Considerations Related To The Application Of Deep Learning And Neural Networks In Finance And Banking. A Bibliometric Approach

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Abstract

The aim of this paper is to examine the impact and applications of Deep Learning (DL) and Neural Networks (NN) in financial markets and especially on banking markets, using a bibliometric analysis based on 970 articles published between 2015-2024. The study highlights key trends, collaboration networks and influential contributions using data extracted from the Web of Science database and analyzed with VOSviewer software. Findings illustrate the widespread integration of those two AI applications in financial approaches such as credit evaluation, stock market forecasting and risk modeling. The study highlights the prominence of areas such as computer science and business economics while pointing out the need for hybrid models and explainable AI, essential for meeting regulatory compliance. Additionally, it emphasizes the interdisciplinary nature of this field, connecting AI with big data and financial systems.

Key words: deep learning, neural networks, banking, bibliometric analysis, VOSviewer
J.E.L. classification: G10, G20, G17, G45

1. Introduction

Due to the rapid advancement of artificial intelligence technologies, financial markets, including the banking sector were profoundly reshaped with the use of diverse techniques such as neural networks and deep learning taking an important role in solving complex challenges in the financial industry. This paper carries out a bibliometric analysis to explore the impact and trend of these innovations. The analysis aims to consolidate current insights, identify dominant patterns and highlight promising directions for future research on AI application in finance.

This study reviewed the neural networks (NN) and deep learning (DL) literature in the finance field. Using a bibliometric approach, we collected 970 articles published in a 10-year period between 2015-2024 from articles indexed in Web of Science database.

This research focuses on the essential role of artificial intelligence, particularly neural networks and deep learning in shaping the future of financial markets broadly, with a particular emphasis on the banking sector. The main framework of this paper focuses on exploring how neural networks and deep learning have been used in the financial sector, the extent of their influence, and the direction that future research in this area is taking.

The article begins with a literature review which provides an overview of the existing research on neural networks and deep learning in financial markets. Methodology presents the bibliometric analysis methods, including data collection and analysis approaches using VOSviewer software. In the end of the paper, the Findings section presents the results of the analysis, highlighting key trends, influential publications and collaboration networks between authors. Finally, the study concludes with reflections on the impact of these findings for future research in the financial industry, especially in banking industry.

2. Literature review

The studies on neural networks and deep learning in financial markets is vast and comprehensive. Jiayu et al. (2020) state in their research the fact that neural networks, particularly deep learning models such as Long Short-Term Memory (LSTM) networks, have been widely applied for stock price prediction and financial time series forecasting due to their ability to capture complex nonlinear relationships in data.

Other studies have illustrated that the use of neural networks could substantially enhance financial distress prediction achieving superior outcomes compared to traditional methods like logistic regression (Zizi et al., 2021). This ability is essential for banking entities aiming to reduce risks related to loan default and insolvency. (Zizi et al., 2021; Bracke et al., 2019).

There are also papers that focus on analyzing the impact of convolutional neural networks on stock market prediction, using various datasets beyond just historical prices, including information from news articles and social media sentiment analysis. (Hoseinzade and Haratizadeh, 2019; Matsubara et al., 2018).

Huang et al. (2020) stated that in finance and banking field, various deep learning models offer remarkable performance depending on the context:

- Neural Networks (NN) are ideal for processing cross-sectional data used in exchange rate forecasting, price estimation and macroeconomic analysis;
- Recurrent Neural Networks (RNN) and short-term memory (LSTM) are more efficient for serial data specific to stock market predictions;
- Reinforcement Learning (RL) proves optimal for stock trading scenarios involving autonomous decision-making and the self-learning process;
- Convolutional Neural Networks (CNN) are excellent at handling data with multicollinearity, being suitable for complex and multivariate environments in the financial and banking sphere.

Predictive modeling implying neural networks has emerged as a fundamental aspect of adopting artificial intelligence in the financial sector. For financial predictions, there are architectures such as deep learning and recurrent neural networks (RNNs) which are widely employed for financial predictions due to their potential to identify complex, non-linear relationships in large datasets. (Strielkowski et al., 2023). These models have been applied across diverse economic forecasting purposes, such as predicting risk assessment, stock prices and credit scoring.

