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The evolution of financial technology: A comprehensive bibliometric review of robo-advisors

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Abstract This bibliometric study delves into the rapidly evolving domain of robo-advisors—digital platforms that offer automated, algorithm-driven financial planning services with minimal human intervention. Utilizing a robust dataset extracted from Scopus, the research employs the PRISMA flow chart methodology for meticulous screening, inclusion, and exclusion of relevant studies. Advanced bibliometric analysis tools such as Biblioshiny, VOSviewer, and CiteSpace are employed to conduct the analysis, facilitating a multifaceted examination of the literature. The findings of this study are extensive and informative, covering various aspects of the research on robo-advisors. It highlights the annual scientific production, identifying trends and growth patterns within the field. The study also spotlights the most productive authors and sources, shedding light on the leading contributors to the discourse on robo-advisors. Furthermore, it provides insights into the most globally cited documents, author cocitations, and keyword co-occurrences, revealing the core themes and discussions shaping this area of study. Significantly, the research identifies keywords with the strongest citation bursts and offers network visualizations of cited authors, showcasing the dynamic interactions within the academic community. Timezone and timeline views of cited journals and country collaborations offer a geographical and temporal perspective on the research landscape. Through these analyses, the study uncovers identified research gaps and practical implications, guiding future investigations and the practical application of robo-advisors in the financial industry.

Keywords: automated investment, fintech, bibliometric analysis, biblioshiny, VOSviewer, citespace

1. Introduction

Technological advancements play a crucial role in driving productivity in most economic sectors. The term "fintech" basically refers to the integration of internet-based technologies, including cloud computing and the mobile internet, with the provision of financial services, among others, such as money lending and transaction banking (Cull, 2022; Fischer, 2021; Imerman & Fabozzi, 2020; Ryu & Ko, 2020). Among these, investment advice (IAds) has traditionally been part of the service offered to a small circle of well-off clients only. However, the innovative solution by fintech of a Robo-advisor (RA) aims at making IAds available to a far wider clientele (Afaq & Gaur, 2021; Cull, 2022). Robo-advisors are a major technological development in the financial service industry (Brenner & Meyll, 2020a). Robo-advisors transform investing with an automated, low-fee alternative to manage their money (Baker & Dellaert, 2018). Think of a robo-advisor as an online platform that functions in lieu of an old brick-and-mortar financial advisor, making use of algorithms rather than human expertise. Robo-advisors basically gather information about their financial objectives, risk tolerance, and time horizon for investments through a set of very basic questions (Brenner & Meyll, 2020a). Based on your answers, the robo-advisor crafts a diversified investment portfolio tailored to your needs. Such a portfolio usually consists of a mixture of assets such as stocks and bonds, striving to reach one's goals and manage risks at the same time.

One of the greatest benefits of the use of robo-advisors is that they are relatively cheap (Belanche et al., 2023a). The fees of robo-advisors are much lower than those of traditional financial advisors, who, in most cases, charge percentages from the assets they manage (Brenner & Meyll, 2020b; Cardillo & Chiappini, 2024). This, therefore, makes them a great choice for people who are either beginners or who would not have much money to invest in. Second, convenience is realized. The fact that robo-advisor services are available on the internet means that one can easily and comfortably manage their investments from anywhere at any given time (Figà-Talamanca et al., 2022). They also automate tasks such as portfolio rebalancing and reinvesting dividends. Thus, you do not have to worry about managing your investments proactively. In addition, most robo-

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advisors have considerably low minimum requirements for investment, and therefore, it even becomes possible for one to invest with little funds (Savchenko & Kobets, 2022).

Robo-advice service brings with it the strength of increased productivity and the capacity to charge low commissions and fees, which makes it affordable for the majority of people (Belanche et al., 2023b; Glaser et al., 2019). High accessibility to customers, easy and reduced friction account opening, and finally, the absence of a requirement for a deep financial background all make for the democratization of financial advice (Au et al., 2021). It is truly a kind of service that offers more transparency and diversifies the portfolio, given that mainly ETFs are used; hence, it is ideal for customers whose financial needs are very simple (Cull, 2022; Figà-Talamanca et al., 2022). Additionally, they are good at monitoring, rebalancing, and reporting about portfolios; meanwhile, they appeal to a nontraditional client, mostly a younger generation, since it is delivered through the use of easy tools with a simple client experience.

There are many opportunities where robo-advice services can be applied. This means that they are perhaps enabling businesses with the ability to bring in assets not currently managed by wealth management firms; hence, this derives synergy and added value from cooperation with financial advisors (Puhle, 2019). There is also a growing interest in passive investing, where one can streamline several financial goals, such as college savings, retirement, and estate planning. In addition, the following are good growth opportunities: their inclusion of more asset classes such as equities, fixed income, hedge funds, and real estate; and adaptive questioning that takes into consideration client complexities to help the client understand the portfolio in a better way (Nguyen et al., 2023). However, Robo-advisors are not free from their weaknesses: The risk of the SGGTCI may not answer all investors' needs. The profile questionnaire given to them may be very basic for drawing out necessary information, and the final document may not necessarily be very presentable to all types of investors. The functionalities brought about are relatively basic, with almost no capacity to actually provide reasoned explanations for more intricate and detailed issues or follow up with questions that could allow for customized advice. Threats that robo-advice services face include undermining the confidence of clients in automated and digitized methods (Hyun Baek & Kim, 2023; Ku & Wang, 2022). However, some parts of the client base feel the need for person-to-person interaction with their advisor, so a fully digital approach from robo-advisors would not be needed. These signs point toward the importance of the humanized part or a hybrid model that supports areas where robo-advisory platforms are unavailable (Brunen & Laubach, 2022; Guo, 2020).

This study attempts, therefore, to carry out bibliometric analysis of the literature on Robo-advisors so that a map of the research landscape and development path of this emerging field, its key themes, and intellectual structure can be drawn (Amaliasita & Rahayu, 2024; Ellegaard & Wallin, 2015; Godin, 2006). Such trends, influential studies, authors, and research clusters that have provided insights into the discipline up to the present and emerging trends are determined using advanced bibliometric tools and visualization software, such as BiblioShiny, VOSviewer, and CiteSpace (Ali et al., 2022; Mahmoud et al., 2024; Zhang, 2023). It identifies critical research gaps and emerging trends, guiding future scholarly inquiries into unexplored areas (Babu & Thomas, 2022; Chen et al., 2023; Joseph et al., 2024; Thomas et al., 2023). Moreover, by showcasing the interdisciplinary nature of robo-advisor research between finance, technology, and behavioral science, the analysis supports cross-disciplinary collaborations that will be key to enriching our understanding and application of these increasingly prevalent automated financial advisory services. This, therefore, means that the insights from this bibliometric study are very valuable for practitioners and policymakers for the development of user-centered robo-advisory service provisions, regulatory frameworks, and industry standards that embody the most current research findings. Distilled knowledge will benefit both educators and students; it puedes the development of improved curricula that encourage interest in innovations related to financial technologies. This adds to the global perspective provided through this analysis to outline the universal and localized factors relating to robo-advisor adoption and regulation and hence provides a full perspective that, while localized, ensures the world view of these technologies. This bibliometric analysis, in essence, is able to map not only the robo-advisor knowledge territory but also lay a foundation for budding innovations and interdisciplinary research in the rapidly evolving field of financial technology.

BiblioShiny is an advanced user interface for the R package, while 'bibliometrix' is designed to achieve a more interactive and user-friendly experience in conducting analyses (Komperda, 2017; Merlin & Prabakar, 2024; Racine, 2012; Souza de Cursi, 2023). This provides researchers with the opportunity to impulsively picture data and study trends and to conduct detailed analyses with minimal programming knowledge. VOSviewer focuses on creating and picturing bibliometric networks such as keyword co-occurrence, cocitation and coauthorship networks. It is extensively used for its capacity to instinctively map and comprehend intricate relationships and organisations within the scientific literature (Maryanti et al., 2023; Uzkiyyah et al., 2023; Van Eck & Waltman, 2009, 2010). CiteSpace, which is a Java-based application particularly used for visualization and trend analysis, acknowledges the patterns in the scientific literature (Niazi, 2016; Yang et al., 2017). It focuses more on studying and mapping important points where research is progressing, and it is known for its capacity to expose growing trends, impactful publications, and dominant authors, often by means of joint citation analysis and clustering methods (Chen et al., 2023; Zhang, 2023).

This study seeks to address the following research questions:

RQ1: What are the key research themes and topics within the scholarly literature on robo advisors?
RQ2: How has research on robo advisors evolved over time, and what are the emerging trends in this field?
RQ3: Who are the leading researchers within the field of robo-advisors, and what patterns of collaboration exist among authors and their institutions?
RQ4: What effect do these findings in robo-advisor research have in terms of citation counts, and what publications seem most influential in shaping the discourse?
RQ5: How is the distribution of research output related to robo-advisor-related work geographically and institutionally across regions and disciplines?
RQ6: Are there any knowledge gaps or underexplored areas within the literature on robo-advisors, and what are the implications for future research?

2. Literature Review

The rise and presence of robo-advisors within the investment advisory space of the financial technology ecosystem is drawing much academic attention. The following literature review will combine selected studies that cover the dynamics of robo-advisor interaction with traditional financial advice, the adoption and trust factors in robo-advisors, and the respective regulatory frameworks and design considerations.

Brenner and Meyll (2020) used US investor data to determine whether the involvement of robo-advisors displaces the traditional human model for financial advice. Their results imply a strong, negative relation between the use of robo-advisors and demand for human financial advice, especially among those investors who are more concerned with fraud in investment; the results seem to suggest that robo-advisors may provide a credible source of advice for investments (Brenner & Meyll, 2020b).

