, JA, EA, DD	KA, JCA, DCA,	99	Biblioshiny, VOSviewer
Nazareth N, and Reddy YV [22]	2023	Science Direct	2015 to 2023	EN, JA	KA, JCA, CCA	126	NA
Ahmed S et.al., [23]	2022	Scopus	2011 to 2021	EN, JA	KA, DCA, ACA, CO	348	RStudio, VOSviewer, and Excel
Henrique BM et.al., [24]	2019	Scopus	1991 to 2017	EN, JA	KA, DCA, ACA, CCA	547	NA
Duong QH, et.al, [25]	2022	Scopus, WoS and EBSCOhost	1991 to 2021	EN, JA	JCA, ACA, DCA	1209	VOSviewer
Jaramillo, M et.al, [1]	2023	Scopus	2015 to 2023	-	KA, CCA	-	VOSviewer
Bahoo, S et.al, [2]	2024	WoS	1950 to 2021	EN	KA, JCA, CCA,	1,218	CiteSpace

struct a citation network visualization, depicting the influential publications and citation patterns in the SMP research field.

A. STRATEGY FOR RESEARCH

The framework for the research strategy is illustrated in Figure 3. The procedural steps are outlined as data acquisition, software choice, screening, analysis of data, and result and discussion. These steps are elaborated upon in detail in the subsequent sections. Filtration must be applied to refine the result and choice made with the respected steps illustrated in Figure 3.

B. DATA ACQUISITION

The authors conducted a literature search by selecting the Web of Science (WoS) and Scopus databases, considering their comprehensive coverage of standard publications in the field of stock market prediction. The records retrieved from these databases were subjected to specific criteria and restrictions, as outlined in Table 3. The collected records were then downloaded and saved in a format compatible with CiteSpace, a bibliometric analysis tool. The data extraction from the WoS and Scopus databases was performed using the TITLE-ABS-KEY (title-abstract-keyword) search field.

Initially, 7,639 and 30,027 documents were shown in the search results for WoS and Scopus databases respectively as shown in Table 3. However, to ensure the quality and relevance of the data, rigorous filters and criteria were applied. These filters aimed to eliminate irrelevant or duplicate records, resulting in a refined dataset of qualified documents. The data filtration process played a crucial role in ensuring the reliability and accuracy of the subsequent scientometric analysis by reducing noise and focusing on the most pertinent documents. After applying the filters and duplicate removal,

TABLE 3. A table for the summary of Data Retrieval and Filtering Process

Database	Initial Results	Filtering Results	Valid Results	Merge & Remove Duplicate
WOS Scopus	7639 30027	6991 8585	6900 8490	10976
Logic Statement	ALL ((machine AND learning OR deep AND learning OR artificial AND intelligence OR knowledge AND discovery) AND (stock*)) AND PUBYEAR > 2013 AND PUBYEAR < 2023 AND (LIMIT-TO (SUBJAREA , "COMP") OR LIMIT-TO (SUBJAREA , "ENGI")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "re") OR LIMIT-TO (DOCTYPE , "ch")) AND (LIMIT-TO (LANGUAGE , "English"))			

a total of 10,976 documents were collected for further processing.

C. SELECTION OF SOFTWARE TOOLS

Over the years, researchers have utilized a variety of software tools for conducting scientometric analyses of scholarly literature [26]. Most of the popular tools are listed in Table 4. Many of these tools are freely available online for different versions of Windows. It is important to note that these tools serve different purposes and come with their own sets of strengths and weaknesses. Therefore, careful consideration is crucial when selecting the appropriate tool that aligns with the objectives of the study. In this study, the CiteSpace tool was chosen for data processing. CiteSpace is a paid software that offers unique capabilities for evaluative analysis through network visualization. It allows for the generation of clusters to highlight research areas and overall trends. Furthermore,