Important studies have indicated that neural networks exceed classical methods in terms of forecasting precision and resilience (Nazareth and Reddy, 2023). For instance, Razak et al. (2023) shown that neural networks significantly improve the precision of credit rating evaluations, thereby contributing to enhanced risk management strategies within financial institutions.

3. Research methodology

For this study we adopt a bibliometric methodology that involves the use of quantitative approach to examine scientific literature by focusing on its external features. It employs statistical and mathematical methods to interpret the research landscape, identify trends and understand the attributes of specific academic fields.

In contrast to traditional systematic literature reviews, a bibliometric analysis has the capability to provide insights across disciplines marked by substantial volumes of citation metrics and bibliographic data. This method excels in handling fields where large quantities of such information are present. In essence, the bibliometric analysis provides a structured and data-driven way to explore the evolution, current state and future trajectory of deep learning and neural networks in financial markets. It highlights how these advanced artificial intelligence applications have reshaped the field and identifies opportunities for further exploration.

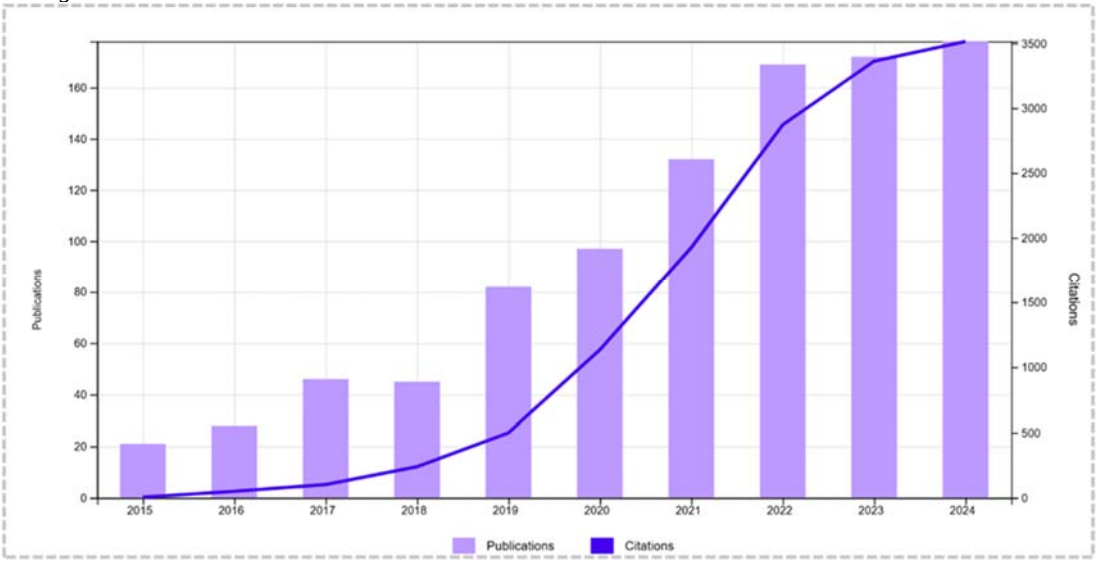
Web of Science database was the source for data collection in this material. Birkle et al. states that Web of Science (WoS) is the world's oldest, most widely used and authoritative database of research publications and citations. We selected this resource because it offers an extensive collection of academic publications, enabling us to access a wide and pertinent assortment of studies on the application of neural networks and deep learning within financial markets. Using the

Web of Science database, we compiled a substantial dataset totaling 970 articles published between 2015 and 2024, which will form the framework of our bibliometric analysis. Focusing on the last decade, the research aims to emphasize recent trends and methodologies that have appeared in financial markets

Our methodological approach implied collecting relevant data from the Web of Science database, including article titles, author identities, abstracts, key terms and citation data. This gathered information was then imported into the VOSviewer software to conduct various analyses, which are discussed in the following section.