Ku and Wang (2022) conducted an empirical survey to explore the factors affecting the willingness of investors to use robo-advisors. From this study, it can, therefore, be generally deduced that perceived ease of use, perceived control, social presence, and trust in vendors are all very important in deciding the willingness to use robo-advisors, understanding the key marketing implications in promoting robo-advisor services (Ku & Wang, 2022).

Wang and Pradhan (2020) researched aged persons about their adoptive likelihood of becoming robo-advisors. The research revealed that the significant variables influencing adoption were trust, anxiety, and e-literacy, astonishingly showing a negative relationship with the likelihood of adopting robo-advisors among aged persons. These findings underscore the need for tailored FinTech development and research to benefit older populations (Wang & Pradhan Dr, 2020).

Hong et al. (2023) investigated the effects of the investment intentions of robo-advisor users who applied strategies to reduce the related uncertainties. This paper postulates and empirically tests a model wherein algorithmic interpretability, structural assurance, and interactivity all affect investment intention via a value-based adoption mechanism, thus extending the understanding of this financial robo-advisor context (Hong et al., 2023).

Guo (2020) delves into the regulatory challenges with investment robo-advisors in China, which helped hamper the growth of the industry with a restrictive and unsupportive legal environment. The research recommends developing an incremental regulatory approach inspired by information disclosure, fiduciary duties, and algorithm regulation that may foster growth in the robo-advisor industry in China, the US and Australia (Guo, 2020).

Deng and Chau (2021) empirically tested the effect of the anthropomorphized design elements of service financial robo-advisors on customers' investment advice-taking behavior. This study indicates that anthropomorphic features could increase the trust of a user and, therefore, the perceived risk, positively contributing to investment advice acceptance (Deng & Chau, 2021).

Xia et al. (2023) focused on the emotional response mechanism linking investors' willingness to use robo-advisors. Using the cognition-affect-constitution model with a set of drivers derived from affective components in their study, they established trust, perceived usefulness, and perceived risk as the external drivers; among the internal drivers of using willingness for robo-advisors, they found investor sentiment. This study focuses on the importance of emotional response in the adoption of financial technologies (Xia et al., 2023).

Kwon et al. (2022) presented a rigorous study on the determinants of robo-advisor acceptance by integrating an extended model of technology acceptance and innovation resistance. Their findings thus contribute to the understanding of how, specifically, transparency, customization, social presence, and user control jointly help rojo, which is now wholly owned and operated by robo-advisors, form the acceptance and resistance of robo-advisors to provide practical insights for the development of robo-advisor services and the promotion of robo-advisors (Kwon et al., 2022).

3. Materials and Methods

Scopus was chosen as this study's primary bibliographical data source because it covers a broader range of quality journals than other databases (Archambault et al., 2009; Gavel & Iselid, 2008; Harzing & Alakangas, 2016). The publications were retrieved using the keywords "Robo-Advisor", “Robo Advice”, “Robo Investment” or “Automated Investment Advice”.

There were no language restrictions; only journal articles, conference papers, and book chapters were considered. A total of 870 documents were gathered from 518 distinct sources spanning the years 2006 to 2024. Figure 1 illustrates the PRISMA approach for selecting papers for bibliometric analysis. It is a three-phase procedure in which we identify and extract the data for analysis initially from the databases. We excluded reviews, editorials, books, short notes, and surveys from the second phase. The documents included are articles, conference papers, and book chapters. The findings were stored as "CSV" and RIS files, and bibliometric analysis was performed on the data using CiteSpace version 6.2. R3 (Advanced) VOSviewer and Bibloshiny software. The main aspects of this investigation are summarized in Table 1.

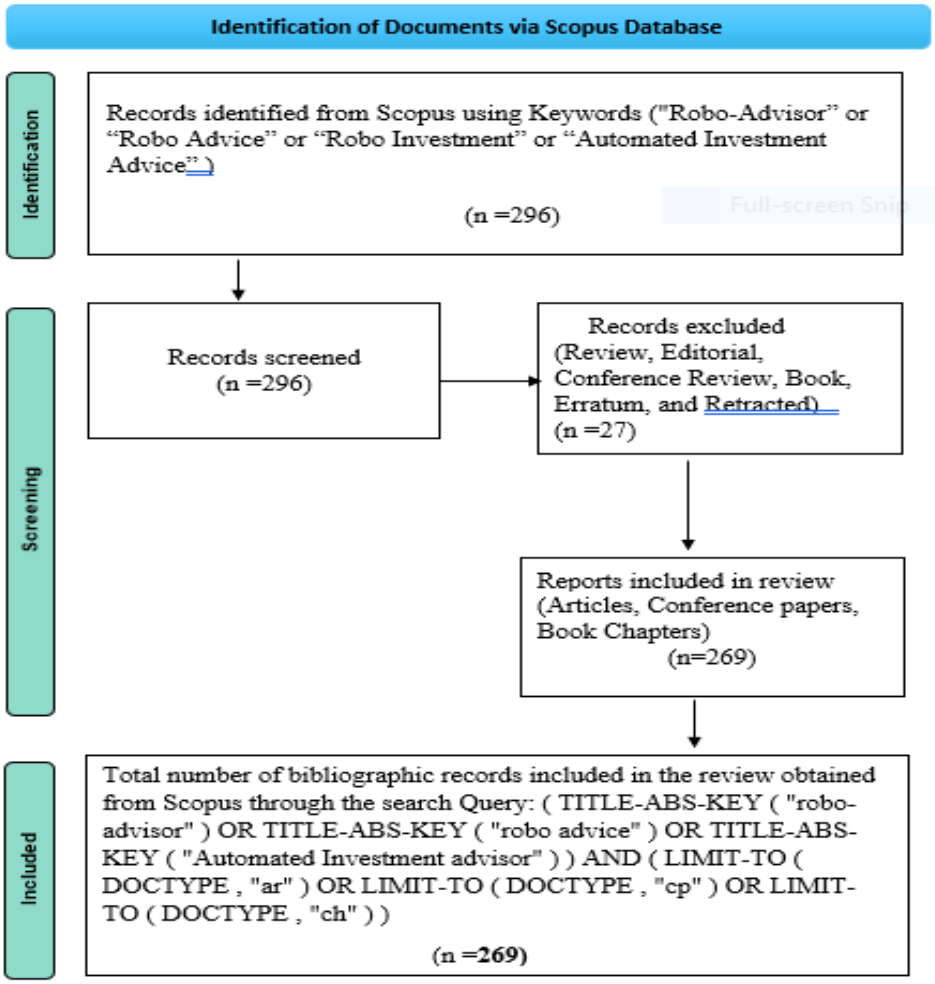

Figure 1 PRISMA flow diagram used to identify, screen, and include papers in the bibliometric analysis.

4. Findings

4.1. *Annual scientific production*

The progression began with 10 articles in 2017, indicating an early stage of research in this area. The following year, 2018, experienced a significant increase to 34 articles. This upward trajectory continues, albeit with some fluctuation; in 2019, the number of articles dropped slightly to 26 before increasing again to 39 in 2020. The subsequent years show a steady increase: 45 articles in 2021, 51 in 2022, and 57 in 2023, suggesting a consolidating interest and expansion in robo-advisor research, and 7 papers are currently published in 2024.

4.2. Most significant authors

Figure 3 presents a summary of the most relevant authors in the domain of robo-advisor research, ranked by their number of published documents. At the forefront is Kobets, V., who stands out with a total of 12 documents, indicating a substantial contribution to the field. Kobets, V., is Jung, D., with 7 documents, underscoring a strong presence in the area. The table also lists Bhatia, A., Chandani, A., Glaser, F., Oehler, A., and Savchenko, S., each with 4 documents to their credit, showcasing their consistent research output. Furthermore, authors Belanche, D., Casaló, L.V., and Day, M.Y., have made notable contributions, with 3 documents each, rounding out the list of influential voices in the research community of robo-advisors.

Table 1 Key aspects of the investigation.

Description	Results
Main information about data	
Timespan	2017:2024
Sources (Journals, Books, etc.)	203
Documents	269
Annual Growth Rate %	-4.97
Document Average Age	3.17
Average citations per doc	10.61
References	10302
Document contents	
Keywords Plus (ID)	816
Author's Keywords (DE)	684
AUTHORS	
Authors	607
Authors of single-authored docs	53
Authors collaboration	
Single-authored docs	55
Co-Authors per Doc	2.67
International coauthorships %	17.47
Document types	
article	160
book chapter	37
conference paper	72

Source: Generated by the author using Biblioshiny

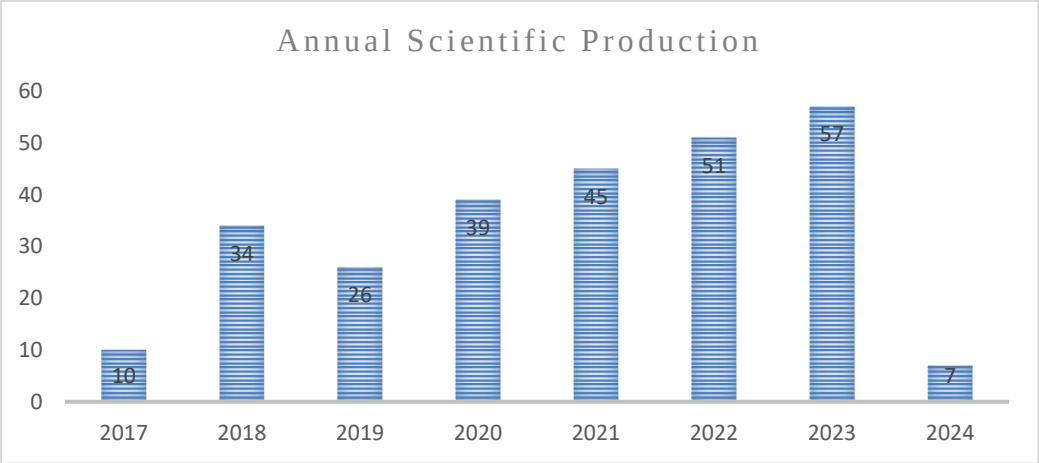

Figure 2 Annual scientific article production from 2017 to 2024.

