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A Worldwide Assessment of Quantitative Finance Research through Bibliometric Analysis

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Abstract

The field of quantitative finance has been rapidly growing in both academics and practice. This article applies bibliometric analysis to investigate the current state of quantitative finance research. A comprehensive dataset of 2,723 publications from the Web of Science Core Collection database, between 1992 to 2022, is collected and analyzed. CiteSpace and VOSViewer are adopted to visualize the bibliometric analysis. The article identifies the most relevant research in quantitative finance according to journals, articles, research areas, authors, institutions, and countries. The study further identifies emerging research topics in quantitative finance, e.g. deep learning, neural networks, quantitative trading, and reinforcement learning. This article contributes to the literature by providing a systematic overview of the developments, trajectories, objectives, and potential future research topics in the field of quantitative finance.

Keywords: quantitative finance, mathematical finance, computational finance, bibliometric analysis, systematic overview, research trend.

1. Introduction

1.1 Background

Quantitative finance has a rich history dating back to the early 20th century. The development of quantitative analysis techniques, e.g. statistical models, probability theory, computational algorithms, and big data, has led to the emergence of quantitative finance. Quantitative finance can be defined as a field that uses mathematical techniques and large datasets to analyze and model financial markets and financial products. It involves making judgments regarding investments, risk management, and other financial activities by using mathematical models, statistical approaches, and computing algorithms to comprehend and evaluate financial occurrences. The father of quantitative finance is considered to be Markowitz, who created portfolio theory and laid the foundation for quantitative investment strategies. The rise of computerized trading and the abundance of financial data have accelerated the growth and development of quantitative finance, making it a key component of the financial sector.

Financial institutions commonly rely on quantitative methods and tools to make investment decisions and manage risk, which makes quantitative finance a crucial part of the financial industry. Furthermore, the field is continuously evolving due to ongoing advancements in technology and data analytics. Quantitative finance research covers a wide range of topics, e.g. financial modeling, risk management, volatility, portfolio optimization, high-frequency trading, statistical arbitrage, machine learning, artificial intelligence, and financial regulation. A comprehensive bibliometric analysis of quantitative finance articles published in reputable journals helps to better understand the fast-growing quantitative finance field.

The objectives of this article are manifold. First, it seeks to provide an early comprehensive understanding of emerging trends in quantitative finance. Second, the research aims to provide an overview of the distribution of quantitative finance research publications, journals, research areas, authors, institutions, and countries in the academic community. Third, the article depicts the intellectual structure of quantitative finance research and their collaboration networks, based on article co-citation analysis and author co-citation analysis. Finally, science mapping identifies significant achievements that have contributed to the field of quantitative finance. The article also explores the evolution of research topics and identifies emerging research areas in the quantitative finance field.

1.2 Contribution

The article conducts a comprehensive bibliometric analysis of publications within the quantitative finance field. First, the article offers a complete overview of publications in the quantitative finance field, providing researchers, investors, and traders with a visual representation of the field. Second, the findings help researchers better understand the current state and evolution of quantitative finance research and identify valuable research topics. Third, the article examines the evolution of quantitative finance publications and identifies the main discipline categories, journal distributions, the most cited articles, landmark nodes, pivot nodes, and influential authors. Fourth, the analysis presents collaboration networks among authors, institutions, and countries through co-authorship analysis. Fifth, the article explores citation bursts, time zone view of keyword co-occurrence, and burst analysis of keyword co-occurrence. Sixth, the article reveals that emerging research topics in quantitative finance include deep learning, neural network, quantitative trading, and reinforcement learning. Overall, the article contributes to the analysis of developments and trajectories in the quantitative finance field, which can help scholars, investors, and traders to appreciate the trend and potential future research.

The rest of the article is organized as follows. Section 2 literature. Section 3 data and methodology. Section 4 descriptive statistical analysis. Section 5 collaboration network analysis. Section 6 science mapping analysis. Section 7 concludes.

2. Literature

Bibliometric analysis has gained significant popularity as an academic research methodology in recent years. Garfield and Merton (1979) highlight citation analysis as an effective way to identify the most important publications in a research field. Co-citation analysis, introduced by Small (1973), explores connections among publications that co-occur in other articles' reference lists and is an essential process in cluster analysis (Boyack et al., 2013). Callon et al. (1983) introduce co-word analysis to explain the relationships between various stages of innovation and to determine whether fundamental or applied research is the driving force behind these stages.

The bibliometric analysis of the co-citation network has been widely adopted to explore the emerging trend and the evolution of a scientific field. Gaviria-Marin et al. (2019) present an overview of research in knowledge management using bibliometric analysis. Wang et al. (2021) analyze blockchain-related research using bibliometric analysis. They summarize the hot areas in the blockchain field and recommend emerging topics for future research. Cai and Guo (2021) explore the publications in green finance filed via bibliometric analysis. They present and visualize the intellectual structure, publications, and corresponding networks in green finance research. Donthu et al. (2021) provide an overview of the bibliometric methodology. They also present a guideline and techniques on how to conduct a bibliometric analysis. Goodell et al. (2021) present an overview of the research in Artificial intelligence and machine learning via co-citation and bibliometric-coupling analysis. Patel et al. (2022) combine bibliometric analysis and meta-analysis to explore the financial market integration literature. This article contributes to the literature by using bibliometric analysis to investigate the evolution of quantitative finance research.

3. Data and Methodology

3.1 Data Collection

The data for this article is gathered from the Web of Science (WoS) Core Collection, which is a leading database containing records of articles from high-impact journals around the world. Various keywords related to quantitative finance, e.g. quantitative investing, computational finance, and statistical arbitrage, are selected. The article applies a topic search in the WoS since broader literature is preferred in conducting a bibliometric analysis (Chen, 2017). The publication date range for the search is from January 1, 1992, to December 31, 2022, and only article, proceeding paper, and early access document types are considered. The result is refined by limiting the document types to article, proceeding paper, and early access. In addition, the article uses CiteSpace to remove potential duplicated publications. The result is a sample of 2,723 publications in quantitative finance (downloaded on January 31, 2022). This sample can be used to conduct a comprehensive bibliometric analysis in the field of quantitative finance.

3.2 Methodology

The article employs both descriptive statistical analysis and bibliometric analysis to investigate the sample collected. Descriptive statistical analysis provides a comprehensive overview of the development in the field of quantitative finance, e.g. the number of publications over the year, discipline categories, journal distributions, highly cited papers, and productive authors. Bibliometric analysis is a quantitative method used to analyze bibliometric data, commonly used to provide insights into the state of the intellectual structure and emerging trends in a specific research field (Chen, 2006). The main technique of bibliometric analysis is science mapping, which focuses on the interconnections between research constituents, such as citations, co-citations, coupling, co-word, co-authorship, and clustering (Donthu et al., 2021).

Bibliometric analysis results are commonly visualized via networks. This article applies CiteSpace 6.1.R5 (64-bit) and VOSViewer in the bibliometric analysis of the retrieved literature on quantitative finance. The parameters in CiteSpace are as follows. Timespan = 1992-202. Year per slice = 1. Term Source: Title, abstract, and author keywords. Look back years = -1. Other parameters are set to default.

4. Descriptive Analysis

4.1 Publications Over the Year

Figure 1 shows the number of publications and citations in quantitative finance by year. The number of articles published from 1992 to 2007 is relatively low, indicating that the quantitative finance field attracts relatively low interest. The number of publications surpasses 50 in 2008 and continues to grow. The number of publications exceed 200 in 2018 and exceed 300 in 2021. Interestingly, the number of publications decreases slightly in 2022. The trend in citations follows a similar pattern to that of publications. Overall, the consistent increase in publications and citations demonstrates that quantitative finance has gained immense attention in the academic field.

