Artificial Intelligence and Deep Learning in Stock Prediction: A Bibliometric Review

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Abstract: Artificial intelligence (AI) and deep learning (DL) are advancing in stock market prediction, attracting the attention of researchers in computer science and finance. This bibliometric review analyzes 525 articles published from 1991 to 2024 in Scopus-indexed journals, utilizing VOSviewer software to identify key research trends, influential contributors, and burgeoning themes. The bibliometric analysis encompasses a performance analysis of the most prominent scientific contributors and a network analysis of scientific mapping, which includes co-authorship, co-occurrence, citation, bibliographical coupling, and co-citation analyses enabled by the VOSviewer software. Among the 693 countries, significant hubs of knowledge production include China, the US, India, and the UK, highlighting the global relevance of the field. Various AI and DL technologies are increasingly employed in stock price predictions, with artificial neural networks (ANN) and other methods such as long short-term memory (LSTM), Random Forest, Sentiment Analysis, Support Vector Machine/Regression (SVM/SVR), among the 1399 keyword counts in publications. Influential studies such as LeBaron (1999) and Moghaddam (2016) have shaped foundational research in 8159 citations. This review offers original insights into the bibliometric landscape of AI and DL applications in finance by mapping global knowledge production and identifying critical AI methods advancing stock market prediction. It enables finance professionals to learn about technological developments and trends to enhance decision-making and gain market advantage.

Keywords: Bibliometric Analysis, Artificial Intelligence (AI), Deep Learning (DL), Stock Prediction, VOSviewer, Scientific Mapping Knowledge

1. Introduction

This study explores the impact of Artificial Intelligence (AI) and deep learning (DL) on stock prediction. AI has revolutionized stock market prediction with machine learning (ML) and natural language processing techniques, analyzing diverse data sources for trend discovery and forecasting (Valle-Cruz et al., 2024). However, unpredictable events make forecasting challenging, necessitating AI predictions as part of a diversified investment plan (Kanthimathi et al., 2023). Techniques like DL and neural networks outperform traditional methods, and hybrid models integrating multiple AI techniques handle non-linear complexities effectively (Lin and Lobo Marques, 2024). As a broad field, AI encompasses various techniques, among which DL is a prominent subset characterized by its ability to model complex, non-linear relationships in large datasets. It uses DL algorithms to predict stock price movements and handle complex dynamics (Lin and Lobo Marques, 2024). AI enhances stock price prediction by enabling predictive analytics and evaluating real-time data and past trends (Raman and Tiwari, 2024). It improves prediction models through feature engineering and preprocessing techniques (Abunasser et al., 2023; Lin and Lobo Marques, 2024).

AI and DL in stock prediction have transitioned from various predictive approaches to hybrid models (Lin and Lobo Marques, 2024). DL algorithms, adept at handling big data and non-linear relationships, have become a promising solution for stock market prediction (Dwiandiyanta et al., 2023). The application of AI and ML in finance, focusing on stock price prediction, portfolio management, and big data analytics, has seen an upward trend (Ahmed et al., 2022). While previous research has acknowledged the transformative potential of AI technologies in finance, there remains a lack of comprehensive bibliometric analyses that specifically focus on the evolution and application of these technologies in stock market prediction. To guide this investigation, the following research questions (RQs) are formulated:

1. RQ 1: How have the applications of AI and DL in stock market prediction changed over the past three decades, and what are the key trends identified in the bibliometric analysis?
2. RQ 2: What AI and DL techniques have significantly impacted stock prediction accuracy?
3. RQ 3: How do geographical and institutional factors influence the research output and collaboration patterns in AI and DL applications for stock prediction?

Employing a bibliometric approach, this study examines 525 articles from 1991 to 2024 in Scopus-indexed journals, conducting assessments such as co-authorship, co-occurrence, citation, bibliographic coupling, and co-citation analysis using VOSviewer. It outlines the research procedures of bibliometric analysis, providing insights into crucial research trends, influential entities, and emerging themes in the field.

