



Research Article/Araştırma Makalesi

The Use of Artificial Intelligence and Expert Systems in Finance: A Bibliometric Analysis

Finans Alanında Yapay Zekâ ve Uzman Sistemlerin Kullanımı: Bibliyometrik Bir Analiz

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Abstract

Developments in artificial intelligence technology have also had an impact on various sectors. One of the sectors where artificial intelligence technology is most widely used is finance. This fact arouses the interest of researchers, and the literature on applications of artificial intelligence in finance continues to grow. Therefore, the aim of this study is to examine the evolving literature on artificial intelligence and expert systems in finance. The bibliometric analysis approach was used to evaluate 452 articles published in the Scopus database between 1988-2022. Analyzes by country, university, journal, and author were performed using the R-based bibliometric program. As a result of the study, it was found that although the number of articles has increased over the years, the largest increase occurred in recent years. The most productive and impactful journal is "Expert Systems with Applications", and the most impactful author is Doumpos (2001). However, the institution and country with the highest number of publications are "Hunan University of Finance and Economics" and China, respectively. Moreover, China is the country with the most interactions. On the other hand, it was found that the most frequent keyword in the studied papers is artificial intelligence and that this concept has a strong connection with the concepts of finance and machine learning. The concept of expert systems ranks sixth in terms of the number of uses. The results of this study provide an overview of the literature on artificial intelligence and expert systems in finance.

Jel Codes: G00, M15, O14

Keywords: Finance, Artificial Intelligence, Expert Systems, Bibliometric Analysis

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Öz

Yapay zekâ teknolojisindeki gelişmeler çeşitli sektörler üzerinde de etkili olmaktadır. Yapay zekâ teknolojisinin en fazla kullanıldığı sektörlerden biri de finans alanıdır. Bu durum araştırmacıların da ilgisini çekmekte ve finans alanındaki yapay zekâ uygulamalarına yönelik literatür de gün geçtikçe artmaktadır. Bu doğrultuda çalışmanın amacı, finans alanındaki yapay zekâ ve uzman sistemler üzerine gelişen literatürü incelemektir. Bibliyometrik analiz yaklaşımı kullanılarak Scopus veri tabanında yer alan 452 makale 1988-2022 dönemi için değerlendirilmiştir. Bu bağlamda R tabanlı bibliometrix programından yararlanılarak ülkeler, üniversiteler, dergiler ve yazarlar açısından analizler gerçekleştirilmiştir. Çalışmanın sonucunda, araştırılan konudaki makalelerin sayısı yıllar itibarıyla artmakla birlikte en fazla artışın son yıllarda gerçekleştiği belirlenmiştir. En üretken ve en etkili dergi "Expert Systems with Applications" ve en etkili yazar ise Doumpos (2001) olmuştur. Bununla birlikte en fazla yayın yapan kurum ve ülke sırasıyla "Hunan University of Finance and Economics" ve Çin'dir. Üstelik Çin en fazla etkileşimde bulunan ülke konumundadır. Diğer taraftan incelenen çalışmalarda en fazla yer alan anahtar kelimenin yapay zekâ olduğu ve bu kavramının finans ve makine öğrenimi kavramlarıyla arasında güçlü bir bağ olduğu tespit edilmiştir. Uzman sistemler kavramı ise kullanım sayısı açısından altıncı sırada yer almaktadır. Bu çalışmanın sonuçları finans alanındaki yapay zekâ ve uzman sistemler literatürünün genel bir görünümünü sunmaktadır.

Jel Kodları: G00, M15, O14

Anahtar Kelimeler: Finans, Yapay Zekâ, Uzman Sistemler, Bibliyometrik Analiz

1. Introduction

Artificial intelligence is referred to as the acquisition of human-related capabilities such as understanding, reasoning, and learning to machines (Gao et al., 2021: 1545). In other words, Artificial intelligence is identified as a computer system that simulates human-specific characteristics to make decisions based on data from different sources or systems and learn from emerging models (Hassani et al., 2020: 145). In this context, since the Dartmouth Conference in 1956, researchers around the world have been studying the theory and principles of artificial intelligence (Gao et al., 2021: 1545).

Today, artificial intelligence plays a significant role in mainstream social and economic technologies as well as academic studies (Hassani et al., 2020: 145). Therefore, artificial intelligence, which is at the center of the new industrial revolution (Industry 4.0), is directly or indirectly affecting various sectors. Artificial intelligence is being applied in areas such as manufacturing, health, security, education, and finance. Within this framework, the financial sector is one of the areas where artificial intelligence technologies are being used extensively (Milana & Ashta, 2021: 189).

Artificial intelligence can learn new things without outside help by developing models from existing data. There is a large amount of sensitive data that companies in the financial sector need to store and process securely. For this reason, artificial intelligence applications have an important place in the financial sector (Mandala et al., 2022: 2362). The financial sector is constantly evolving by using and adopting technological developments such as artificial intelligence and data analytics. Artificial intelligence technologies have strong predictive capabilities and are becoming progressively important for decision-making processes in various situations. In this direction, academic studies on artificial intelligence in finance are also increasing (Weber et al., 2023: 2).