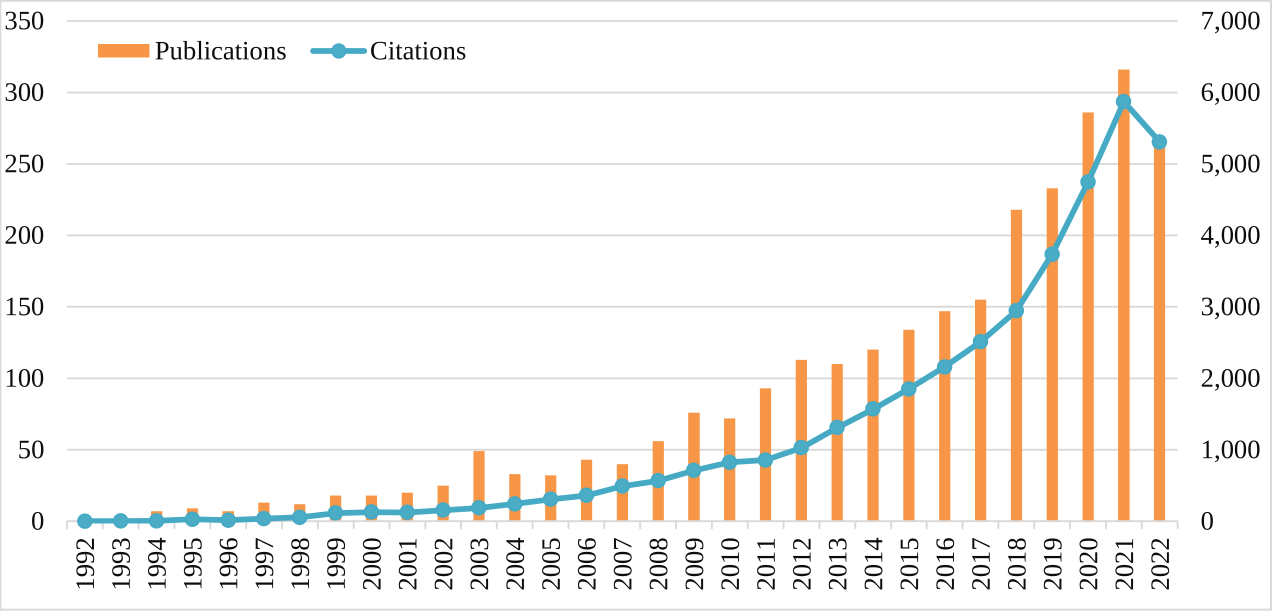

Figure 1. Publications and citations in quantitative finance, 1992-2022.

4.2 Discipline Categories

Scholars from various disciplines are taking an increasing interest in quantitative finance. Figure 2 presents the discipline categories defined by the WoS, based on the journals in the sample retrieved. The top three research areas are Business Finance, Economics, and Mathematics Interdisciplinary Applications and Mathematics Applied, with 28.24%, 24.61%, and 16.93%, respectively. These findings align with the definition of quantitative finance, which employs mathematical and statistical methods to analyze and model financial markets and instruments. In addition, researchers from Statistics Probability, Computer Science Artificial Intelligence, and Operations Research Management Science have explored topics in quantitative finance from their respective perspectives. The diversified range of disciplines engaged in quantitative finance research illustrates its growing impact.

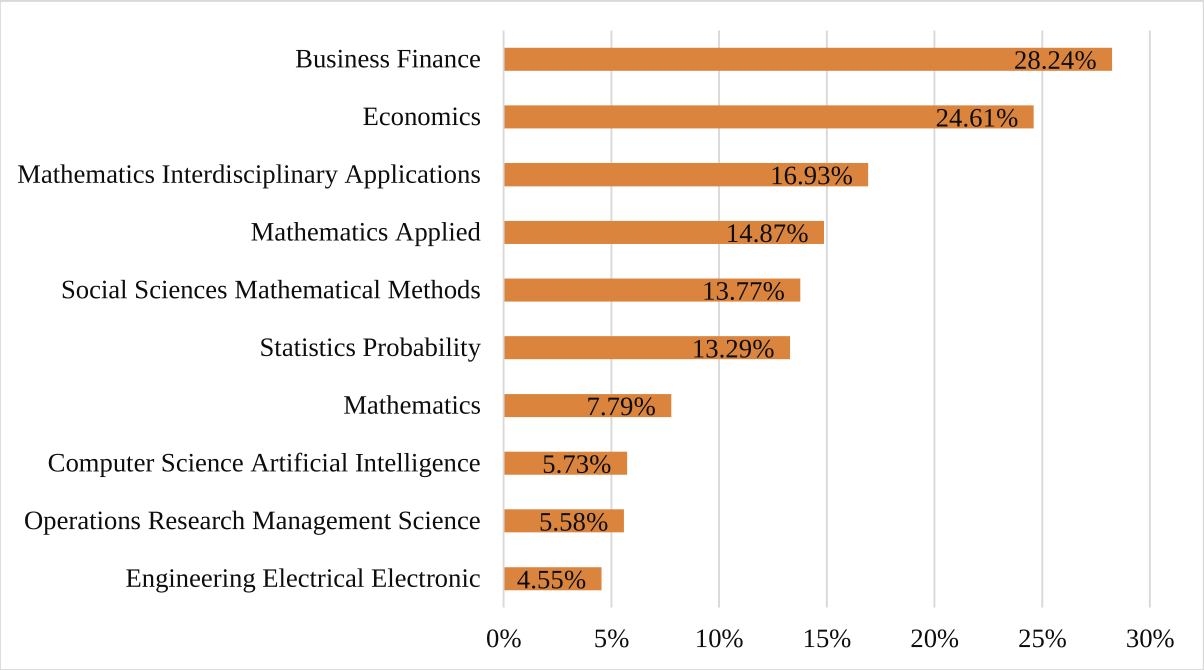

Figure 2. Discipline categories of the publications in quantitative finance, 1992-2022.

4.3 Journal Distributions

Table 1 displays the high-published journals in quantitative finance ranked by the number of publications in the sample. The majority of these journals are leading publications in finance and mathematics. Notably, Quantitative Finance has the most publications, with 201 articles and 2,462 citations. Stochastic Processes and Their Applications, and Physica A-Statistical Mechanics and Its Applications follow behind, with 44 publications and 806 citations, and 42 publications and 921 citations, respectively. Mathematical Finance and the Journal of Financial Markets have high citations per article, with values of 74.3 and 40.9, respectively. This suggests that the articles on quantitative finance published in these two journals have had a significant impact on subsequent research.

Table 1. High-published journals in quantitative finance, 1992-2022.