2. Data and Methodology

2.1 Data Collection

2.1.1 Data Collection Sources

As demonstrated by earlier research, data was collected from the Scopus database (Ahmed et al., 2022; Lin and Lobo Marques, 2024). Scopus, a globally recognized bibliometric data source, is known for its extensive collection of high-quality articles. It offers comprehensive coverage and enriched metadata, ensuring data quality through rigorous processes (Baas et al., 2020). As a trusted resource, it's used for large-scale research analyses and offers free access to the academic community. Journals indexed in Scopus continue to be cited, influencing scholars' metrics and attesting to their reliability (Cortegiani et al., 2020). Importantly, for the objectives of this research, Scopus is indeed a more comprehensive and diverse resource for academic research compared to the Web of Science, as it covers a higher percentage of scientific literature and indexed documents across various research fields (Aksnes and Sivertsen, 2019; Tsay et al., 2019).

2.1.2 Keyword Selection Strategy and Refinement Procedure

A two-phase approach was adopted for keyword selection in the quest for precision in the bibliometric analysis of stock prediction. The first phase entailed a thorough review of online glossaries and dictionaries focused on AI and DL to identify the most germane keywords (Rafee et al., 2023; Prahani et al., 2023; Thayer, 2022). The second phase involved a two-step process utilizing Scopus to search for AI and DL terminologies. The initial step was exploratory, leveraging the Scopus keyword feature to augment our final query with additional keywords constrained only by the character limit of the Scopus search bar. The final step involved a manual review of each keyword, ensuring the relevance of the selected terms.

We executed a search query based on the title and keyword criteria to pursue our investigation's most pertinent articles and reviews. This search was confined to English language journals within the field of finance, resulting in a yield of 525 documents (515 articles and ten reviews) from 160 sources and 70 countries. Despite the substantial volume of preliminary data, we undertook a series of online refinements to hone our dataset further. Firstly, while there was no explicit restriction on the temporal range of the documents, the dataset naturally spanned from 1991 to 2024. Secondly, we narrowed the subject area of the journals to Economics, Econometrics, and Finance. Thirdly, we restricted the document type to articles and reviews. Fourthly, we ensured that the publication stage was at its final phase. Fifthly, we imposed a language restriction, accepting only English documents. Lastly, we confined the source type to journals. Thus, the search query is delineated as below:

TITLE-ABS-KEY (("artificial intelligence" OR "machine learning" OR "deep learning" OR "reinforcement learning" OR "deep reinforcement learning" OR "automated machine learning" OR "transformer" OR "support vector machine" OR "support vector regression" OR "neural network" OR "artificial neural network" OR "long short-term memory" OR "sentiment analysis" OR "transformer" OR "AI" OR "SVM" OR "SVR" OR "LSTM" OR "ANN" OR "DRL") AND ("stock" OR "stock market" OR "stock price" OR "stock index") AND ("prediction" OR "forecasting" OR "forecast")) AND (LIMIT-TO (SUBJAREA , "ECON")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j"))

To ensure comprehensive topic coverage, a dataset of 525 academic articles and reviews was prepared using specific inclusion and exclusion criteria. After filtering, these works underwent bibliometric analysis, facilitated by specialized software, providing a systematic exploration of the research field. Further details will follow in the next section. Simultaneously, it's important to note that the concept of AI was introduced in 1956 (Clermont, 2023) and has been applied to financial investment since the 1990s (Ferreira et al., 2021), particularly in stock price forecasting to address market volatility. The focus has been on time series algorithms and the use of AI in combination with multiple approaches for stock market prediction (Sarma et al., 2023). A systematic review of the literature from 1995 to 2019 shows a continuous interest in this area (Ferreira et al., 2021). Recent

advancements have emphasized using hybrid models that integrate multiple models, leveraging DL algorithms to handle non-linear complexities and temporal dynamics in predicting stock price movement (Lin and Lobo Marques, 2024). This reflects the ongoing evolution and potential of AI in stock prediction.

