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► To cite this version:

Alexandra Horobet, Sabri Boubaker, Lucian Belascu, Cristina Carmencita Negreanu, Zeno Dinca. Technology-driven advancements: Mapping the landscape of algorithmic trading literature. *Technological Forecasting and Social Change*, 2024, 209, pp.123746. <10.1016/j.techfore.2024.123746>. <hal-04990283>

HAL Id: hal-04990283

<https://hal.science/hal-04990283v1>

Submitted on 13 Mar 2025

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Technology-driven advancements: Mapping the landscape of algorithmic trading literature

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ARTICLE INFO

Keywords:

Bibliometric analysis
Algorithmic trading
Energy trading
Science mapping
Lotka's law

ABSTRACT

Our study is a comprehensive examination of the existing literature pertaining to algorithmic trading and its temporal progression in a framework driven by technology development. A total of 4552 papers were analyzed, spanning the period from 1990 to 2023. Performance metrics evaluation and science mapping approaches were utilized in this study. The data was obtained from the Scopus database, and the analysis was conducted using the Biblioshiny environment. The research landscape has undergone significant changes in recent years due to advancements in data-driven technology and the implementation of sophisticated algorithms such as machine learning, deep learning, and genetic algorithms. The shift in research interest has been particularly pronounced in the last decade compared to earlier periods. The most significant contribution in terms of production is associated with authors who are affiliated with the People's Republic of China. Another significant discovery is the limited knowledge dissemination and collaboration among scholars, as seen by the examination of co-authorship in academic papers. In relation to the conceptual framework of the study domain, we have identified two primary trajectories, specifically financial markets, and energy markets, whereby the utilization of deep learning techniques has garnered significant attention.

1. Introduction

The use of AI-powered processes in the field of finance has been an avidly explored subject in the last few decades. Predictive modelling employing machine learning techniques and the more intricate deep learning models are highly regarded within the scientific community for their improved forecasting over traditional statistical methods. Wong and Selvi (1998) believe that the ability to identify non-linear relationships in time series helps artificial neural networks gain an edge over statistical benchmark methodologies. Machine learning algorithms classify past data and predict future outcomes, enabling financial risk reduction through integration in credit scoring, loan underwriting, and portfolio management (Pallathadka et al., 2023), as they were recorded, to outperform regression-based strategies in risk premium measurement (Gu et al., 2020).

The research community's interest in machine learning (henceforth ML) and deep learning (henceforth DL) is show cased in the numerous papers published in the last decade. Several literature reviews and bibliometric analyses were conducted to ascertain the development of data-driven technologies in the field of finance. The covered topics include fraud detection, risk assessment, sentiment analysis, cryptocurrencies, portfolio management, and algorithmic trading. The literature available between 1991 and 2017 related to the use of machine learning in stock market value prediction was covered in an analysis by Henrique et al. (2019). Their results showed that support vector machines and neural networks were the most popular topics in machine learning research related to price prediction. Ayitey Junior et al. (2023) conducted a meta-analysis meant to assess the effectiveness and size effect of different ML models, revealing comparable performance scores among foreign exchange forecasting methods. Wong and Selvi (1998)

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<https://doi.org/10.1016/j.techfore.2024.123746>

Received 20 December 2023; Received in revised form 5 August 2024; Accepted 4 September 2024

Available online 11 September 2024

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conducted a review of the published literature between 1990 and 1996 concerning the application of artificial neural networks in the financial sector. [Ozbayoglu et al. \(2020\)](#) carried out a survey including 144 papers published between 1998 and 2018 covering different applications of DL in the field of finance, their results showing that DL models outperform traditional ML models with increasing usage frequency in behavioural finance, high-frequency trading, cryptocurrencies, and blockchain technology. [Goodell et al. \(2021\)](#) showed, through their bibliometric analysis, that research efforts have steadily shifted from studying simpler ML modelling to more complex DL modelling. Similarly, the focus moved from asset price forecasting to the field of behavioural economics and the development of AI-powered trading algorithms ([Liu et al., 2018](#)).

Popular ML techniques include Random Forests, Support Vector Machines, and Artificial Neural Networks (ANN), are highly adaptable due to their complexity and are used for various purposes such as credit scoring, bankruptcy prediction, and stock performance forecasting ([Lin et al., 2014](#)). Modern means of appraising the creditworthiness of large borrowers often involve the use of data-mining techniques built around decision trees and neural networks. Deep neural architectures and reinforcement learning are increasingly being used in finance to optimize profit and minimize losses ([Mosavi et al., 2020](#)). ML algorithms can predict the default risk of creditors and classify them based on both financial and non-financial metrics but may warrant data preprocessing through augmentation techniques such as SMOTE ([Khemakhem and Boujelbene, 2018](#)). The advantages of ML can lead to the replacement of popular statistical risk classification approaches, such as logistic functions, with more accurate alternatives, such as Fermi-Dirac distributions ([Brunel, 2019](#)).

Sentiment analysis can be used to decompose the relationship between social media and news flows, and equity dynamics. Cryptocurrency price point forecasting could benefit from ML-powered behavioural analysis, as seen in [Karalevicius et al. \(2018\)](#) where it was revealed that Bitcoin predictably surges in the short to medium term in reaction to noteworthy financial news. Furthermore, sentiment analysis can help predict the price evolution of non-financial assets, the real estate market being a good example ([Kunze et al., 2020](#)). DL research is also present in the field of stock price and trend prediction. High-frequency trading and algorithmic trading often use deep learning and machine learning ([Dutta et al., 2022](#)). The aim of this technology is to minimize transaction costs and maintain profit margins by becoming market makers, attracting exchange rebates, and running trading algorithms based on these discount programs ([O'Hara, 2015](#); [Zaharudin et al., 2021](#); [McGowan, 2010](#)). Algorithmic trading models can detect speculative profit opportunities from informational asymmetry among investors that could increase adverse selection costs of trading certain equity categories ([Ravi and Hong, 2015](#)).

Through the analysis of the published works, one can acquire an outlook of the research trajectory in a specific domain. Literature reviews encompass a diverse range of typologies, each presenting distinct methodologies and research tactics aimed at comprehending the present condition of a particular academic field. Often employed methodologies include meta-analysis, systematic review, and bibliometric analysis ([Hart and Turk, 2019](#)). [Grant and Booth \(2009\)](#) present a comprehensive taxonomy of fourteen distinct types of literature reviews commonly employed by scholars across various disciplines. Among these, three key types stand out: the critical review, which entails an extensive research effort and a critical evaluation of the literature's quality; the literature review, which focuses on summarizing the findings of relevant articles without critical assessment; and the systematic map or bibliometric approach, a method developed that involves classifying and mapping existing literature.

This paper consists of a bibliometric analysis of the literature pertaining to algorithmic trading, meant to reveal the current state of research in this area. We use the PICO (Population, Intervention, Comparison and Outcomes) framework to identify the papers published

between 1990 and 2023 that were included in our review. We used science mapping to ascertain the links between papers covering the topic of algorithmic trading through methods such as co-citation or co-authorship analysis. A performance analysis was also conducted to reveal the influence of algorithmic trading in the field of finance. At the early stages of algorithmic trading development, our findings show a greater emphasis on articles pertaining to portfolio optimization and trading strategies. Subsequently, we note an increase in the number of articles discussing more intricate models that have the potential to enhance performance. Likewise, we would expect that as we move forward alongside the time scale, the literature focus will shift from generic algorithmic trading towards fine-tuned high-frequency trading, fueled by the increase in the number of high-frequency traders (HFTs) and their disruptive effects on the market. An increase in the participation of HFTs in a market populated by profit-driven traders correlates to an increase in the bid-ask spread of retail and small traders ([Brogaard and Garriott's, 2014](#)), an increase in the market liquidity provisions when acting as market makers ([Boehmer et al., 2012](#)) as well as liquidity consumption when they enact aggressive or predatory spread-crossing trading strategies ([Baron et al., 2012](#); [Easley et al., 2012](#)). Furthermore, this leads to increases in market volatility ([O'Hara, 2015](#); [Frank, 2010](#)) and directly impacts trading volume, surplus and market efficiency ([Hanson, 2016](#)). HFTs became very widely spread accounting for roughly 50 % to 60 % of all US market participants ([Nutti et al., 2011](#)) and a third of European market participants ([Zaharudin et al., 2021](#)).

This study makes several contributions to the extant literature. Firstly, it addresses a notable gap in the existing literature by conducting a bibliometric analysis of algorithmic trading. Our research revealed that no current bibliometric analysis has been conducted in this area, specifically centered on the use of algorithmic trading and its interrelation with other ML and DL techniques, evolutionary algorithms, and cryptocurrencies. We identified the collaboration network formed around this topic and the core literature that sits as its foundation, revealing the literature's intellectual and social structure. Secondly, the paper discusses the evolution of algorithmic trading, considering technological advancements and the chronological utilization of complex mathematical models for trading optimization. Through alluvial diagram representation and keyword analysis we were able to outline the different thematic periods and clusters of the published works. Lastly, the study identifies the most influential authors, articles, and countries in the field, considering their affiliations and sponsors, which significantly impact the current state of research in this area of study as well as a thematic shift in the usage of automated algorithms in other thematic areas of interest (for example, energy trading). This way, we identified the influential scholars and emerging trends in the field of computer-assisted trading. We recognize that field as a turntable for collaboration between research groups in the West and Asia.