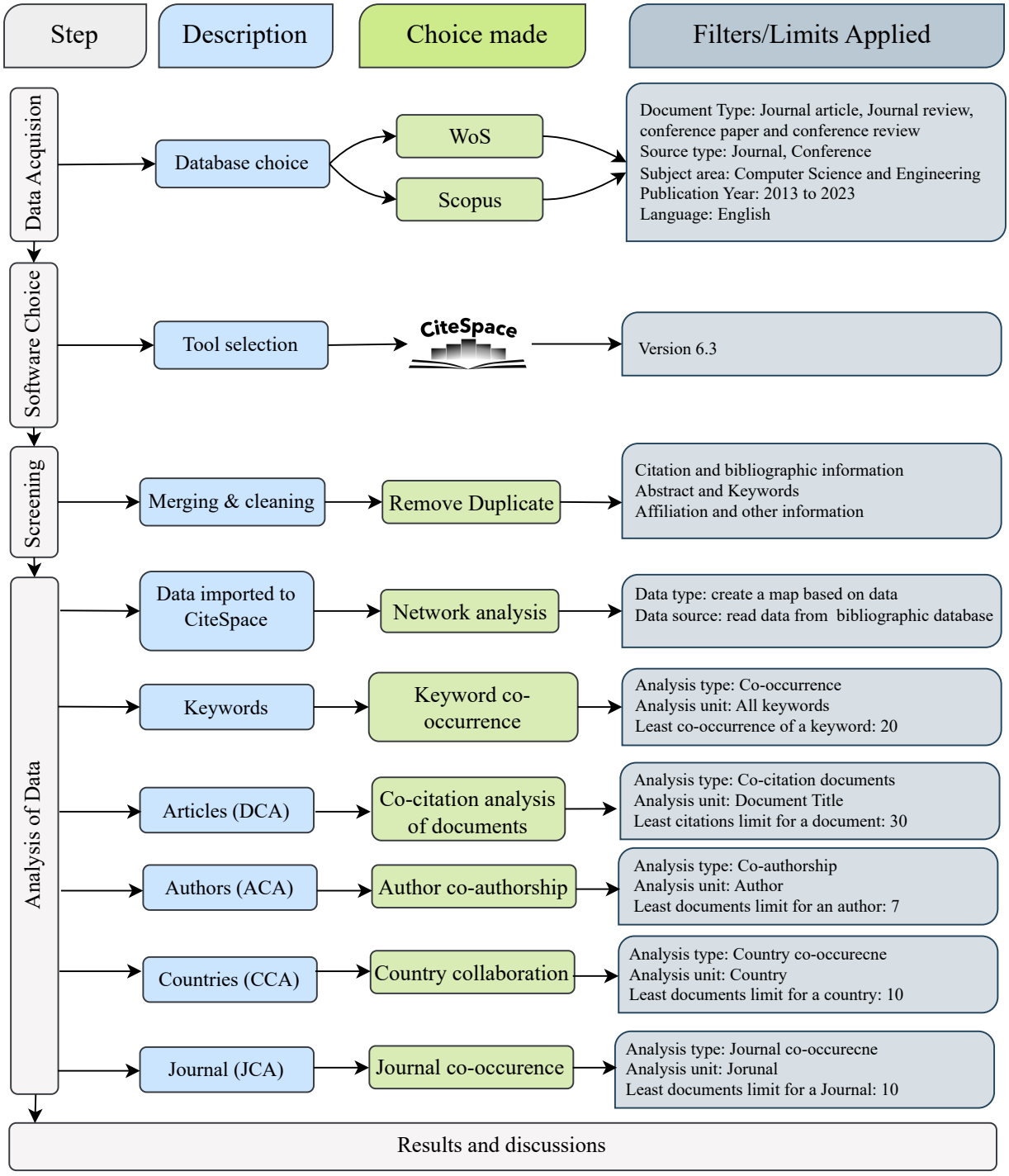

FIGURE 3. Flowchart of the strategy, indicating various choices selected and limits applied during each step.

CiteSpace V.6.2 R6 includes parameters such as citation burstiness, silhouette score, modularity, and centrality, which help validate the results obtained through visualization. By utilizing the CiteSpace tool, this study aims to leverage its advanced features and functionalities to gain deeper insights into the analyzed data.

D. SCREENING OF DATA

Following the filtration process of the searched data, a careful screening was conducted to ensure the inclusion of valid records for scientometric analysis. To enhance the relevance of the retrieved records, further refinement was conducted based on additional parameters.

Subject area: Computer Science and Engineering

TABLE 4. A table for the overview of Scientometric Analysis Software Tools and Associated References

Scientometric Analysis Tool	Year	References
IN-SPIRE	2004	Hetzler E, Turner A. Analysis experiences using information visualization. IEEE Computer Graphics and Applications. 2004 Oct 4;24(5):22-6.
CiteSpace	2006	Chen C. CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. Journal of the American Society for Information Science and Technology. 2006 Feb 1;57(3):359-77.
Gephi	2009	Bastian M, Heymann S, Jacomy M. Gephi: an open source software for exploring and manipulating networks. InProceedings of the international AAAI conference on web and social media 2009 Mar 19 (Vol. 3, No. 1, pp. 361-362).
Bibexcel	2009	Persson O, Danell R, Schneider JW. How to use Bibexcel for various types of bibliometric analysis. Celebrating scholarly communication studies: A Festschrift for Olle Persson at his 60th Birthday. 2009 Jun;5:9-24.
Sci2 Tool	2009	Team S. Science of science (Sci2) tool. Indiana University and SciTech Strategies. 2009 Jan;379.
VOSviewer	2010	Van Eck N, Waltman L. Software survey: VOSviewer, a computer program for bibliometric mapping. scientometrics. 2010 Aug 1;84(2):523-38.
BiblioMaps/ BiblioTools	2011	Grauwin S, Jensen P. Mapping scientific institutions. Scientometrics. 2011 Dec 1;89(3):943-54.
SciMAT	2012	Cobo MJ, López-Herrera AG, Herrera-Viedma E, Herrera F. SciMAT: A new science mapping analysis software tool. Journal of the American Society for Information Science and Technology. 2012 Aug;63(8):1609-30.
CoPalRed	2012	Sangam SL, Mogali MS. Mapping and visualization software tools: a review. InInternational conference on Content Management in Networked 2012 Dec.
CitNetExplorer	2014	Van Eck NJ, Waltman L. CitNetExplorer: A new software tool for analyzing and visualizing citation networks. Journal of informetrics. 2014 Oct 1;8(4):802-23.
Bibliometrix/ BiblioShiny	2017	Aria M, Cuccurullo C. bibliometrix: An R-tool for comprehensive science mapping analysis. Journal of informetrics. 2017 Nov 1;11(4):959-75.

Document Type: Article
Source Type: Journal, Book chapter
Publication Year: 2013–2023
Language: English

From the Web of Science (WoS), a total of 6,900 valid records were selected, while 8,490 valid records were chosen from Scopus. Subsequently, the process of merging and removing duplicate records was carried out using CiteSpace, resulting in the identification of 10,976 unique records out of the initial 15,390. It was observed that 4,414 records were duplicates or invalid (incomplete in some manner). The final dataset for scientometric analysis consisted of the selected 10,976 unique records. This meticulous screening and filtration process paved the way for a comprehensive and reliable scientometric analysis of the chosen literature.

E. ANALYSIS OF DATA

Upon importing the data into the science mapping software CiteSpace, a meticulous series of analyses were undertaken at distinct stages to ensure the precision and reliability of the process. A comprehensive review was conducted to eliminate any potential errors in data interpretation, with scrutiny applied to avoid discrepancies in the analysis of the collected data. The initial step involved launching the CiteSpace software and configuring the data type as "map-based bibliographic data." This enabled the execution of a range of analyses as given in Figure 2 and mapping activities, including DCA, ACA, KA, JCA, and CCA. These analyses provided valuable insights into the relationships and patterns within the dataset, facilitating a comprehensive understanding of the scholarly landscape in the chosen research area. These analyses are:

1) Annual distribution of publications: It refers to the pattern or distribution of publications over different years. It provides information on the number of publications published in a specific field or topic during each year. By analyzing the annual distribution of publications, researchers can identify trends, patterns, and changes in the volume of research output over time.
2) Document Co-Citation Network Generation: Utilizing the CiteSpace visualization tool, a document co-citation network was generated to explore the broad domains within the forecasting literature. Additionally, the entire dataset was segregated into specific domains using subqueries within the WoS database.
3) Descriptive Scientometric Analysis: A comprehensive scientometric analysis was conducted across all categories of forecasting. This entailed examining publication growth, country collaboration, and identifying high-yield countries within each domain. Furthermore, citation pattern analysis was performed to assess citation distribution and identify the most influential journals within each domain.
4) Co-citation Cluster Analysis: Through an analysis of co-citations based on references, research frontiers within each domain were identified for potential future study.
5) Identification of Key Challenges: Finally, key challenges within the forecasting knowledge domain were elucidated through a thorough literature review.

These mapping activities allowed for a comprehensive analysis of the dataset, uncovering key trends, relationships, and patterns within the scholarly literature. They provided valuable insights into the research landscape and facilitated a deeper understanding of the chosen research area.