2.2 Bibliometric Analysis and VOSviewer Software

Bibliometrics, a methodological paradigm originally conceived by Alfred Lotka and Samuel Bradford (Thompson and Walker, 2015; Danesh and Mardani-Nejad, 2020), leverages mathematical and statistical techniques to scrutinize scholarly literature. This paradigm was subsequently honed by Eugene Garfield, who pioneered the concept of citation analysis and systematic processing (Thompson and Walker, 2015). The fundamental purpose of bibliometrics is to evaluate the influence of scientific contributions, employing parameters such as the Impact Factor (IF) and the h-index (La Torre et al., 2017). A notable merit of bibliometrics lies in its ability to unearth innovative perspectives on academic and broader scientific trends. It has been efficaciously applied in a wide array of areas, including the evaluation of the historical progression of academic disciplines, the patterns of authorship and publication, and usage trends (Thompson and Walker, 2015; La Torre et al., 2017; Aleixandre-Benavent et al., 2017). This method encapsulates contributions to a specific research topic in conjunction with content analysis (Mayring, 2014; Schreier, 2012).

In this research, we adhered to the PRISMA guidelines for conducting bibliometric analysis (Donthu et al., 2021; Page, McKenzie et al., 2021). The initial step involved defining the objectives and scope of the bibliometric study. Subsequently, we selected the appropriate techniques for bibliometric analysis as the fourth step below. The third step encompassed the collection of data pertinent to the bibliometric analysis. The fourth step entailed the execution of the bibliometric analysis, followed by the reporting of the results. Within this fourth step, we undertook a performance analysis, including the most significant contributors in the literature. A network analysis of scientific mapping followed this (Perianes-Rodriguez et al., 2016). This analysis incorporated co-authorship, co-occurrence, citation, bibliographic coupling, and co-citation analysis using VOSviewer (Li, 2018; van Eck and Waltman, 2023; Van Eck and Waltman, 2014). This comprehensive analysis extensively unveiled participants' performance in the scientific field, including documents, authors, and countries. The final step involved planning the bibliometric summary and crafting a discussion on the findings and their implications (Lim and Kumar, 2024; Montazeri et al., 2023; Szomszor et al., 2021).

3. Results and Discussion

3.1 Performance Analysis

This section aims to provide comprehensive answers to RQ 1 and RQ 3. As depicted in Figure 1, the body of literature from 1991 to 2024 demonstrates an average growth rate of 29%. It is noteworthy that the productivity in research remained relatively constant from 1991 through 2016. Nevertheless, a significant surge has been observed since 2017, indicating a growing interest in these technologies. This trend suggests that integrating AI and DL into stock prediction methodologies has gained momentum, reflecting technological advancements and increased recognition of their predictive capabilities. Cioffi et al. (2020) have noted a substantial expansion in the literature on AI and DL since 2013. Interestingly, Figure 1 reveals that the literature on the application of AI and DL in stock prediction experienced a marked increase in 2018, suggesting a lag period of approximately five years compared to the general literature on AI and DL. This could be interpreted as an indication that the field of stock prediction required some time to incorporate these emerging technologies. The growth in the literature surrounding AI and DL in stock prediction presents significant opportunities for researchers and practitioners to explore new methodologies and applications and enhance predictive accuracy and investment strategies through these advancements.

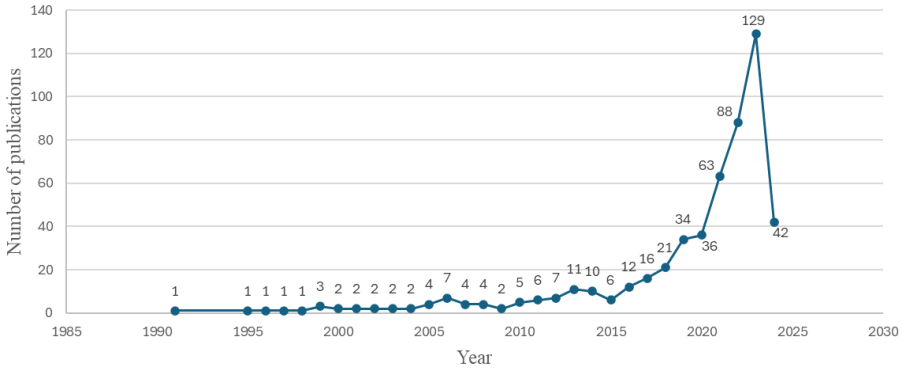

Figure 1: The literature growth of AI and DL in stock prediction

As shown in Figure 2, examining the AI and DL literature reveals the countries most engaged in stock prediction research. The countries demonstrating the highest productivity in this domain are China (14%), the US (12%), India (8%), and the UK (5%). The methodology employed for this analysis involved tallying the affiliations of each author to their respective countries. Furthermore, we also considered the corresponding authors' affiliations to provide a more comprehensive representation of each country's productivity.