Rank	Journal	Publications	Citations	Citations per article
1	Quantitative Finance	201	2462	12.2
2	Stochastic Processes and Their Applications	44	806	18.3
3	Physica A-Statistical Mechanics and Its Applications	42	921	21.9
4	Mathematics	38	160	4.2
5	Siam Journal on Financial Mathematics	36	331	9.2
6	Finance and Stochastics	30	529	17.6
7	Expert Systems with Applications	29	639	22.0
8	Journal of Financial Markets	28	1145	40.9
9	Computational Economics	27	105	3.9
10	Journal of Computational and Applied Mathematics	27	211	7.8
10	Journal of Statistical Mechanics-Theory and Experiment	27	146	5.4
10	Mathematical Finance	27	2005	74.3

5. Collaboration Network Analysis

5.1 Authors

5.1.1 The Most Productive Authors

A total of 5,313 authors have contributed to at least one publication in quantitative finance. However, only 831 of these authors have published more than two articles in this field. Table 2 presents the most productive authors in quantitative finance, based on a minimum of eight publications. The top two authors are Sebastian Jaimungal and Alvaro Cartea, with 21 and 19 publications, respectively. Sebastian Jaimungal is a professor of mathematical finance in the Department of Statistical Sciences at the University of Toronto. Alvaro Cartea is a professor of mathematical finance at the

Mathematical Institute at the University of Oxford. Notably, Christopher Krauss has only published eight articles, but they have been cited 948 times, resulting in an impressive citation rate of 118.5 per article. This is mainly due to his influential research on deep learning for financial prediction (Fischer & Krauss, 2018). Christopher Krauss is a professor of deep learning and statistical arbitrage at the University of Erlangen-Nuremberg.

Table 2 The productive authors by publications in quantitative finance, 1992-2022.

Rank	Author	Publications	Citations	Citations per article
1	Jaimungal, Sebastian	21	261	12.4
2	Cartea, Alvaro	19	229	12.1
3	Jacquier, Antoine	10	137	13.7
4	Stuebinger, Johannes	10	129	12.9
5	Touzi, Nizar	10	347	34.7
6	Zhang, Wei	10	79	7.9
7	Beiglboeck, Mathias	9	153	17.0
8	Leach, P. G. L.	9	84	9.3
9	Oosterlee, Cornelis W.	9	123	13.7
10	Bouchaud, Jean-Philippe	8	122	15.3
10	Feehan, Paul M. N.	8	90	11.3
10	Krauss, Christopher	8	948	118.5
10	Mackenzie, Donald	8	241	30.1
10	Madan, Dilip B.	8	100	12.5
10	Manahov, Viktor	8	58	7.3
10	Wang, Xiaoqun	8	104	13.0
10	Wong, Hoi Ying	8	148	18.5

5.1.2 Co-authorship Network

An analysis of co-authorship among authors has been conducted to investigate collaborations in the field of quantitative finance. Figure 3 shows the co-authorship network based on the sample, with a minimum of five publications. An example of collaboration is seen among Mariani, Francestra, Zirilli, Francesco, and Recchioni, Maria Cristina. Overall, the collaborations among authors in quantitative finance are relatively weak. Therefore, there is a need to encourage scholarly collaboration in the field of quantitative finance.

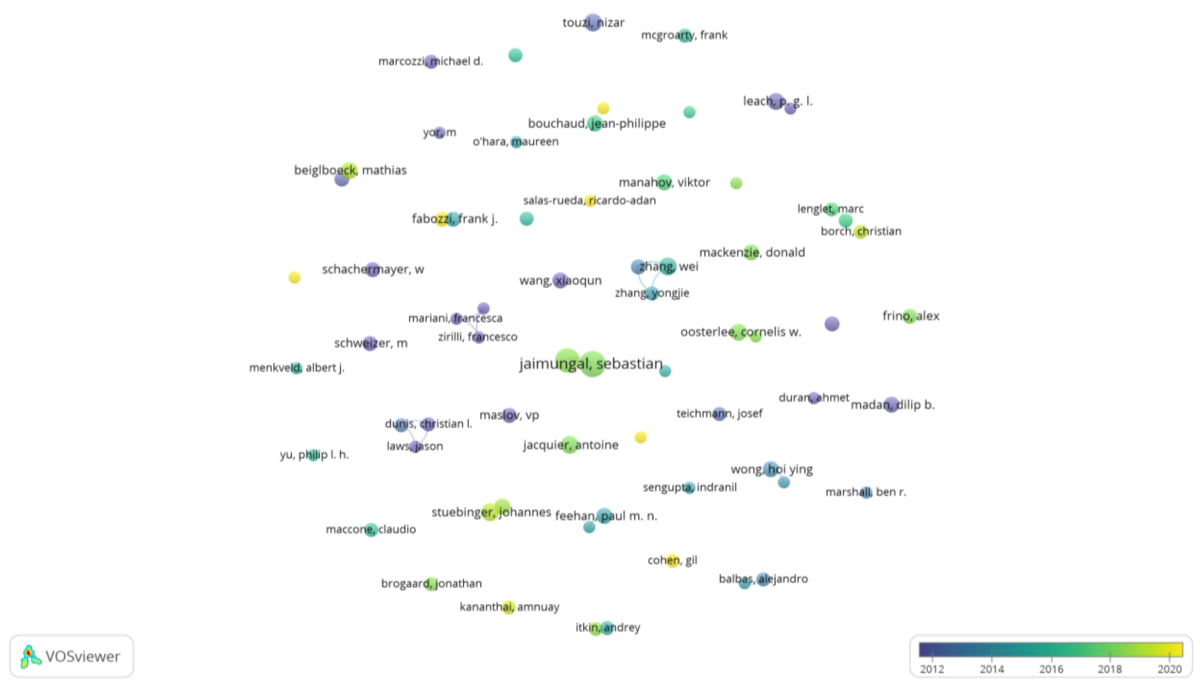

Figure 3. Co-authorship network in quantitative finance with a minimum of five publications, 1992-2022.

5.2 Institutions

5.2.1 Influential Institutions

Table 3 presents the influential institutions in quantitative finance research, ranked by the number of publications, with a minimum of 20 publications. The University of Oxford in England tops the list, with 43 publications and 588 citations, followed by École Polytechnique in France and the University of Toronto in Canada, with 32 publications, 690 citations, and 31 publications, 349 citations, respectively. The majority of institutions are in the United States and England. This indicates that institutions from these two countries play a significant role in quantitative finance research.

Table 3. The most productive institutions in quantitative finance, 1992-2022

Rank	Institution	Publications	Citations	Citations per article
1	Univ Oxford	43	588	13.7
2	Ecole Polytech	32	690	21.6
3	Univ Toronto	31	349	11.3
4	NYU	30	381	12.7
5	Swiss Fed Inst Technol	26	228	8.8
6	Columbia Univ	25	877	35.1
7	Cornell Univ	25	975	39.0
8	UCL	23	312	13.6
9	Univ Paris 06	23	2062	89.7
10	Imperial Coll London	22	335	15.2
10	Univ Vienna	22	447	20.3
11	MIT	20	518	25.9

Figure 4 presents the institutional collaboration network represented by co-authorship among institutions, with a minimum of ten publications. The collaboration network portrays the regional features of institution cooperation, where institutions in the USA, England, and France have established a relatively robust network. For instance, the University of Oxford collaborates well with UCL, the University of Toronto, and Columbia University. Chinese institutions, such as the University of Chinese Academy of Sciences, primarily collaborate with institutions in Singapore and mainland China. Enhancing institutional cooperation internationally helps to broaden and deepen the scope of quantitative finance research.