Expert systems, one of the technologies of artificial intelligence, have been used in the past and are still being used in finance. Expert systems are used to simulate the decision-making ability of a human expert in a particular field. Expert systems can solve complex problems by processing information in the form of rules rather than traditional codes. For example, expert systems can be used to obtain expert opinions on risk management in order to make the best decision when granting loans. In this context, combining financial forecasts with qualitative information enables appropriate loan evaluation (Chan et al., 2022: 104).

This study aims to examine the studies that have been conducted on the use of artificial intelligence and expert systems in finance. For this purpose, the technique of bibliometric analysis was used. Bibliometric analysis is used to identify developing trends in article and source performance, collaborations, and research components, and to examine the intellectual composition of a given field in the existing literature. Bibliometric analysis provides researchers to obtain an overview, identify research gaps, develop ideas for new research, and identify intended contributions to the area (Donthu et al., 2021: 285). In this regard, it is believed that the study will provide researchers in the field with a general perspective. However, there are only limited number of studies (e.g., Goodell et al., 2021; Ahmed et al., 2022; Nazareth & Reddy, 2023) that examine the literature on the use of artificial intelligence technologies in finance. Therefore, this study will contribute to the expansion of the literature

in relevant area. In addition, according to the best of the researcher's knowledge, no study has been found that examines the studies on applications of artificial intelligence in finance, especially expert systems.

In the following parts of the study, studies that examine the applications of artificial intelligence techniques in finance with bibliometric analysis are included. Then, the data and methodology are explained, and the findings are presented. Finally, the study is concluded with the conclusion section.

2. Literature

In this section of the study, studies are included that examine the literature on artificial intelligence technologies in finance are included. In this context, related studies are briefly explained.

Shi & Li (2019) evaluated the research trends on the use of intelligent techniques in bankruptcy prediction. In this regard, they conducted a bibliometric analysis of 413 studies in the Web of Science (WoS) database published during 1991-2018 using the VOSviewer program. They found that relevant publications have increased significantly since 2008 and collaboration among authors is low in the international level.

Goodell et al. (2021) examined studies on financial applications of artificial intelligence and machine learning using co-citation and bibliometric matching analyses. In this context, they evaluated 283 studies in the Scopus database in the 1986 to April 2021. They found that relevant techniques applied in areas such as portfolio management, behavioral finance, fraud detection, forecasting, and planning.

Janková (2021) evaluated 353 studies in the WoS database using the VOSviewer technique in the context of artificial intelligence applications in financial markets. It was found that the use of artificial intelligence in finance increased in the 1991 to March 2020, especially in recent years, and that artificial neural network and fuzzy logic are the most used methods.

Ahmed et al. (2022) investigated the studies on artificial intelligence and machine learning in finance in the Scopus database between 2011 and 2021. In this context, they evaluated 348 articles using the RStudio and VOSviewer programs. As a result of the study, they found that studies were conducted in fields such as portfolio management, behavioral finance, bankruptcy prediction, big data analysis, and blockchain.

Herrmann & Masawi (2022) assessed the literature on the applications of artificial intelligence technologies in the banking, financial services, and insurance sectors. To this end, they examined the studies published in the Scopus database between 1984 and 2020 using the scientific mapping method. The researchers found that studies in the insurance sector were limited and focused on investments, financial markets, lending, risk management, fraud detection, and customer relations.

Kumbure et al. (2022) reviewed 138 articles published between 2000 and 2019 to conduct a bibliometric analysis of studies on machine learning applications for stock market forecasting. Relevant articles were retrieved from Scopus, IEEE Xplore, WoS, and Science Direct databases.

Accordingly, they found that publications have increased significantly in recent years. However, they revealed that mostly stocks and indices were researched in the USA. Regionally, they found that most studies were conducted in Asia.

Ren et al. (2022) analyzed bibliometrically and thematically studies on the use of machine learning in cryptocurrencies. For this purpose, they examined 431 studies in the WoS database for the period from 2014 to 2022. Accordingly, they concluded that related studies tend to increase over the years and that most of the research topics are about common cryptocurrencies. They also noted that researchers focus on predicting price trends and revenue fluctuations of cryptocurrencies.

Nazareth & Reddy (2023) reviewed the literature on machine learning applications in finance. In this context, they analyzed 126 articles in the Science Direct database for the period from 2015 to July 2022 using the PRISMA approach. Accordingly, they found that studies on the machine learning applications in finance have increased significantly, especially in recent years. However, they noted that machine learning applications are more likely to be used in the areas of stock market and cryptocurrency.

When the studies in the literature are reviewed, it is seen that the studies examining the related literature in finance are usually conducted in the context of artificial intelligence and machine learning applications. In the current study, studies on the use of artificial intelligence and expert systems in finance are examined. It is expected that the aspect attributed to the study will contribute to the literature and guide researchers conducting research on this topic.