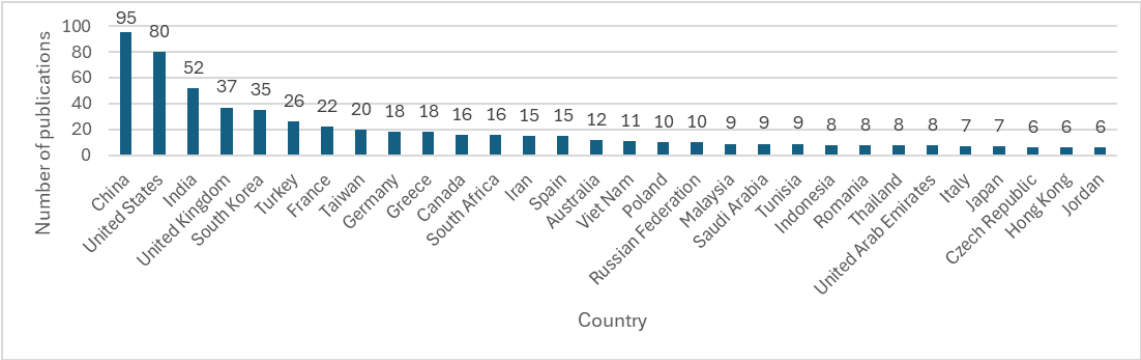

Figure 2: The top 30 most productive countries

3.2 Network Analysis and Discussion of Scientific Mapping

We focus on addressing RQ 2 and RQ 3 in this section, presenting the network analyses of scientific mapping, including co-authorship, co-occurrence, citation, bibliographical coupling, and co-citation analyses enabled by the VOSviewer software. In academic research, the interpretation of map features is crucial. The size of an item, such as an author or journal, indicates the number of associated publications, and the distance between two items signifies their normalized relatedness. Colors differentiate clusters of related items, and a link represents the relation between two items. Clusters are non-overlapping groups of items in VOSviewer, and an item can belong to only one cluster. The weight and score attributes of an entity, which are numerical, indicate the importance and other characteristics of the entity, respectively. This comprehensive approach ensures a scientific and precise depiction of the research landscape (Li, 2018; van Eck and Waltman, 2023).

3.2.1 Co-authorship Analysis

As revealed in Figure 3, the co-authorship patterns within the examined literature are elucidated. Data was procured from a pool of 1000 authors, and it was discerned that a mere 13 authors were interconnected. This paucity of co-authorship underscores the need for more research collectives to contribute to the stock prediction field. The implications of this finding suggest that fostering collaborative research networks could enhance the quality and impact of future studies, ultimately benefiting the field.

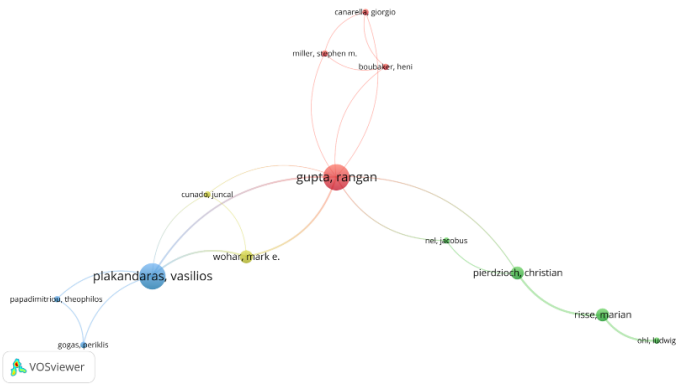

Figure 3: Co-authorship analysis for authors

3.2.2 Co-occurrence Analysis

In the initial phase of the analysis, the focus is placed on keyword analysis utilizing the full-count method (Perianes-Rodriguez et al., 2016). This approach entails counting each instance of a keyword term within a document. From a pool of 1787 keywords, only those networks were chosen for further analysis, where the keywords appeared at least six times. This selection criterion resulted in a final map displaying 73 keywords. Figure 4 illustrates the co-occurrence of keywords using the full-count method, presenting 73 items organized into seven clusters.