IV. RESULTS AND DISCUSSIONS

A. ANNUAL DISTRIBUTION OF PUBLICATIONS

Although research on the stock market has made significant progress since the 1930s [27], it appears that studies specifically focused on stock market prediction (SMP)

emerged approximately twenty years ago. Our investigation encompasses a dataset of 10,976 documents in one decade published between 2013 and 2023. It answer the RQ2, key findings and trends in SMP. Although our search query was not limited to a specific date range, our analysis of Scopus output indicates that the earliest publication on stock forecasting was found in 2013, specifically in the Asia-Pacific Journal of Operational Research [28]. In this publication, the author utilized the Neural Network (N.N.) algorithm for stock market forecasting.

Figure 4 illustrates the annual publication trends in the research area. From the 2010s to now, the publication activity displayed a gradual progression until it gained momentum in 2015. This acceleration was expected, considering that pioneering research necessitates robust models to accurately forecast the volatile and dynamic nature of the market. There was exponential growth in 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, and 2023. Furthermore, the research area experienced a remarkable surge in 2023, reaching an all-time high of 25k articles. This peak can be attributed to the growing interest in combining techniques to enhance stock market prediction models. These findings suggest that despite the temporary setbacks and the challenges posed by the pandemic, the research area continues to show resilience and offers great prospects for future growth and development.

B. TOP RESEARCH OUTLETS

Dissemination of academic discoveries and breakthroughs primarily occurs through research outlets or Journal Co-citation Analysis (JCA), which publish groundbreaking research based on various factors such as discipline, scope, and other significant metrics. Analyzing trends within a specific field often involves examining publications in major journals. In this study, CiteSpace was employed to systematically map the prominent journals using relevant metrics and indicators. For this purpose, a criterion of 5 articles and 40 citations was set. It is important to note that the metrics utilized in the mapping analysis were not predetermined benchmarks but rather based on previous scientific reviews, taking into account the discretion and understanding of the authors [29]. The network map of the prominent journals is generated based on these parameters. The findings are summarized in Table 5, which provides details such as the source title, citation count (TC), quartile ranking (Q-Index), Scimago Journal and Country Rank (SJR), Impact factor (IF), and Hirsch Number (H-Index) to provide insights into their standing and significance.

When considering the publication frequency as a measure of productivity, the journals "PLOS ONE" and "IEEE Access" emerged as the top two research outlets in terms of the number of articles published in the field of SMP, with 2,219 and 2,110 outputs, respectively. Table 5 presents the remaining top 10 journals, which are ranked equally based on their publication frequency. Additionally, the authors evaluated the influence and impact of these research outlets in the scientific community.

TABLE 5. Leading research outlets in stock market prediction (Details retrieved from scimagojr.com/journalrank.php on 20th March 2024)

S. No.	Journal	TC	SJR	Q	H Index	IF
1	PLOS ONE	2219	0.89	1	404	3.7
2	IEEE ACCESS	2110	0.93	1	204	3.9
3	NATURE	1938	20.96	1	1331	64.8
4	EXPERT SYST APPL	1592	1.87	1	249	8.5
5	NEUROCOMPUTING	1546	1.48	1	177	6.0
6	SCIENCE	1520	13.33	1	1283	47.7
7	DECISION SUPPORT SYSTEMS	1227	2.08	1	170	7.5
8	P NATL ACAD SCI USA	1107	4.03	1	838	22
9	SCI REP-UK	1028	0.97	1	282	4.6
10	APPL SOFT COMPUT	899	1.88	1	171	8.7

Figure 5 shows the network visualization depicting the top research outlets in the field of SMP (Stock Market Prediction). The size and color of each node represent the publication frequency and influence of the respective journal, with larger and darker nodes indicating higher publication frequency and impact. The connections between nodes represent collaborations and citations among the research outlets, highlighting the interconnectedness of the scientific community in this domain.

Figure 6 illustrates the top 10 journals that have received the highest number of citations and have experienced significant citation bursts in the field of stock market prediction. This visualization highlights the journals that have made significant contributions to the field and have attracted substantial attention and recognition from researchers and scholars.

C. TOP RESEARCH KEYWORDS

Keywords are essential elements in scientific publications, representing the context of the paper. It explain the future research directions in emerging application areas of SMP. They can include words chosen by the authors themselves and keywords commonly found in the titles of the article's references, even if they don't appear in the article itself. In the keyword analysis (KA), textual information, whether in the title or in the form of author keywords, plays a significant role in scientific publications. In this study, both author keywords, manually provided by the document authors, and keyword plus, automatically suggested by the Web of Science program based on cross-referenced articles, were utilized. Additionally, manual text data pre-processing was performed to integrate different semantically similar expressions and writing formats. The detailed analysis of the results is duly presented in Table 6. The "Forecasting", "Time series", "Financial markets", and "Stock market" are the most commonly used authors trending keywords.

The field of stock market prediction has seen the widespread adoption of advanced computational techniques, which have proven to be more effective than traditional statistical methods. Approaches such as Artificial Neural Net-

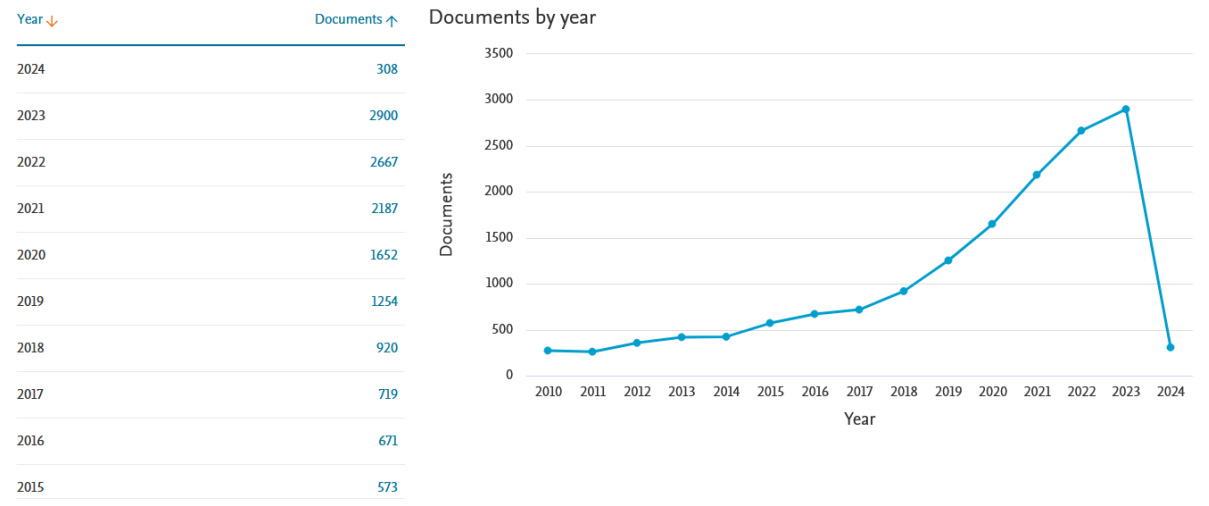

FIGURE 4. Annual distribution of publications. step.