To guarantee the inclusion of relevant publications, the data selection process implied the use of specific filters. In the analysis, only publications in English were took into consideration given that English is the main language used in scientific communication and in this way this criterion ensures access to a large range of works while maintaining consistency in the interpretation of basic concepts and terminology. In addition, in order filter the search and to conduct our study at the crossroad of financial markets and artificial intelligence, we use specific keywords such as financial markets* deep learning* or financial markets* neural networks*.

Figure no. 1 Publications and citations



Source: Graph exported from Web of Science

During the analyzed period, a total of 970 publications were searched from Web of Science. The total sum of times cited is 13,753 with the average citation per publication of 14.18 times.

Figure 1 illustrates a clear upward trend in both volume of publications and the number of citations from 2015 to 2024. This evolution reveals the growing relevance and interest in this research field over time and highlights the way AI techniques like deep learning and neural networks has gained relevance in financial markets, underscoring its value in both academic research and practical fields.

The sustained growth in publications involves continuous engagement and productivity in the field, while the significant boost in citations signals the broader acceptance of its importance and influence. This frame emphasizes the evolving and influential nature of the field, driving advancements in knowledge and innovation.

The continuous increase in the number of publications is closely linked to the rapid amplification of citations. As more and more papers appear, they expand the existing knowledge base, which leads to an increase in references and citations in related studies.

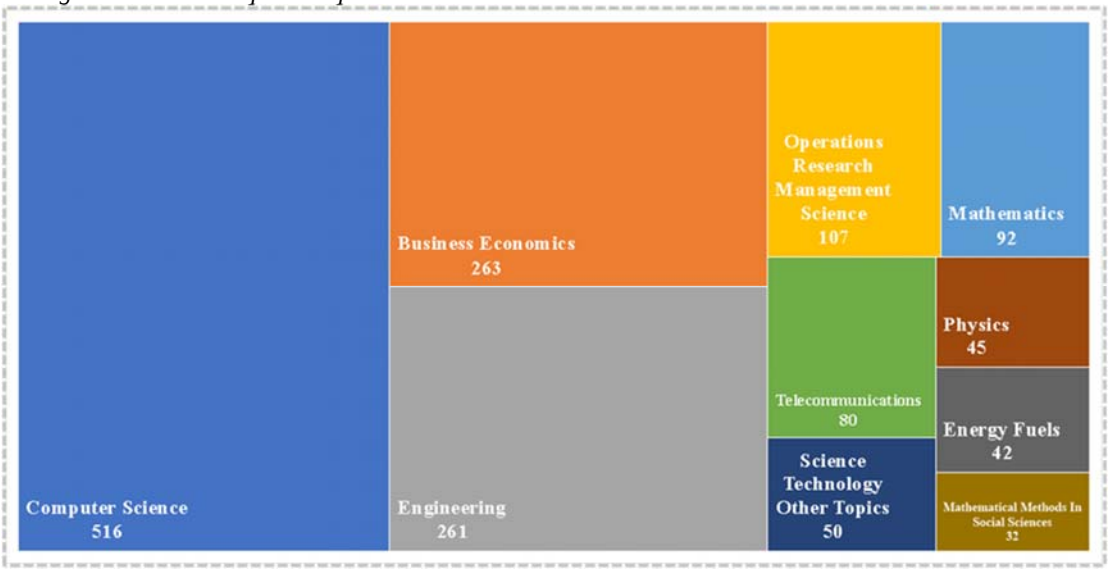
In addition, the significant jump in citations, observed especially after 2018, may suggest that previous works have reached a level of maturity and become important reference points, with the increasing interest and dynamism in this field.

A strong relationship between the continuous increase in the number of publications and the rapid expansion of citations highlights how a larger volume of works supports the development of a broader base for future studies.

4. Findings

Starting from the analysis of publications and citations, which highlighted a constant evolution of scientific production and a rapid amplification of academic references, the investigation of the tree map with the spread of publications in various areas brings a detailed perspective on the structure of the research field.

Figure no. 2 Tree map with top 10 research areas



Source: Author contribution based on data extracted from Web of Science

The provided tree map visualizes the top 10 research areas from a dataset of 970 articles that focus on the application of deep learning and neural networks in financial markets. The chart highlights the distribution of publications across different fields, emphasizing the multidisciplinary nature of this research area.