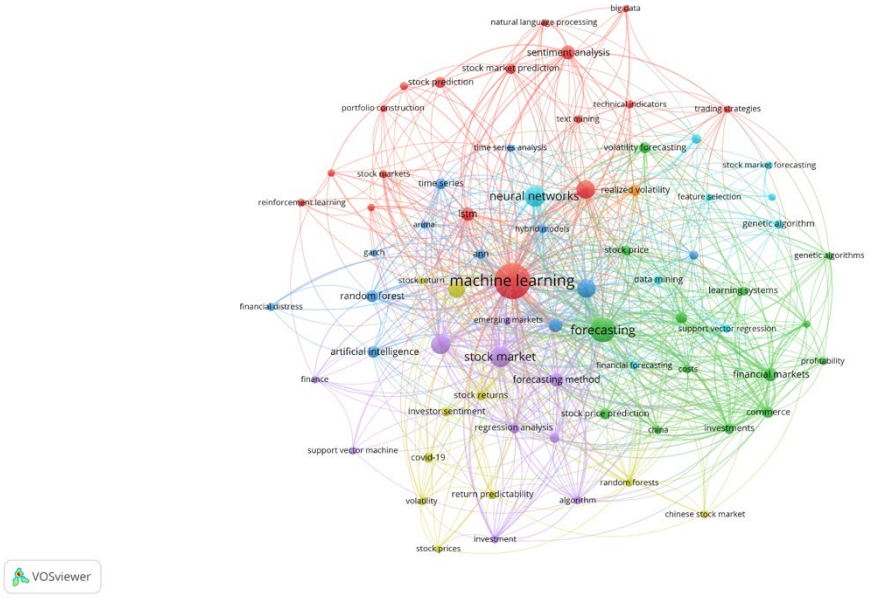

Figure 4: Network visualization of co-occurrence analysis for keywords

The three keywords with the highest total link strength are "machine learning," "forecasting," and "stock market." These keywords are distributed across three distinct clusters. The cluster centered around "machine learning" includes terms such as "deep learning," "LSTM," "sentiment analysis," and "stock market prediction." The cluster revolving around "forecasting" encompasses "financial markets," "commerce," "investments," and "long short-term memory." Lastly, the cluster with "stock market" at its core includes "prediction," "forecasting method," "financial market," and "regression analysis." The implications of these keyword trends indicate a strong focus on ML and forecasting techniques, suggesting that future research should continue to explore these areas while also considering emerging topics such as sentiment analysis and hybrid models.

The spatial relationship between the expression bubbles is relatively close, with all clusters demonstrating significant overlap. This overlap indicates a substantial interconnectedness among these clusters and the keywords employed in the analyzed scientific and research articles.

Figure 5 provides insights corresponding to the average year of usage for each term as a keyword. This figure explains the terms' validity and evolution over time, employing a color scale classification that transitions from blue to green to yellow. Terms represented in blue have an older average publication value, while those in yellow are the most recent ones.

