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TIME-SERIES FORECASTING AND PARAMETER ESTIMATION IN AGRICULTURAL COMMODITY PRICES: A BIBLIOMETRIC ANALYSIS

Wu Ziou Hon[1,2*], Siti Mariam Norrulashikin[1], Siti Rohani Mohd Nor[1], Tan Wei Lun[3], Masitah Zulkepli[2], Noor Fatihah Mazlam[4]

[1]Faculty of Science, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia
zhwu@sc.edu.my https://orcid.org/0009-0003-8236-0578
sitimariam@utm.my https://orcid.org/0000-0002-0567-5467
sitirohani@utm.my https://orcid.org/0000-0002-9498-3516
[2]Faculty of Business and Management, Southern University College, Jalan Selatan Utama, KM 15, Off, Skudai Lbh, 81300 Skudai, Johor, Malaysia
masitah@sc.edu.my https://orcid.org/0009-0002-1115-9108
[3]Lee Kong Chian Faculty of Engineering and Science, Universiti Tunku Abdul Rahman, Malaysia
tanwl@utar.edu.my https://orcid.org/0000-0002-0271-7676
[4]Faculty of Engineering and Information Technology, Southern University College, Jalan Selatan Utama, KM 15, Off, Skudai Lbh, 81300 Skudai, Johor, Malaysia
noorfatihah@sc.edu.my https://orcid.org/0009-0003-1284-5908
*Corresponding Author

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Abstract:

This study provides a detailed and comprehensive bibliometric analysis of the time series forecasting technique and parameter estimation methodologies in agricultural commodity price analysis, a field that has gained increasing attention due to the growing price volatility, market uncertainty and the demand for effective decision-support tools. Despite the substantial growth of publications, a systematic understanding of the intellectual structure, influential contributions and methodological evolution remain limited. Thus, to fill the gap, this study analyses 761 articles indexed in Scopus from 2000 to January 2026. Bibliographic data were standardized using Scopus Analyzer and OpenRefine to ensure consistency in author names, affiliations, and keywords. Bibliometric techniques, including citation analysis, keyword co-occurrence analysis, and country-level co-authorship network analysis, were conducted using VOSviewer. The results of the study show a steady growth in the number of research articles published in the domain, especially since 2010, suggesting

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that the research domain is mature. The citation analysis identifies a handful of research articles that have made a significant contribution to the advancement of the research field, especially with respect to long-memory processes, fractional integrations, volatility modelling and estimation techniques. The co-occurrence of keywords indicates that research articles published in the domain have been centred on long-memory processes, fractional integrations, ARFIMA models, volatility modelling, and estimation methodologies. The study also reveals a shift in research methodological approaches from traditional techniques to Bayesian estimation, state-space models, time-varying parameters and volatility modelling. Finally, the analysis also shows that research output and impact are concentrated in a limited number of countries, suggesting a strong degree of author collaboration.

Keyword:

Commodity Price, Forecasting, Long-memory, Parameter Estimation, Time Series

Introduction

Accurate forecasting of agricultural and commodity prices is essential for ensuring economic stability, safeguarding food security, and supporting strategic decision-making in global markets (R L & Mishra, 2021; Vikranth et al., 2022; Wei et al., 2023). In recent years, this importance has intensified due to increasing price volatility driven by supply chain disruptions, climate variability, geopolitical tensions, and financial market integration. Agricultural commodities are especially vulnerable to such dynamics, as they exhibit structural characteristics such as seasonality, inelastic demand, and production uncertainty, resulting in significant price volatility (Nayak et al., 2023, 2024; Shankar et al., 2023). These volatilities create a significant challenges for farmers, traders, policymakers, and other stakeholders as it affects their production decisions, profitability, and stability of the market (Pandit et al., 2024; Tran et al., 2023; D. Zhang et al., 2024; Sabu & Kumar, 2020). Climate change, extreme weather events, and greater market interdependence add to this complexity and uncertainty, requiring more sophisticated price modelling techniques (Rahmani et al., 2024). Over the years, these developments have increasingly revealed the shortcomings of conventional modelling assumptions such as linearity, stationarity, and constant variance. Consequently, the research on time series forecasting and estimation of parameters has grown to a considerable extent aimed at increasing the forecasting accuracy and providing some information to support decision making for various economic actors (F. Sun et al., 2023). These approaches include statistical methods, machine learning techniques, and deep learning methods, each with its own set of strengths and limitations in capturing the complex dynamics of agricultural price data (Cheung et al., 2023; Ray et al., 2023; C. Sun et al., 2023).