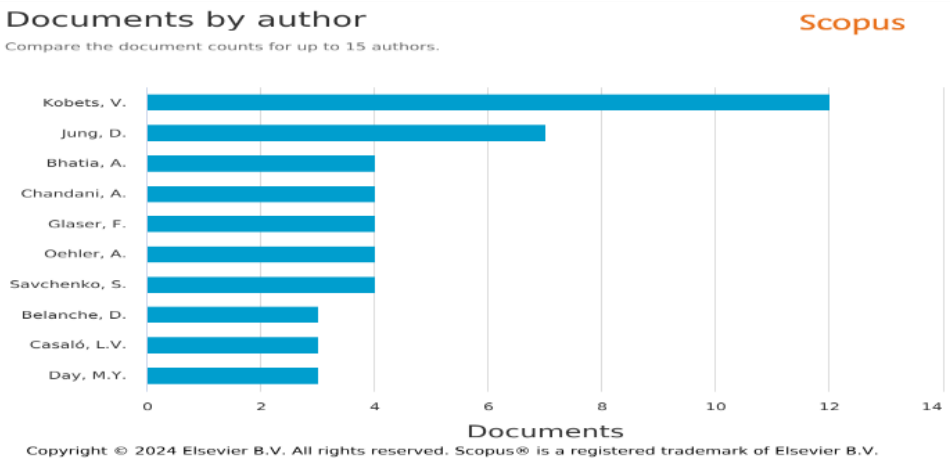

Figure 3 Most Relevant Authors.

4.3. Most relevant sources

Figure 4 displays a list of academic journals and conference proceedings that are prominent in the publication of robo-advisor research, along with the number of articles published in each source. "Sustainability (Switzerland)" leads this list with six articles, indicating a significant interest in the sustainability aspects or impacts of robo-advisors. This is followed by a group of sources each with five articles: "Communications in Computer and Information Science," which suggests a strong link to the technical and computational side of robo-advisors; "Finance Research Letters" and "Journal of Wealth Management," both highlighting the financial and investment relevance of robo-advisors; and "Lecture Notes in Computer Science," which includes subseries focused on artificial intelligence and bioinformatics, pointing to the technical depth and interdisciplinary applications of robo-advisors. Furthermore, "CEUR Workshop Proceedings," "Frontiers in Artificial Intelligence," "Lecture Notes in Networks and Systems," "Management for Professionals," and "Risks" each published four articles, indicating that these sources are also key contributors to the discourse on robo-advisors.

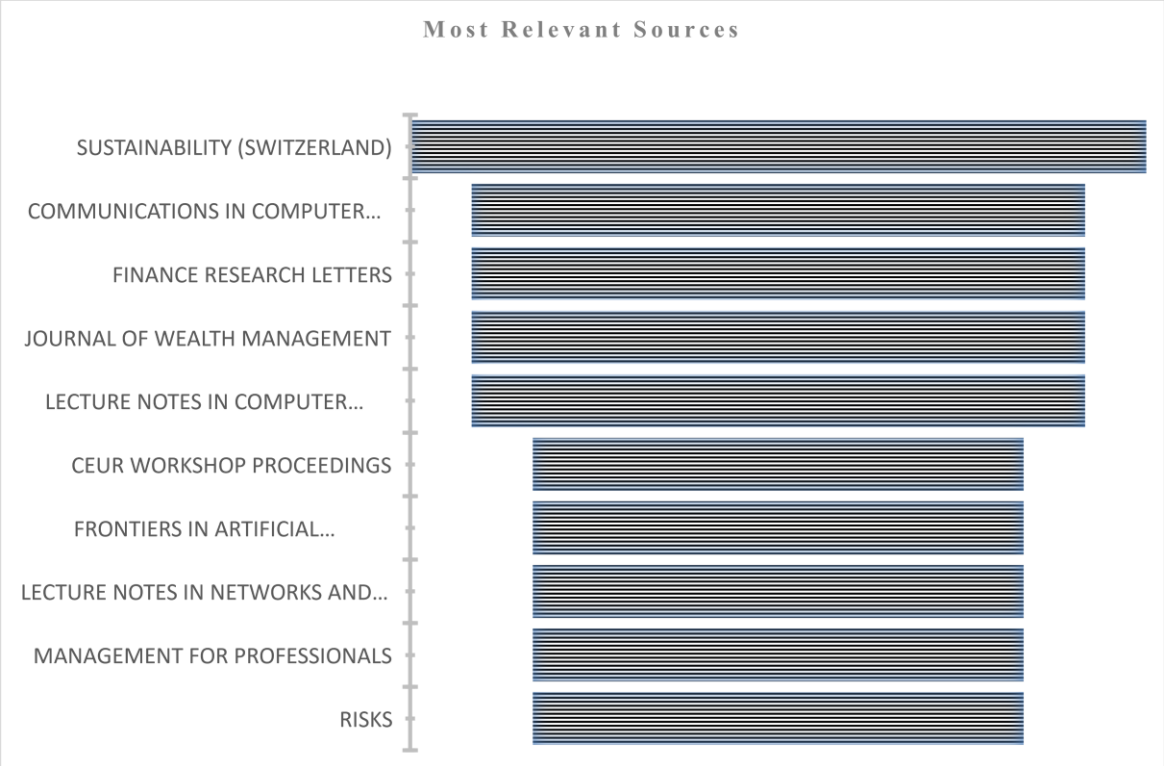

Figure 4 Most relevant sources.

4.4. Most global cited documents

Table 2 presents the lists of globally cited documents in robo-advisor research, ranked by the total number of citations received, which provides some measure of the most influential papers in this field according to some form of the international academic community. Similarly, the number of papers by Belanche D. from 2019 found in "Industrial Management & Data Systems" is 277, which is noted as the highest echelon of citation influence, considering the large annual citation rate of 46.17 and a normalized citation of 11.56. Next is JUNG D's 2018 work in "Business & Information Systems Engineering," which was referenced 120 times, showing a very high relevance level with an annual citation of 17.14 and normalized to 6.14. For example, Zengin in "The Computer Journal" has 108 citations and an annual citation impact of 18, meaning that this publication indicates great interest in the field of computational robo-advisor research at a very high level. Indeed, the article by FLAVIÁN C et al., "A Note on Virtual Value Chains in Electronic Commerce," published in 2022 in the "Journal of Service Management," is already capturing due attention with 99 citations, a very high velocity of yearly citation at a rate of 17.29. JUNG D also displays another influential paper in "Electronic Markets," published in 2018, with great impact accounting for 98 citations in the field and an annual rate of 14. Further notable contributions are MANNARO K's paper in 2017 at the AEIT International Annual Conference, TAO R's paper in 2021 at "Technological Forecasting & Social Change," HILDEBRAND C's paper in 2021 at "Journal of the Academy of Marketing Science," BRENNER L's work in 2020 in the "Journal of Behavioral and Experimental Finance," and PHOON K's article from 2018 in the "Journal of Alternative Investments," all of which point to enormous citations. The contributions are, therefore, representative of their significant involvement and influence in furthering research on robo-advisors. The following documents underline, through their citation metrics, the pivotal place of such works to outline the future orientations of research in an evolving field such as robo-advisor.

Table 2 Most globally cited documents.

Paper	Total Citations	TC per Year	Normalized TC
BELANCHE D, 2019, IND MANAGE DATA SYS	277	46.17	11.56
JUNG D, 2018, BUSIN INFO SYS ENG	120	17.14	6.14
ENGIN Z, 2019, COMPUT J	108	18	4.51
FLAVIÃ⍰N C, 2022, J SERV MANAGE	99	33	17.29
JUNG D, 2018, ELECTRON MARK	98	14	5.02
MANNARO K, 2017, AEIT INT ANNU CONF: INFRASTRUCTURES ENERGY ICT: OPPOR FOSTER INNOV, AEIT	95	11.88	4.97
TAO R, 2021, TECHNOL FORECAST SOC CHANGE	75	18.75	6.86
HILDEBRAND C, 2021, J ACAD MARK SCI	69	17.25	6.31
BRENNER L, 2020, J BEHAV EXP FINANC	61	12.2	5.07
PHOON K, 2018, J ALTERN INVESTM	61	8.71	3.12

Source: Generated by the author using Biblioshiny

4.5. Trend topics

The trend topics depicted in Figure 5 exemplify critical themes in the research landscape of robo-advisors over the period from 2018 to 2022, whereby this great dynamism in focus is pinpointed. A trend that, thanks to machine learning, is presented to have prominence and growth until 2022, in which there will be a peak development, and this will be the rise of the importance of increasingly sophisticated algorithms for robo-advisor Robo-advisors; financial markets, investments, artificial intelligence, and decision-making are all core topics that seem to have a continuous presence throughout the timeline, hinting that these are some of the foundational themes within robo-advisor research. There was only a surge of focus in deep learning in 2020, which seems to suggest that the use of complex neural networks within the subfield became particularly popular that year. Meanwhile, finance and automation are observed as steady research interests, indicating their integral role in robo-advisor technology. The peak in topics related to costs and learning systems approximately 2020 might reflect a momentary emphasis on the efficiency and educational aspects of robo-advisors. Furthermore, a rise in the discussion on information systems and investment decisions in 2021 could signal a shift toward the exploration of the integration of robo-advisors with broader information systems and their impact on investment strategy formulation. Although less frequently mentioned, the financial industry and data handling also emerge as pertinent subjects, possibly highlighting specific operational and data-related challenges in earlier years. The trends depicted through the size and distribution of the bubbles across the years indicate the evolving nature of robo-advisor research, reflecting technological advancements, shifts in market focus, and the ongoing development of financial advisory solutions.