5.2.2 Network of Co-author's Institutions

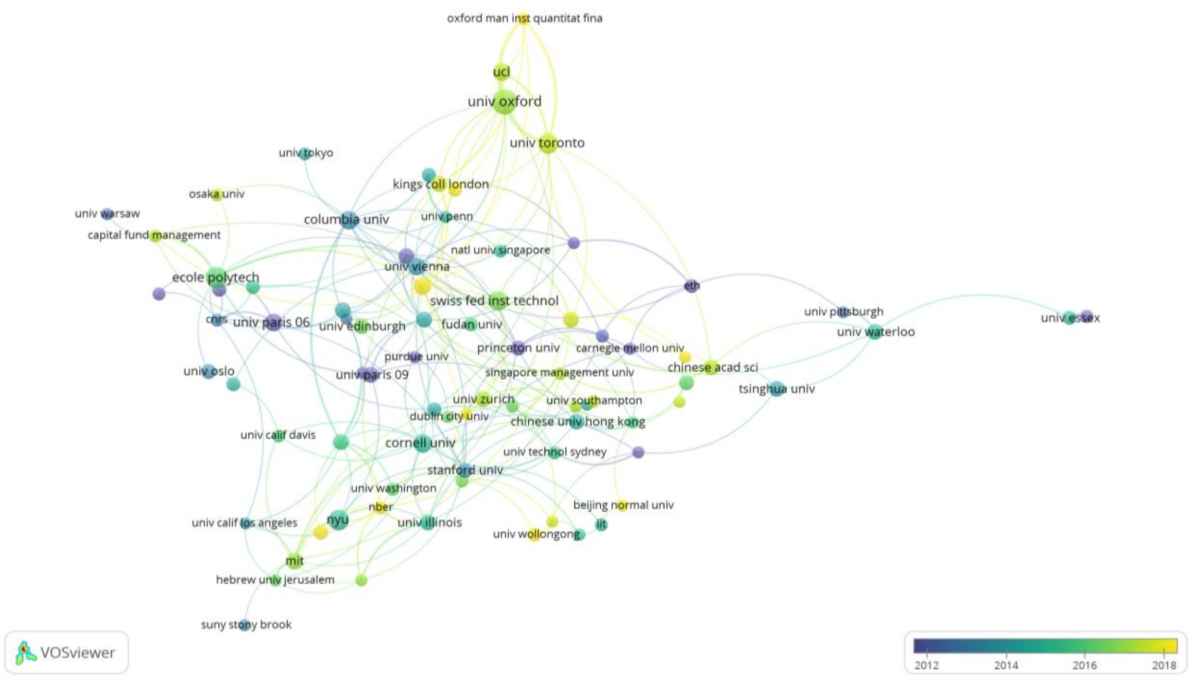

Figure 4. Institutional collaboration network in quantitative finance with a minimum of ten publications, 1992-2022

5.3 Countries

5.3.1 Influential Countries

A total of 94 countries and regions contributed to the field of quantitative finance research. Table 4 presents the top ten countries based on the number of publications in the sample. The US is the leading country in this field, with 677 publications and 12,445 citations. Thereafter comes China and England, with 359 publications, 4,895 citations, and 337 publications, 5,248 citations, respectively. It is worth noting that France has the highest citations per paper (22.3), which signifies that France produces influential research in the field of quantitative finance.

Table 4. The top ten productive countries in quantitative finance, 1992-2022.

Rank	Country	Publications	Citations	Citations per article
1	USA	677	12445	18.4
2	Peoples R China	359	4895	13.6
3	England	337	5248	15.6
4	France	243	5410	22.3
5	Germany	236	4062	17.2
6	Canada	157	2757	17.6
7	Italy	142	1240	8.7
8	Australia	116	1287	11.1
9	Switzerland	100	1423	14.2
10	Japan	88	844	9.6

5.3.2 Network of Co-Authors' Countries

Collaboration among nations in scientific research is advantageous for the advancement of knowledge. Co-authorship between countries serves as a significant example of such international cooperation. A network consisting of nodes representing the collaborating countries based on the sample is shown in Figure 5. The US stands as the world's most prolific country in this field, with a robust network of international collaborations with countries such as Canada, China, England, France, Germany, Italy, and Australia.

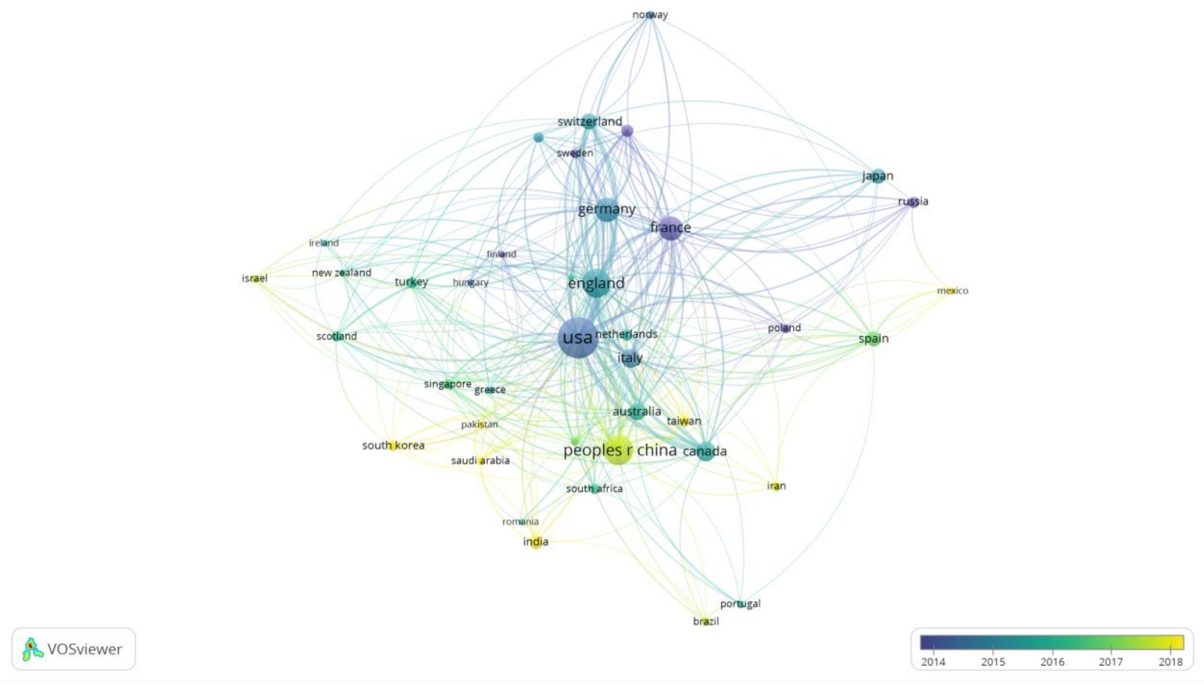

Figure 5. International collaboration network with a minimum of 15 publications in quantitative finance, 1992-2022

6. Science Mapping Analysis

6.1 Co-citation Analysis

6.1.1 Cluster Analysis of Co-Cited Articles

Co-citation analysis investigates the similarity between two articles based on their co-cited relationship. It helps to identify the most significant publications and find out the theme clusters. The lag-likelihood ratio method (Chen, 2006) is used in identifying the cluster labels from keywords within the co-citation network. Figure 6 shows the result of a cluster analysis of co-cited articles. The radius of a node in a co-citation network represents its betweenness centrality or importance within the network.