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Forecasting attempts in the early days were mainly using classical stochastic models such as ARIMA models and SARIMA models, that are derived from well-known theoretical models and have relatively simple parameter estimation procedures (F. Sun et al., 2023). The linearity and stationarity assumptions, however, restrict their capacity to describe the nonlinear, non-stationary, and multi-scale dynamics of agricultural prices series, thereby reducing their reliability for accurate forecasting (Diop & Sadefo Kamdem, 2022; Pozdilkova et al., 2021; Ray et al., 2023; F. Sun et al., 2023; L. Zhao et al., 2024). These restrictions have encouraged the use of non-linear methods such as threshold autoregressive and bilinear models, and heteroscedastic models with time-varying volatility including ARCH and GARCH. However, these strategies are still limited to fixed functional forms and may fail to capture the full complexity of agricultural price dynamics. Meanwhile, the multivariate econometric modelling approaches, such as VAR/VEC models and the dynamic model averaging (DMA), have been developed to incorporate macroeconomic, financial, climatic, and fundamental factors, into forecasting models. These approaches account for time-varying parameter structures and model uncertainty, and empirical evidence suggests that they can improve forecast performance over fixed-parameter models by exploiting information from fundamentals in the markets and external influences (Cuaresma et al., 2021; Drachal, 2019).

In recent years, with the growing evidence of nonlinear relationships, structural instability, an and interactions at multiple time scales, there has been a trend towards machine learning and deep learning methods (Rahmani et al., 2024; F. Sun et al., 2023; Tran et al., 2023). Techniques such as support vector regression, ensemble learning methods, and neural networks have demonstrated strong predictive performance in capturing nonlinear relationships and high-dimensional interactions (Pandit et al., 2024; Paul et al., 2022; D. Zhang et al., 2020). Further advances are made with deep architectures, such as TDNN, LSTM, GRU, BiLSTM, and TCN, which capture the long-term and short-term temporal patterns of the high frequency spot and wholesale price time series, as well as the complex autocorrelation structure (Manogna et al., 2025; ManognaR. & Mishra, 2021; Nayak et al., 2023; Pandit et al., 2024; T. Zhao et al., 2025). LSTNet, which combines convolutional layers, recurrent components, temporal attention, and an autoregressive shortcut, yields superior multivariate forecasts for agricultural futures relative to ARIMA, VAR, and other state-of-the-art methods, reflecting the importance of capturing both linear and nonlinear, short- and long-term patterns within a single unified forecasting architecture (Ouyang et al., 2019). More recent hybrid models further combine TCNs with gradient boosting (XGBoost) or BiLSTM with optimization techniques and multi-scale decompositions, using convolutional-based temporal feature extraction with ensemble-based nonlinear regression techniques for robust accuracy, even in large price movements (L. Zhang et al., 2025; T. Zhao et al., 2025). Hidden Markov Model-based deep learning models extend this frontier by simultaneously addressing latent regime effects with sequential dependencies using deep nonlinear sequence learning, resulting in a clear accuracy improvement over traditional deep learning models alone (Nayak et al., 2023).