The paper is structured as follows: the next section is dedicated to discussing the methodology employed in our bibliometric analysis as well as the source, nature, and preparation of the data we have employed. The third section showcases the results of our bibliometric analysis and their interpretation. Lastly, in the Conclusions section, we analyze our findings in the context of the previously available literature and the impact it has on our understanding of algorithmic trading, high-frequency trading, and ML.

2. Materials and methods

The data was obtained from the Scopus database, established in 2004 under the auspices of Elsevier Science. As of the year 2023, Scopus encompasses a vast collection of over 84 million items derived from a wide range of sources, including >26,000 journals and 243,400 books. In comparison, the Web of Science (WoS) Core Collection boasts a slightly larger compilation, with over 89 million entries sourced from >21,981 articles and 143,000 books. However, according to a bibliometric investigation ([Stahlschmidt and Stephen, 2020](#)), the evaluation of

publication effect across many fields and industries is often more favorable in Scopus compared to WoS. This phenomenon arises due to the extensive coverage of articles in Scopus, which enhances the likelihood of citations for all items and thus leads to an elevation in the average observed citation count. Additionally, the Scopus database encompasses information pertaining to citation counts and performance indicators, including the CiteScore™ metrics, SCImago Journal Rank (SJR), Source-Normalized Impact per Paper (SNIP), which are journal-based metrics, as well as author-based metrics such as the h-index, h-graph, and various other article-related metrics. We also used the Scopus database for research of the papers included in our study considering that a considerable amount is also part of Web of Science, Google Scholar, and other databases. The choice of only using the Scopus database was due to the duplication problem as well (Donthu et al., 2021).

Subsequently, we structured our research considering the PICO¹ approach, where we identified the population as the collection of articles in which the search query for keywords, titles, and abstracts include the terms “algorithmic trading” OR “algor* AND trading”. The “intervention” phase in our research focused on the examination of certain algorithmic trading methods, techniques, or systems employed. The “comparison” stage entailed contrasting several algorithmic trading strategies and assessing the performance of algorithmic trading in comparison to traditional trading approaches. Ultimately, the term “outcome” referred to the evaluation of the efficiency of algorithmic trading.

Then, we employed the PRISMA² protocol through which we defined the eligibility criteria. The initial dataset consisted of a total of 11,449 scholarly articles. To ascertain the most relevant sample, we opted to employ the criteria outlined below. Nevertheless, despite a thorough selection of search terms, a database search often yields studies that fall outside the scope of the review. Unmatching publications have the potential to exert an effect on the outcomes of bibliometric analysis, thereby introducing outliers into the pool of cited articles and diminishing the overall validity of the results (Zupic and Čater, 2015). Hence, at the outset, we established several defining criteria when selecting the most relevant papers.

The inclusion and exclusion criteria were defined as follows: firstly, we used the document type, year of publication, language, and subject area as criteria for selection. We proceeded by filtering the results by document type, for which we chose only articles. We argue that selecting only articles that are mainly focused on case studies compared to book chapters, whose approach to the subject, in general, is more theoretically based offers a better representation of the intellectual structure of the field. Next, we defined the period studied. We considered it appropriate to analyze results starting from 1990 until 2023 (only 26 articles were eliminated through this filtering). Another important criterion was represented by the subject area. The inclusion criteria were subject areas of interest that responded to our research question, the broad categories held under the “Other” segment were eliminated considering the manual verification of checking if the articles in question were related to our research purpose.

After we had prepared our dataset, we continued by using two fundamental approaches linked to bibliometric analysis, namely performance analysis and science mapping (Cobo et al., 2011). The first stage of our study involved conducting a performance analysis, in which

¹ PICO model is utilized more frequently in healthcare studies than in other fields of research to develop structured systematic reviews (Frandsen et al., 2020).

² The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) is a guideline used to enhance the transparency, reproducibility and quality of reporting systematic reviews and meta-analyses across various fields (Moher, 2009). In 2021, this framework was further developed and encompasses a twenty-seven items checklist (Page et al., 2021).

we assessed the research output by calculating the annual number of publications, with the aim of delineating the framework of the research domain (Donthu et al., 2021). Additionally, we conducted an analysis of the influence of these papers, considering the number of citations they acquired. Furthermore, we conducted an analysis of the principal authors of the research, taking into consideration their nationalities, institutional affiliations, and sources of financial support.

Further, we examined the intellectual, conceptual, and social structure of the research domain by employing science mapping techniques. Firstly, we employed co-citation analysis (Small, 1973) that involved the calculation of co-citation counts to establish measures of similarity among documents and authors. The concept of co-citation refers to the frequency at which two units are quoted in conjunction with each other. A core premise underlying co-citation analysis argues that the frequency with which two items are referenced in conjunction is indicative of a higher likelihood that their content is interconnected. Various forms of co-citation can be employed, contingent upon the chosen unit of analysis. The present study employs paper co-citation analysis and author co-citation analysis techniques which were encountered in the scientific literature (White and Griffith, 1981; McCain, 1990; White and McCain, 1998). We also considered bibliographic coupling, but we concluded that this approach would not be appropriate since the timeline of our research exceeds the five-year period recommended for this approach (Small, 1999). The conceptual structure of the field was studied through a co-occurrence network, and a thematic evolution based on the author’s keywords. Regarding the social structure, co-authorship analysis examines the interactions among scholars in a research field. Since co-authorship is a formal way of intellectual collaboration among scholars, it is therefore important to understand how scholars interact among themselves (including associated author attributes such as affiliated institutions and countries). With the increasing methodological and theoretical complexity in research, collaborations among scholars have become commonplace (Peters and Van Raan, 1991; Acedo et al., 2006). We developed a collaboration network based on authors and institutions as well as an inter-country collaboration map.

The Bibliometrix package was employed in the R environment. The software provides a broad range of tools specifically developed for doing quantitative research in the domains of bibliometrics and scientometrics. The code has been created utilizing the R programming language, an open-source environment. Considering the arguments brought by Aria and Cuccurullo (2017), we chose to make use of the Bibliometrix package in R, considering the convenient statistical algorithms, the accessibility of dependable numerical routines, and the incorporation of integrated data visualization tools. These are significant determinants in favour of using R as a more favorable option compared to other programming languages. The web-based application Biblioshiny, which is designed within the Shiny environment, was utilized in our study.

3. Results

3.1. Performance analysis

This section provides an overview of the primary patterns in the production of publications linked to algorithmic trading. Firstly, the dataset used in the analysis is described, and then we examine the influence of each study, the most active and influential authors and other performance indicators.

The data set consisted of a sample of 4552 articles published between 1990 and 2023 with an average of 0.863 articles written per author considering 12,888 different authors. Sole-authored publications represent 9 % of the sample (410 articles). The articles were published in 291 different sources, out of which 98 % were journals and the rest were book series, conference proceedings, and trade journals.

3.1.1. Production

The proliferation of complex algorithms implementation has been

enabled by technological developments and the pervasive integration of the Internet. The role of algorithmic trading has exhibited a progressive increase over time, as depicted in Fig. 1. The annual production of publications witnessed a very modest emergence of initial works throughout the end of the previous century. The first academic article on this topic was published by Domowitz in 1990 (Domowitz, 1990) in the “Journal of Financial Intermediation”. According to Scopus, this work, whose aim was to assess the efficacy of the systems in place at that period, which had either undergone recent regulatory evaluation or were already operational, has received only 33 citations, a relatively small number. Specifically, the focus was on how these systems facilitated the process of price discovery and quantity determination. The existence of regulatory concerns made it imperative to provide a clear and precise statement regarding the processes used for trade execution.

During the period leading up to the 2000s, a total of 95 papers were published, with 75 of these originating from the United States. The remaining publications were primarily linked to European academic institutions. Based on the number of citations, the most influential papers were the following: Davis and Jedwab (1999), Allen and Karjalainen (1999), Altman et al. (1994), Cover (1991), Davis et al. (1993). In the next period (2000–2023), there was a notable surge in scholarly publications, with the production of papers increasing from 23 to about 590 by 2023. Nevertheless, in some years, the production of articles experienced a modest decline in absolute terms. Specifically, in 2002, there was a notable fall of 82 % compared to the previous year, 2001. Similarly, in 2008, there was a year-on-year decrease of 15 % in article output. The decrease in trading activity during these periods can be attributed to the economic recession and the prevailing pessimistic investing outlook. These factors led to reduced scholarly interest in financial markets and portfolio optimization and more towards economic resilience and diminishment of the recession consequences. This led to a fall in the production of articles related to this specific topic. Notwithstanding these declines, the general pattern exhibits an upward trend.