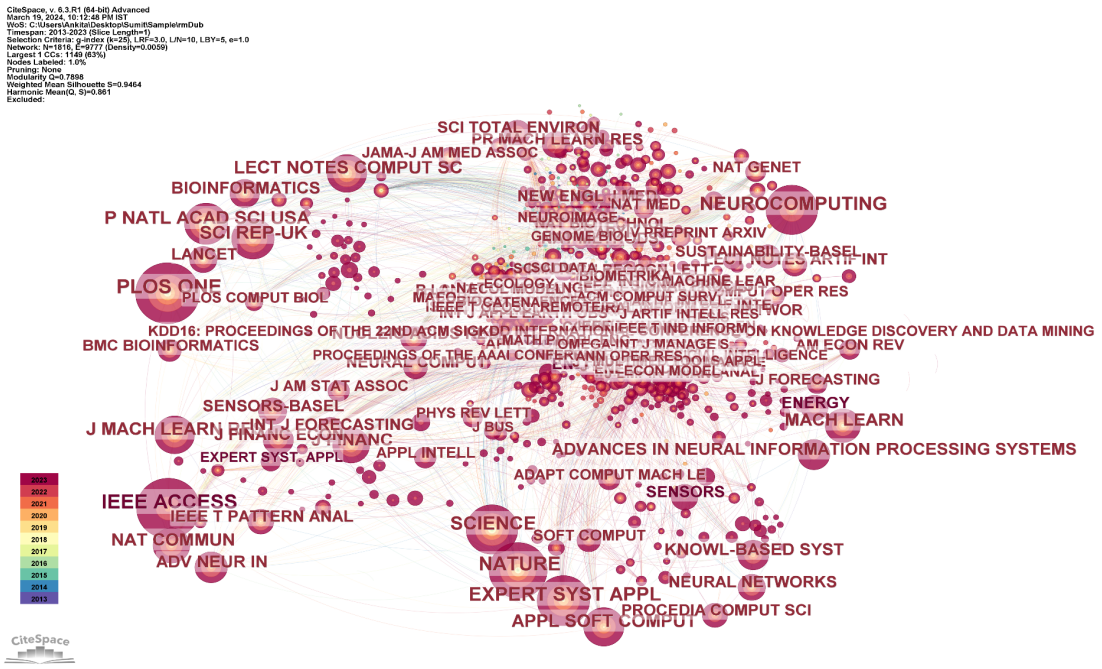

FIGURE 5. Network visualization depicting the top research outlets in the field of SMP (Stock Market Prediction).

works, Machine Learning, Deep Learning, Hidden Markov Models, Decision Support Systems, Random forest, Recurrent Neural Networks, sentiment analysis, and Support Vector Machines have gained popularity for their ability to accurately forecast stock performance. These modern techniques possess robust mechanisms for capturing the nuanced dynamics and determinant factors of stock markets.

The understanding of these keywords can provide researchers with guidance on how to appropriately index, retrieve, and use specific words. By calculating the correlation coefficient between occurrences (O) and total link strength (TLS), a strong positive correlation (r = 0.927) was found between the two indices. In Figure 7, the mapping of all authors' extracted keywords is presented. The size of each node in the Figure 7 represents the frequency of occurrence at which multiple authors have used a specific keyword.

D. DOCUMENT CO-CITATION ANALYSIS (DCA)

Over the years, scientometric performance has been viewed as a measure of citation counts of the articles [30] and as

Top 10 Cited Journals with the Strongest Citation Bursts

Cited Journals	Year	Strength	Begin	End	2013 - 2023
P NATL ACAD SCI USA	2013	168.71	2013	2021	
LECT NOTES COMPUT SC	2013	95.31	2013	2021	
PLOS ONE	2013	87.03	2013	2021	
DECIS SUPPORT SYST	2013	62.89	2013	2021	
IEEE T NEURAL NETWOR	2013	62.5	2013	2021	
EXPERT SYST APPL	2013	62.02	2013	2021	
J FINANC	2013	59.77	2013	2021	
LECT NOTES ARTIF INT	2013	55.97	2013	2021	
NEW ENGL J MED	2013	54.89	2013	2021	
EUR J OPER RES	2013	46.09	2013	2021	

FIGURE 6. Top 10 cited journals with the strongest citation bursts in the field of stock market prediction.

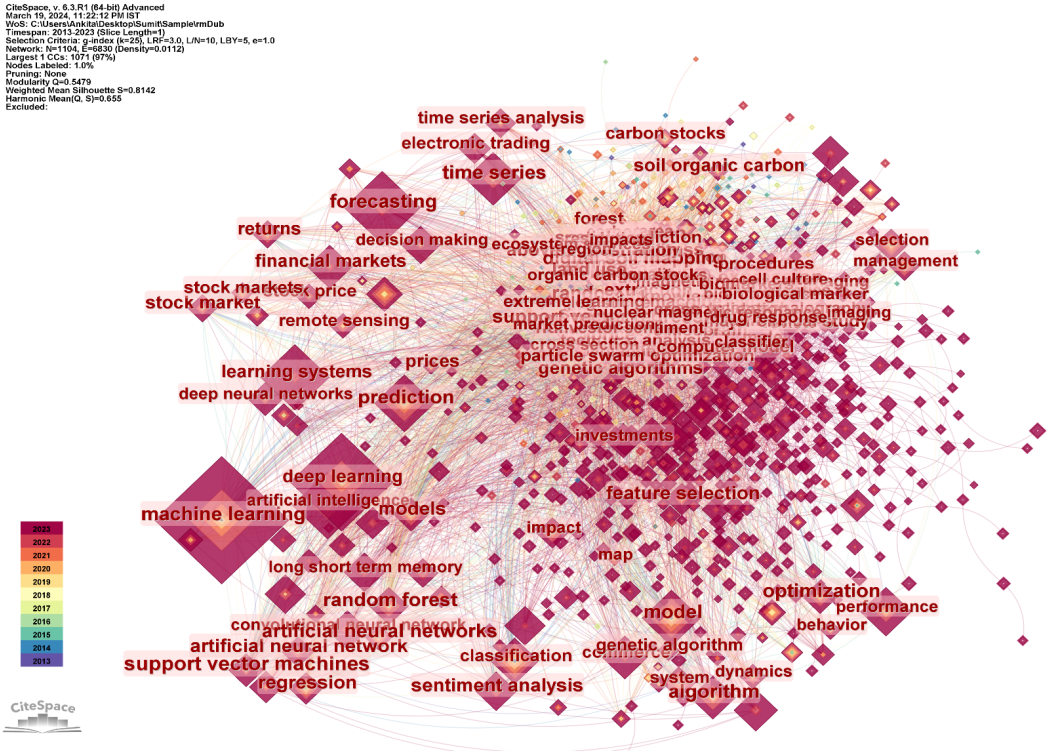

FIGURE 7. Network visualization depicting the top research keywords in the field of SMP.

a result, most publications were usually assessed by their frequency of citations. To analyze the articles that have had a significant impact on the field of SMP, we set an intuitive threshold of 40 citations. When it comes to impact, the focus

TABLE 6. Top-10 Keywords with High-Frequency Values.