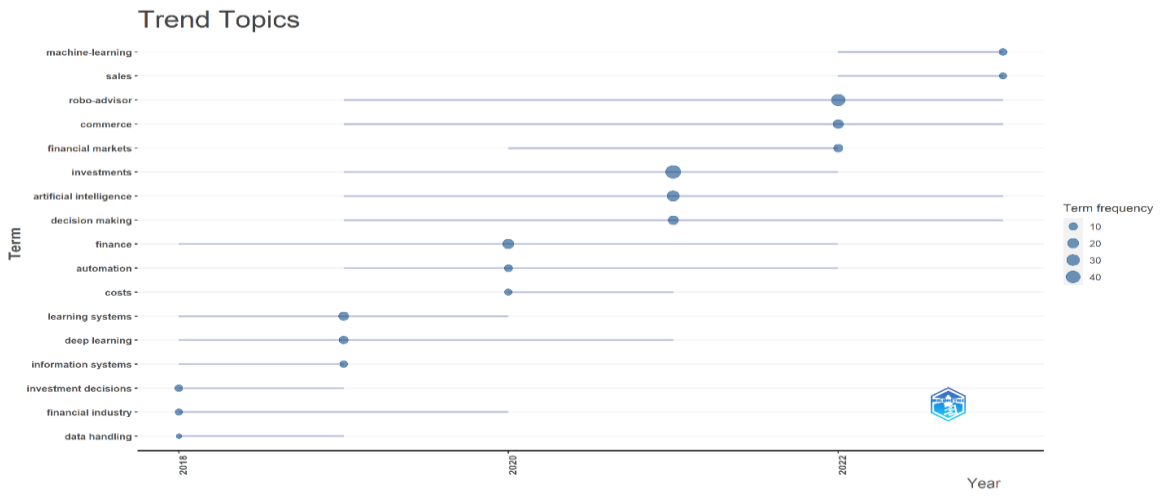

Figure 5 Displays a visual representation demonstrating the popularity of various topics.
Source: Generated by the author using Biblioshiny

4.6. Thematic map

The thematic map in Figure 6 shows the landscape of research on robo-advice by categorizing topics into four quadrants based on their developmental degree (density) and relevance degree (centrality) in the field. In the **"Motor Themes"** quadrant, we see terms such as "financial service," "investment decisions," "investment portfolios," and "investments" alongside "robo-advisor" and "commerce." These terms are considered central to robo-advice research, driving the field forward due to their high centrality and development. They are well-established topics that receive continuous attention and contribute to the progression of the domain. The "Niche Themes" quadrant

comprises themes such as "blockchain," "digital transformation," and "business opportunities," which have high development and low centrality in comparison to the Motor Themes. These are highly specific, highly developed topics that may be at the cutting edge of robo-advice research, pushing the boundaries of the field into new and interesting territory. A number of thematic areas are positioned in the "Basic Themes" quadrant, relating to "artificial intelligence," "finance," and "decision making" as key foundational elements, which have high centrality and low development in comparison to the Motor Themes, underlying a significant number of other topics in the field. Last, the "Emerging or Declining Themes" quadrant comprises terms such as "perceived risk," "risk perception," "financial robo-advisor," "surveys," "intention to use," and "user perceptions", which possess relatively low centrality and development, being either on the rise as new areas of related interest blossom or on the decline as factions of the research lifecycle reach maturation. The presence of "robo-advisor" and "commerce" as central themes across all quadrants underscores their foundational nature to the field. The strategic positioning of themes across the map provides insights into the state of research within the robo-advisor literature, indicating which areas are saturated, which are developing, which are fundamental, and which might represent future trends or gaps in the current research landscape.

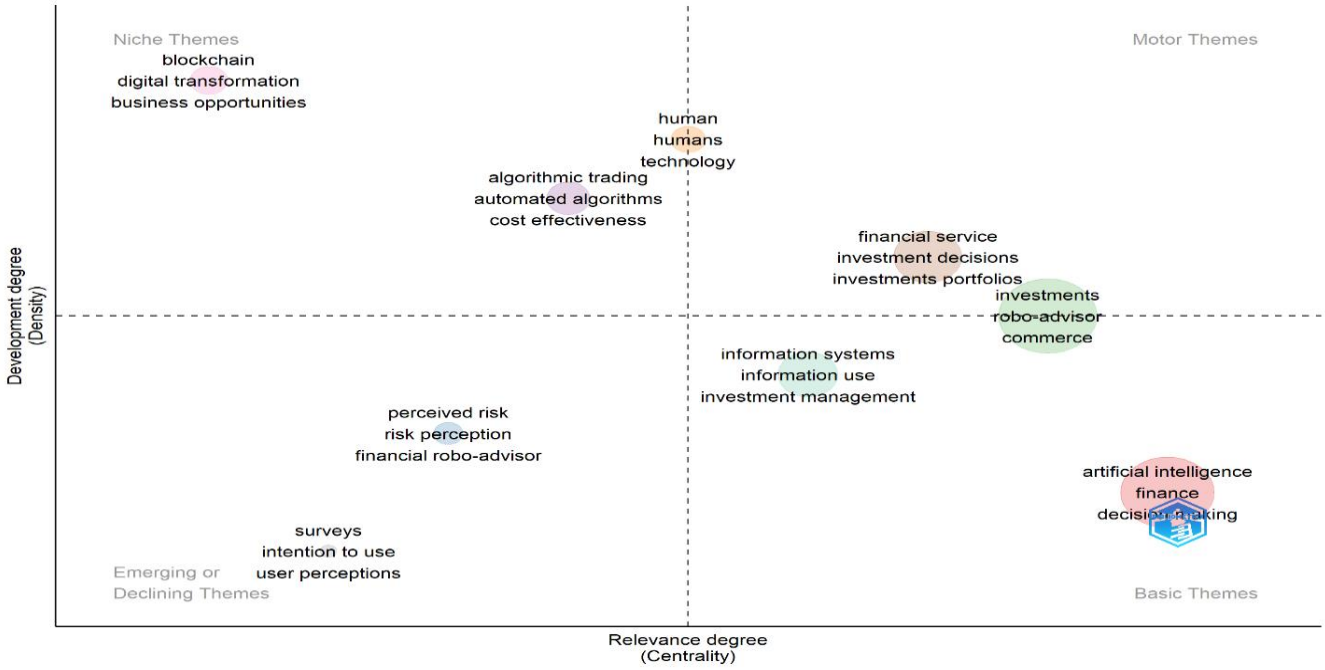

Figure 6 Thematic visualization of keywords.
Source: Generated by the author using Biblioshiny

4.7. Conceptual structure map using multiple correspondence analysis

The conceptual structure map using multiple correspondence analysis (MCA) in Figure 7 visualizes the relationships between different research themes in the field of Robo-advisors, as depicted in Figure 5. MCA is a statistical technique that is used to detect and represent underlying structures in categorical data. It helps in understanding the relationships between different categories by projecting them into a lower-dimensional space. The map is color-coded to distinguish between clusters of related themes:

Axes: The map has two axes, Dim 1 and Dim 2, which explain a certain percentage of the variance in the data. Dim 1 explains 36.1% of the variance, which is quite significant, and is the primary axis of differentiation among the categories. Dim 2 explains a smaller percentage and is orthogonal to Dim 1.

Color Regions: There are typically three regions, each color-coded, which might represent different groups of related concepts or categories. In this case, there is green, red, and blue.

Concepts: The words spread across the map are the categories or concepts that are being analyzed. Their positions relative to each other and to the axes provide information about their relationships.

Green Region: The concepts in this area are 'decision support systems', 'robo-advisory', and 'information systems'. These seem to be closely related and possibly represent the technical and informational aspects of robo-advisors.

Red region: This region includes terms such as 'investment decisions', 'risk assessment', 'compliance', 'consulting', 'auditing', and 'management'. These terms are likely related to the functions and services provided by robo-advisors, who focus on decision-making processes, compliance with regulations, and investment management.

Blue Region: The concepts 'perception', 'technology adoption', and 'option' are in the blue area, which might indicate factors influencing the adoption of robo-advisors, the perception of users toward this technology, and the options available in the robo-advisory space.

Proximity of Concepts: Concepts that are closer to each other are more closely related in the context of the data analyzed. For example, 'risk assessment' is close to 'compliance', suggesting a strong relationship between these two in the context of robo-advisors.