3. Data and Methodology

To find the most relevant studies on the use of artificial intelligence and expert systems in the financial sector, a search was conducted using the criteria "Article Title" and "Keywords". In this context, information on the search criteria is presented in Table 1.

Table 1: Search Criteria

Database	Scopus
Search date	23.02.2023
Review period	1988-2022
Search terms	(TITLE ("artificial intelligence" "finance") OR TITLE ("expert system" "finance") OR KEY ("artificial intelligence" "finance") OR KEY ("expert system" "finance"))
Publication type	Article
Number of articles	452

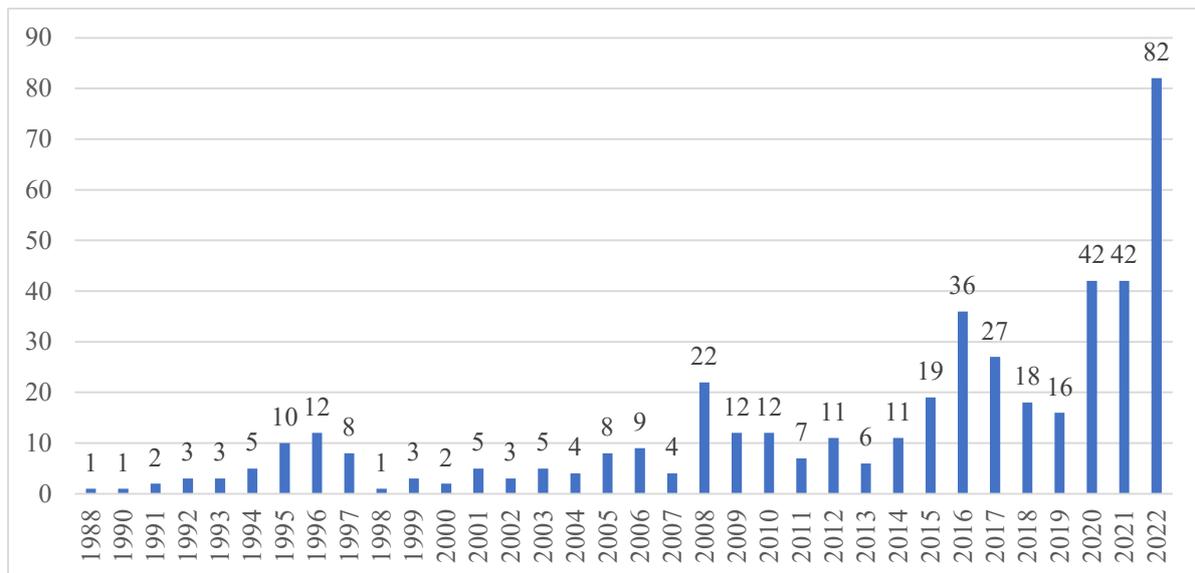
As shown in Table 1, the articles were retrieved from the Scopus/SciVal database during the period studied. Scopus is considered one of the most important databases for publications such as articles, books, and conference proceedings. Through this database, information such as author, institution, source title, abstract, keywords, journal, and document type can be retrieved. Therefore, the advanced search options of Scopus/SciVal provide access to information criteria that are extremely important for assigning the bibliometric status of the study (Singh et al., 2021: 5116; Şeker & Atasel, 2023: 868).

In this study, the bibliometric analysis was used as an approach for literature review. Bibliometrics provides a systematic, transparent, and repeatable review process based on statistical analysis of researchers or scientific activities. Bibliometric analysis helps to analyse large amounts of data and provide an overview of existing studies. Thus, bibliometric analysis allows understanding trends over the years, changes in the boundaries of the researched topics and disciplines, and identification of the most impactful authors, institutions or countries and the relationships between them (Aria & Cuccurullo, 2017: 959). In the study, the R-based bibliometrix program (Aria & Cuccurullo, 2017) used to conduct these analyses.

4. Findings

In the study, articles on financial applications of artificial intelligence and expert systems were examined using the bibliometric analysis method and the results were revealed. In this framework, the results related to performance analysis, citation analysis, and network analysis were included. The trend of these studies between the years 1988 and 2022 is shown in Figure 1. According to this, the number of relevant articles averaged 4 or 5 per year until 2008, about 24 studies were conducted per year during the period 2008-2022, and the highest number of publications was made in 2022. Accordingly, although the financial sector benefits from technological developments, it can be stated that the COVID-19 pandemic has accelerated the trend toward the adoption of artificial intelligence technologies in the financial sector (Boukherouaa et al., 2021: 5). In this direction, it can be said that the interest of researchers has increased significantly.

Figure 1: Number of Articles by Years



The top 10 journals on the subject examined are shown listed Table 2. According to this, "Expert Systems with Applications" is the journal with the highest number of publications with 53 articles. This journal is followed by the "European Journal of Operational Research" and "Computational Intelligence and Neuroscience".