The third important improvement has been the development of hybrid modeling, decomposition, and selection approaches that integrate statistical and intelligent models with advanced parameter optimization techniques. Decomposition based hybrids, such as CEEMDAN-TDNN, VMD–EEMD–LSTM, and STL–VMD–BiLSTM, which first decompose the price series into quasi-stationary components such as intrinsic mode functions, trend, seasonal, and residual series, and then apply specialized models to each component before recombining forecasts (Pandit et al., 2024; C. Sun et al., 2023; L. Zhang et al., 2025). These approach enhances forecast accuracy and robustness by reducing high-frequency noise and

enabling parameter estimation at more homogenous scales (C. Sun et al., 2023; L. Zhang et al., 2025). Other studies include a meta-heuristic optimization into parameter estimation, using particle swarm optimization or sparrow search algorithms to optimize the hyperparameters of SVR, ELM, GRNN, and BiLSTM models, and then combining individual forecasts with induced ordered weighted averaging or residual correction methods (Li & Lian, 2025; L. Zhang et al., 2025). Ensemble learning and forecast combination frameworks further improve predictive performance by leveraging multiple models and addressing model uncertainty (Cuaresma et al., 2021; Drachal, 2019; Ragunath & Rathipriya, 2025). Along with that, model selection approaches based on temporal characteristics, forecast horizon, and even image encodings such as GAF, MTF, recurrence plots, have emerged to automate the choice among candidate forecasting models such as ANN, SVR, ELM, and deep architectures (Jiang et al., 2025; D. Zhang et al., 2020). Additionally, model and feature selection techniques including dimensionality reduction methods such as PCA, minimum redundancy and maximum relevance, principal component analysis, and image-based information fusion are employed to reduce dimensionality and mitigate overfitting, improving generalization and making model choice adaptive to commodity-specific dynamics and horizon length (Jiang et al., 2025; D. Zhang et al., 2020). These models promote a move away from the single “best” parametric model, and towards a more flexible and data-driven selection and combination of models, often with parameter estimation as an implicit step in the optimization process.

Recent studies have also developed forecasting systems that use multimodal and exogenous information other than price information. Methods that combine meteorological information, trading volume, spatial production patterns, and textual sentiment data have been shown to enhance the forecasting accuracy by accounting for a wider range of factors influencing prices (Y. H. Gu et al., 2022). Similarly, market intelligence systems that combine statistical and deep learning models with real time platform data to assist with operational decision making (Aher et al., 2025). Some existing studies also highlight the need for robust parameter estimation in the case of time-varying dynamics and for using horizon-specific forecasting strategies, as well as for dealing with model uncertainty (Cuaresma et al., 2021; Drachal, 2019). Despite the recent progress, there are several challenges yet to be addressed, such as the need for the interpretation of complex models, high-dimensional data integration without overfitting, and the creation of comprehensive evaluation frameworks which cover the performance of point, density and directional forecasting.

Although the field has seen rapid advances in research, available literature is fragmented, with most studies typically focusing on specific methodologies or specific applications of the methods available, rather than providing a comprehensive synthesis of the field. Especially, the evolution and interaction of various forecasting methods and parameter estimation techniques have not been understood in a coherent manner in the context of agricultural commodity price analysis. This study aims to address these deficits and will undertake a comprehensive bibliometric analysis of 761 publications indexed in the Scopus database between 2000 to January 2026. The proposed study aims at mapping the evolutions of research output, identifying influential research outputs, studying the intellectual structure of the field and methodological developments, assessing collaboration patterns, and highlighting emerging research directions. This systematic review offers a systematic guide to the development and structure of research in agronomy and the commodity price analysis.

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Table 1: Main Families of Forecasting Methods and Examples in Agricultural Price Analysis