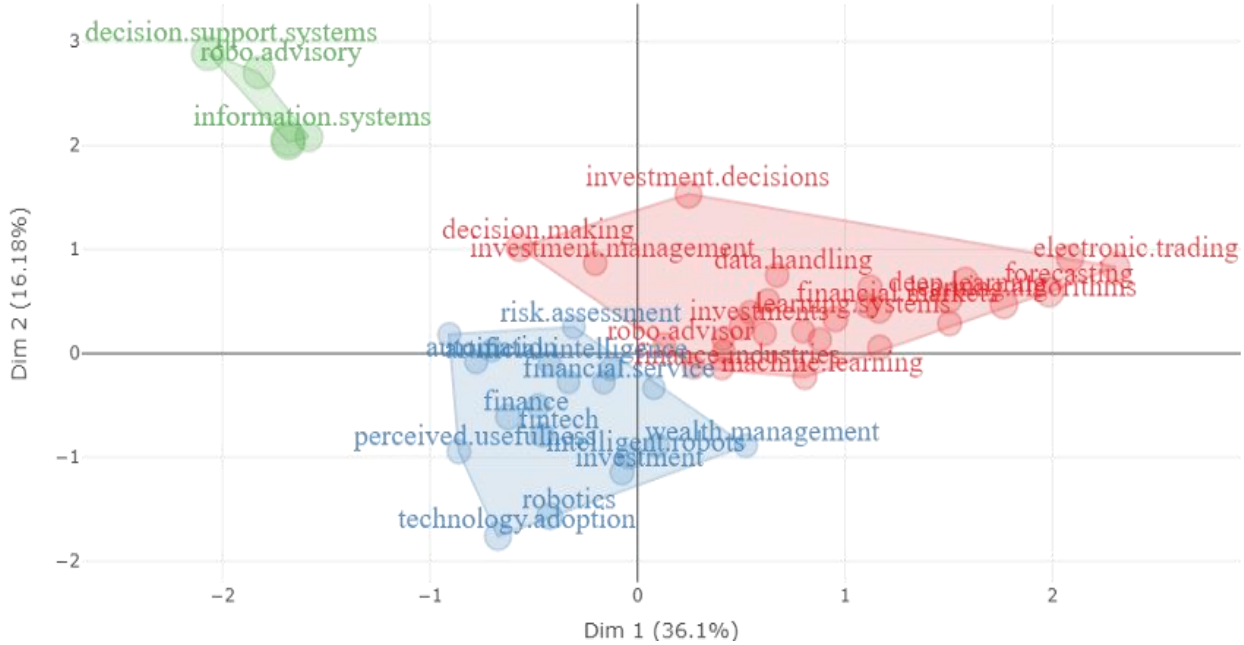

Figure 7 Conceptual arrangement of the subject area.
Source: Generated by the author using Biblioshiny

4.8. Cocitation of authors

The cocitation of cited authors refers to a situation where two authors are cited together in other research papers. It is a method used to establish a relationship between authors in a particular field of study, helping to map scholarly communication and to identify influential authors, thought leaders, and collaborative networks. Figure 7 depicts the graphical representation of scholarly connections between authors based on the frequency of their cocitation in other works. The minimum citation threshold of 5 for an author to be included in the network ensures that the visualized connections represent significant and influential scholarly relationships. With 775 authors out of 13331 meeting this criterion, the network highlights the most prominent and influential authors within the Robo-Advisors research community. The network consists of 7 clusters. The size of each cluster and the density of connections within them suggest how prolific or interconnected the authors are in each thematic area. Cluster 1 (red, 146 items) is the largest in terms of item count, suggesting that the authors in this group are frequently cited together and may represent a core area of research within the robo-advisor field. The density of connections could indicate a well-established area of research, with many authors contributing to a common theme or set of themes. Cluster 2 (green, 145 items) is almost as large as the first, with 145 items. This implies that another significant body of research closely related to the main themes of robo-advisors. The authors in this cluster may focus on a different aspect of the research field compared to Cluster 1 but still contribute significantly to the overall discourse. Cluster 3 (blue, 137 items) represents another major component of the network, suggesting that these authors may be involved in a specific thematic niche within robo-advisor research or represent an emerging trend that is gaining traction. Cluster 4 (Yellow - 128 items) represents a group of authors whose work is seminal or fundamental to the field of robo-advisors, potentially including foundational theories or methodologies that other research builds upon. Cluster 5 (Purple - 113 items) signifies a specialized area of robo-advisor research, possibly a subfield or a cross-disciplinary area that intersects with the central themes of robo-advisors. Cluster 6 (Light Blue - 55 items) indicates a group of authors who are either new to the field, work on highly specialized topics, or represent an emerging area of research within the domain of robo-advisors. In Cluster 7 (Orange - 50 items), the smallest cluster suggested a niche area within the research field.

By analyzing the influence of authors based on citation count in robo-advisor research, Jung D. clearly emerges as a highly influential figure with 167 citations and the highest total link strength of 1335, indicating extensive connections within the research community. Similarly, Dorner V. and Glaser F. demonstrated substantial contributions, with 112 citations and 108 citations, respectively, along with robust total link strengths. Flavian C., Belanche D., and Casalo L.V. also exhibited significant influence on their notable citation counts and strong total link strengths, highlighting their extensive connections and contributions to the field. Although Morana S., Venkatesh V., Kobets V., and Rossi A.G. have slightly lower citation counts, their work still holds influence within the robo-advisor research community, albeit with varying degrees of connectivity.

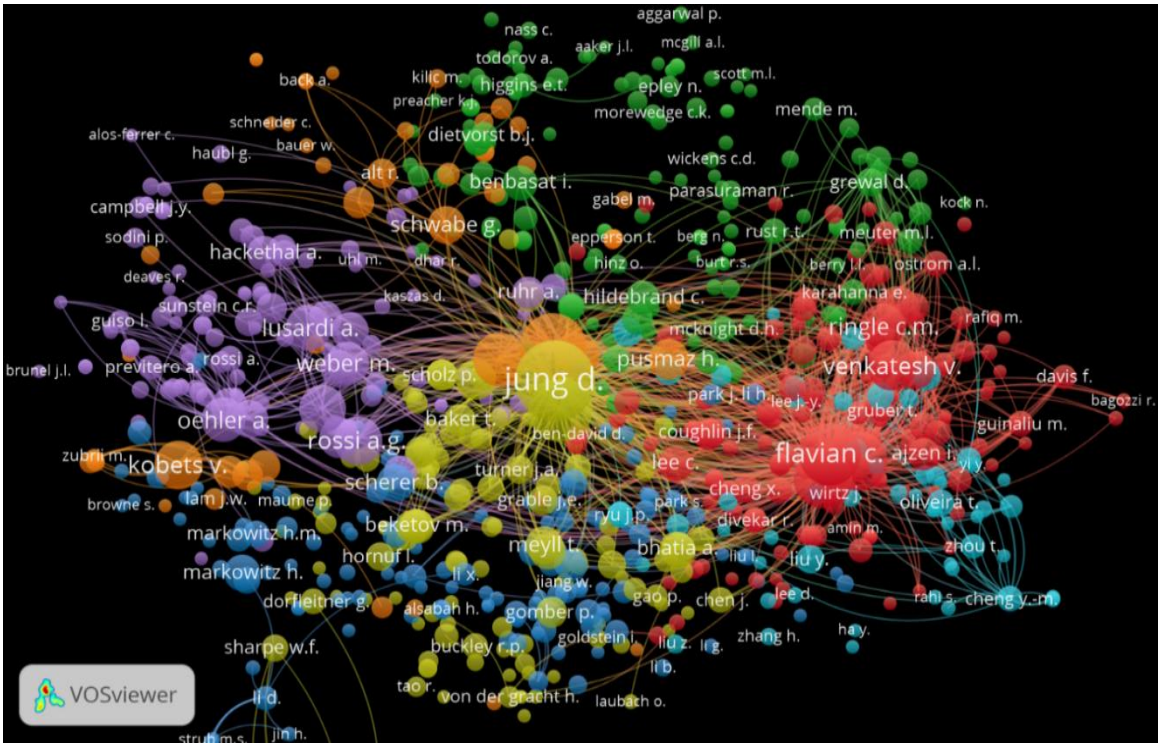

Figure 8 Cocitation of Cited Authors.
Source: Generated by the author using VOSviewer

4.9. Co-occurrence of authors

The co-occurrence network visualized in Figure 9 represents the interrelation of keywords in the Robo-advisor research domain. The network, with a minimum occurrence threshold of 5, consisted of 63 keywords out of 1302, which were categorized into four distinct clusters. Cluster 1 (red, 22 items) included terms such as “machine learning”, “forecasting”, “learning systems”, and “neural networks”. It bears the imprint of a robotic-advisor technical spine because these are the methods and approaches developed via algorithms, which allow robo-advisors to process data and forecasts. This translates in practical terms into a great deal of support for the implementation of technologies related to artificial intelligence and, more specifically, data science within the practice of financial advising. Cluster 2 (green-18 items) included keywords such as 'blockchain', 'financial literacy', 'portfolio management', and 'financial advice'. They mention in this group those applications of personal finance and asset management where the robo-ad mode is being used: wealth management using blockchain technology. This paper presents research on the influence of robo-advisors on consumers' understanding of finance and investment management strategies. The most prominent keywords in Cluster 3 (blue–13 items) include 'fintech', 'artificial intelligence', 'finance', and 'innovation'. Here, the focus seems to be where financial technology and innovation meet to underscore the importance of AI in changing finance. The fact that this cluster is conjoined with "robo-advisory" and "robo-advisors" points to a wide discourse on both technologies' impacts within the finance sector. Cluster 4 (yellow—10 items) contains 'Technology acceptance', 'Electronic trading', 'Asset allocation', and 'Commerce'. This cluster refers to the market and consumer side of robo-advisors and how the tools are accepted by the users in relation to their integration into the broader commercial landscape. This might be the cluster reflecting research on the adoption of robo-advisors by retail investors and its impact on the trading practices carried out.

The analysis of the most common keywords in robo-advisor research revealed that "robo-advisor" was the most frequently used keyword, occurring 93 times with a total link strength of 109, indicating its central role and extensive discussion in the literature. "Fintech" and "artificial intelligence" follow closely, with 63 and 61 occurrences, respectively, showing the intersection of financial technology and advanced algorithms in robo-advisors. "Investments" also feature prominently, reflecting the primary focus of robo-advisors on automated investment management. Additionally, "machine learning" underscores the utilization of advanced computational techniques in developing robo-advisor platforms. Other notable keywords include "finance," "commerce," and "decision making," highlighting broader concepts within the realm of financial technology and automated investment advice. "Robo-advice" appears with slightly fewer occurrences but is still relevant, while its lower total link strength suggests a narrower focus or less interconnectedness compared to other keywords. Overall, these keywords collectively represent the core themes and areas of research interest within the field of robo-advisors, emphasizing the integration of technology, finance, and decision-making processes.