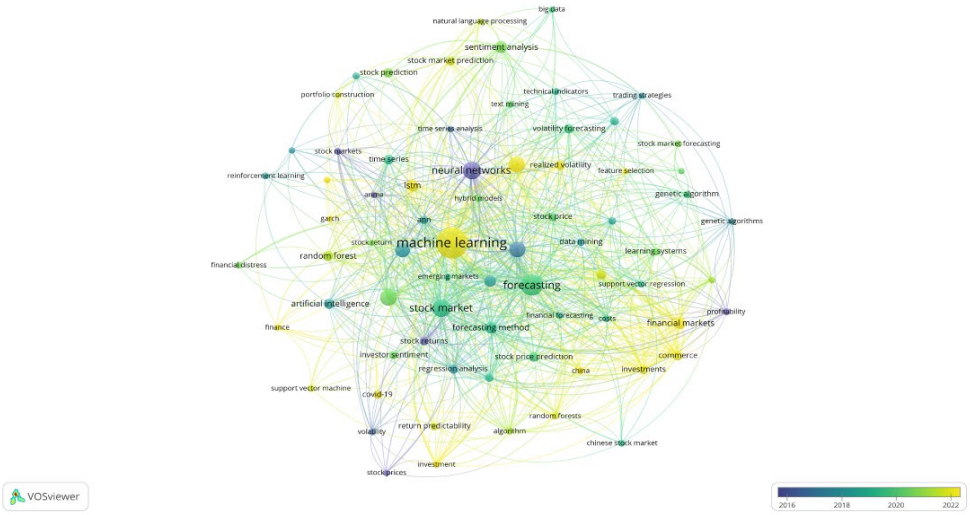

Figure 5: Overlay visualization of co-occurrence analysis for keywords

The time window analyzed spans from 2016 to 2022. During this period, some of the terms with the highest occurrence include "machine learning," "forecasting," "stock market," and "neural networks." Terms such as "neural networks," "stock markets," "stock prices," and "time series analysis" have been utilized in the academic spectrum for over eight years (from 2016 to 2024), indicating the maturity of these topics.

From the map, it is possible to extract terms such as "machine learning," "long short-term memory," "support vector machine," and "stock market prediction," which exhibit an average publication value of 2021. The result is similar to recent systematic literature reviews (Lin and Lobo Marques, 2024). Additionally, terms like "deep learning," "financial markets," "investment," and "China" present an average publication value of 2022, highlighting them as the most recent or emerging topics that are garnering the interest of researchers.

3.2.3 Citation Analysis

As illustrated in Figure 6, the citation trajectory for a specific scholarly work from 2011 to 2024 presents a captivating temporal pattern. The initial stage, encompassing 2011 to 2013, was distinguished by a marked citation escalation. This surge intimates that the work was progressively accruing recognition and being increasingly invoked in subsequent scholarly publications. Nevertheless, from 2014 to 2023, the span witnessed fluctuations in citation counts, with an apex in 2019 succeeded by a trough in 2015.

Intriguingly, 2019 was characterized by an unparalleled surge in citations, insinuating that the work had been acknowledged as seminal or had experienced a resurgence of interest due to advancements in cognate fields. After this apex, there was a precipitous decline in 2020, yet the citation counts exhibited stability, hovering around 717–725 from 2021 through 2022. Despite the overall upward trend in the number of citations from 2011 to 2024, it is noteworthy that the citation counts in 2023 experienced a decline compared to 2022.

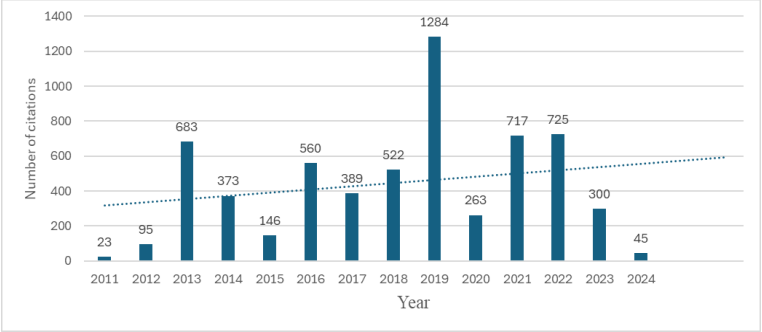

Figure 6: Change in citation over time

Table 1 elucidates the ten most frequently cited articles from 1991 to 2024, spotlighting the most influential and significant contributions to the field. The study entitled "Time series properties of an artificial stock market" by LeBaron et al. (1999) has garnered a noteworthy 457 citations (6%) in 8159 citations. Similarly, the research by Moghaddam et al. (2016), which focused on "Stock market index prediction using artificial neural network," has been cited 269 times (3%). Furthermore, it was observed that the three most cited articles were published in esteemed journals of high repute, namely the Journal of Economic Dynamics and Control, the Journal of Economics, Finance and Administrative Science, and the International Review of Financial Analysis. This observation underscores these journals' prestige and academic influence in economic and financial research.