The largest segment in the tree map is Computer Science with 516 publications, reflecting the majority of the given dataset. This dominance shows that research in deep learning and neural networks is strongly embedded in the field of computer science. This reflects the emphasis on technical and computational expertise necessary for designing AI algorithms and systems tailored to financial use cases. Significant developments in this field encompass neural network architectures, deep learning frameworks, algorithm optimization and the handling of large-scale datasets.

Business Economics accounts for 263 publications, this being the second-largest research area. This significant proportion underscores the practical use of neural networks and deep learning in areas such as investment planning, analyzing market dynamics and risk mitigation. It illustrates the integration of artificial intelligence into financial models and economic frameworks to tackle real-world issues effectively.

Engineering follows closely with 261 publications, demonstrating its role in supporting the technological infrastructure for artificial intelligence in financial industry. This field is likely centered on enhancing computational efficiency, optimizing hardware and designing systems, all of which are essential for applying deep learning models in areas such as big data analytics, high-frequency trading and cloud-driven financial platforms.

Other segments, smaller than previous, such as Operations Research and Management Science (107 publications), Mathematics (92 publications), Telecommunications (80 publications), Science Technology Other Topics (50 publications), Physics (45 publications), Energy Fuels (42 publications) and Mathematical Methods in Social Sciences (32 publications) reflect the variety of interdisciplinary applications.

This distribution highlights the significant influence and promise of AI-powered methods in shaping the landscape of financial systems.

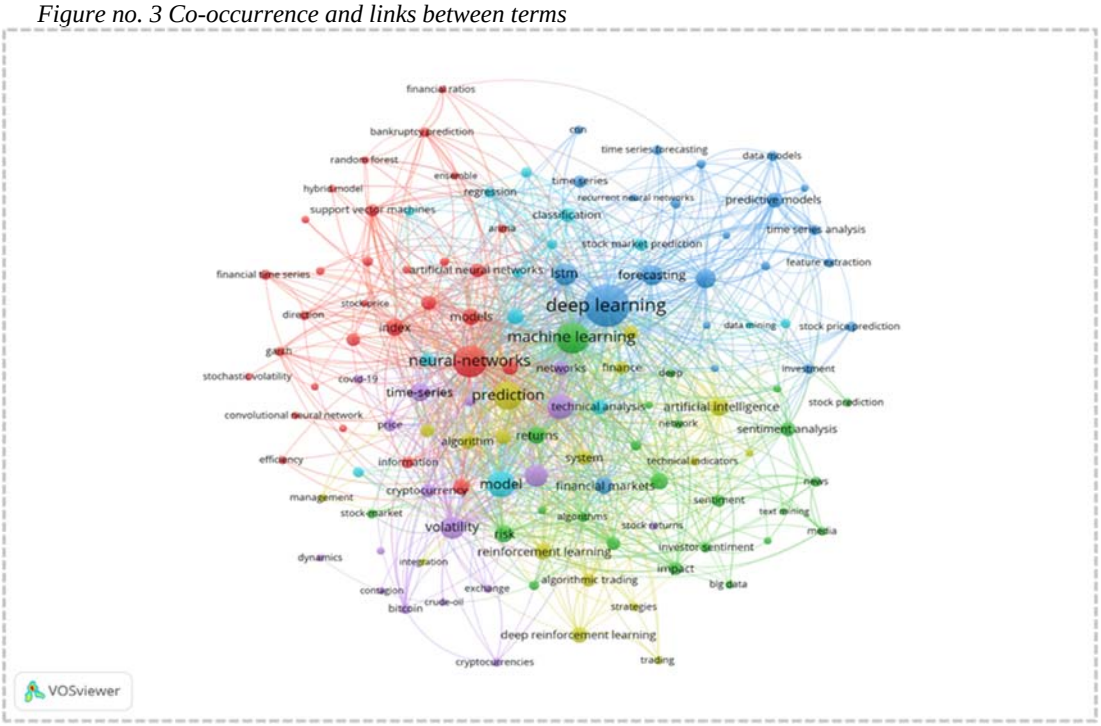
Moving forward, the paper focuses on the detailed exploration of bibliometric networks, including the co-occurrence network map, co-citation network and co-authorship network for countries. Building on the findings from the prior analysis, this section aims to deepen the understanding of how key terms, international collaborations and influential works shape or transform the academic framework in the implication of deep learning and neural networks in financial markets.