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Table 2: Most Relevant Journals

Rank	Sources	Articles
1	"Expert Systems with Applications"	53
2	"European Journal of Operational Research"	15
3	"Computational Intelligence and Neuroscience"	12
4	"IEEE Access"	10
5	"Decision Support Systems"	9
6	"Information Sciences"	8
7	"Journal of The Operational Research Society"	8
8	"Applied Soft Computing Journal"	7
9	"Wireless Communications and Mobile Computing"	7
10	"Expert Systems"	6

Table 3 shows the h, g, and m index scores, the total number of citations (TC), the total number of publications (NP), and the year of first publication (PY Start) of the top 10 authors with publications on artificial intelligence and expert systems in finance. It can be seen that Doumpou M. ranks first with a total of 3 articles and 171 citations. However, Wang H. is in the second place and Wang L. is in the third place. In addition, Table 3 shows that Zhang J., Zhou Y., and Zopounidis C. have similar scores.

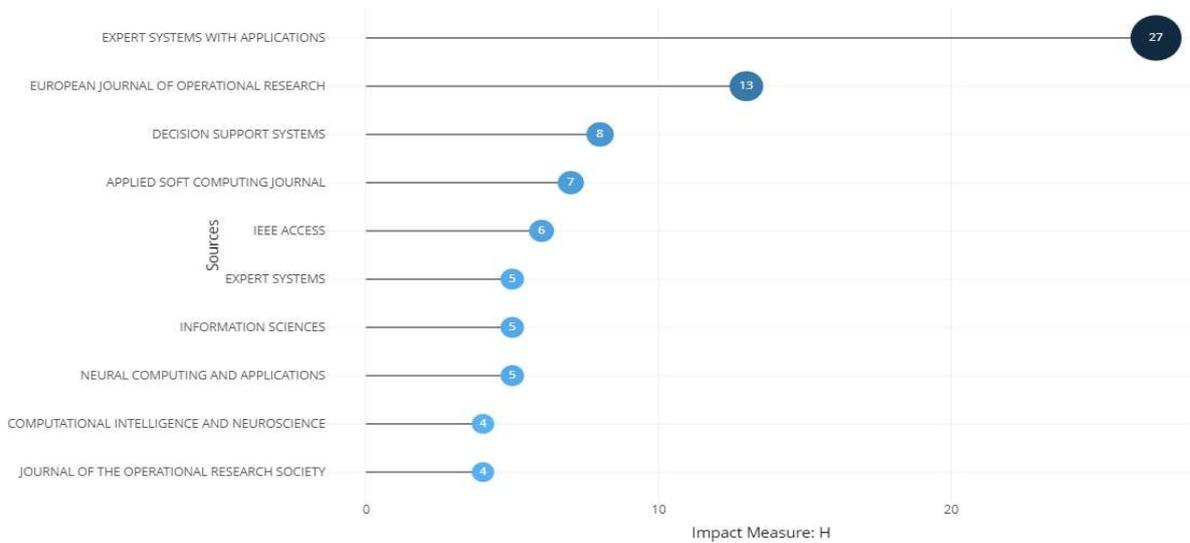
Table 3: Author Impact

Researcher	h-index	g-index	m-index	TC	NP	PY Start
Doumpou M.	3	3	0,13	171	3	2001
Wang H.	3	3	0,2	101	3	2009
Wang L.	3	3	0,75	78	3	2020
Zhang J.	3	4	0,214	50	4	2010
Zhou Y.	3	3	0,5	84	3	2018
Zopounidis C.	3	3	0,13	171	3	2001
Arakpogun E.O.	2	2	1	21	2	2022
Belatreche A.	2	2	0,25	144	2	2016
Benaroch M.	2	2	0,069	20	2	1995
Chen M.-Y.	2	2	0,154	150	2	2011

Notes: The h-index indicates that the author has h articles, each with h or more citations. The g-index means that the top g article of an author has been cited g times. The m-index is the author's h-index value divided by the number of years since the PY start date (Choudhri et al., 2015: 738, 740; Ahmed et al., 2022: 8).

The most impactful journals are shown in Figure 2. It can be seen that the journal "Expert Systems with Applications" takes the first place. This journal is followed by the "European Journal of Operational Research" and "Decision Support Systems".

Figure 2: Most Impactful Journals



Information about the most cited articles is shown in Table 4. According to this, the study by Das & Chen (2007) ranked first with a total of 763 citations. Moreover, it was found that the annual number of citations of these authors is about 45. The second ranked study by Zhang et al. (1999) was cited a total of 416 citations and received about 17 citations per year. The third ranked study by Cavalcante et al. (2016) received a total of 335 citations and about 42 citations per year.