Table 1: Top ten most cited articles

Authors	Title	Year	Source Title	Cited by
LeBaron B.; Arthur W.B.; Palmer R.	Time series properties of an artificial stock market	1999	Journal of Economic Dynamics and Control	457
Moghaddam A.H.; Moghaddam M.H.; Esfandyari M.	Stock market index prediction using artificial neural network; [Predicción del índice del mercado bursátil utilizando una red neuronal artificial]	2016	Journal of Economics, Finance and Administrative Science	269
Hernandez Tinoco M.; Wilson N.	Financial distress and bankruptcy prediction among listed companies using accounting, market, and macroeconomic variables	2013	International Review of Financial Analysis	248
Shah D.; Isah H.; Zulkernine F.	Stock market analysis: A review and taxonomy of prediction techniques	2019	International Journal of Financial Studies	202
Renault T.	Intraday online investor sentiment and return patterns in the U.S. stock market	2017	Journal of Banking and Finance	199
Moody J.; Wu L.; Liao Y.; Saffell M.	Performance functions and reinforcement learning for trading systems and portfolios	1998	Journal of Forecasting	181
Maasoumi E.; Racine J.	Entropy and predictability of stock market returns	2002	Journal of Econometrics	175
Henrique B.M.; Sobreiro V.A.; Kimura H.	Stock price prediction using support vector regression on daily and up-to-the-minute prices	2018	Journal of Finance and Data Science	174
Kim S.-H.; Kim D.	Investor sentiment from internet message postings and the predictability of stock returns	2014	Journal of Economic Behavior and Organization	157
Selvamuthu D.; Kumar V.; Mishra A.	Indian stock market prediction using artificial neural networks on tick data	2019	Financial Innovation	151

3.2.4 Bibliographic Coupling Analysis

Bibliographical Coupling is a methodological approach to examine the interrelationships among documents that share standard references. This technique facilitates the analysis of any shared links between studies, potentially providing valuable insights for future research endeavors. A bibliographic coupling analysis was conducted on a corpus of 100 documents. Utilizing the VOS Viewer software, clusters were formed, as depicted in Figure 7, representing the bibliographical coupling. Out of the 100 documents, 98 were interconnected. This analysis resulted in the emergence of seven distinct clusters. The three documents with the highest number of citations were "Time Series Properties of an Artificial Stock Market" by LeBaron (1999), "Stock Market Index Prediction Using Artificial Neural Network" by Moghaddam (2016), and "Financial distress and bankruptcy prediction among listed companies using accounting, market and macroeconomic variables" by Hernandez Tinoco (2013). These highly cited documents are distributed across three clusters containing 22, 19, and 14 items, respectively. This distribution underscores the diversity and breadth of the research landscape in this field.