The chart (Figure 3) illustrates a co-occurrence network map of keywords drawn from the analyzed publications, created with the help of VOSviewer. This map reflects the connections between frequently appearing keywords in the dataset, where the nodes symbolize the keywords, and the links represent their simultaneous presence within the same publication.

The co-occurrence map generated with VOSviewer provides valuable insights into the interconnections and emerging research patterns related to the use of deep learning and neural networks in financial markets.

From the co-occurrence analysis, 3486 keywords were extracted, of which 124 keywords met the threshold of a minimum of 10 occurrences. These keywords were grouped into 6 clusters, which indicate major thematic areas of research, their interconnections and prevailing trends.

Figure no. 3 Co-occurrence and links between terms



Source: Author contribution using VOSviewer, based on data extracted from Web of Science

The analysis identified 124 frequently occurring keywords, with the most relevant being *deep learning, neural networks and machine learning*. Among these, deep learning demonstrated the highest total link strength (842) and occurrence frequency (257), positioning it as the central theme of research. This dominance reflects the widespread adoption of deep learning techniques for solving complex problems in financial markets, such as predicting stock prices, evaluating credit risks and analyzing financial time-series data.

Similarly, *neural networks*, appearing in two variations, *neural networks and neural-networks*, further underscore their essential position in financial research. The combined influence of these terms illustrates the critical role of AI-driven techniques in modern financial analysis and modeling.

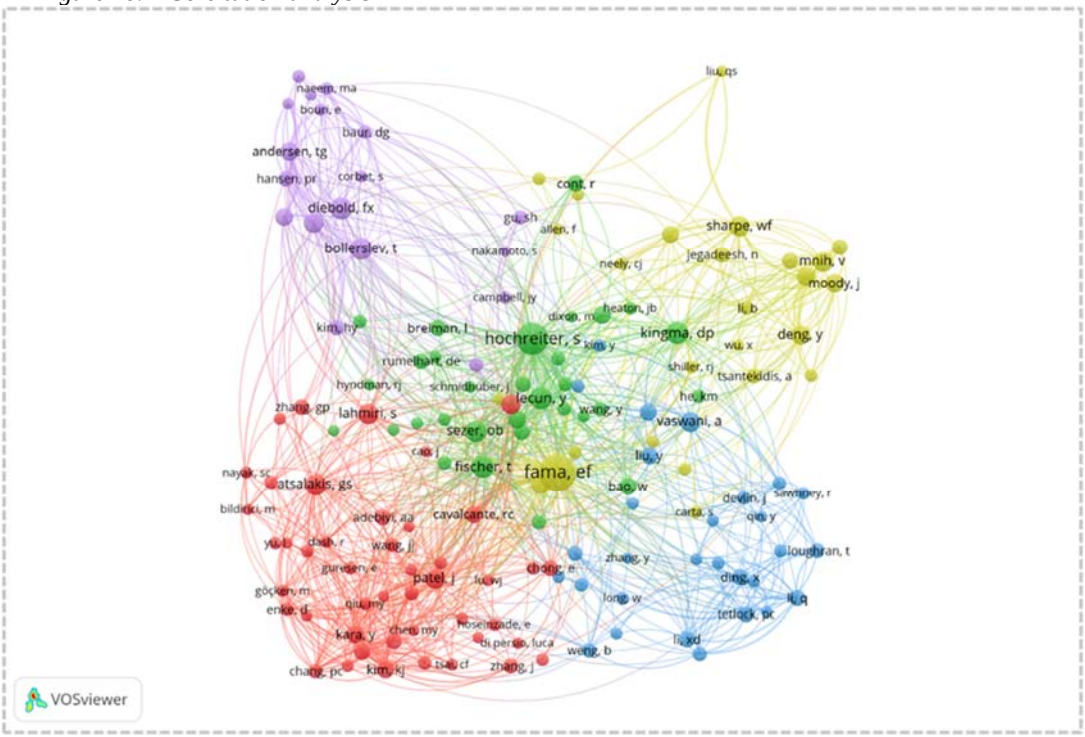
The clustering of keywords into six groups highlights distinct but interconnected themes. At the core of these connections is deep learning (Cluster 3) which shows strong associations with keywords like machine learning (Cluster 2) and prediction (Cluster 4). This relationship demonstrates that machine learning methods are frequently used to build deep learning models, particularly for predictive purposes in financial research.