Table 4: Most Global Cited Documents

Paper	Journal	Title	Total Citations	TC per Year	Normalized TC
Das & Chen (2007)	Manage Sci	"Yahoo! for Amazon: Sentiment Extraction from Small Talk on The Web"	763	44,88	3,49
Zhang et al. (1999)	Eur J Oper Res	"Artificial Neural Networks in Bankruptcy Prediction: General Framework and Cross-Validation Analysis"	416	16,64	2,98
Cavalcante et al. (2016)	Expert Sys Appl	"Computational Intelligence and Financial Markets: A Survey and Future Directions"	335	41,88	6,83
Patel et al. (2015)	Expert Sys Appl	"Predicting Stock Market Index Using Fusion of Machine Learning Techniques"	295	32,78	4,99
Bahrammirzaee (2010)	Neural Comput Appl	"A Comparative Survey of Artificial Intelligence Applications in Finance: Artificial Neural Networks, Expert System and Hybrid Intelligent Systems"	294	21,00	5,17
Sezer et al. (2020)	Appl Soft Comput J	"Financial Time Series Forecasting with Deep Learning: A Systematic Literature Review: 2005–2019"	294	73,50	10,92
Pindoriya et al. (2008)	IEEE Trans Power Syst	"An Adaptive Wavelet Neural Network-Based Energy Price Forecasting in Electricity Markets"	256	16,00	8,95
Malekipirbazari & Aksakalli (2015)	Expert Sys Appl	"Risk Assessment in Social Lending Via Random Forests"	243	27,00	4,11
Canbas et al. (2005)	Eur J Oper Res	"Prediction of Commercial Bank Failure Via Multivariate Statistical Analysis of Financial Structures: The Turkish Case"	198	10,42	5,76
Preis et al. (2010)	Philos Trans R Soc A Math Phys Eng Sci	"Complex Dynamics of Our Economic Life on Different Scales: Insights from Search Engine Query Data"	194	13,86	3,41

Information about the 10 institutions with the highest number of publications is shown in Table 5. According to this, it is seen that "Hunan University of Finance and Economics" ranks first with 12 articles, "Hunan University" ranks second with 11 articles, and the next three universities have 9 articles.

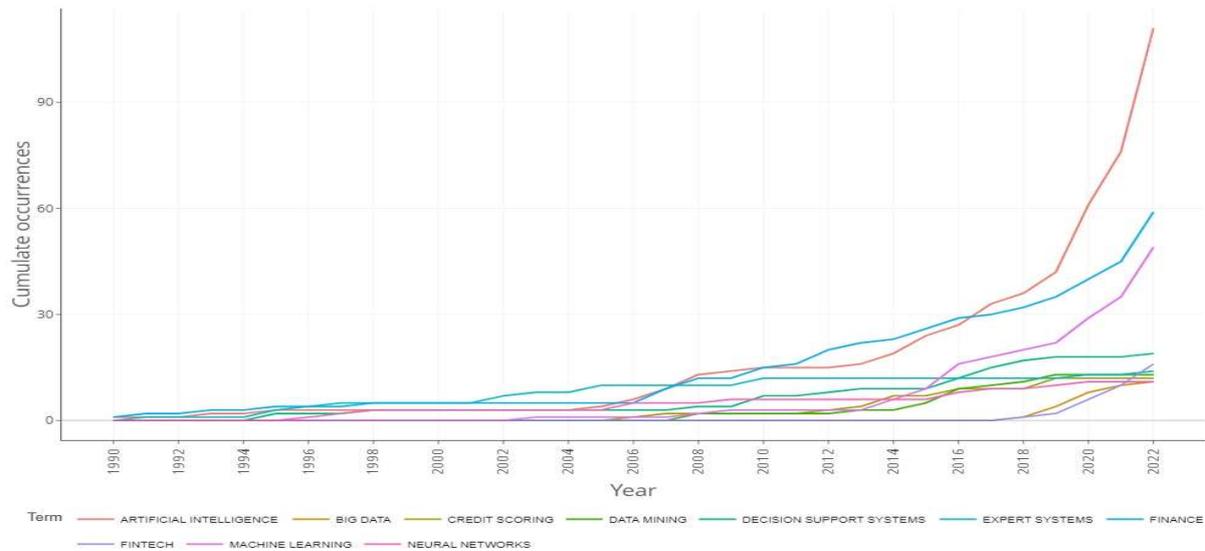
Table 5: Most Relevant Affiliations

Rank	Affiliation	Articles
1	"Hunan University of Finance and Economics"	12
2	"Hunan University"	11
3	"Nanyang Technological University"	9
4	"Notreported"	9
5	"Universidad Carlos III De Madrid"	9
6	"Shenzhen University"	8
7	"Qatar University"	7
8	"University of Antwerp"	7
9	"Guilin University of Electronic Technology"	6
10	"Rise Research Institutes of Sweden"	6

Figure 3 shows the distribution of keywords used in the articles by year. From this it can be seen that the most frequently used keyword is artificial intelligence. It was found that the

concept of artificial intelligence has continuously increased during the examined period and reaching 111 in 2022. In second place is the concept of finance (59) and in third place is the concept of machine learning (49). The concept of expert systems is in sixth place in terms of the number of uses. However, it can be observed that the use of concepts such as fintech, data mining and big data has increased in recent years.