S.No	Count	Centrality	Year	Keywords
1	720	0.00	2022	forecasting
2	452	0.00	2015	time series
3	270	0.00	2020	financial markets
4	168	0.00	2013	stock market
5	143	0.00	2013	stock
6	133	0.00	2022	electronic trading
7	106	0.00	2016	stock price
8	95	0.00	2022	time series forecasting
9	85	0.00	2013	stock price prediction
10	77	0.00	2020	stock market prediction

is on quality rather than quantity. Therefore, we prioritize the citation counts and give less or no emphasis on the frequency of publications. However, out of the 10,976 documents, only 1589 were links found. Figure 8 displays the density map of the connected articles. Used tools have grouped similar terms into clusters. We have found 10 clusters as shown in Figure 8, out of which 6 are relevant with the related keywords "stock market prediction", "stock price prediction", "machine learning", "technical indicator", "stock price movement prediction", "stock trading" and many more. The top 10 most cited research articles are given in Table 7 with the citation score and the journal. We have found that author Patel J et.al, the article entitled "Predicting stock and stock price index movement using trend deterministic data preparation and machine learning techniques" is the most cited article in the field of SMP with the strongest citation bursts 4 years of coupling. We also have concluded that most of the top cited work has been published in the "Expert Systems with Applications" Journal. These research articles help the new researchers in the SMP.

E. AUTHOR CO-CITATION ANALYSIS

In academia, articles published without collaboration is tantamount to lower productivity [31]. Thus, the partnership among investigators and educational establishments enriches valuable ideas, which habitually leads to significant landmarks and productivity in research outputs. This section discusses the co-authored research articles to determine the leading researchers in the area of interest. Generally, most articles are published with multiple authors as shown in the Figure 9; this analysis reveals the vital collaborations among several authors in SMP research. From the Table 8, the top-ranked item by citation counts is Xiao, Ming in Cluster #11, with citation counts of 53. The second one is Wang, Lihui in Cluster #142, with a citation count of 41. The third is Vinuesa, Ricardo in Cluster #97, with a citation count of 31. The 4th is Mokdad, Ali H in Cluster #5, with a citation count of 24. The 5th is Majeed, Azeem in Cluster #5, with a citation count of 23. The 6th is Fischer, Florian in Cluster #5, with citation counts of 23. The 7th is Hay, Simon I in Cluster #5, with citation counts of 20. The 8th is Bhutta, Zulfiqar A in Cluster #5, with citation counts of 20. The 9th is Jacobs, Reinhilde in Cluster #410, with citation counts of 20. The 10th is Heuvelink G.B.M in Cluster #0, with citation counts of 19. We also observed that the top 3 highly cited authors are from Sweden.

F. COUNTRY COLLABORATION NETWORK ANALYSIS

Country Co-author Citation Analysis provides the geographical distribution of publications in this research field illustrated in the Figure 10. The analysis show that Sweden, USA, Germany, England are leading country followed by India publishing the articled related to the SMP. This countries are to assess scientific information about the number of publications, citation impact, and the share of total publications of a SMP domain.

The country collaboration network exhibits 211 nodes and 2760 connections, with a density of 0.1246. Each node in Figure 11 represents a distinct country or province. The node size indicates the total publications produced by the corresponding nation; a bigger node size signifies that the node has a greater number of publications. The links between the two nodes represent the collaboration attempt. The direct links between the nodes in the network show the close connections of those nations. The top 10 most prolific nations in terms of publication numbers are listed in Table 9. This table shows the country along with the Citation Count (number of articles), share % of documents, and centrality. Sweden is the most significant contributor in terms of documents (2664) with a share of 10.49%, followed by the United States (2369), Germany(1097), England (972), India (808), Canada(666), Italy (673), Australia (679), France (615), and Spain (603) in this research domain. In terms of central strength, India is at the eye of the picture with a % share of 1.99, followed by Germany (2.47%) and England (2.33%). It indicates that these countries have strong connections with other countries and act as mediators in the forecasting research. In terms of citation count, all countries (as mentioned in Table 9) hold the same rank as per their frequency value. It indicates that the research articles of this nation have yet to yield a substantial influence in this field of research. In contrast, Sweden has contributed quality publications with an average citation ratio of 7.95.

V. DISCUSSION AND FUTURE RESEARCH IMPLICATIONS

The present research articulates a thorough and in-depth investigation of the stock market prediction literature to promote scientific progress and provide innovative value to researchers. The study reveals a consistent upward trajectory in the utilization of AI, including ML and DL, in the finance domain since 2017, indicating growing interest and adoption. Four prominent research domains including neural networks and stock market simulations, portfolio optimization and risk management, time series analysis and forecasting, and high-frequency trading were identified. The study analysis highlights the influential role of key authors in the field of stock market prediction (SMP) using AI techniques.

The review of the important research literature on stock market prediction (SMP) suggests much information about