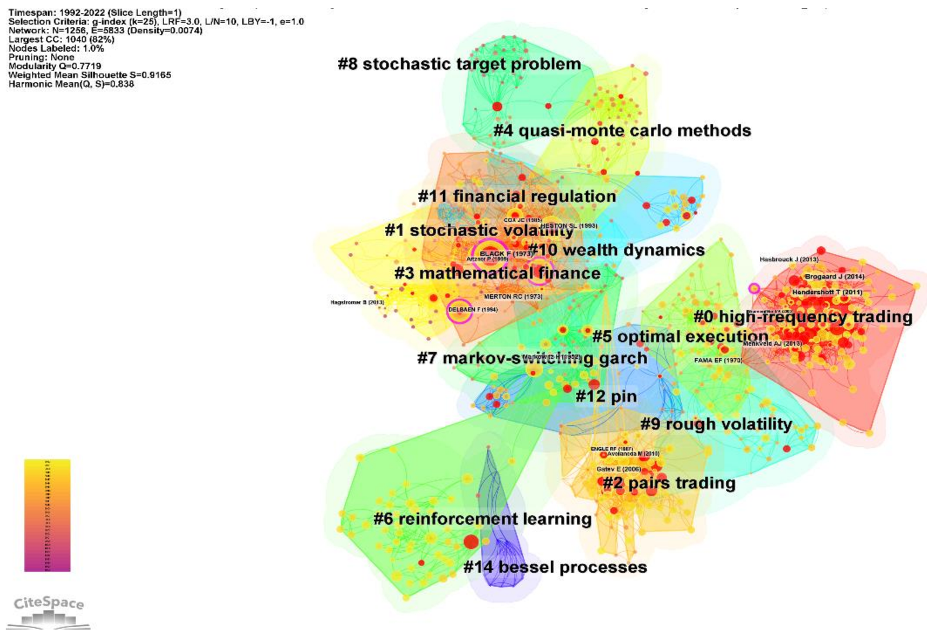

Figure 6. Clusters network of co-cited articles in quantitative finance, 1992-2022.

Table 5 summarizes the cluster analysis of co-cited articles in the field of quantitative finance. CiteSpace generates a Cluster ID based on the size of the cluster, which is determined by the number of publications within the cluster. As the cluster size increases, the Cluster ID becomes smaller. The Silhouette shows the homogeneity of each cluster. The Mean (Year) provides the average publication year for the articles within each cluster. The top seven clusters with more than 50 articles are high-frequency trading, stochastic volatility, pairs trading, mathematical finance, quasi-monte Carlo methods, optimal execution, reinforcement learning, Markov-switching garch, and stochastic target problem. The mean publication year of each cluster varies, with most clusters ranging from 1992 to 2013.

Table 5. Co-citation cluster summary

Cluster ID	Size	Silhouette	Mean (Year)	Label
#0	195	0.877	2008	High-frequency trading, liquidity, market quality, price discovery, market efficiency
#1	192	0.857	1993	Stochastic volatility, high-frequency trading, financial mathematics, option pricing, algorithmic trading
#2	95	0.932	2003	Pairs trading, statistical arbitrage, cointegration, hurst exponent, finance
#3	76	0.958	1992	Mathematical finance, equivalent martingale measure, stochastic integrals, incomplete markets, high-frequency trading
#4	68	0.932	1995	Quasi-monte Carlo methods, Brownian bridge, principal component analysis, effective dimension, randomly shifted lattice rules
#5	65	0.93	2004	Optimal execution, market impact, Hawkes processes, price impact, stochastic optimal control
#6	52	0.966	2013	Reinforcement learning, deep learning, deep reinforcement learning, online portfolio selection, artificial intelligence
#7	49	0.939	1991	Markov-switching garch, high-frequency trading, active portfolio management, stochastic programming, behavioral finance
#8	46	0.971	1992	Stochastic target problem, nonlinear degenerate Kolmogorov equation, Harmandir operators, viscosity solution, quantile hedging
#9	39	0.937	2000	Rough volatility, signal processing, sentiment analysis, concept drift, rough Heston model

#10	38	0.927	1994	Wealth dynamics, evolutionary finance, quantitative finance, convex duality, Markowitz model
#11	37	0.965	2003	Financial regulation, algorithms, method of heat potentials, first hitting time density, economic sociology
#12	30	0.964	1999	PIN (Probability of Information-based Trading), VPIN (Volume-synchronized Probability of Informed Trading), fake Brownian motion, model-independent pricing, optimal transport
#14	16	0.996	1982	Bessel processes, Brownian motion with drift, integral of geometric Brownian motion, last-exit times, complex analytic methods in stochastics
#23	7	1	1971	Eigendecomposition, exponential correlation model, Toeplitz matrix, market exposure, exchange-traded fund
#41	3	1	2002	Weather derivative pricing, time series analysis, applied mathematical finance, quantitative finance, high-frequency trading

6.1.2 Analysis of Landmark and Pivot Nodes

Landmark nodes represent a highly cited or influential paper in a co-citation network. These nodes represent publications that have a significant impact on the field. Pivot nodes are nodes with high betweenness centrality scores, serving as central linking points within a co-citation network. These nodes are marked with purple trims in CiteSpace. Table 6 summarizes the five typical landmark nodes, four pivot nodes and five highly cited articles in quantitative finance.

The five landmark articles are Hendershott et al. (2011), Heston (1993), Gatev et al. (2006), Artzner et al. (1999), and Markowitz (1952). The research fields of the five landmark nodes are algorithmic trading, options, pairs trading, risk measurement, and portfolio selection. The five landmark articles are published in top journals in the finance field, i.e. The Journal of Finance, The Review of Financial Studies, Journal of Financial Markets, and Mathematical Finance. Regarding pivot nodes, Black and Scholes (1973) and Robert C. Merton (1973) develop the well-known Black Scholes Merton equation. Delbaen and Schachermayer (1994) present a general version of the fundamental theorem of asset pricing. Brunnermeier and Pedersen (2005) explore predatory trading. They find that predatory trading can lead to price overshooting and reduced liquidation value for distressed traders.

Table 6. Details of landmark nodes, pivot nodes and highly cited article

Article	Title	Journal	Cluster ID
Landmark nodes			
Hendershott et al. (2011)	Does Algorithmic Trading Improve Liquidity?	The Journal of Finance	#0
Heston (1993)	A Closed-Form Solution for Options with Stochastic Volatility with Applications to Bond and Currency Options	The Review of Financial Studies	#1
Gatev et al. (2006)	Pairs Trading: Performance of a Relative-value Arbitrage rule	The Review of Financial Studies	#2
Artzner et al. (1999)	Coherent Measures of Risk	Mathematical Finance	#3
Markowitz (1952)	Portfolio Selection	The Journal of Finance	#7
Pivot nodes			
Black and Scholes (1973)	The Pricing of Options and Corporate Liabilities	Journal of Political Economy	#1
Robert C. Merton (1973)	Theory of Rational Option Pricing	The Bell Journal of Economics and Management Science	#1
Delbaen and Schachermayer (1994)	A General Version of The Fundamental Theorem of Asset Pricing	Mathematische Annalen	#3
Brunnermeier and Pedersen (2005)	Predatory Trading	The Journal of Finance	#0
Highly cited articles			
Brogaard et al. (2014)	High-Frequency Trading and Price Discovery	The Review of Financial Studies	#0
Hasbrouck and Saar (2013)	Low-latency Trading	Journal of Financial Markets	#0
Fama (1970)	Efficient Capital Markets: A Review of Theory and Empirical Work	The Journal of Finance	#0
Menkveld (2013)	High Frequency Trading and The New Market Makers	Journal of Financial Markets	#0
Hagströmer and Nordén (2013)	The Diversity of High-frequency Traders	Journal of Financial Markets	#0

6.1.3 References with Citation Bursts

Citation bursts indicate potential hot topics within a dynamic research field. Chen (2014) suggests that a cluster containing a significant number of references with citation bursts is indicative of such a field. CiteSpace uses

Kleinberg's algorithm (2002) to detect these bursts through its "Burst Detection" function. Table 7 shows the top 15 articles with the strongest citation bursts. In the timeline spanning from 1992 to 2022, each reference's burst is highlighted in red. Black and Scholes (1973) have the highest burst strength at 16.64, ranging from 1996 to 2015. Together with Robert C. Merton (1973), they develop the fundamental equation in quantitative finance, known as the Black Scholes Merton equation, which is a mathematical model for the dynamics of a financial market containing derivative investment instruments. Thereafter comes Harrison and Pliska (1981), who present a general stochastic model of a frictionless security market with continuous trading. Notably, Kirilenko et al. (2017) explore the flash crash within high‐frequency trading, with an article strength of citation burst of 12.68, ranging from 2019 to 2022. This indicates that the flash crash remains a hot topic in quantitative finance.