Based on an examination of the average mean of total citations per year (MeanTCperYear), which serves as a performance metric for evaluating both the overall publications and the average total citations received annually, the year 2019 exhibited the largest number of citations - see Fig. 2. The MeanTCperYear score was computed by dividing the average number of citations per article by the number of years between the present year and the year of publication. For the year 2019,

the average number of citations per article is 25.8, while the number of citable years is 5, leading to a score of 5.16. Throughout this year, a cumulative sum of 378 articles was disseminated. The scholarly publication by Zhong and Enke (2019) in the prominent “Financial Innovation” journal garnered a commendable citation score of 121, showing its significant impact and influence among scholars in the field. The year 2020 also stands out as a noteworthy year, achieving a score of 4.89 with 13 articles that exceeded 100 citations, the most relevant authors being: Pang et al. (2020), Tushar et al. (2020), Shahid et al. (2020), Zhou et al. (2020) and Chen et al. (2020). The least cited year is 1992, with only 3 published articles: Tanaka et al., 1992; Molnar, 1992; Sha and Steiglitz, 1992.

Furthermore, a Sankey diagram was generated to visually represent the distribution of research across various countries, affiliations, and sources. The diagram focuses on the top 20 countries and illustrates the relative proportions of research conducted by each country. Additionally, it highlights the relationship between affiliations and sources, shedding light on the association between these two variables. According to data presented in Fig. 3, a significant proportion of the published articles, around 30 %, are associated with Chinese institutions. These institutions include 17 universities from China and 3 universities from other countries. The North China Electric Power University emerges as the primary Chinese institution, as evidenced by its notable publication record of 92 articles across 47 distinct academic journals. The United States of America (USA) ranks second, which closely resembles that of China. Nevertheless, it is important to mention that most affiliations associated with the USA are unrecorded, indicating the presence of many independent scholars. This could suggest a greater dispersion of authors and decreased collaboration. In contrast, the Republic of Singapore is mostly linked to Nanyang Technological University, as seen by the presence of 98 papers related to this institution. Similarly, the Islamic Republic of Iran is predominantly associated with Islamic Azad University, with 161 articles primarily published in IEEE journals. Another noteworthy affiliation is the University of Toronto, which has 55 publications primarily published in the “Mathematical Finance” journal.

Based on the most relevant sources (Table 1), we conducted a study of performance-related measures, including the h-index, g-index, and m-index and total citations (TC). Additionally, we employed Bradford’s law to conduct a comprehensive cluster analysis. The h-index is a quantitative indicator utilized to evaluate the productivity and citation

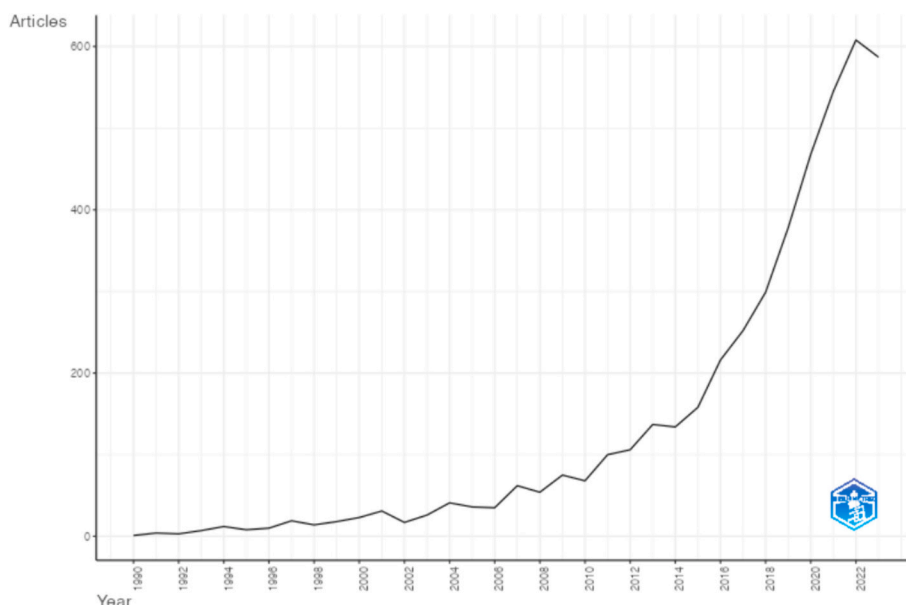


Fig. 1. Annual evolution of productivity.

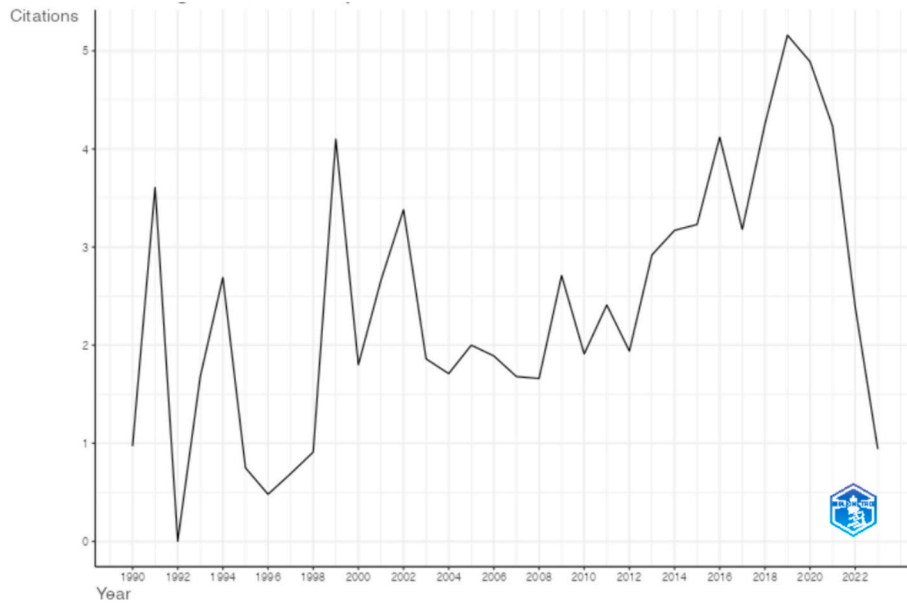


Fig. 2. Average mean of total citation per year (MeanTCperYear).

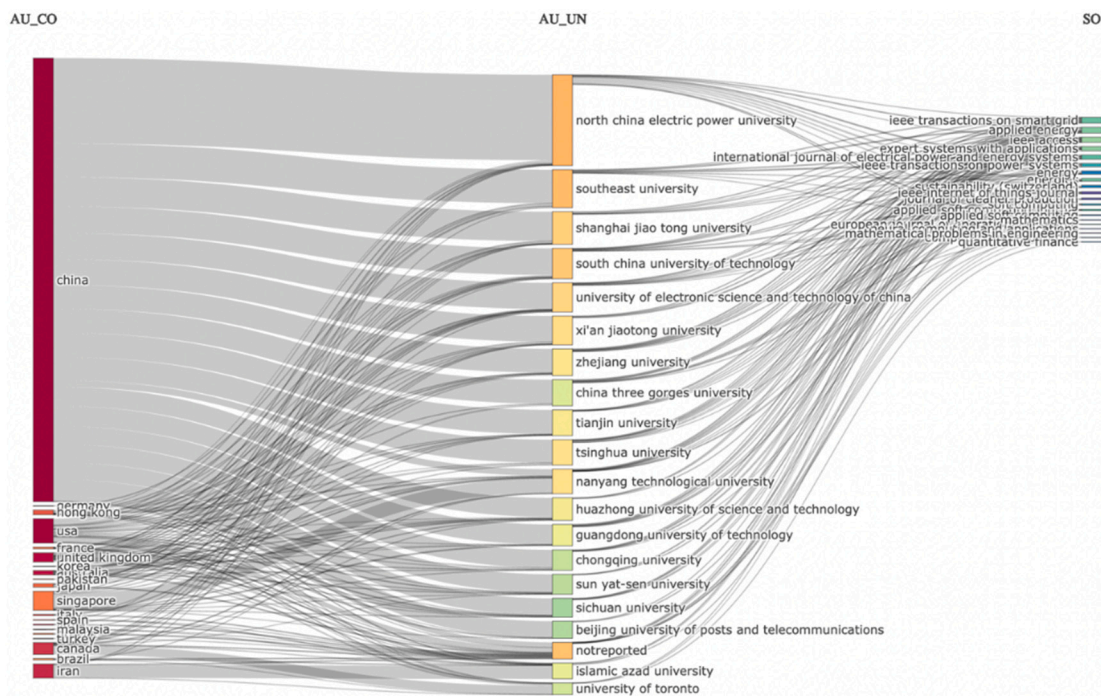


Fig. 3. Sankey diagram based on the top 20 author's countries, affiliations, and sources. Source: Authors' work.

impact of scholarly articles (Hirsch, 2005). The first cluster of sources includes all relevant sources based on their h-index. It is observed that the journal "Expert Systems with Applications" has achieved the highest h-index of 44, placing it second according to Bradford's law. This achievement is accompanied by a publication count of 178 papers. Hence, it can be argued that the publication of articles in this journal results in a higher level of impact and visibility, in contrast to other journals. The journal "Applied Energy" has an h-index of 33, indicating that a minimum of 33 articles published in the journal received at least 33 citations each. The g-index was also computed, considering the constraints of the h-index, which are associated with its reliance on the number of publications (Costas and Bordons, 2008). This limitation

arises from the fact that the h-index of a journal is constrained by the total number of documents it has published and, hence, fails to adequately account for the impact of highly cited publications. The correlation between the h-index and g-index for the journals in our sample was determined to be 97.27 % using our calculations. The journal "IEEE Transactions on Smart Grid" stands out as an exception in terms of its scholarly impact. It has achieved an h-index of 31, positioning it in fourth place among other journals. However, based on its g-index of 61, it should be ranked second. The disparity arises due to the g-index's emphasis on highly cited publications in contrast to the h-index. Furthermore, if we consider the m-index, which divides the h-index by the number of years since the first published paper, the ranking may

Table 1

Top 10 most relevant sources and source clustering corresponding rank through Bradford's law.