Figure 3: Distribution of Keywords by Years



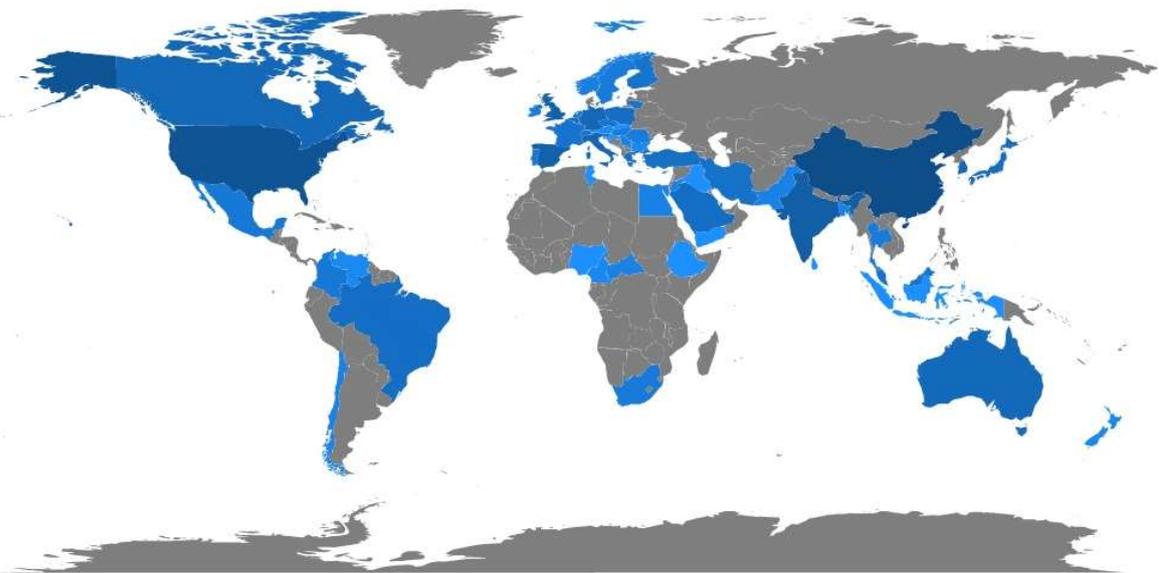
The tree map of the words used in the abstracts of the articles reviewed is shown in Figure 4. In this context, it can be seen that the financial concept is used 995 times and has the highest share (10%). The data concept (536), which is in second place, has a usage rate of 5%. The model concept (429) was used 4% in abstracts. These concepts are followed by system, intelligence, artificial, and based.

Figure 4: Concepts Used in Abstracts



Figure 5 shows the map of the countries with the most publications. The blue tones on the map represent the number of publications in each country. In other words, the number of articles decreases from dark blue to light blue. According to the map, China is first with 103 articles and the United States (US) is second with 39 articles. India and Spain have 16 articles and the United Kingdom (UK) has 14 articles. It was found that Turkey has 4 articles.

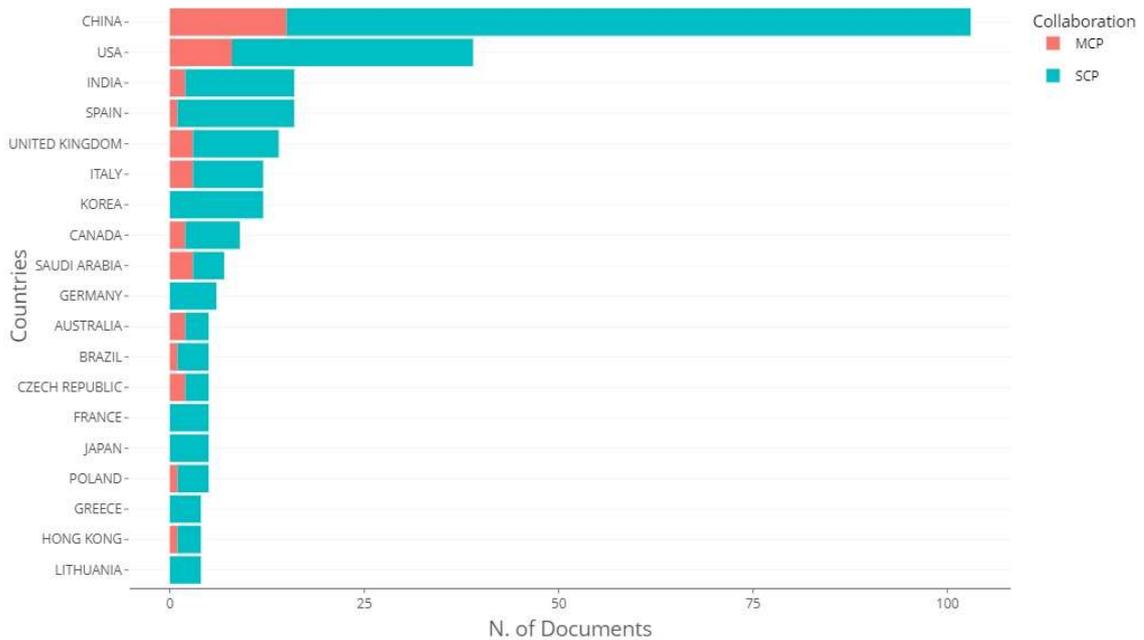
Figure 5: Most Relevant Countries by Corresponding Author