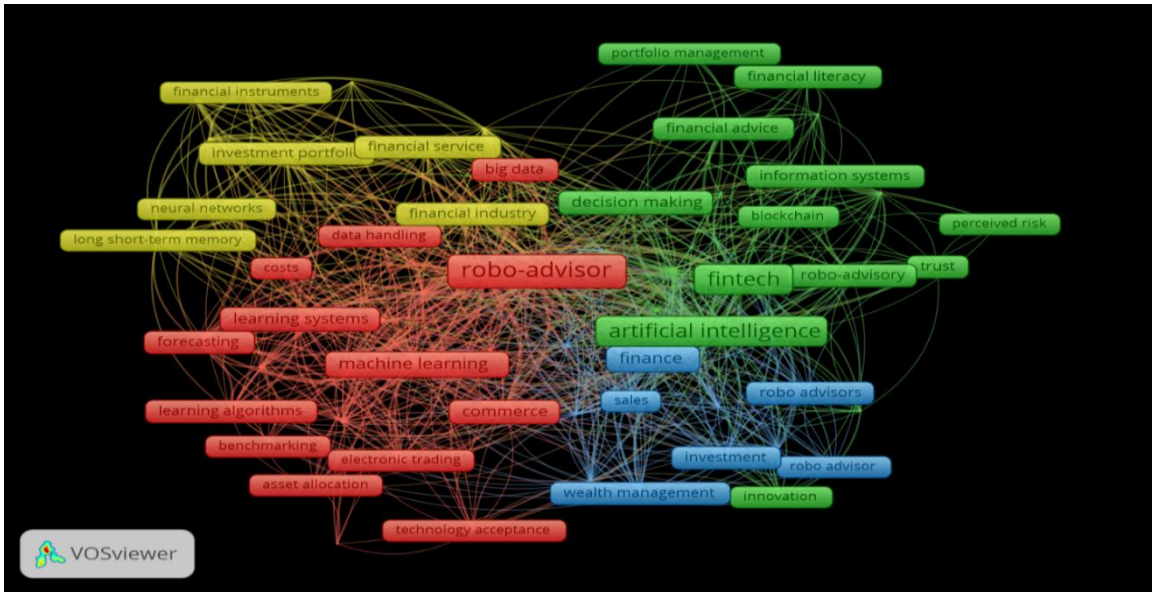

Figure 9 Co-occurrence of all keywords.
Source: Generated by the author using VOSviewer

4.10. Keywords with strongest citation bursts

Figure 10 highlights the top 5 keywords with the strongest citation bursts in robo-advisor research from 2017 to 2024, underscoring pivotal themes in the field. Citation bursts represent periods where a keyword sees a significant spike in mentions, indicating a surge in interest or relevance within the academic community. The keyword "Learning Systems" experienced a burst in 2018, with a strength of 2.93, signifying a keen interest in machine learning and AI's role in advancing robo-advisors. This period marks a crucial point where advancements in AI technology were likely driving the development of more sophisticated, automated financial advice solutions. Both "information systems" and "information use" scored 2.31 in 2018, indicating an aggregate direction toward an activity that is performed, for example, by robo-advisors in terms of managing and deploying information, which reflects the ability of algorithms to handle extensive financial data for making investment decisions and dynamics of interaction with them. For example, the keyword "costs," with a peak force of 2.23 and placed in 2019, seems to announce a developing discourse on the cost efficiency of robo-advisors versus human advice—from the potential that those technologies can help reduce operational costs and lower user fees. Taken together, the increase in "Fintech" to 2.23 in 2019 and the broader exploration of financial technologies focused on robo-advisors, each of which has deepened the acknowledgment of technology as a revolutionary force in finance transformation. These citation bursts not only illuminate the shifting focus within robo-advisor research but also mirror wider trends in finance and technology, particularly the escalating integration of AI and the disruptive impact of fintech on financial services.

Keywords	Year	Strength	Begin	End	2017 - 2024
learning systems	2018	2.93	**2018**	2019	
information systems	2018	2.31	**2018**	2019	
information use	2018	2.31	**2018**	2019	
costs	2019	2.23	**2019**	2020	
fintech	2019	2.23	**2019**	2020	

Figure 10 Keywords with the strongest citation bursts.
Source: Generated by the author using CiteSpace

4.11. Network visualization of cited authors

Figure 10, visualized by CiteSpace, offers a network visualization that maps out the interconnected citations within robo-advisor research, reflecting the evolution of the field through various research papers. This visualization is broken down into distinct clusters, each representing a thematic concentration of studies. Cluster #1, a systematic literature review, is the largest,

with 35 members, and is highly coherent, as indicated by its silhouette value of 0.807. It is prominently cited by Cardillo, G's 2024 article on robo-advisors. Notable within this cluster are works by Jung D (2018) on designing for risk-averse consumers, Brenner L (2020) on robo-advisors as a substitute for human advice, and DAcunto F (2019) on the potential and challenges of robo-advising. Cluster #18, which also focused on robo-advisors, shares its most cited members with Cluster #1, indicating overlapping influences. Clusters #14 and #28 further explore the role of robo-advisors in managing portfolios and the quantitative methods employed within them, while Cluster #10 delves into systematic reviews once again. The presence of significant cross-citations, such as those of Jung D and Brenner L, underscores the impact of certain studies across different areas within this domain. The silhouette values close to or equal to 1 in some clusters suggest a strong thematic alignment within those groups.

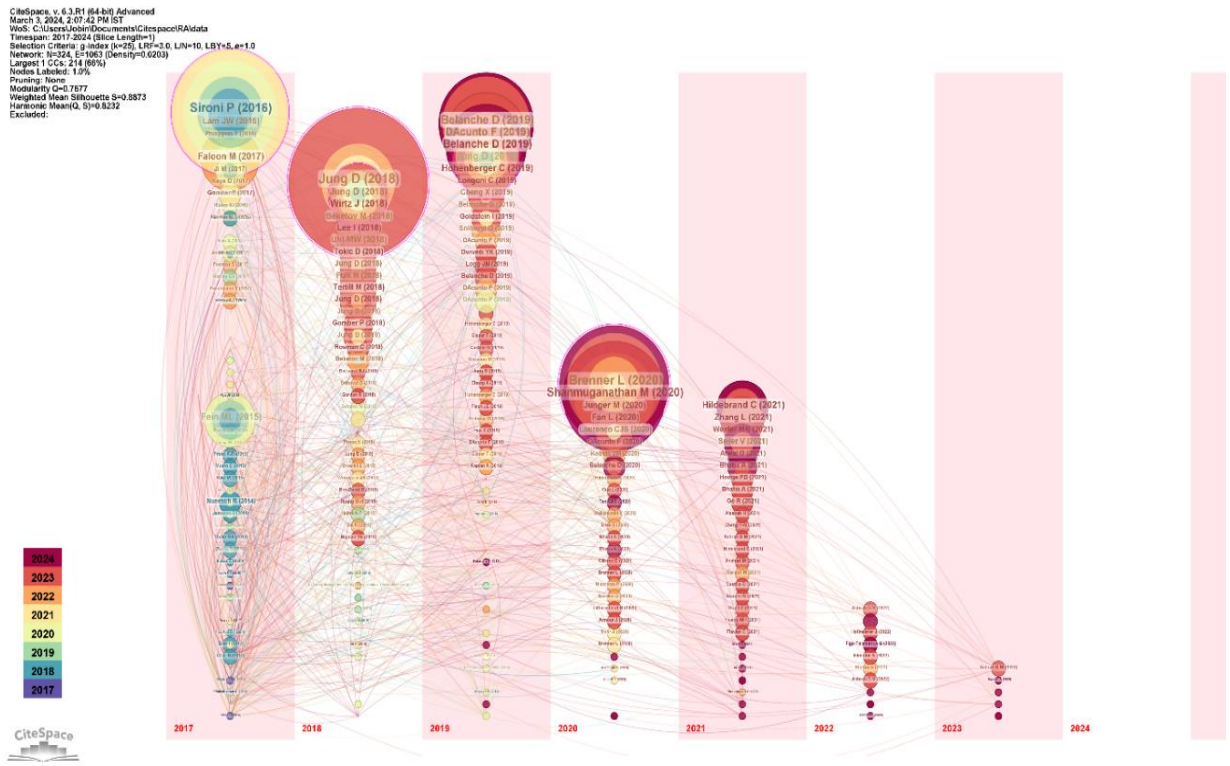

Figure 11 Time zone network visualization of cited authors.
Source: Generated by the author using CiteSpace

4.11. Network visualization of cited journals

Figure 11 depicts the network visualization of cited journals in Robo-Advisors research and elucidates the comprehensive landscape of this field, segmented into 10 distinct clusters. Each cluster embodies a unique facet of research focus, linked by overlying themes and highlighted by pivotal scholarly works. Cluster #0, with 54 members, bears a silhouette value of 0.849, signifying its strong internal coherence. This cluster is dedicated to mitigating the adverse impacts within its realm, emphasizing artificial intelligence (AI) in financial services. A key piece, "Managing consumers' adoption of artificial intelligence-based financial robo-advisory services", by Ashrafi, Dm, published in the "Journal of Indonesian Economy and Business," encapsulates the cluster's core aim of counterbalancing the negative implications through AI in financial sectors. With 46 members and a silhouette value of 0.643, Cluster #1 ventures into understanding user interactions and technology utilization, particularly focusing on investment portfolio risk attitudes. The recurrence of Ashrafi and Dm's work underlines the intertwined nature of user engagement and AI in financial decision processes. Cluster #2 highlights the growing importance of consumer behavior, with 31 members and a silhouette value of 0.746. The repeated citation of Ashrafi's and Dm's articles underscores the prevalent theme of consumer adoption of AI-based services across clusters. Exploring company strategies for enhancing onboarding experiences, Cluster #3, with 28 members and a silhouette value of 0.663, delves into the interplay between technology, firm strategy, and user experience in the AI-driven financial advisory domain, as discussed in Ashrafi, Dm's research. Cluster #4 identifies critical drivers within the sector, connecting literature reviews and investment behaviors through 22 members and a silhouette value of 0.841. The pivotal role of AI in financial advisory services is mirrored in the major work cited by Ashrafi, Dm. With a focus on blockchain's impact on the energy market, Cluster #5 showcases 15 members and a remarkable silhouette value of 0.976, marked by Mannaro, K's study on blockchain-oriented energy markets in the context

of crypto-trading. Cluster #6, centered on algorithmic advice in financial investments with 15 members and a silhouette value of 0.743, is highlighted by Hyun, Baek T's investigation into AI robo-advisor anthropomorphism. By addressing decision inertia, Cluster #7, with 14 members and a silhouette value of 0.86, explores robo-advisory's role in nudging decision-making, as discussed in Jung, D's work. Cluster #8, composed of 12 members with a silhouette value of 0.881, confronts big data challenges in robo-advisory development, with Filiz, I's discourse on algorithm aversion. Last, Cluster #9, the smallest with 7 members and a silhouette value of 0.958, focuses on machine learning for trend-following ETF investments, prominently featured in Baek, S's article.