Source	h_index	g_index	m_index	TC	Rank	Freq	cumFreq	Zone
Expert Systems with Applications	44	77	2.000	6699	s2	178	364	Zone 1
Applied Energy	33	55	2.538	3188	3	85	449	Zone 1
Applied Soft Computing Journal	31	51	2.385	2617	7	53	699	Zone 1
IEEE Transactions on Smart Grid	30	61	2.727	3792	5	64	591	Zone 1
IEEE Access	29	47	2.900	3033	1	186	186	Zone 1
IEEE Transactions on Power Systems	28	46	0.966	2443	9	46	797	Zone 1
European Journal of Operational Research	23	37	0.697	1465	8	52	751	Zone 1
International Journal of Electrical Power and Energy Systems	19	33	1.118	1156	6	55	646	Zone 1
Energies	17	28	1.889	975	4	78	527	Zone 1
Energy	17	29	0.944	871	14	41	1015	Zone 1

Note: The table provides the following elements for each source: h-index, g-index, m-index, total citations of the source (TC), rank which represents the ranking (Rank) considering the frequency of citations (Freq), cumulative frequency (cumFreq) which denotes the total number of citations for sources pertaining to a specific zone (e.g. Zone 1) which equals the sum of frequencies of the sources in that zone where zone represents the corresponding cluster according to Bradford's law. Source: Authors's work.

exhibit significant variations. Thus, the journal "IEEE Access" ranked first, followed by "IEEE Transactions on Smart Grid" in second place. However, the journal "Expert Systems with Applications" would be ranked fifth. The rationale behind the consideration of the length of scientific activity in the m-index, as opposed to the h-index, can be attributed to the explanation for this phenomenon.

A cluster analysis was further conducted utilizing Bradford's law (Bradford, 1934). Three clusters (zones) were designated for the purpose of consolidating scientific productivity. By employing this methodology, we detected an initial cluster of 33 scholarly journals. Within this cluster, a comprehensive total of 1519 publications were identified, as presented in Table 1. To attain a similar quantity of publications (1532), we have identified 194 scholarly journals within the second cluster. This observation suggests that to obtain a similar level of publication output, it was necessary to locate an extra 161 journals, emphasizing the extensive dissemination of intellectual activity. The third cluster comprised 966 journals, within which a total of 1501 publications were published. Hence, the initial cluster demonstrated a higher concentration of journals characterized by a greater frequency of articles. The mean number of papers per journal was 46. The scholarly publication "IEEE Access" demonstrated a noteworthy achievement by containing 186 papers that explicitly concentrate on mathematical applications within the domain of algorithmic trading. The journal "Expert Systems with Applications" has a cumulative publication count of 178 articles. The mean number of publications per journal in the second cluster decreases to 7.89. The mean value of articles per journal in the third cluster was only 1.55. Hence, it might be argued that there is an inequitable distribution of scientific output within this domain of study. As a result, there was a notable degree of concentration observed within the first cluster, followed by a rise in dispersion. Among the 1193 journals examined, 51.89 % of the sample published only one paper focused on algorithmic trading. Furthermore, 619 journals had a frequency of only one publication in this subject area. This discovery underscores a discrepancy within the field, as the thematic emphasis of each journal tends to be relatively unique, and the publications are widely scattered across journals.

3.1.2. Documents

To identify the most relevant scholarly articles to the field of algorithmic trading, a research investigation was carried out employing total citations as a measure. The 4552 publications included in our sample yielded a cumulative count of 90,362 citations. Based on the data presented in Table 2, the paper authored by Davis and Jedwab (1999) received the highest number of citations (766). This represents roughly 0.8 % of the total citations identified in our sample. The article primarily addresses coding schemes employed in the transmission of data over several carrier frequencies that are evenly distributed, usually known as orthogonal frequency-division multiplexing. The paper written by

Table 2

Top 10 most globally cited documents.

Cited references	Total citations	TC per year	Normalized TC
Davis and Jedwab (1999)	766	30.640	7.477
Hendershott et al. (2011)	700	53.846	22.364
Altman et al. (1994)	574	19.133	7.108
Allen and Karjalainen (1999)	523	20.920	5.105
Chong et al. (2017)	469	67.000	21.101
Cover (1991)	468	14.182	3.933
Paudel et al. (2019)	426	85.200	16.509
Gai et al. (2019)	397	79.400	15.385
Cavalcante et al. (2016)	365	45.625	11.078
Kurz et al. (2009)	365	24.333	8.984

Source: Authors' work.

[Hendershott et al. \(2011\)](#) is ranked as the second most frequently cited publication, with 700 citations. Its primary emphasis is on the analysis of the liquidity benefit that arises from automated transactions. The findings pointed towards a significant improvement in liquidity on the New York Stock Exchange over a period of five years, which can be attributed to the use of trading algorithms. [Altman et al. \(1994\)](#) reported a cumulative count of 574 citations, positioning it third in Table 3. The researchers performed a comparative analysis to assess the efficacy of conventional statistical methods, specifically linear discriminant and logit analyses, in comparison to neural networks (NN) for the purposes of categorizing and predicting financial distress. The research was centered on a representative sample of 1000 Italian businesses, covering the time frame from 1982 to 1992. [Allen and Karjalainen \(1999\)](#) introduced a genetic algorithm in their publication, which demonstrated its ability to acquire trade rules. The study, ranked fourth in terms of citations (523) and was conducted on the S&P 500 index, covering the period from 1928 to 1995. The results suggest that the adoption of rules did not result in higher excess returns when compared to a conventional buy-and-hold approach. The [Chong et al. \(2017\)](#) work, which ranks fifth in terms of citations (469), introduced a three-layer deep neural network (DNN) model for the purpose of analyzing the Korean stock exchange. The authors demonstrated that deep neural networks (DNNs) possess a primary benefit over linear autoregressive models, namely their capacity to extract features from extensive raw data sets without necessitating prior knowledge of predictors. Moreover, [Cover \(1991\)](#) demonstrated in prior research, ranked sixth when considering citations, that the utilization of a sequential portfolio selection algorithm resulted in the creation of a "universal portfolio" that outperformed the Dow Jones Average in terms of returns. In contrast, [Paudel et al. \(2019\)](#) proposed an innovative game-theoretic framework for peer-to-peer (P2P) energy trading within a community microgrid, which generated 426 citations. This model incorporates direct interactions between buyers and sellers, considering the capabilities and privacy concerns of prosumers. The algorithm is formulated considering the various factors including the

Table 3
Most local cited references.

Cited references	Citations	Topic of cited reference	Topics of papers that include the cited references	Techniques
Boyd and Vandenberghe (2004)	66	Mathematics and optimization	Portfolio optimization, asset allocation, risk management, option pricing	ML, DL
Markowitz (1952)	64	Portfolio optimization	Portfolio optimization, cryptocurrency, behavioural finance, hedging strategies	ML, DL, genetic algorithms, natural language processing (NPL)
Holland (1992)	46	Artificial Intelligence	Portfolio optimization, renewable sources, behavioural finance, volatility modelling	ML, DL, genetic algorithms
Murphy (1999)	35	Trading methods	High-frequency trading, price prediction	ML, DL, genetic algorithms
Hochreiter and Schmidhuber (1997)	34	Recurrent neural networks	Portfolio optimization, option pricing, cryptocurrency, price prediction	ML, DL, genetic algorithms
Sutton and Barto (2018)	34	Reinforcement learning	Portfolio optimization, asset allocation, blockchain	ML, DL
Cartea et al. (2015)	32	Trading methods	Portfolio optimization, high-frequency trading, renewable sources, hedging strategies	ML, DL
Koza (1994)	31	Genetic algorithms	Portfolio optimization, cryptocurrency, price prediction, energy efficiency	ML, DL, genetic algorithm
Nakamoto (2008)	30	Blockchain	Cryptocurrency, energy efficiency, price prediction	DL

Source: Authors' work.

players involved, the population dynamics, the strategic considerations, and the utility functions. Furthermore, the privacy concern of energy trading customers was addressed by Gai et al. (2019) through the utilization of a consortium blockchain framework. There are also further studies that focus on the environment and sustainable economy. For instance, researchers have built models that utilize advanced algorithms to convert volume to biomass and explicitly replicate individual annual disturbance occurrences (Cavalcante et al., 2016).

The Normalized Citation Score (Normalized TC) of a document is determined by dividing the number of citations it has received by the anticipated citation rate for documents published in the same year. When evaluating the Normalized TC, it is apparent that the articles deemed most relevant or influential in the field are those with a normalized TC value exceeding 13.7. Only these papers are included in the top ten rankings, while the remainder papers are excluded from this ranking. The rank would include the papers published by Zhang et al. (2023), Elhedhli and Merrick (2012), Yang et al. (2023), Djenouri et al. (2023), Li et al. (2023), and Wang and Huang (2018).