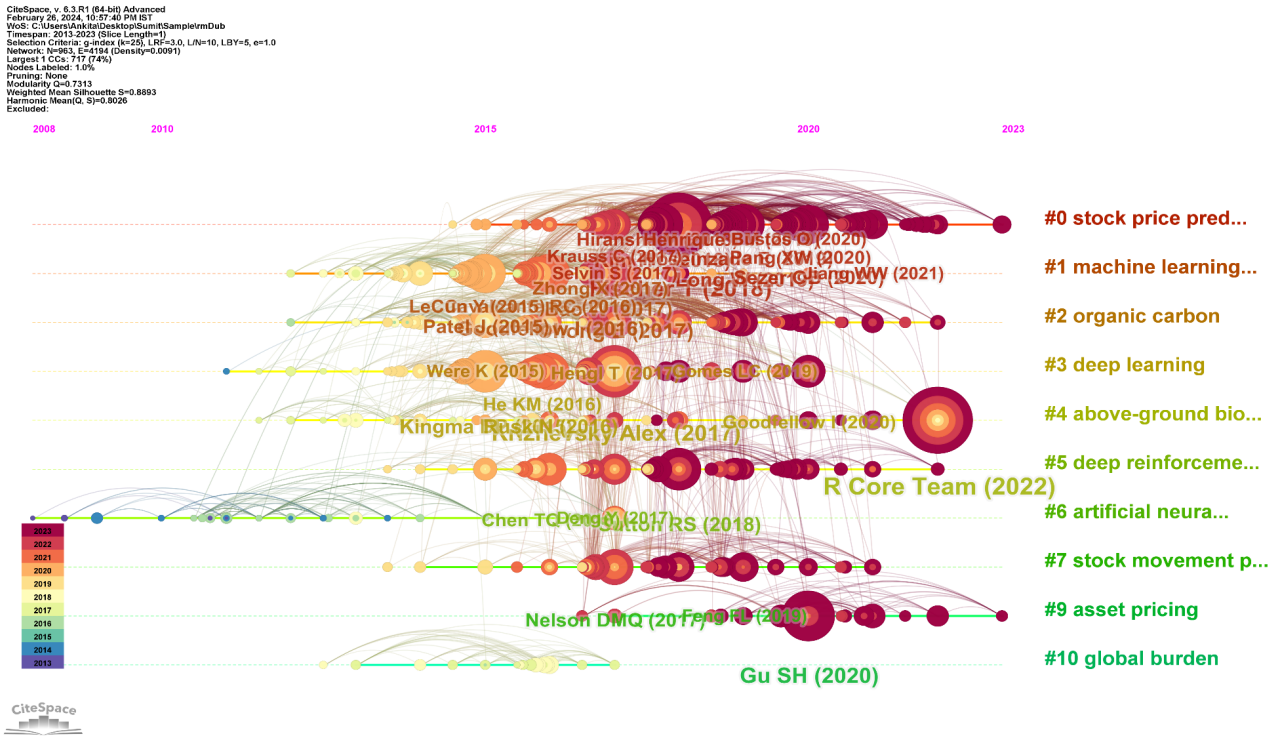

FIGURE 8. Timeline view of article citation network analysis.

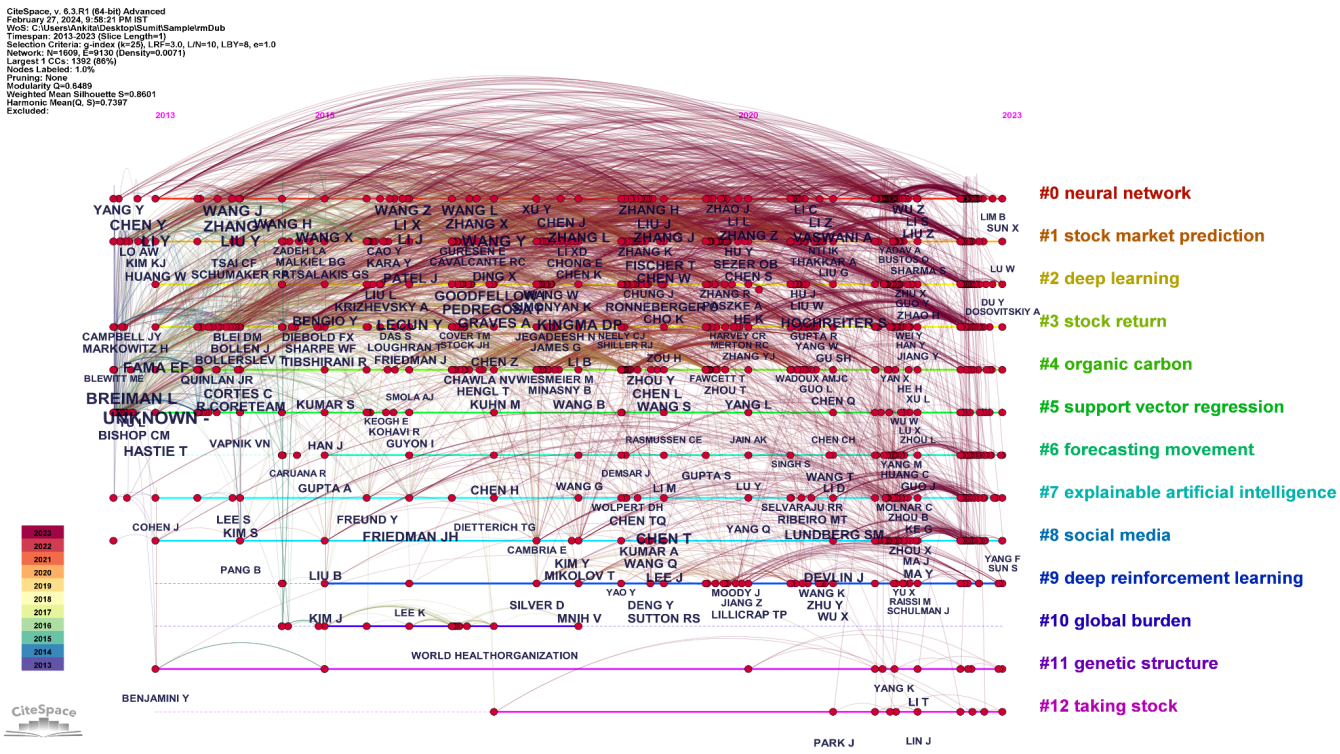

FIGURE 9. Timeline view of collaboration network of authors in the SMP field.

TABLE 7. Most cited research articles in the field of SMP.

Rank	Author	Year	Strength	Interval	Title	Journal	Citation
1	Patel J, Shah S, Thakkar P, Kotecha K.	2015	27.78	2017- 2020	Predicting stock and stock price index movement using trend deterministic data preparation and machine learning techniques.	Expert systems with applications.	1144
2	Kara Y, Boyacioglu MA, Baykan ÖK	2011	14.66	2018-2021	Predicting the direction of stock price index movement using artificial neural networks and support vector machines: The sample of the Istanbul stock exchange.	Expert Systems with Applications	1132
3	Were K, Bui DT, Dick ØB, Singh BR.	2015	17.94	2017- 2020	A comparative assessment of support vector regression, artificial neural networks, and random forests for predicting and mapping soil organic carbon stocks across an Afromontane landscape	Ecological Indicators	713
4.	Nguyen TH, Shirai K, Velcin J.	2015	7	2017- 2020	Sentiment analysis on social media for stock movement prediction.	Expert Systems with Applications	681
5	Ballings M, Van den Poel D, Hespeels N, Gryp R.	2015	14.73	20162020	Evaluating multiple classifiers for stock price direction prediction	Expert Systems with Applications	670
6	Cavalcante RC, Brasileiro RC, Souza VL, Nobrega JP, Oliveira AL	2016	13.52	2017- 2021	Computational intelligence and financial markets: A survey and future directions.	Expert Systems with Applications.	663
7	Patel J, Shah S, Thakkar P, Kotecha K.	2015	12.46	2017- 2020	Predicting stock market index using fusion of machine learning techniques	Expert Systems with Applications	612
8	Zhong X, Enke D.	2017	5.14	2017- 2021	Forecasting daily stock market return using dimensionality reduction.	Expert Systems with Applications.	460
9	Groth SS, Muntermann J.	2011	3.91	2013- 2016	An intraday market risk management approach based on textual analysis.	Decision Support Systems.	241
10	Chiang WC, Enke D, Wu T, Wang R.	2016	5.48	2017- 2021	An adaptive stock index trading decision support system.	Expert Systems with Applications.	177