Table 7. The top 15 references ranked by the strength of citation bursts

Article	Strength	Begin	End	1993-2022
Black and Scholes (1973)	16.64	1996	2015	
Harrison and Pliska (1981)	14.05	1995	2009	
Robert C. Merton (1973)	12.83	2000	2014	
Delbaen and Schachermayer (1994)	12.74	1995	2005	
Kirilenko et al. (2017)	12.68	2019	2022	
Hendershott et al. (2011)	12.26	2013	2017	
Cont and Tankov (2004)	11.74	2008	2015	
Heston (1993)	11.55	2009	2015	
Harrison and Kreps (1979)	10.4	1995	2008	
Crandall et al. (1992)	9.61	1997	2013	
Carr et al. (2002)	8.7	2008	2012	
Vasicek (1977)	8.65	2001	2012	
Hochreiter and Schmidhuber (1997)	8.63	2019	2022	
Duffie et al. (2000)	8.53	2006	2014	
Glasserman (2004)	8.35	2006	2015	

6.1.4 Network of Author Co-Citation

Table 8 illustrates the top ten most cited authors ranked by citation frequency (the total citation within the sample). All these authors are widely acknowledged researchers in their respective fields.. For example, Fama, Eugene F. is renowned for his empirical work on portfolio theory and the efficient-market hypothesis (Fama, 1991; Fama & MacBeth, 1973). Black and Scholes (1973) and Robert C Merton (1973) are famous for their Black Scholes Merton equation, which laid the foundation for finance. Hendershott et al. (2011), Brogaard et al. (2014), and Menkveld (2013) are notable for their focus on high-frequency trading and algorithmic trading.

Table 8. The top ten most cited authors in the sample

Rank	Name	Citation frequency	Centrality	Institution	Area
1	Black Fischer	303	0.15	University of Chicago	Mathematical finance, Black Scholes Merton equation
2	Hendershott, Terrence	260	0.03	University of California, Berkeley	Algorithmic trading, market microstructure
3	Fama, Eugene F.	252	0.09	University of Chicago	Financial, portfolio theory, asset pricing
4	Merton, Robert C.	236	0.05	Massachusetts Institute of Technology	Finance, Black Scholes Merton equation, fractional Finance
5	Brogaard, Jonathan	221	0.02	University of Utah	Market microstructure, high-frequency trading
6	Hasbrouck, Joel	209	0.03	New York University	Market microstructure, regulation of trading mechanisms for securities
7	Cont Rama	162	0.04	University of Oxford	Probability, mathematical Finance
8	Heston Steven L.	160	0.06	University of Maryland	Quantitative research, investment modeling, stochastic volatility, gambling-related research
9	Menkveld Albert J.	159	0.01	Vrije Universiteit Amsterdam	Algorithmic trading, high-frequency trading, securities trading, asset pricing
10	Engle Robert Fry	157	0.05	New York University	Econometrics, time-varying volatility

Figure 7 presents the author co-citation network. Black Fischer is a pivot node in the author co-citation network. Co-citation relationships among Fischer Black and Merton, Robert C. Terrence Hendershott and Jonathan Brogaard, Fama, Eugene F., Harry Max Markowitz, and Engle Robert Fry are strong, which shows papers by these authors are usually cited at the same time.

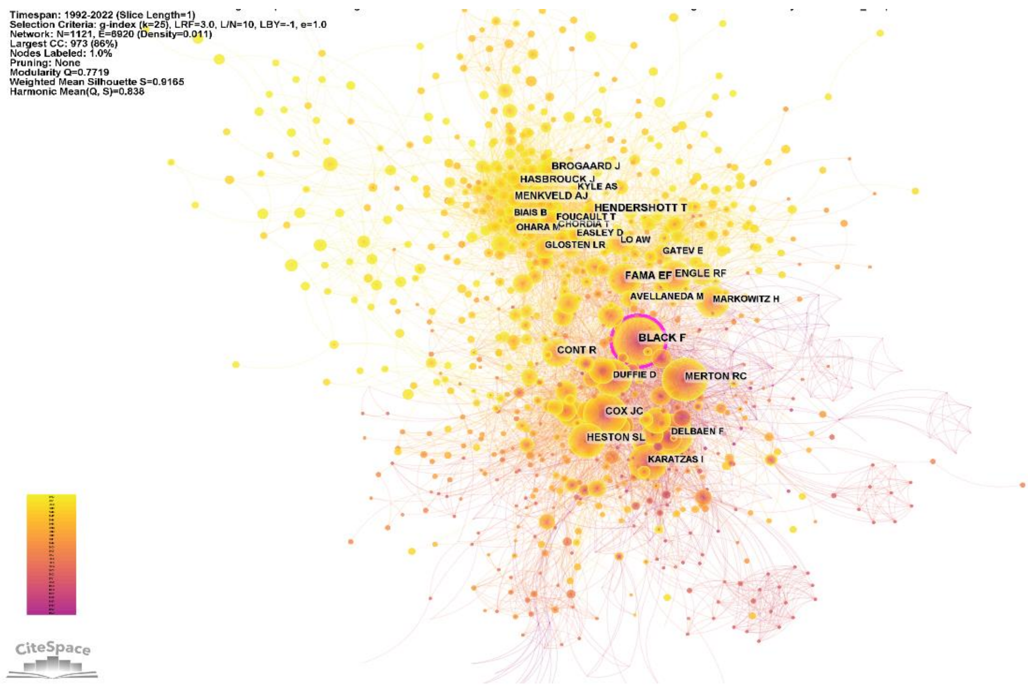

Figure 7. Author co-citation network in quantitative finance, 1992-2022.

6.2 Topic Trends

6.2.1 Keyword Co-Occurrence Analysis

A keyword co-occurrence network is a graphical representation of the relationships between keywords based on their frequency of co-occurrence in a dataset. It helps to identify important concepts and their relationships in a research field. To conduct keyword co-occurrence analysis, the article selected only those keywords that occurred at least 15 times. Figure 8 presents the keyword co-occurrence network in quantitative finance based on the given sample. The size of the node represents the frequency of the keyword co-occurrence with other keywords.