With respect to the most frequently referenced papers within the local context (the number of citations that a reference has received from documents in our data set) – see Table 3, the results were in line with expectations. The analysis reveals that the two most frequently mentioned sources in our dataset are the works of Boyd and Vandenberghe (2004) and Markowitz (1952), with citation counts over 60 in a total of 4552 documents. It has been observed that the presence of relevant references can serve as a reliable measure of the specificity of academic papers. For instance, a paper that includes citations to Markowitz's Portfolio selection indicates a focus on the advancement of machine learning models for optimizing portfolios and mitigating liquidity risks on stock exchanges. On the other hand, papers that reference Sutton and Barto (2018) encompass a broader range of topics, including financial markets, energy markets, and sustainable economics.

3.1.3. Authors

The ranking of the scholars, as illustrated in Table 4, is established based on the number of publications they have published. Jaimungal Sebastian has achieved the highest ranking by authoring 24 articles over the period spanning from 2015 to 2023.³ Cartea Álvaro emerges as the second most productive and influential author in the field, having authored a total of 18 publications, out of which 16 were co-authored

with Jaimungal S. The authors' highly cited paper, entitled "Buy low, sell high: a high-frequency trading perspective" (Jaimungal & Alvaro, 2015), was published in the prominent "SIAM Journal on Financial Mathematics" and has received a substantial number of citations (73) until 2023.

The h-index, as determined for each author in the Scopus database, was also considered. The data reveals that Poor Vincent is the author with the highest productivity and highest h-index (139), generating an average of 2.56 articles each year, which are closely aligned with the intellectual framework of the area in question. In the second position, Shahidepour Mohammad has an h-index of 111, indicating a significant level of scholarly impact. Throughout his career, he has written an average of approximately 2.04 articles per year. It is evident that there is no inherent correlation between the quantity of articles authored and a high h-index. This is exemplified by the situation of the most prolific author, Jaimungal S., whose substantial number of published papers does not correspond to a correspondingly high h-index.

Moreover, upon examining the progressive accumulation of citations over the period, it becomes apparent that the authors who are deemed to be the most influential exhibit a consistent presence in the field. In Fig. 4, the line represents the author's timeline, the node at a given year represents the article published, the size of the node represents the number of articles written within that year, and the colour intensity represents the number of citations. This consistent presence suggests that these influential authors have made significant contributions to their respective fields through their papers, and their work continues to be cited by other researchers. Their ability to consistently generate impactful research indicates a high level of expertise and relevance in their areas of study. It is noticeable that Javid Nadeem has a comparatively shorter research duration of only five years compared to the other authors, although the author demonstrates a higher level of output with an average of 1.86 publications published per year. Another author who has a considerably shorter career length compared to the others, spanning only seven years, is Hirasawa Kotaro. However, he has published a higher number of articles compared to most of the sample, resulting in a productivity rate of two articles per year. This suggests that while both authors may have had a shorter career until now, they were able to maintain a consistent level of productivity in terms of article publications.

We employed Lotka's law, also referred to as the inverse square law of scientific productivity, as a bibliometric index. The main objective of its usage relied on facilitating the distribution of academic articles within a specialized scientific community in a certain field of study. When employing Lotka's law, it is justifiable to apply it to authors who exhibit diverse research capabilities within a particular discipline, hence yielding a distribution that is commonly non-proportional (Lechuga Sancho et al., 2020). It is important to recognize that the utilization of

³ Jaimungal S. holds the position of director for the professional Master of Financial Insurance Program and is affiliated with the Department of Statistical Science at the University of Toronto, Canada. He holds the title of a Fields Institute Fellow and has previously held the position of chair for the SIAM activity group in Financial Mathematics and Engineering (SIAG/FM&E).

Table 4
Top 10 most relevant authors.

Authors, Scopus author code	Articles	Articles fractionalized	Total citations	Total citations/articles	h-Index
Jaimungal, Sebastian (6602313862)	24	9.667	495	21	16
Cartea, Álvaro (10640005400)	18	7.083	411	23	19
Hirasawa, Kotaro (35510098600)	14	3.983	177	13	2
Han, Zhu (55767186700)	13	2.635	986	76	105
Javaid, Nadeem (26428797500)	11	1.860	488	44	59
Poor, H. Vincent (55665272100)	11	2.552	1375	125	139
Shahidehpour, Mohammad (6603715241)	11	2.253	464	42	111
Deng, Shangkun (39361484000)	11	2.044	146	13	9
Manahov, Viktor (55760692100)	10	5.833	97	10	9
Mabu, Shingo (12794389800)	9	2.233	203	23	20

Note: Articles fractionalized quantify an individual author's contributions to a published set of papers. It is calculated as $\sum_{h \in AU_j} \frac{1}{\text{number of co-authors}(h)}$ where AU_j

represents the set of documents co-authored by the author j and h is a document included in AU_j .

Source: Authors' work based on Scopus data.

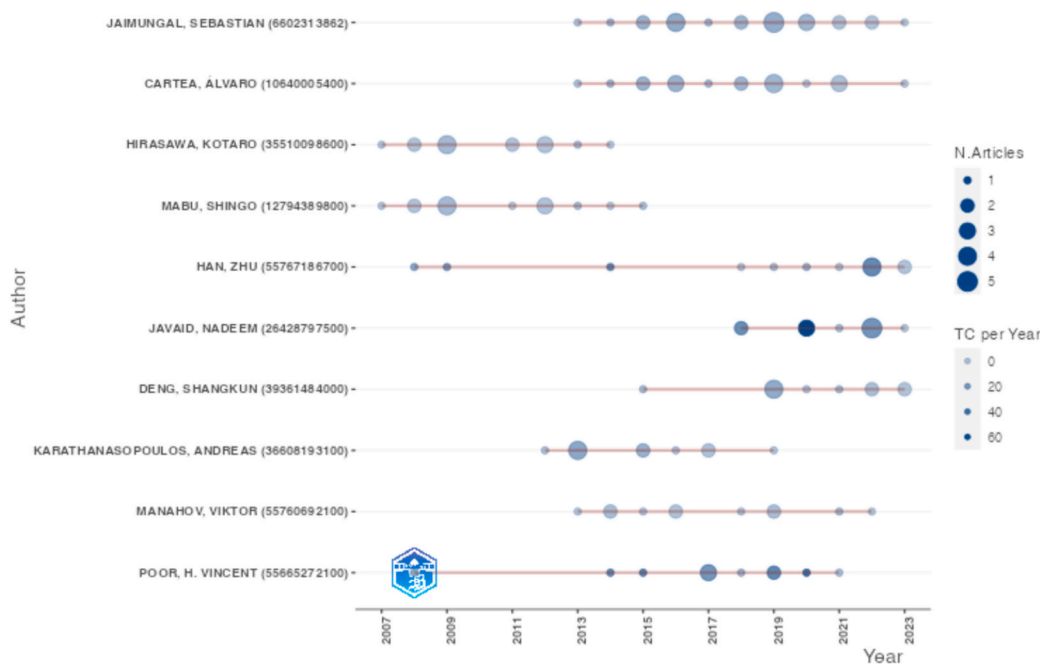


Fig. 4. Authors' productivity during the sample period.
Source: Authors' work.

Lotka's law is limited to quantitative analysis, hence excluding the assessment of document and author quality through this metric. According to the data presented in Fig. 5, a significant majority of authors, 87.7 %, contributed to the field by publishing only one paper. Additionally, a smaller proportion of authors, 8.8 %, engaged in the field by publishing two articles. Conversely, it is noteworthy that fewer than 1 % of individuals published more than four papers over time. The authors, arranged in descending order based on the number of articles they have published, are as follows: Jaimungal Sebastian (24 articles); Cartea Álvaro (18 articles); Hirasawa Kotaro (14 articles); Han Zhu (13 articles); and Javaid Nadeem, Poor Vincent, Shahidehpour Mohammad, and Deng Shangkun, each with 11 articles. It was previously confirmed that the literature dedicated to ML followed Lotka's distribution (Henrique et al., 2019).

3.2. Science mapping

This section presents the findings obtained through the application of science mapping techniques. We conducted an analysis of the

intellectual, conceptual, and social framework of the discipline, examining how the use of automated algorithms in trading has evolved over time and the collaborative networks formed among authors.