Prediction emerged as another critical theme (Cluster 4), with strong connections to other keywords. This finding underscores the importance of forecasting in financial studies, including predicting market trends, volatility analysis and risks assessment. Additionally, the concept of a model (Cluster 6), which appears frequently (103 occurrences) and have a notable link strength of 455 facilitates the connection between theoretical deep learning architectures and practical financial applications such as risk modeling and algorithmic trading.

The analysis confirms that the core focus of research is on the application of AI, neural networks and deep learning for prediction-related tasks. Keywords such as algorithmic trading, financial time-series analysis and technical indicators suggest the broad use of AI in processing financial data, improving decision-making processes and forecasting market dynamics. These applications are essential for tasks such as stock price prediction, credit risk assessment and sentiment analysis.

Moreover, the relationships between keywords such as volatility, returns and financial markets suggest a wider investigation into how AI can be involved to address financial uncertainty and enhance investment strategies.

Figure no. 4 Co-citation analysis

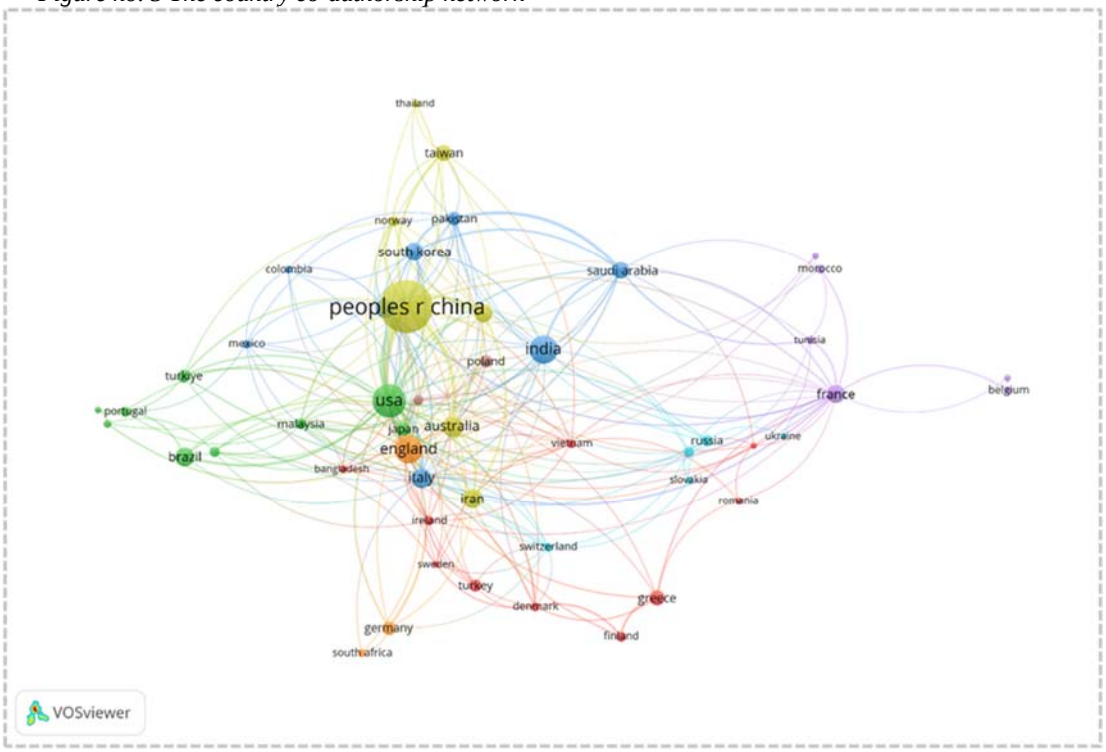


Source: Author contribution using VOSviewer, based on data extracted from Web of Science