According to the corresponding author, national (Single Country Publications-SCP) and international (Multiple Country Publications-MCP) collaborations are presented in Figure 6. According to this figure, China ranks first with 88 national collaborations and 15 international collaborations. In the US, the number of SCP and MCP is 31 and 8, respectively. In India, the

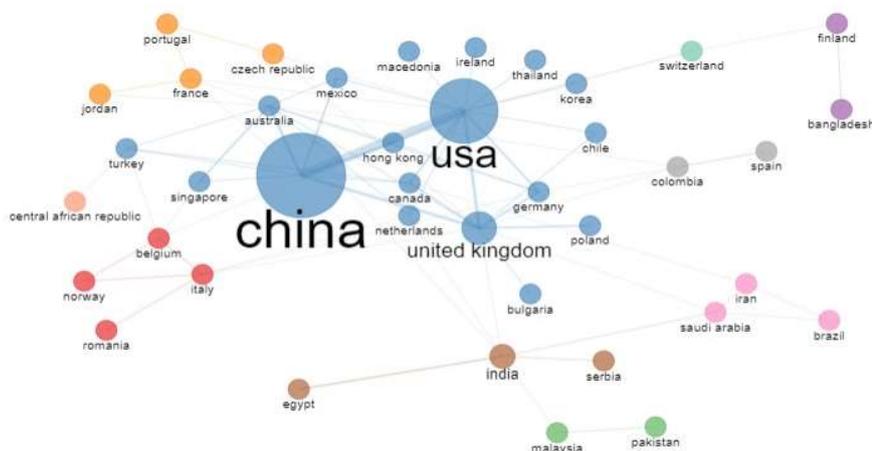
third-ranked country the number of national and international collaborations is 14 and 2, respectively. In contrast in South Korea, Germany, France, Japan, Greece, and Lithuania, the form of collaboration is national. Turkey ranks 20th in terms of national (3) and international (1) collaborations.

Figure 6: SCP and MCP by Corresponding Author



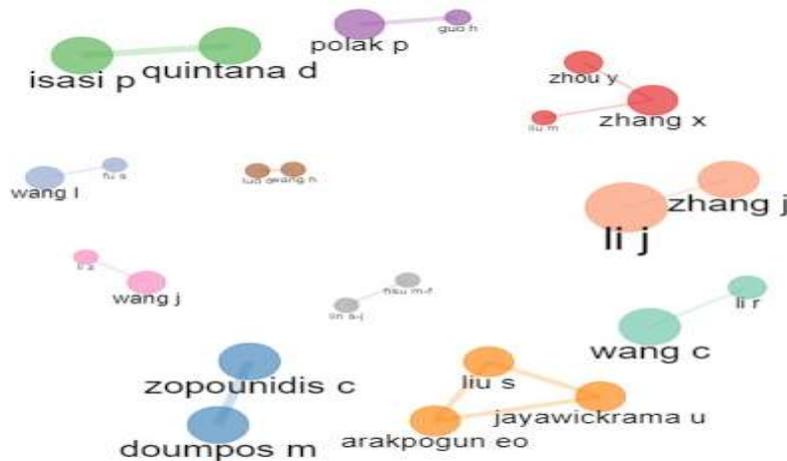
The network of collaboration between countries is shown in Figure 7. Here, each node represents one country. The size of the node indicates the number of articles published in the country or the level of impact of the countries. The connections between the nodes explain collaboration of authors between the countries, and the distance between the nodes and the thickness of connections explain the degree of collaboration between the countries. Accordingly, it can be said that there are 8 different clusters that interact. As can be seen in the blue cluster, it was found that the country with the highest connection strength is China, followed by the US and the UK.