3.2.1. Intellectual structure

By using the method of paper co-citation analysis, a total of six distinct clusters were detected (Fig. 6). Co-citation refers to the establishment of a relationship between authors through the act of citation. To achieve a high level of co-citation, it is important that a substantial number of authors make references to receding works. The initial cluster (shown in red in Fig. 6) consists of a total of nine papers, with the most notable contributions being attributed to Markowitz (1959) and Hochreiter and Schmidhuber (1997). This cluster has a cohesive connection to the third cluster (green), which comprises ten articles, all of which pertain to the portfolio selection and optimization topic. The remaining four clusters lack interconnectivity. The second cluster, shown in blue, has a collection of five articles that are all interconnected with the topic of high-frequency trading (HFT). The fourth cluster, denoted by purple, comprises thirteen papers that explore the

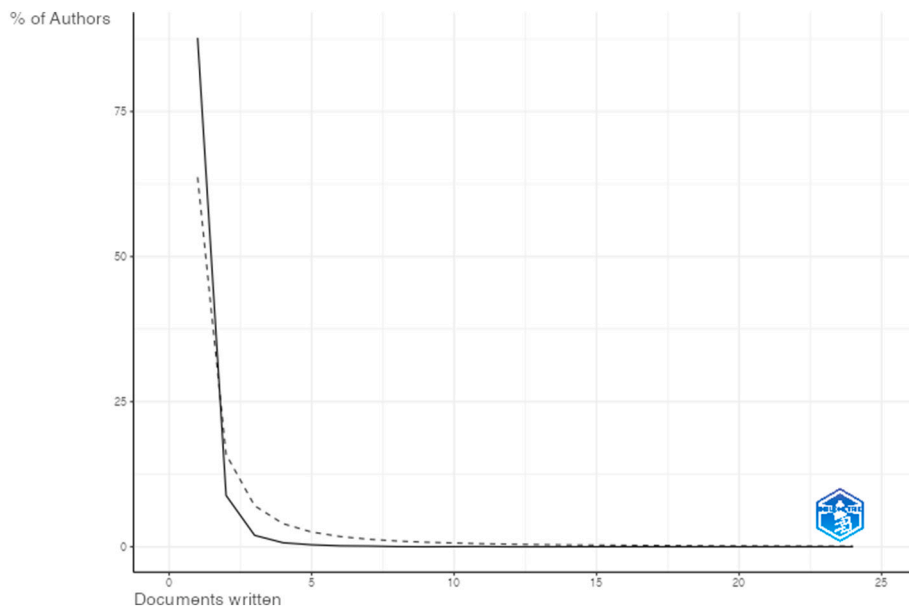


Fig. 5. Lotka's Law authors' productivity. Source: Authors' work.

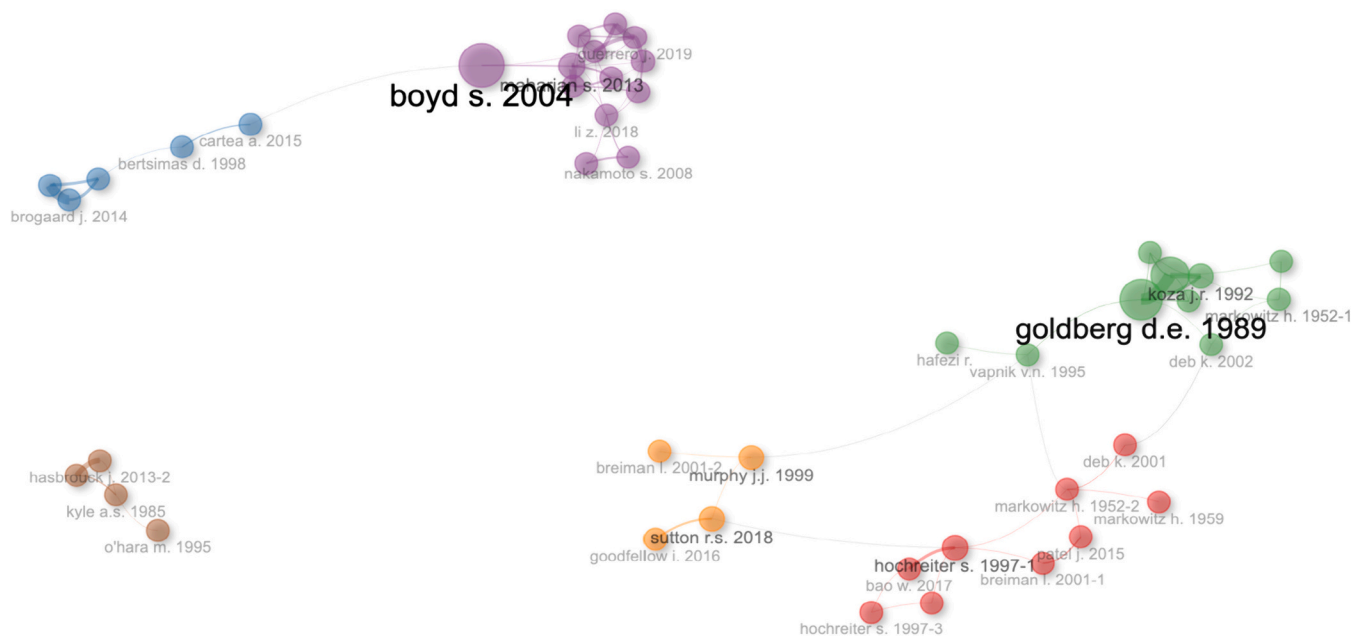


Fig. 6. Paper co-citation network. Source: Authors' work.

mathematical applications of machine learning and deep learning. On the other hand, the fifth cluster, represented in yellow, focuses on the technical analysis and indicators used for evaluating performance in financial markets. The sixth cluster, in brown, encompasses four articles that pertain to the concept of transaction costs. These articles discuss the various factors and methodologies involved in measuring and minimizing transaction costs in financial markets. They provide insights into the impact of transaction costs on investment strategies and highlight the importance of efficient execution and trading practices.

In contrast, implementing the author's co-citation mapping led to the identification of four clusters (see Fig. 7). The initial cluster has seven authors, specifically Hendershott T., Cartea A., Hasbrouck J., Brogaard J., Easley D., Almgren R., and Foucault T. These authors exhibit a

connection as they appear to co-occur within the reference list of a separate publication. All the scholarly publications in the first cluster pertain to the field of automated trading. The second cluster, shown in blue, comprises a group of five authors whose research publications primarily focus on the understanding of how markets operate and how efficiently incorporate all available information. Their research explores various aspects of market efficiency, such as price discovery, liquidity provision, and the impact of trading strategies on market dynamics. Their collective body of work provides valuable insights for both academics and practitioners in the field of automated trading. Compared to the paper co-citation analysis, the nodes are all inter-linked, indicating a strong interconnectedness among the research papers. This suggests that there is a significant level of knowledge sharing within the research

split our database considering the two main research directions identified: financial markets and energy markets. Synonyms were excluded to enhance the discernibility of the subjects explored by researchers. There were 26,079 distinct keywords for the whole sample. Also, considering the results obtained from the co-occurrence network analysis, the second most used word is “genetic algorithm” (Table 5). Genetic algorithms are extensively exploited across diverse domains, including optimization issues, machine learning, and data mining. The algorithms constitute a collective of closely interconnected computational models that are rooted in the principles of Darwinian evolution and genetics (Carter, 2003). Genetic algorithms represent a category of optimization algorithms, which are employed for the purpose of identifying the most efficient solution to a given computing issue by either maximizing or minimizing a specific function (Goldberg and Holland, 1988). They enable users to identify resolutions for issues that are beyond the scope of traditional optimization techniques due to the absence of continuity, derivatives, linearity, or other characteristics (Allen and Karjalainen, 1999). Furthermore, evolutionary algorithms have demonstrated efficacy in other domains, including feature selection, parameter tweaking, and pattern recognition (Mateo et al., 2010; Zhang, 2020). Genetic algorithms can be employed in portfolio optimization problems for estimating the Value-at-Risk of an equity bundle and it was shown by Sharma et al. (2015) to yield more conservative results than Monte Carlo simulations. On the other hand, for the second direction, the words with the highest frequency differ greatly. Specifically, we found that papers pertaining to energy tend to prioritize the subject matter over the methodologies employed in the studies.

Based on the alluvial diagram (Fig. 9), there are four distinct thematic periods that pertain to the conceptual framework. These periods include the initial phase spanning from 1990 to 2015, the subsequent phase from 2016 to 2019, the third phase from 2020 to 2022, and finally, the closing phase in 2023. The initial thematic chronology is characterized by the presence of 15 distinct clusters, but only 12 of these clusters are visible in Fig. 9. These clusters together encompass a total of 1199 articles. During the specified time frame, the most prominent clusters were identified as “emerging markets” and “competitive analysis.” These clusters were characterized by their significant thematic relevance, exhibiting both high density and centrality. In the subsequent temporal sequence, these clusters exhibited a tendency towards “portfolio optimization” and “smart grid” topics. Additionally, there is another cluster of main themes exemplified by the concept of “reinforcement learning”. Furthermore, there was a decrease in the number of performance evaluation papers during the period spanning from 1990

to 2015. The second period, consisting of 1145 publications and encompassing 10 clusters, is distinguished by extensive research centered on portfolio optimization and portfolio selection. In contrast, one-way trading and cloud computing remained rather specialized topics during this period. The third timeline consisted of five clusters, which collectively had a total of 1612 articles. Blockchain and DL were the main themes for the period, while algorithmic trading and HFT emerged as prominent topics in the field. The concluding period encompasses a total of 19 clusters, mostly in 2023. However, only the largest nine clusters are visible in Fig. 9. Consistent with the preceding timeline, blockchain-related publications have emerged as a significant subject in 2023, alongside environmental and energy-related themes, as indicated by the usage of terms such as “carbon emission” and “carbon price.” The application of deep learning has recently seen a surge of interest in the areas of cryptocurrency and intraday trading. The terms “deep learning,” “genetic algorithms,” and “machine learning,” which are associated with automated algorithms, are representative of fundamental themes that are present in the field regardless of the times in which they are applied. These fundamental themes highlight the importance of using advanced algorithms to analyze and make predictions in various industries. They demonstrate the ongoing need for innovative solutions that can adapt to changing times and technologies. Additionally, the application of these algorithms in different fields showcases their versatility and potential for driving advancements across diverse sectors.