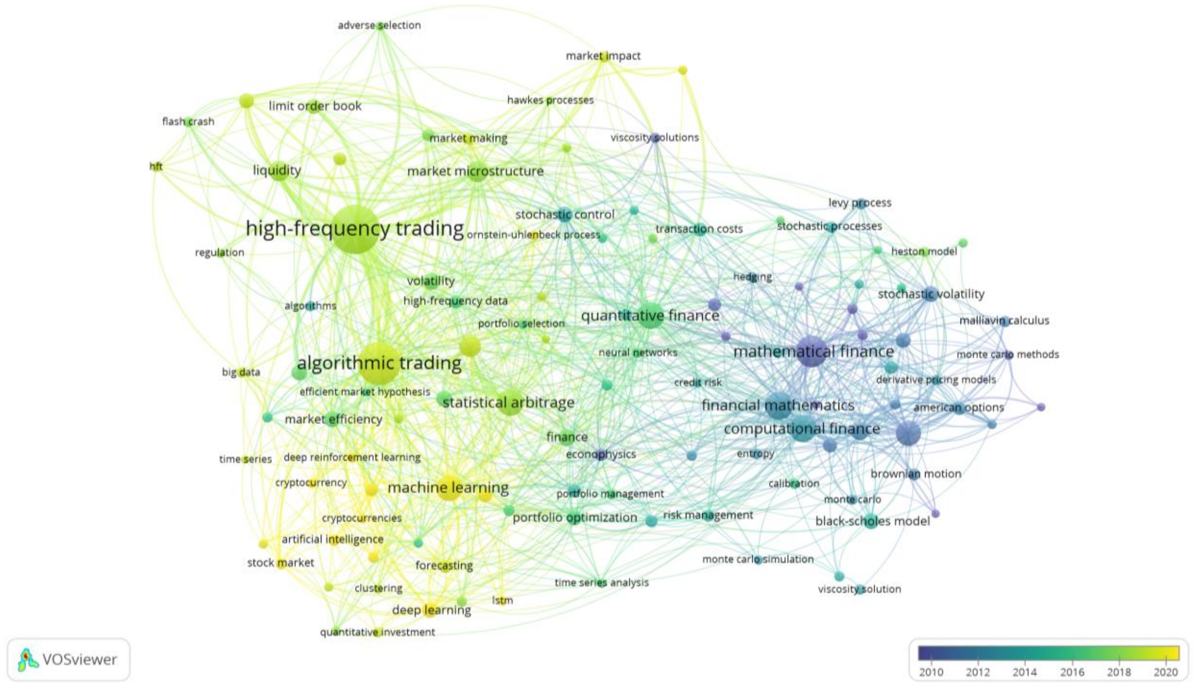

Figure 8. Keyword co-occurrence network in quantitative finance, 1992-2022.

According to co-occurrence frequency, the top ten keywords are high-frequency trading, algorithmic trading, mathematical finance, financial mathematics, quantitative finance, computational finance, statistical arbitrage, machine learning, option pricing, and pairs trading. Figure 8 reveals that high-frequency trading is commonly associated with algorithmic trading, volatility, liquidity, and market microstructure. Algorithmic trading is frequently associated with machine learning, statistical arbitrage, quantitative finance, market efficiency, and high-frequency trading. Mathematical finance is frequently linked to quantitative finance, computational finance, option pricing, and stochastic volatility.

6.2.2 Cluster of Keyword Co-Occurrence

A cluster co-occurring keywords analysis enriches understanding of topic trends in the field of quantitative finance. Keywords in an article reflect key ideas and themes, and the frequency of keyword co-occurrence indicates research hotspots in a particular topic area. Figure 9 illustrates the clusters of keyword co-occurrence based on the sample, which divided the research topics in quantitative finance into 11 categories: high-frequency trading, applied mathematical finance, machine learning, mathematical finance, option pricing, financial mathematics, stochastic differential equations, pairs trading, transaction costs, and Bessel processes.

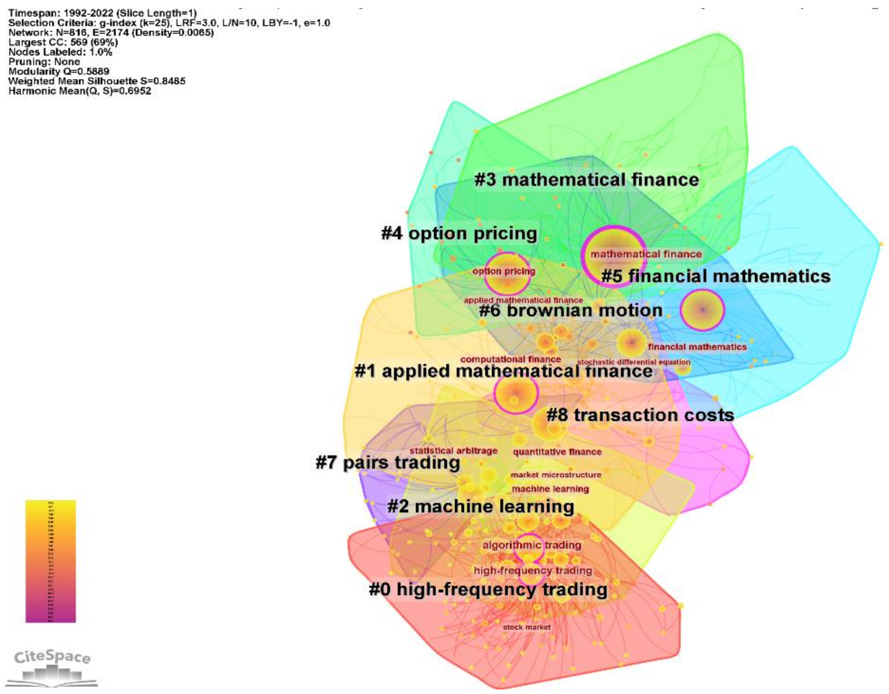

Figure 9. Cluster of keyword co-occurrence in quantitative finance, 1992-2022.

6.2.3 Time Zone View of Keyword Co-Occurrence

Figure 10 shows the time-zone view of the co-occurrence keyword, which shows how the frequency of co-occurrence between keywords changes over time. In 1994, the keywords are mathematical finance, and financial mathematics, The keyword computational finance shows up in 1996. and option pricing. Around 2000, the keywords are stochastic differential equation, portfolio optimization, Black Sholes model, and stochastic control. This suggests that during this period, researchers were exploring issues related to defining quantitative finance or its fundamentals. During 2008-2014, researchers focus more on algorithmic trading, statistical arbitrage, trading strategy, and high-frequency trading. More recently, the topics are deep learning, neural network, quantitative trading, and reinforcement learning.