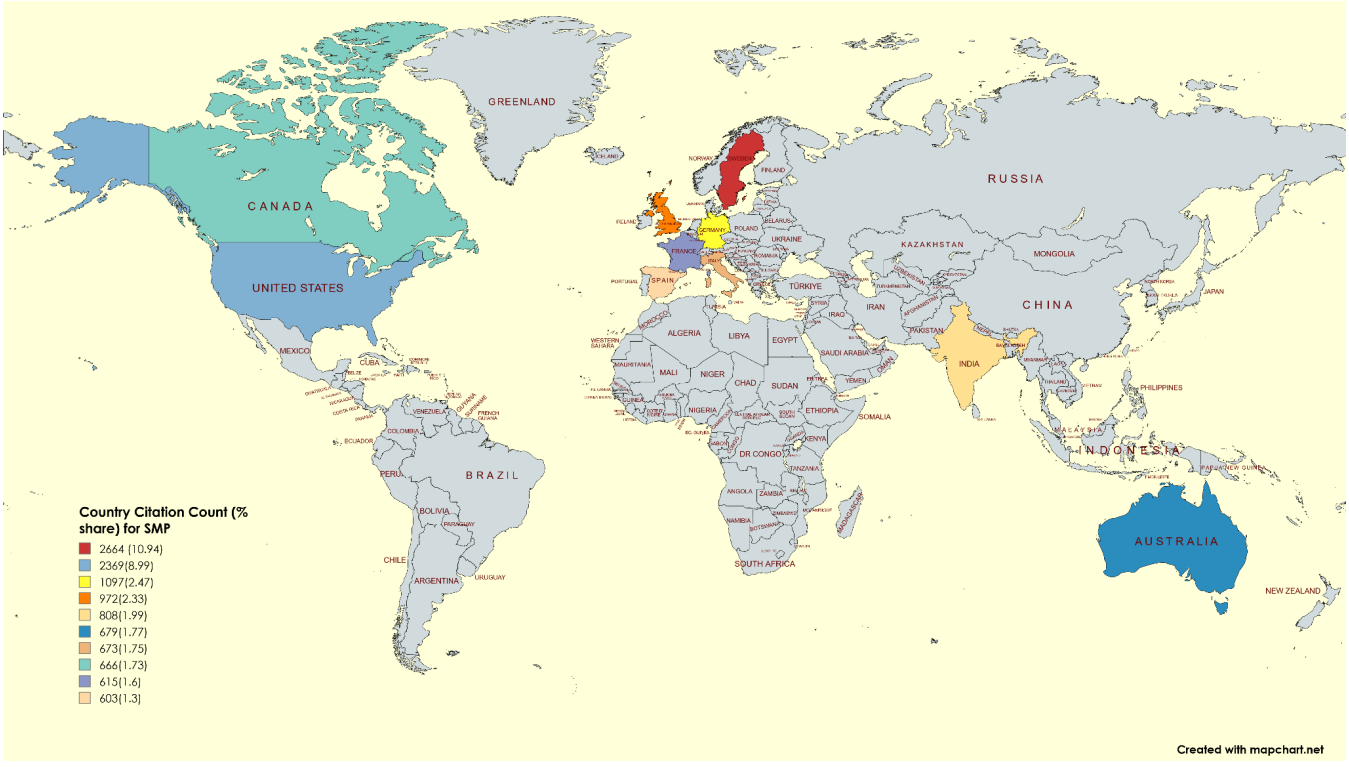

FIGURE 10. Network visualization illustrates the co-citation patterns between countries based on the research publications included in the study.

the research status. The analysis of existing problems and challenges has primarily concentrated on the period from 2013 to 2023. While the summary of relevant technologies and the research status quo provides a useful foundation,

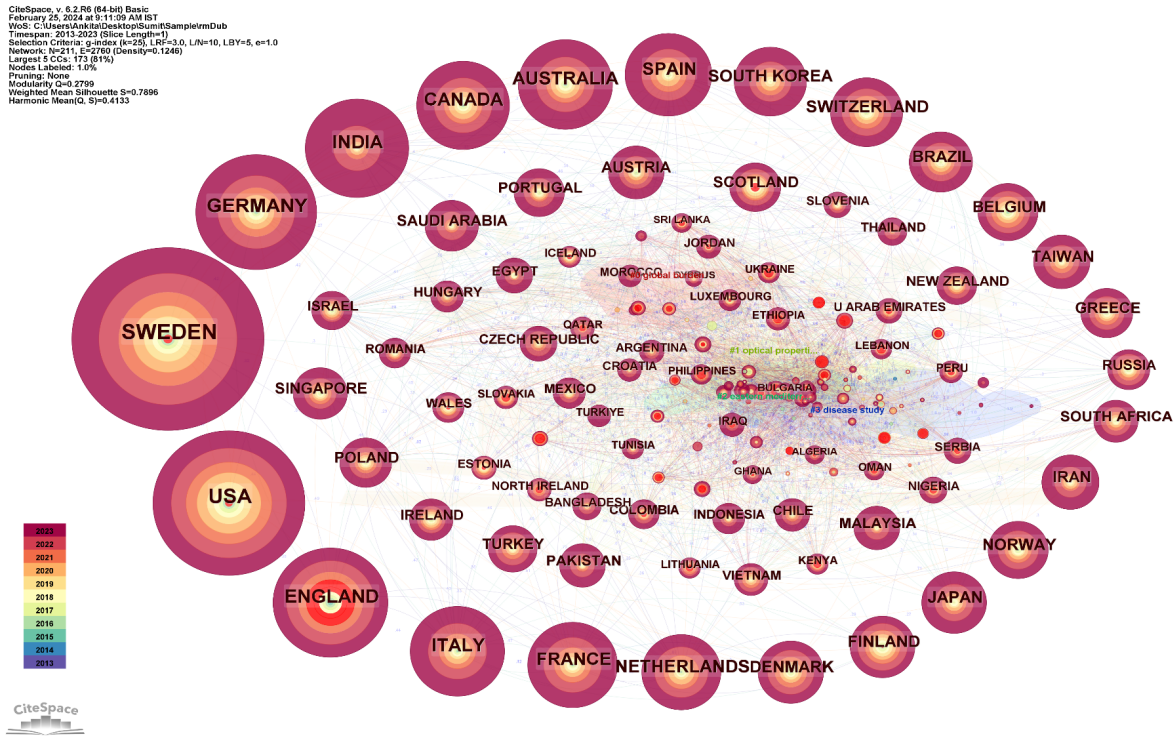

FIGURE 11. Country collaboration network diagram.