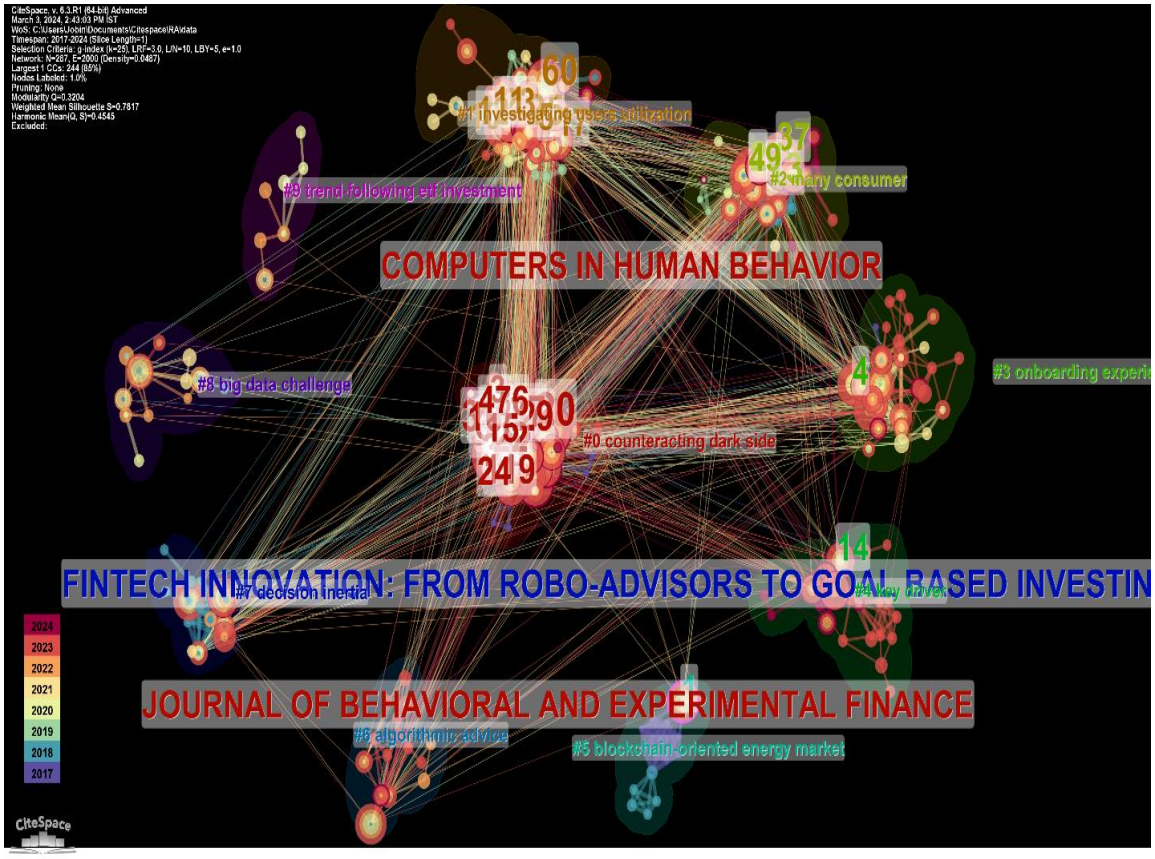

Figure 12 Curved cluster network visualization of cited journals.
Source: Generated by the author using CiteSpace

4.12. Timeline network visualization of countries collaborations

Figure 12 presents the Timeline Network Visualization of Countries Collaborations, which illustrates the collaboration landscape among countries in robo-advisor research, segmented into distinct clusters with unique themes and research foci. The network consists of 6 clusters and 3 major clusters as follows. Cluster #1, "COUNTERACTING DARK SIDE," addresses the potential negative aspects of robo-advisors, such as justice and privacy concerns, which are especially pertinent to young retail investors. Malaysia, Pakistan, and Sweden are leading this research area, with Aw's 2024 article shedding light on mitigating the undesirable effects of robo-advisors being a pivotal piece. "FINANCIAL ROBO-ADVICE," designated Cluster #2, focuses on the quintessential advisory role of robo-advisors within finance, with a particular interest in the use of genetic algorithms. This theme is primarily spearheaded by Australia, Singapore, and Portugal. Lourenço's 2020 work critically investigated the influences on the acceptance of financial robo-advice, highlighting trust and perceived expertise as core factors. Cluster #3, identified as "FINANCIAL CRISIS," explores the functionality and influence of robo-advisors in times of economic downturn, including the modulation of effects and trust mechanisms. Germany leads the most citations within this cluster, followed by Italy and Switzerland. The 2021 publication by Avgouleas offers an in-depth look at the governance of digital finance in the European Union, emphasizing regulatory frameworks. Each cluster exhibited high silhouette values, indicating strong intracluster coherence and well-differentiated research areas. The interlinking lines between countries likely represent joint research initiatives, with the most cited countries taking a leading role in their respective clusters. The map also reflects the dynamic evolution of the research field from 2017 through 2024, demonstrating the progressive collaboration and growing body of work in robo-advisor research.

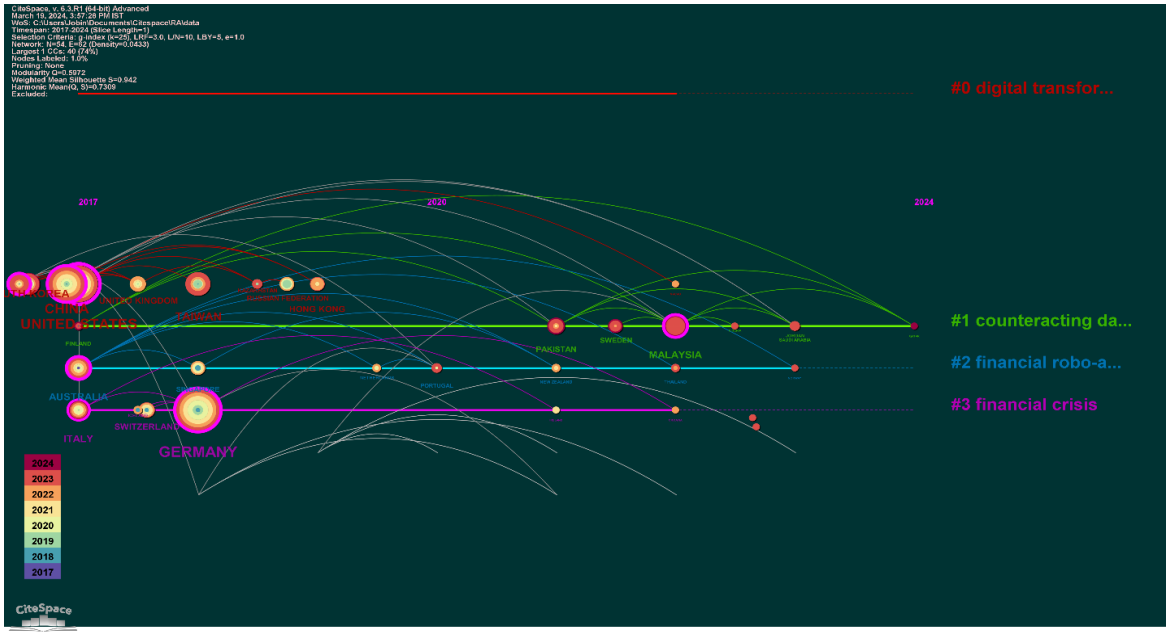

Figure 13 Timeline network visualization of country collaborations.
Source: Generated by the author using CiteSpace

5. Discussions

Research on robo-advisors spanning from 2017 to 2024 analyzed 269 documents from 203 sources, showing an annual growth rate of -4.97%, with an average number of citations per document of 10.61. The document analysis revealed a significant emphasis on collaboration, with 607 authors contributing, yet only 53 producing single-authored documents, and a coauthorship rate of 2.67 per document, including 17.47% international coauthorships. The documents comprised various types, including 160 articles, 37 book chapters, and 72 conference papers, highlighting a diverse range of research outputs on the topic. The annual scientific production on robo-advisor research from 2017 to 2024 shows a steady increase from 10 articles in 2017 to 57 in 2023, indicating growing interest and research activity in this field. Kobets, V. leads in robo-advisor research with 12 publications, followed by Jung, D. with 7, and several authors, including Bhatia, A., Chandani, A., Glaser, F., Oehler, A., and Savchenko, S., contributing 4 each, demonstrating a diverse and engaged academic community. Sustainability (Switzerland) leads in robo-advisor research publications with six articles, followed closely by several sources with five, reflecting a strong interest in the sustainability, technical, and financial aspects of robo-advisors. The research on robo-advisors highlights Belanche D.'s 2019 paper in "Industrial Management & Data Systems" as the most cited with 277 citations, signifying its major influence, followed by JUNG D.'s work in 2018 with 120 citations, indicating significant relevance and impact in the field. These works, along with other highly cited documents such as those by Zengin, FLAVIÁN C, and JUNG D.'s second paper, demonstrate the pivotal role these publications play in shaping the direction of robo-advisor research globally.