Approach type	Core idea and role of parameters	Representative contributions	Citations
Classical linear & econometric	ARIMA/SARIMA, VAR/VEC, regression; explicit parametric estimation, often via MLE or Bayesian methods	ARIMA-dominated early work; composite ARIMA–SARIMA; VAR/VEC and DMA with macro-financial drivers	(Cuaresma et al., 2021; Drachal, 2019; L. Zhao et al., 2024)
Machine learning & deep learning	Non-parametric or high-dimensional parameter learning (NN, SVR, RF, XGBoost, LSTM/GRU/TCN/LSTNet) from data	Deep models outperform ARIMA/TDNN; multivariate LSTNet; TCN–XGBoost and HMM-guided DL	(Manogna et al., 2025; ManognaR. & Mishra, 2021; Nayak et al., 2023; Ouyang et al., 2019; Pandit et al., 2024; Paul et al., 2022; D. Zhang et al., 2020; T. Zhao et al., 2025)
Hybrid, decomposition & ensembles	Decompose series; fit multiple models; combine or select forecasts; parameters tuned by meta-heuristics or feature-based selection	CEEMDAN-TDNN; VMD–EEMD–LSTM; STL–VMD–BiLSTM; SSA-optimized SVR/ELM; feature- and image-based model selection	(Cuaresma et al., 2021; Drachal, 2019; Jiang et al., 2025; Li & Lian, 2025; Pandit et al., 2024; Ragunath & Rathipriya, 2025; C. Sun et al., 2023; D. Zhang et al., 2020; L. Zhang et al., 2025)
Multimodal & exogenous data	Integrate weather, volume, macro, sentiment, spatial patterns; parameters learned in multivariate, attention, or text-augmented models	DIA-LSTM with weather and dynamic areas; text-mining plus decomposition; ARIMA–LSTM MIS; review of combined models	(Cuaresma et al., 2021; Y. H. Gu et al., 2022; An et al., 2023)

Research Objectives

RO1:
To examine the growth of publication, temporal distribution, and development trends of research on time series forecasting and parameter estimation methods in agricultural and commodity price analysis from 2000 to January 2026.

RO2:
To identify and evaluate the most influential publications in the field based on citations impact and scholarly visibility.

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RO3:
To analyze the contribution of countries and regions to the field in terms of publication productivity, citation performance, and research collaboration.

RO4:
To investigate the intellectual structure of the field by identifying dominant, evolving, and emerging research themes through author key-word co-occurrence analysis.

RO5:
To explore international research collaboration patterns and examine the global knowledge network through country-level co-authorship analysis.

Methodology

Bibliometric Analysis is the process of systematic collecting, structuring, and quantitative evaluation of the collected bibliographic information on time series and parameter estimation in agricultural commodity price analysis (Alves et al., 2021; Assyakur & Rosa, 2022; Verbeek et al., 2002). Bibliometric studies extend beyond merely describing the publications in terms of outlets, temporal patterns of publication, prominent authors and involve the use of sophisticated analytical tools such as document co-citation analysis (Wu & Wu, 2017). The research process of this study is systematic with a transparent method, starting from designing keywords, literature retrieval, and quantitative analysis. This systematic literature review methodology can be used to design and build credible and reliable literature corpus to boost the credibility of the research results (Fahimnia et al., 2015). In this context, this research study emphasizes high-impact publications since such publications provide important information on theory building and evolutionary patterns in the research domain. In order to ensure accuracy, consistency, and replicability of research outcomes, this research study used Elsevier's Scopus database as a credible source for literature collection (Al-Khoury et al., 2022; di Stefano et al., 2010; Khiste & Paithankar, 2017). Scopus was chosen due to its extensive coverage of peer-reviewed journals and its suitability for large-scale bibliometric analysis. This practice aligns with widely accepted standards for conducting literature reviews. This research study excluded books and lecture notes from consideration but limited itself to peer-reviewed journal articles (D. Gu et al., 2019). This research study leverages the multidisciplinary nature of the Scopus database to collect relevant literature from 2000 to January 2026.

Data Search Strategy

The bibliometric data set for the purpose of the current investigation was created using an advanced and structured search strategy carried out on the Scopus database provided by Elsevier, ensuring the exhaustive coverage of the research landscape for the topic "Time Series Forecasting and Parameter Estimation Methods in Agricultural and Commodity Price Analysis." The search query was constructed to capture key methodological and application-oriented aspects of the field using the integration of different thematic clusters. For instance, the query was formulated to cover the core concepts in the field of time series analysis using keywords such as "time-varying", "time-varying," "temporal data" and the application-oriented concepts such as "forecasting", "predictive modeling", "parameter estimation", "parameter optimization", "estimation" etc. The keyword structure was designed to capture both methodological developments and application contexts, ensuring comprehensive coverage of the research domain. Considering the increasing importance of persistence in price dynamics,

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the query was further expanded to cover concepts such as "long-range dependence" and "fractional integration." The application-oriented concepts such as "commodity price" and "commodity pricing" ensured the relevance of the obtained results to the field of agricultural and commodity price analysis.