the literature appears to have a stronger focus on these descriptive aspects rather than a deeper exploration of the pressing issues and challenges facing the field. This research in the area of SMP can become really impactful, informative, and relevant to both the academic community and real-world financial practitioners.

The findings suggest that emerging research themes, particularly in the application of DL in finance, remain relatively underexplored and present ample opportunities for further investigation. While the study provides a comprehensive overview of the current state of research, future studies could delve deeper into specific AI techniques and their comparative performance in various finance-related tasks. The present research has utilized the comprehensive and widely adopted Scopus and Web of Science database as the primary source for extracting relevant research articles. However, the exclusive reliance on the these database may limit the scope of the study, as it does not capture research articles and other document types (e.g., books, book chapters, editorial notes, websites) that may be indexed in other databases, such as ACM, IEEE Xplore, and Google Scholar. Future studies should consider incorporating data from multiple databases, including ACM, IEEE Xplore, and Google Scholar, to provide a more comprehensive and holistic view of the research landscape. Expanding the document types beyond just journal articles, such as including books, book chapters, conference proceedings, and grey literature, can offer additional perspectives and insights. The presented research can be further extended by incorporating document co-citation cluster analysis and co-authoring institution analysis in the current study.

VI. CONCLUSION

This study has presented a scientometric analysis conducted using CiteSpace to explore the research landscape of stock market prediction. By employing this powerful tool, we have gained valuable insights into the trends, patterns, and key contributors in this field. By considering the works from 2013 to 2023, the findings reveal a consistent upward trajectory in the utilization of AI in finance since 2017, indicating growing interest and adoption within the industry [32]. The scientometric analysis revealed the growth and evolution of research on stock market prediction, highlighting the emergence of new research directions, influential authors, and pivotal works. The proposed country collaboration analysis identifies Sweden, with a share of 12.80%, followed by the United States 8.99%, and Germany 2.47%, whereas India has 1.99% share to collaborate in the respective field. The author's co-citation network analysis identifies Xiao Ming, Wang Lihui, and Vinuesa Ricardo as influential authors that assist the researchers in keeping abreast with the latest developments and to commence joint initiatives. Furthermore, the visualization generated by CiteSpace provided a comprehensive overview of the network of research publications, enabling us to identify clusters of related studies and the interconnections between them [33].

TABLE 8. Top-Ranked Authors by Burst and Centrality.

Citation Count	Author	Cluster-ID	Year	Affiliation
53	Xiao, Ming	11	2019	Royal Inst Technol, Sch Elect Engn & Comp Sci, S-10044 Stockholm, Sweden
41	Wang, Lihui	142	2020	KTH Royal Inst Technol, Dept Prod Engn, SE-10044 Stockholm, Sweden
31	Vinuesa, Ricardo	97	2021	KTH Royal Inst Technol, SimEx FLOW, Engn Mech, SE-10044 Stockholm, Sweden.
24	Mokdad, Ali H	5	2017	University of Washington: Seattle, WA, US
23	Majeed, Azeem	5	2017	Imperial Coll London, London, England
23	Fischer, Florian	5	2017	Univ Bielefeld, Sch Publ Hlth, Bielefeld, Germany
20	Hay, Simon I	5	2017	Li Ka Shing Ctr Hlth Informat & Discovery, Oxford, England.
20	Bhutta, Zulfiqar A	5	2016	Aga Khan Univ, Ctr Excellence Women Child Hlth, Karachi, Pakistan
20	Jacobs, Reinhilde	410	2021	Katholieke Univ Leuven, Fac Med, Dept Imaging & Pathol, Leuven, Belgium
19	Heuvelink G.B.M	0	2016	Wageningen Univ, Soil Geog & Landscape Grp, Wageningen, Netherlands

TABLE 9. Top 10 Most Collaborating Countries in SMP Research.

S. No.	Country	Citation Count	Share %	Centrality
1.	SWEDEN	2664	10.94	0.01
2.	USA	2369	8.99	0.02
3.	GERMANY	1097	2.47	0.07
4.	ENGLAND	972	2.33	0.06
5.	INDIA	808	1.99	0.10
6.	AUSTRALIA	679	1.77	0.01
7.	ITALY	673	1.75	0.01
8.	CANADA	666	1.73	0.01
9.	FRANCE	615	1.67	0.01
10.	SPAIN	603	1.3	0.01

Through this analysis, we have observed the increasing interest and interdisciplinary nature of stock market prediction research. We have witnessed the collaboration between researchers from diverse fields, such as finance, economics, computer science, and machine learning, indicating the recognition of the complexity and multifaceted nature of stock market prediction. Moreover, the scientometric analysis has shed light on the prominent topics and methodologies utilized in stock market prediction research. It has revealed the use of various techniques including machine learning algorithms, statistical models, sentiment analysis, and data mining. These findings underscore the continuous efforts to improve prediction accuracy, enhance decision-making processes, and develop robust frameworks for stock market forecasting. Approaches such as Artificial Neural Networks, Machine Learining, Deep Learning, Hidden Markov Models, Decision Support Systems, Random forest, Recurrent Neural Networks, sentiment analysis, and Support Vector Machines have gained popularity for their ability to accurately forecast stock performance. By leveraging the power of machine learning and data-driven modeling, they can effectively extract and analyze complex patterns from the vast amount of financial data, enabling more accurate and reliable stock performance predictions.

By providing a scientometric analysis using Citespace, this study contributes to the understanding and advancement of stock market prediction research. It offers researchers and practitioners a comprehensive overview of the field, allowing them to identify gaps, explore potential collaborations, and discover new avenues for future investigations. Furthermore, studies have proposed intelligent forecasting models of stock prices based on neighborhood rough sets and multivariate empirical mode decomposition, which warrant further investigation. Therefore, future research should aim to address these gaps and limitations to enhance the accuracy and reliability of stock price forecasting models.

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