The co-citation analysis reflects the intellectual framework of the research domain by examining the connections among 149 frequently cited authors, grouped into five distinct clusters. Each cluster represents a specific thematic area with key contributions from influential authors such as Hochreiter, S., Fama, E.F. and LeCun, Y., whose work in the green cluster links advancements in deep learning to financial theory. Similarly, the yellow cluster, led by Kingma, D.P. and Vaswani, A. focuses on cutting-edge AI methods such as transformers and optimization algorithms, while the red cluster, featuring Zhang, G.P. and Atsalakis, G.S. centers on practical applications in risk management and financial forecasting.

With a total link strength of 33,765 and 7,714 co-citation links, the map demonstrates a well-integrated field with robust connections between artificial intelligence and financial industry. Clusters such as the purple (econometrics and volatility modeling) and blue (text mining and behavioral finance) indicate emerging areas of research. These findings underscore the interdisciplinary nature of the field, where foundational AI techniques are increasingly being applied to solve complex financial challenges. Collaborative efforts between clusters, such as econometrics and applied AI has the potential to foster innovation and to promote a strengthen integration within the research community.

Figure no. 5 The country co-authorship network



Source: Author contribution using VOSviewer, based on data extracted from Web of Science

The country co-authorship network was created using specific selection criteria to identify significant contributors to the research field. In the analysis were included only countries with at least 5 publications and no citation. Among these, the total strength of co-authorship links was assessed, selecting the 51 nations with the strongest collaborative links. For a better visualization, the analysis displayed only the largest connected group which consisted of 50 countries.

The co-authorship network for countries highlights the collaborative landscape in research involving 50 countries grouped into 8 clusters with a total of 450 links, representing co-authorship relationships between nations. Key players like China, USA and India emerge as dominant nodes, reflecting their significant research contributions and robust international collaborations. China dominates the network with the highest link strength, building solid collaborations with nations like the USA, South Korea and India, while the USA acts as a global hub connecting Western nations, including England and Germany, to emerging centers such as Brazil and Malaysia.

The eight clusters identified outline regional or thematic research alliances. For example, China and India dominate a cluster reflecting strong intra-Asian collaboration, while USA and England anchor another cluster focused on transatlantic research partnerships. Smaller clusters, like those centered on France or Russia, highlight regional ties within Europe and North Africa. While the 450 links showcase a well-connected research community, the division into clusters suggests that some regions remain relatively isolated.

5. Conclusions

This study has offered a comprehensive perspective on the current state of deep learning and neural networks in the context of financial markets, including banking industry. It has pinpointed both the strengths of these techniques in specific applications and the gaps that require additional exploration and innovation. The international collaborations and high citation rates of influential documents reflect the global impact and relevance of this research area.

Our work has effectively illustrated the dynamic transformation of financial markets, where deep learning and neural networks are playing an increasingly central role. Through bibliometric analysis, the paper showed the growing adoption and continuous improvement of these methods over traditional approaches.

The present analysis underscored the increasing implementation of AI techniques, including neural networks and deep learning in financial fields. This supports the idea that AI's integration into banking sector is not only growing but shaping the strategic evolution of the industry.

The co-occurrence analysis revealed the central role of deep learning and neural networks in advancing financial market research, particularly in managing uncertainty and improving investment strategies. While progress is evident, gaps persist, such as the limited focus on explainable AI and interpretable machine learning, which imposes the need for transparent and accountable models, especially in regulated financial industries.

The paper emphasized the interdisciplinary nature of AI, highlighting its integration with big data, behavioral finance and computational methods. This demonstrates the potential of AI to tackle critical challenges in banking like customer segmentation, the offer of personalized financial services and dynamic decision-making processes.

Synthesizing the key points, the application of AI, with particular focus on deep learning and neural networks, is strongly impacting the future of banking industry. These techniques equip banks with powerful tools to navigate complexity, mitigate risks and discover new opportunities. Thus, we can admit that the application of AI, like deep learning and neural networks for market dynamics, credit scoring and risk modeling align with banks` strategic objectives to mitigate operational risks and enhance decision-making approaches.

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