Figure 7: Country Collaboration Network



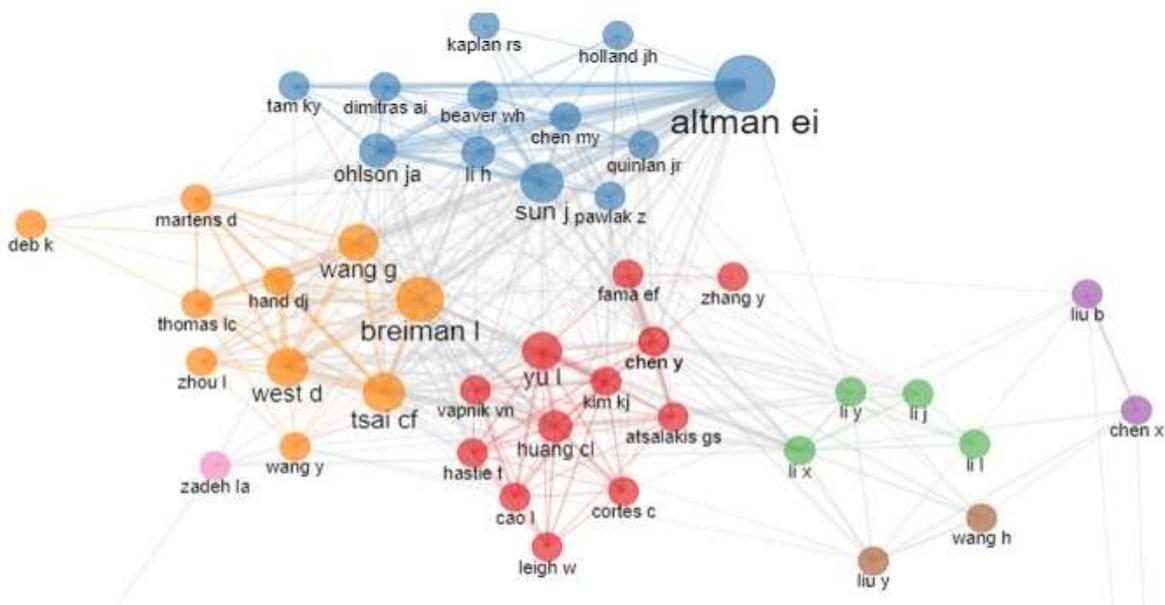
The collaboration between the authors of the articles is shown in Figure 8. Here, each node denotes an author, and the connections between nodes indicate the collaboration between authors. Accordingly, it can be seen that eleven different clusters are formed. It can be said that Li J. and Zhang J. are the most impactful authors in the studied field. However, it can be stated that there is a strong connection between Zopounidis C. and Doumpou M. in the blue cluster and between Isasi P. and Quintana D. in the green cluster.

Figure 8: Author Collaboration Network



The network map of the cited authors is shown in Figure 9. Here, each node denotes the cited author, and its size indicates the number of citations to the article. The connections between the nodes indicate the degree to which the authors are co-citation. As can be seen in figure, seven different clusters were formed. Altman E.I. is the most cited author. This author is followed by Fama E.F., Breiman L., Yu L., and Sun J., respectively.

Figure 9: Co-citation Network





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Zopounidis C. had similar scores. According to the most cited articles, Das & Chen (2007) ranked first with a total of 763 citations, Zhang et al. (1999) ranked second, and Cavalcante et al. (2016) ranked third.

Among the institutions that publish the most, “Hunan University of Finance and Economics” ranks first, “Hunan University” ranks second, and the next three universities have a similar number of articles. When the countries with the most publications were examined, it is concluded that China ranked first, the US ranked second, followed by India, Spain, and the UK. This result supports the findings of Herrmann & Masawi (2022) and Nazareth & Reddy (2023). In terms of national and international collaboration among the countries, it was found that China, the US, and India each ranked first three. It can be said that this result is in line with the finding of Ahmed et al. (2022). Turkey ranked 20th among these countries. However, the form of collaboration has been realized at the national level in South Korea, Germany, France, Japan, Greece, and Lithuania.

It was found concluded that the most frequently used keyword in articles over the years is artificial intelligence, followed by the concept of finance and machine learning in third place. The concept of expert systems ranks sixth in terms of number of uses. At the same time, the use of concepts such as fintech, data mining and big data has increased in recent years. Based on the words used in the abstracts of the relevant studies, it was found that the finance term is the most frequently used, the data term is in second place, and the model term is in third place.

In terms of the collaboration network between countries, China has the strongest connection, followed by the US and the UK. It was found that Li J. and Zhang J. are the most impactful authors in terms of collaboration. However, the most frequently cited author is Altman E.I., and this author is followed by Fama E.F., Breiman L., Yu L., and Sun J., respectively. The co-occurrence network of keywords used in the articles, it was found that the term of artificial intelligence is the most frequently used and this concept is closely related with the concepts of finance and machine learning. Similarly, this concept is related to concepts such as financial management, fintech, risk management, and behavioral finance.

According to the above results, it can be said that artificial intelligence applications in finance are an important research area that has been going on for decades. OECD (2021a) states that developments in big data and computing technologies have significantly increased the adoption of artificial intelligence systems and techniques. However, the COVID-19 pandemic has accelerated the digitalization trend and the use of artificial intelligence, which continued before the pandemic (OECD, 2021b). In addition, it is estimated by International Data Corporation (2022) that this trend will continue and global spending on artificial intelligence will be more than \$300 billion in 2026.

This study provides a perspective to researchers by reviewing the literature on artificial intelligence and expert systems in finance. In this context, 452 articles in the Scopus database were evaluated using bibliometric analysis. This fact represents the limitation of the study. In future studies, a more comprehensive evaluation can be done by including studies in different databases. However, other types of publications can also be included in the evaluation. In addition, the bibliometric analysis can be performed in a specific financial area.



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Etik Beyanı: Bu çalışmanın tüm hazırlanma süreçlerinde etik kurallara uyulduğunu yazar beyan eder. Aksi bir durumun tespiti halinde Fiscaeconomia Dergisinin hiçbir sorumluluğu olmayıp, tüm sorumluluk çalışmanın yazarına aittir.

Ethical Approval: The author declares that ethical rules are followed in all preparation processes of this study. In the case of a contrary situation, Fiscaeconomia has no responsibility, and all responsibility belongs to the study's author.