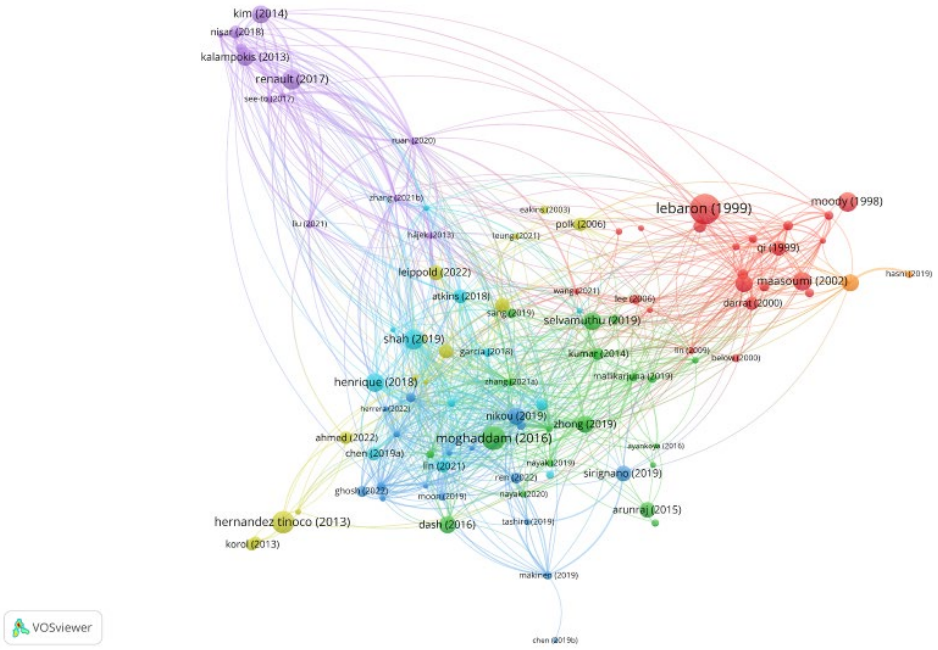

Figure 7: Bibliographic coupling analysis for documents

3.2.5 Co-citation Analysis

This section analyzes the co-citation network of journals about AI and DL resources employed in stock market prediction. The frequency with which two sources are co-cited indicates the similarity between the scope and research topics of the journals. Figure 8 depicts sources that have been cited a minimum of 35 times. Out of 7,980 journals cited in the analyzed corpus, 77 journals satisfied the citation threshold criterion. Each node in the network represents a source, with the node's size corresponding to the number of citations received by that source. The presence of an edge between two nodes indicates a citation relationship. Furthermore, the nodes are clustered based on similarity, such that sources within the same cluster (color) and in closer proximity are more analogous to one another.

The journal "Expert Systems with Applications" garnered the highest number of citations, with 812 citations and 72 links. It is noteworthy that although the scope of this journal encompasses the publication of high-quality articles across various domains and spheres, extending beyond financial markets, it is evident that authors primarily draw upon the technical details of AI systems from this journal, subsequently applying them to the subject area under investigation (Janková, 2021).

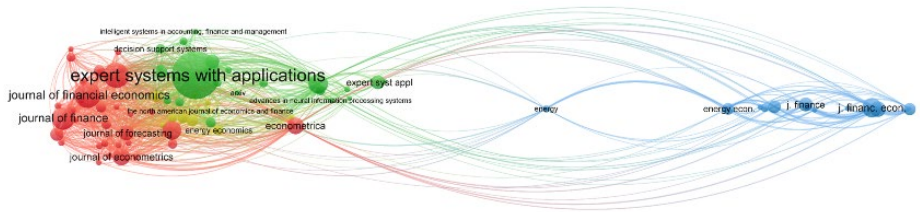

Figure 8: Co-citation analysis for sources

4. Conclusion

In this scientific exploration, we have executed a bibliometric analysis on a corpus of literature from the Scopus database, concentrating on deploying AI in stock market forecasting. The strategic selection and refinement of keywords were instrumental in our analysis employing VOSviewer, culminating in the collation of 525 relevant documents, which spanned 160 sources and encompassed contributions from 70 nations.

Our research delineates the exponential proliferation of AI and DL studies within the financial sphere, emphasizing stock market prognostication. The literature exhibits a notable escalation in research output from 2017, with China, the United States, India, and the United Kingdom emerging as the foremost contributors to

this scholarly pursuit. The network analyses conducted have unveiled a pronounced synergy amongst the various research clusters, with "machine learning," "forecasting," and "stock market" identified as the central keywords underpinning this field.

The citation analysis sheds light on the seminal contributions significantly influencing the domain. In contrast, the bibliographic coupling and co-citation analyses have rendered a holistic perspective of the research milieu. Despite its robust dataset and rigorous methodology, our study acknowledges limitations due to using a single bibliometric database. Future research should expand data sources, incorporate qualitative methodologies, adopt interdisciplinary approaches, and assess the real-world impact of AI and DL applications in stock prediction. Our study outlines the past and present of AI in stock market prediction, serving as a guide for future work and a valuable resource for scholars in AI and financial analytics.

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