The trend topics in robo-advisor research from 2018 to 2022 emphasize the evolution of themes such as machine learning, financial markets, investments, artificial intelligence, and decision-making, with a notable peak in deep learning interest in 2020 and shifting focuses toward efficiency, information systems, and investment strategies over time. The thematic map of robo-advice research categorizes topics into four quadrants, revealing "financial service" and "investment decisions" as central motor themes, "blockchain" and "digital transformation" as cutting-edge niche themes, foundational elements such as "artificial intelligence" in basic themes, and "perceived risk" in emerging or declining themes, highlighting the field's evolving focus and foundational areas. The Conceptual Structure Map using Multiple Correspondence Analysis (MCA) on robo-advisors research delineates three main thematic clusters—technical and informational aspects in green, decision-making and management functions in red, and factors influencing adoption in blue—with the map axes Dim 1 and Dim 2 explaining significant portions of the data variance. This mapping suggests distinct yet interconnected areas of focus within the field, highlighting the multifaceted nature of robo-advisor research.

A cocitation analysis between authors revealed 13,331 authors in total, of which only 775 met a minimum range; hence, a network of seven unique clusters representing key scholarly relationships in the field and thematic areas was plotted. These are the largest clusters, which in representation tend to highlight most of the frequently cocited authors, such as Jung D., Dorner V., and Glaser F., showing that exams on collaboration and thematic concern are very common in studies of robo-advisors. The co-occurrence network of keywords in robo-advisor research reveals nodes in clusters of four, which clearly depict a thrust on domains that have already or are still diving into advanced technology integration with investment management. In summary, they encapsulate "machine learning," "blockchain," "Fintech," and "technology acceptance" as their

prime thematic areas. This network places robo-advisory services in the amalgamation of finance and technology by outlining a shift to the practical orientation of intelligent algorithms to financial and advisory services, impacts on investment strategies, and consumer acceptance. Analysis citations most often burst in Learning Systems between 2017 and 2024, Information Systems, Information Use, Costs, Fintech—particularly high mentions in temporal interest peaks connected to them, or part of particularly important new relations to advancements regarding AI, cost efficiency, and fintech integration in the development of the field of Robo-Advisors. The network visualization in CiteSpace of cited authors in robo-advisor research highlights key thematic concentrations, with a systematic literature review cluster led by Cardillo, G's 2024 article and notable works by Jung D and Brenner L, demonstrating the field's evolution and the interconnected impact of seminal studies. The network visualization of cited journals in Robo-Advisors research forms a complex landscape with 10 clusters highlighting diverse research focuses, such as AI in financial services, user interactions, consumer behavior, technology strategy, and blockchain impacts, showcasing the field's multifaceted scholarly dialog. The timeline network visualization of country collaborations in robo-advisor research highlights significant international collaborations across 6 clusters, with Malaysia, Pakistan, Sweden, Australia, Singapore, Portugal, Germany, Italy, and Switzerland leading distinct research themes on the dark side, financial advice, and crisis management in robo-advisors.

The literature on robo-advisors highlights their transformative impact on the financial advisory landscape, showcasing both opportunities and challenges. Several studies indicate that robo-advisors provide a cost-effective and accessible alternative to traditional human advisors, democratizing investment advice for a broader audience (Belanche et al., n.d.; Brenner & Meyll, 2020b). The low fees and automated processes attract novice investors and those with smaller portfolios. Additionally, the integration of advanced algorithms enables personalized portfolio management, enhancing investment efficiency and effectiveness (Brenner & Meyll, 2020b). However, the literature also points out the limitations of robo-advisors, such as the lack of personalized human interaction, which can undermine client confidence and trust (Hyun Baek & Kim, 2023; Ku & Wang, 2022). Furthermore, the basic profiling questionnaires used by robo-advisors may not capture the nuanced needs of all investors, potentially limiting the advice's applicability and accuracy (Guo, 2020). As such, there is a growing interest in hybrid models that combine automated advice with human oversight to address these shortcomings and enhance user experience (Brunen & Laubach, 2022; Guo, 2020). This dual approach could offer the best of both worlds, leveraging technology's efficiency while maintaining the personalized touch of human advisors. The current state of research underscores the need for continued exploration of these hybrid models and the development of more sophisticated algorithms to better serve diverse investor needs (Hong et al., 2023; Xia et al., 2023).

6. Research Gaps and Practical Implications

The bibliometric analysis of robo-advisor research highlights several research gaps that warrant further exploration. First, however, machine learning and AI are underpinning the technology of robo-advisors, and the surge in deep learning focus in 2020 suggests underexplored areas in which complex neural networks are applied for financial advice. Second, it shows either a misapprehension of how such technologies interface with and influence financial decision-making processes or discusses the integration of robo-advisors with larger information systems and investment strategy formation influenced by 2021. Third, emergent themes, such as perceived risk, risk perception, and user perceptions, though pointing toward such necessity with low centrality, point to the necessity of further research on the sociopsychological dimensions of robo-advising. Finally, the topics with high development and low centrality included "blockchain" and "digital transformation," which further suggest that the potential of the two technologies, in the context of robo-advising, is largely untapped. This thus points toward opportunities for further research when seeking to bridge such gaps and ultimately pushing the field to new boundaries.

The implications brought up by this research highlight what ought to be working and put in place for furtherance in the field of financial advising, technological integration, and market strategy. First, there is a problem with machine learning and artificial intelligence in such a manner that the call for dramatic growth in the need to push personalization and efficiency in providing financial advice will call for potential pushing of financial institutions to fit in very sophisticated algorithms for more tailored service offerings. The flow of looking at robo-advisor integration with larger information systems likely speaks of platforms that interact seamlessly with many financial ecosystems, thus increasing the chance of positive input into the investment decision-making process. New themes of costs, learning systems, perceived risks, and user expectations underpin a massive consumer rush for transparency and tools in financial services. This has allowed robo-advisory platforms to instill trust and confidence through clear communication but insightful explanations of strategies in place. It should also be emphasized that there is regulatory compliance and ethical consideration of necessity when designing robo-advisory services, with priority given to consumer protection and privacy. Estimation suggests that niche technologies such as blockchain and digital transformation, if explored, represent unexplored innovation potential for robo-advisories and represent new vistas of secure transactions and operational efficiency. This calls for adoption and market penetration strategies that may demystify robo-advisors and broaden their user base. Last but not least, it is obvious that the different technological and thematic issues of robo-advisor research call for cross-disciplinary collaboration, which would further promote innovation and put into place a better regulation that may lead to the cultivation of more mature, friendly robo-advisory services. All these findings have

practical implications for addressing the research gap identified by actors in the robo-advisory ecosystem and, at the same time, finding ways to help increase the impact and reach of robo-advisory services in modern financial markets.

7. Future Recommendations

Future research on robo-advisors should focus on integrating advanced machine learning and AI techniques to improve the personalization and efficiency of financial advice. Investigating how deep learning and neural networks can create more sophisticated robo-advisory systems could lead to significant progress. Additionally, exploring the sociopsychological aspects of user interactions with robo-advisors, particularly perceived risks, trust, and user experience, can provide valuable insights for increasing adoption rates. Research should also examine how robo-advisors can be integrated with broader financial ecosystems, ensuring seamless interaction with other financial services and systems. Moreover, the potential of emerging technologies such as blockchain and digital transformation to enhance the security, transparency, and operational efficiency of robo-advisors requires thorough investigation. Regulatory frameworks and ethical considerations should be continuously updated to address the evolving landscape of robo-advisory services, ensuring consumer protection and privacy. Finally, fostering cross-disciplinary collaboration between finance, technology, and behavioral sciences can drive innovation and lead to the creation of more user-friendly and effective robo-advisory platforms.

8. Limitations of the Study

The analysis is limited by its reliance on the Scopus database, which, despite its extensive coverage, may not include all relevant publications on robo-advisors. Other databases, such as Web of Science or Google Scholar, could provide a broader view of the literature. Furthermore, the study predominantly focuses on quantitative metrics such as citation counts and co-occurrence, which may overlook qualitative aspects of the literature, such as the influence of policy papers or the practical application of robo-advisors in various financial markets.

9. Conclusion

The bibliometric analysis of robo-advisors revealed that the domain of robo-advisory is proceeding at a remarkable pace, and in the domain of robo-advisory, many changes in trends and dynamics can be observed. This reflects increasing academic and practical interest in digital financial advisory services and the impact of technologies on changing the ways in which financial planning and investment management are delivered. This set forth a basic group of major researchers and institutions involved in the scholarly conversation, together with emerging trends within the themes of research and patterns of collaboration. These findings, therefore, would form the rationale on which future studies are anchored for AI and machine-learning technologies to increase the personalization and efficacy of robo-advisor services. It is also important to consider the challenges from a regulatory and ethical point of view of automating the offer of financial advice, taking into account that this evolution should lead to the best for the consumer. Finally, such interdisciplinary cooperation of technologists with financial experts and policymakers may further develop robo-advisors, making them stronger and more secure and, at the same time, allowing them to be available to wider audiences.

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Ethical considerations

Not applicable.

Conflict of interest

The authors confirm that there are no conflicts of interest to declare for this publication.

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