Based on an analysis of the authors’ chosen keywords, the thematic evolution could be categorized into four distinct clusters (Fig. 10). The initial two clusters originating from the third quadrant in Fig. 10 depict niche topics characterized by a substantial concentration within the field, although exhibiting little importance. Despite the increasing capacity to create advanced algorithms, it is evident that scholarly literature pertaining to blockchain, energy trading, and smart grid remains rather scarce within the broader research domain. These specialized topics appear to garner minimal scholarly interest and do not exert a substantial influence on the broader discipline. Nevertheless, it is crucial to acknowledge that this finding does not detract from their potential for future progress and contributions within their respective fields. In contrast, the clusters originating from the second quadrant, specifically cluster 1 (“algorithmic trading”, “machine learning”, “stock market”) and cluster 4 (“genetic algorithm”, “portfolio optimization”, “deep learning”), encompass fundamental themes within the analyzed sample. These clusters exhibit a low centrality score of 0.13 each, indicating their relatively peripheral position within the network. However, they

Table 5
Most relevant words from abstracts.

Research direction	No of articles	Keywords	Frequency	References	Themes
Financial markets	3982	Algorithmic trading	269	Chisci and Zappa (1991); Barucci and Landi (1996) Campi and Garatti (2011); Dunis et al. (2013); Arciero et al. (2014); Bekiros et al. (2017); Bakhach et al. (2018); Manahov et al. (2018); Deng et al. (2022); Yu et al. (2023)	Portfolio optimization, trading strategies, price prediction, behavioural finance
		Genetic algorithm	209		
		Machine learning	184		
		Deep learning	114		
		High-frequency trading	82		
		Optimization	72		
		Stock market	68		
Energy markets	570	Energy trading	111	Wu et al. (2016); Sun and Zhang (2018); Liu et al. (2019); Wang et al. (2019); van Leeuwen et al. (2020); Petrucci et al. (2022); Galarneau-Vincent et al. (2023); Xia et al. (2023)	Energy efficiency, transition to renewables, energy storage, peer-to-peer energy trading
		Smart grid	78		
		Blockchain	58		
		Energy management	26		
		Renewable energy	26		

Note: The column “References” contains only some of the papers reviewed, considering the extensive sample.

Source: Authors’ work.

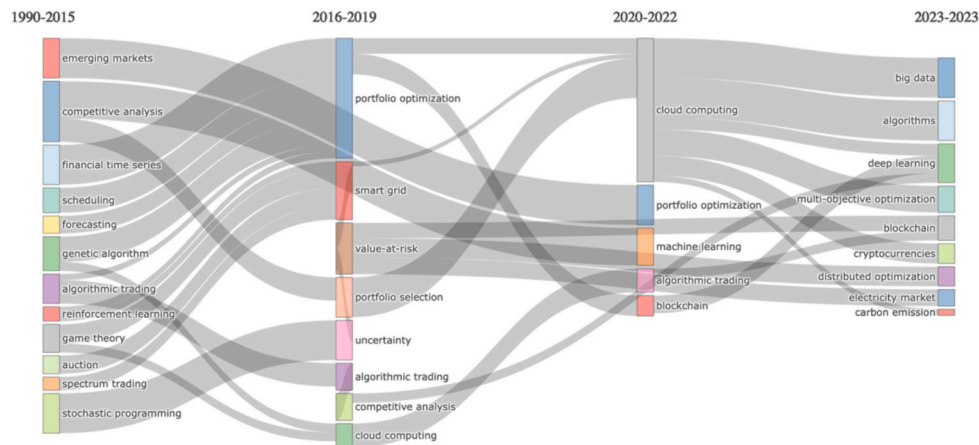


Fig. 9. Alluvial diagram showing the thematic evolution over the period. Source: Authors' work.

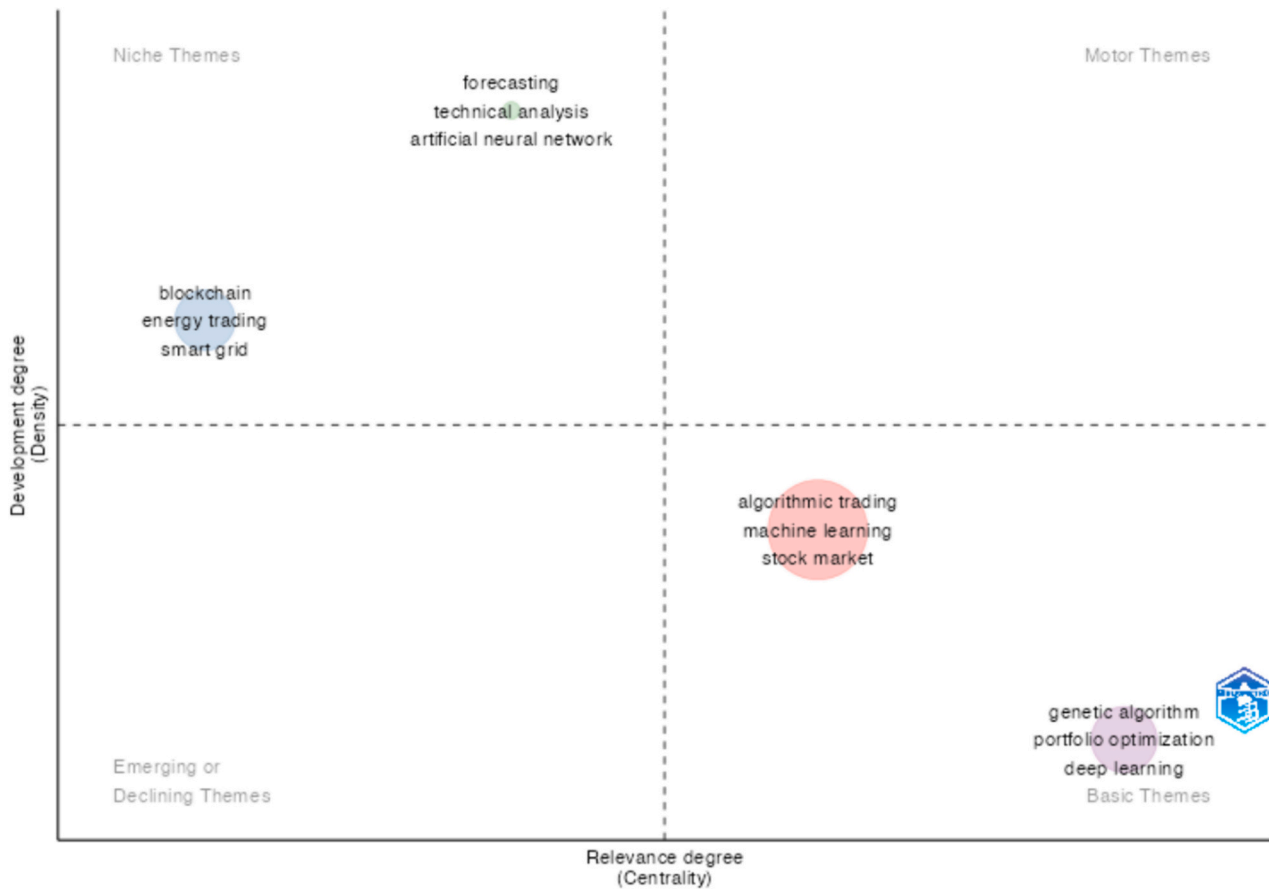


Fig. 10. Thematic map. Source: Authors' work.

demonstrate a high density, with cluster 4 having a density of 3.6 and cluster 1 having a density of 2.3. Cluster 3, consisting of the terms “forecasting,” “technical analysis,” and “artificial neural network,” exhibits a centrality value of 0.05, indicating a relatively low level of importance within the overall network. Nevertheless, it demonstrates a high density of 4.3, suggesting a strong interconnectedness among the terms within the cluster. This indicates that the clusters exhibit a higher degree of specialization and concentration in particular subjects within the domain. The observed high density implies a significant degree of

interconnectedness among the terms inside each cluster, hence demonstrating a close association between the underlying concepts.

3.2.3. Social structure

To enhance the comprehension of the social structure, a co-authorship study was performed utilizing the walktrap clustering method (Fig. 11). The analysis enabled the identification and characterization of the organizational structure of collaborative research networks within the field of algorithmic trading. This encompasses the



Fig. 11. Co-authorship network.
Source: Authors' work.

independent nature of the different fields of research. The nodes provide insight into the authors who have exerted the highest influence, while the thickness and distance between nodes serve as indicators of the extent of collaboration within the field. A total of eleven clusters have been identified, suggesting a dearth of collaboration within the respective field, as well as a potential lack of knowledge dissemination and collaboration among researchers. The node of highest prominence is associated with Jaimungal Sebastian, who has collaborated on scholarly papers with Cartea Álvaro and Donnelly Ryan (cluster five, in yellow). The initial cluster, in red, exhibits the highest level of collaboration among the clusters under analysis, as it comprises six authors. Nevertheless, each author is connected just via a single pathway to the preceding author. The previously mentioned resemblance is likewise observed among the remaining clusters. The absence of collaboration

has the potential to negatively impact the progress and development of research within these specific areas.