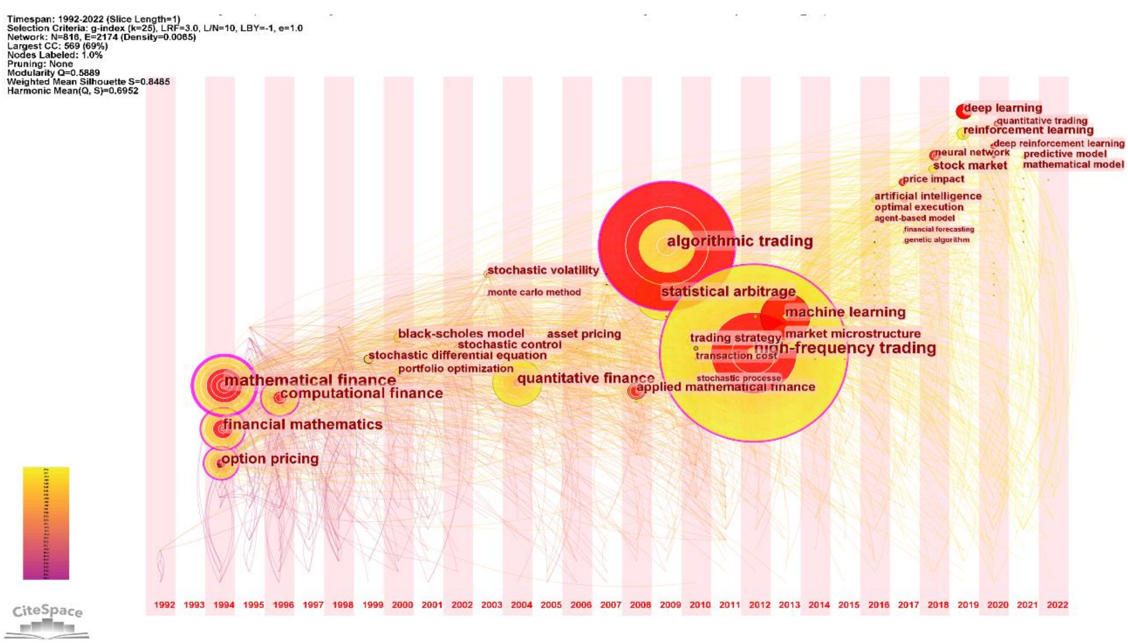

Figure 10. Time-zone view of co-occurrence keyword in quantitative financ, 1992-2022.

6.2.4 Burst Analysis of Keyword Co-Occurrence

Table 9 shows the top 25 keywords with the strongest citation bursts in quantitative finance research during 1992-2022. The analysis reveals that all the keywords have a strength value exceeding 3, with the highest being 17.55 for "mathematical finance" and the lowest being 3.97 for "neural network". "mathematical finance" has the longest duration, lasting for 10 years. The evolution of the quantitative finance field can be categorized into four stages, including the conceptualization and fundamentals of quantitative finance (1992-2000), the exploration of techniques, models, and equations in quantitative finance (2001-2012), the emergence of high-frequency trading, pairs trading and big data (2012-2017), and the advancements in machine learning, deep learning, algorithmic trading, and quantitative trading (2017-2022).

Table 9. The top 25 keywords with the strongest citation bursts in quantitative finance, 1992-202.

Keyword	Year	Strength	Begin	End	1993-2022
Mathematical finance	1994	17.55	1994	2014	
Incomplete market	1996	4.04	1996	2005	
Option pricing	1994	12.78	2000	2010	
Computational finance	1996	7.34	2000	2014	
American option	2001	5.99	2001	2015	
Stochastic volatility	2003	7.13	2003	2012	
Asset pricing	2005	5.51	2005	2015	
Financial mathematics	1994	9.15	2007	2014	
Applied mathematical finance	2008	15.1	2008	2015	
Levy process	2009	4.36	2009	2016	
Quantitative trading strategy	2010	7.16	2010	2015	
Levy process	2004	4.11	2010	2015	
Derivative pricing model	2011	4.51	2011	2015	
High-frequency trading	2012	15.27	2015	2018	
Pairs trading	2013	7.11	2016	2020	
Price impact	2017	5.41	2017	2020	
Big data	2017	4.01	2017	2020	
Limit order book	2012	4.07	2018	2019	
Neural network	2018	3.97	2018	2022	
Machine learning	2013	13.52	2019	2022	
Deep learning	2019	7.66	2019	2022	
Algorithmic trading	2009	8.66	2020	2022	
Quantitative trading	2020	4.94	2020	2022	
Deep reinforcement learning	2020	4.58	2020	2022	
Hurst exponent	2020	4.09	2020	2022	

7. Conclusions

This article conducts a bibliometric analysis of publications in the field of quantitative finance, with a sample collected from the Web of Science Core Collection. The analysis covers various aspects of the field, e.g. overall growth, citation trends over the years, the main discipline categories, and journal distributions, as well as the most frequently cited articles. In addition, the article identifies the most productive authors, institutions, and countries in the field and examines their collaboration networks via co-authorship analysis. The results shed light on the key players in the field and the extent of collaboration among them. Moreover, the article conducts co-citation analysis using the collected sample, which highlights landmark publications, citation bursts, and clusters of related research topics. The dynamic nature of the field is also visualized through a time zone view of keyword co-occurrence and keyword burst analysis, which provide a comprehensive overview of the most influential themes and sub-themes in quantitative finance research. By analyzing the patterns and trends in quantitative finance research, this study can inform future research directions in the field of quantitative finance.

The key findings are as follows. First, quantitative finance publications have steadily increased since 2007, indicating that it is a hot research topic. Second, the main research areas in quantitative finance are Business Finance, Economics, and Mathematics Interdisciplinary Applications and Mathematics Applied. Third, Quantitative Finance, Stochastic Processes and Their Applications, Physica A-Statistical Mechanics and Its Applications, Mathematics, Journal on Financial Mathematics, and Finance and Stochastics are the most productive journals in quantitative finance. Fourth, the most productive authors, institutions, and countries are Jaimungal, Sebastian, Cartea, Alvaro, Jacquier, Antoine, Stuebinger, Johannes, Touzi, Nizar, Univ Oxford, Ecole Polytech, Univ Toronto, NYU, Swiss Fed Inst Technol, the USA, People's Republic of China, and England, respectively. France produces influential research, which results in the highest citations per paper among top countries. Fifth, the top seven clusters with more than 50 articles in quantitative finance are high-frequency trading, stochastic volatility, pairs trading, mathematical finance, quasi-monte Carlo methods, optimal execution, reinforcement learning, Markov-switching garch, and stochastic target problem. Sixth, the five landmark articles are Hendershott et al. (2011), Heston (1993), Gatev et al. (2006), Artzner et al. (1999), and Markowitz (1952), and the three pivot nodes are Black and Scholes (1973), Robert C. Merton (1973) and Delbaen and Schachermayer (1994). Seventh, and the most cited authors in quantitative finance are Black Fischer, Hendershott, Terrence, Fama, Eugene F., Merton, Robert C., and Brogaard, Jonathan. Eighth, the top ten keywords are high-frequency trading, algorithmic trading, mathematical finance, financial mathematics, quantitative finance, computational finance, statistical arbitrage, machine learning, option pricing, and pairs trading. The research topics in quantitative finance can be divided into 11 categories based on the keyword co-occurrence cluster. Ninth, the time-zone view of co-occurrence keyword and burst analysis of keyword co-occurrence view show that machine learning, deep learning, algorithmic trading, and quantitative trading are recent hot topics in quantitative finance.

Overall, this article provides valuable insights for researchers and practitioners interested in the field of quantitative finance. It identifies the most influential authors, institutions, and countries, highlights the most productive journals, and provides a framework for understanding the research topics in the field. The findings suggest that collaboration among scholars is encouraged in the field of quantitative finance, and research on machine learning, deep learning, algorithmic trading, and quantitative trading is recommended. These insights are useful for future research and can inform policy decisions in the financial industry.

This article has limitations that leave room for future research. First, the analysis is based on a limited dataset of 2,732 articles collected from the Web of Science Core Collection. Future research may expand the scope of data sources to include other databases, e.g. Scopus, and patent databases. Additionally, investigations into well-known quantitative funds such as Renaissance, Bridgewater, and Millennium could provide valuable insights into the field. Second, co-citation analysis may not fully capture the latest research in quantitative finance. Researchers could explore alternative methods to capture the most recent publications in quantitative finance. Third, while bibliometric analysis provides quantitative measures of research impact, it may not capture the full complexity of scientific research. Future research may include qualitative assessments of research impact, e.g. the novelty of the research questions, the practical application of research findings, or the quality of the research methodology.

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