Based on the data collected from our sample, authors hailing from a total of fifty countries across the globe have made significant contributions to the existing body of literature on algorithmic trading (Fig. 12). The publication of >600 works with authors from 50 different countries serves as proof that China exhibits the highest level of collaboration. Chinese authors have engaged in significant collaborations with many countries. Notably, the United States has been the most prominent collaborator, with 184 papers jointly authored between Chinese and American scholars. Hong Kong and the United Kingdom have also emerged as important partners, with 65 and 59 publications, respectively. These collaborations have not only contributed to the diversity and global reach of Chinese research but have also fostered cross-

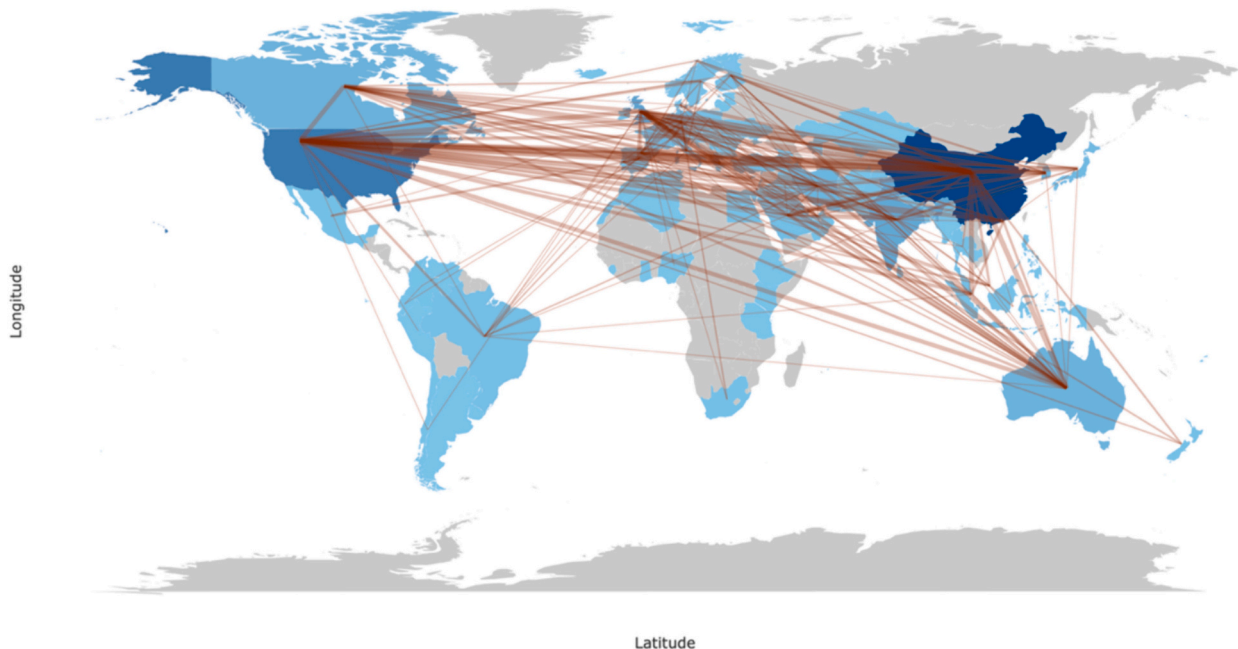


Fig. 12. Collaboration world map.
Source: Authors' work.

cultural exchange and knowledge sharing. The extensive collaborations with the United States, Hong Kong, and the United Kingdom highlight China's commitment to building strong international research networks and promoting scientific advancements on a global scale. The United States secured the second position with a total of 364 collaborations, predominantly with authors from the United Kingdom and Canada, after China. Scholars from the United Kingdom engaged in collaborative efforts for a total of 206 works, involving counterparts from >48 nations across the globe. Notably, a significant proportion of these collaborations occurred with authors from Canada and Australia. In contrast, our findings indicate that scholars from European countries exhibit a limited propensity for engaging in collaborative endeavours with colleagues from nations beyond their own. The remaining countries have comparable profiles. These findings suggest that the United Kingdom has established strong ties with Canada and Australia in terms of collaborative work, indicating a shared interest and willingness to work together. On the other hand, it appears that European writers tend to prioritize collaborations within their own countries, potentially due to cultural or linguistic similarities. However, the remaining countries studied display similar patterns of collaboration as the United Kingdom, Canada, and Australia.

4. Conclusions

The main goal of our research is to fill a notable gap in the existing scholarly literature by investigating the application of algorithmic trading. To date, the literature reviews have primarily focused on the types of machine learning (ML) and deep learning (DL) employed in high-frequency trading (e.g., Hussain et al., 2023) or the financial sector, albeit with a smaller sample size (Biju et al., 2023). This study investigates the progression of research on automated algorithms for the past thirty years and evaluates a comprehensive selection of publications in the finance and energy sectors. Our research uncovers historical and prospective patterns in research about complex mathematical models, when compared to other studies. Unlike previous research, our study presented a broader perspective that serves as a foundation for scholars to recognize contemporary popular subjects more effectively, rather than focusing on the identification of specific models and their characteristics. Moreover, we substantiate a transition in the use of algorithmic models from financial optimization issues to energy usage. This observation underscores the growing recognition of the potential of these algorithms to address challenges beyond the realm of finance, extending their impact to include sustainability and energy management.

Our bibliometric study indicates a consistent rising trend in the number of published articles on our topic, highlighting the growing global interest and significance of algorithmic trading research. The prevalence of nations such as China and the United States in this domain implies a clustering of research endeavours, as well as the possibility of disseminating knowledge and fostering international cooperation. The process of identifying scholars who are frequently cited and influential publications, such as "Expert Systems with Applications," offers valuable information for researchers who aim to connect with the most influential and prominent sources in their respective fields. The analysis of co-citations identified clear groups of interconnected papers, providing insight into the fundamental topics and conceptual frameworks that influence scholarly conversations on algorithmic trading. Additionally, our examination of the co-occurrence network revealed the presence of two primary clusters, namely "algorithmic trading" and "blockchain." This indicates an increasing preference towards the utilization of algorithmic trading techniques in the context of blockchain technology and smart energy systems, which has the potential to create novel opportunities for investigation and advancement.

The conceptual framework we developed, which covers four distinct topic periods, provides a thorough comprehension of an evolving research environment. The most recent cluster has witnessed the

introduction of subjects such as environmental sustainability and energy management, in conjunction with research on blockchain technology. This development underscores the broadening scope of algorithmic trading research, surpassing the traditional boundaries of the finance field. The findings of our study indicate that data-driven technologies such as deep learning, genetic algorithms, and machine learning have gained significant popularity. However, the observation of unlinked clusters in the co-research networks highlights the necessity for increased collaborative endeavours within the field. Enhanced collaboration has the potential to expedite the progress of research and facilitate the exchange of ideas across various disciplines.

The performance analysis we conducted demonstrated the effective utilization of machine learning (ML) and deep learning (DL) techniques in financial markets for tasks such as forecasting stock prices and optimizing trading strategies. Furthermore, the utilization of these algorithms in energy markets has exhibited encouraging outcomes in the optimization of energy usage, prediction of electricity demand, and management of renewable energy sources. These results highlight the capacity of algorithmic trading to stimulate innovation and promote sustainable practices in several sectors.

One possible limitation of our study may involve the omission of relevant scholarly sources during the application of the PICO approach. Moreover, it is plausible that the study may have failed to thoroughly incorporate all pertinent literature associated with algorithmic trading, potentially neglecting noteworthy contributions from non-academic sources. Future literature reviews may consider carrying out a more focused investigation into the identified themes within the current study. The future themes may include the exploration of scholarly literature dealing with the impact of algorithmic trading on market volatility, the assessment of the effectiveness of different trading strategies in various market circumstances, and the examination of the regulatory implications linked to algorithmic trading in the financial and energy industries. Despite its inherent limitations, the bibliometric analysis undertaken in this study makes a valuable contribution to the academic community by addressing a substantial gap in information and offering an in-depth understanding of the progression and present condition of algorithmic trading research. The implications of our research stretch beyond the academic sphere, providing essential knowledge for professionals, politicians, and individuals interested in leveraging the capabilities of algorithmic trading methods in finance, energy, and other developing fields.

Funding

1. Project financed by Lucian Blaga University of Sibiu through the research grant LBUS-IRG-2023 (for Lucian Belascu)
2. This work was funded by the EU's NextGenerationEU instrument through the National Recovery and Resilience Plan of Romania - Pillar III-C9-I8, managed by the Ministry of Research, Innovation and Digitalization, within the project entitled "Non - Gaussian self - similar processes: Enhancing mathematical tools and financial models for capturing complex market dynamics", contract no. 760243/28.12.2023, code CF 194/31.07.2024 (for Alexandra Horobet & Zeno Dinca).

CRedit authorship contribution statement

Alexandra Horobet: Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization. **Sabri Bou-baker:** Writing – review & editing, Validation, Supervision, Methodology. **Lucian Belascu:** Writing – review & editing, Validation, Resources, Funding acquisition, Conceptualization. **Cristina Carmencita Negreanu:** Writing – original draft, Software, Formal analysis, Data curation. **Zeno Dinca:** Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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