Table 2: The Search String

Scopus	TITLE-ABS-KEY ((("time series" OR "time-varying" OR "temporal data") OR ("forecasting" OR "predictive modeling") AND ("parameter estimation" OR "parameter optimization" OR "estimation") AND ("long memory" OR "long-range dependence" OR "fractional integration") OR ("commodity price" OR "commodity pricing" OR "price of commodities"))) AND PUBYEAR > 1999 AND PUBYEAR < 2027 AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (LANGUAGE , "English"))

To ensure methodological rigor and consistency, a set of inclusion and exclusion criteria was applied. The dataset was limited to peer-reviewed journal articles published between 2000 to 2026, thus covering an extended period of time and the recent developments in the field. This reflects only articles published in their final stage and written in English. To maintain consistency and comparability, conference papers, reviews, book chapters, book series and articles in press were excluded. These criteria ensured the inclusion of high-quality, standardized research outputs and reduced noise from non-peer-reviewed or incomplete sources. A total of 761 publications were retained after applying these filters, yielding a solid and representative set of publications for bibliometric analysis. The data provides sufficient empirical basis for examining publication trends, research themes, collaboration patterns, and the intellectual structure of the field.

Table 3: The Selection Criterion

Criterion	Inclusion	Exclusion
Language	English	Non-English
Document type	Article	Conference paper, review, book chapter
Publication stage	Final	Article in press
Source type	Journal	Conference proceeding, book series, book
Timeline	2000 – 2026	<2000

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Data Analysis

VOSviewer (Van Eck & Waltman, 2010, 2017) was used to construct and visualize bibliometric networkds, including co-authoship, citation and keyword co-occurrence networkd. The software applies the VOS mapping technique, where items are positioned based on similarity measures such as association strength.

A particular feature of this tool is its capacity to make complex bibliometric information accessible to understand and visualise. The software has also been shown to be useful for undertaking network analysis, including keyword co-occurrence analysis, cluster detection and density visualization, for the purpose of identifying research hotspots. The software's interface allows both novice and expert researchers to efficiently interpret trends in a given field of research. The software is also constantly being updated, making VOSviewer a cutting-edge bibliometric visualization tool with flexible analysis capabilities for a variety of data sets, ranging from authorship and citation networks to thematic networks.

In this study, bibliographic data such as publication year, article title, author, source journals, number of citations, and keywords were retrieved from Scopus using a Comma-Separated Values (CSV) export format, covering publications between 2000 and January 2026. The data was then analyzed using VOSviewer software version 1.6.20. Using VOS mapping and clustering techniques, bibliometric networks were systematically analyzed. Unlike Multidimensional Scaling (MDS) methods, VOSviewer positions items in a low-dimensional space in such a way that the distance between any two items reflects their level of relatedness (Van Eck & Waltman, 2010). Although conceptually related to MDS (Appio et al., 2014), the VOS methodology differs by employing normalization procedures specifically optimized for co-occurrence data, such as the association strength measure (AS_{ij}), which is computed as follows (Van Eck & Waltman, 2007)

$$AS_{ij} = \frac{C_{ij}}{w_i w_j}$$

which C_{ij} denotes co-occurrence frequency and w_i, w_i represent total occurrences, defined as being proportional to the ratio between the observed frequency of co-occurrence of items i and j and the expected frequency of their co-occurrence under the assumption of statistical independence (Van Eck & Waltman, 2007). While this study does not generate forecast outputs, it systematically analyzes forecasting methodologies and parameter estimation approaches reported in the literature.

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Result and Discussion

RO1: To Examine the Growth of Publication, Temporal Distribution, And Development Trends of Research on Time Series Forecasting and Parameter Estimation Methods in Agricultural and Commodity Price Analysis From 2000 To January 2026.

Table 4: Trend of Research in Time Series Forecasting and Parameter Estimation Analysis by Years

Year	Number of Publication	Percentages (%)	Year	Number of Publication	Percentages (%)
2000	14	1.84%	2014	34	4.47%
2001	18	2.37%	2015	21	2.76%
2002	19	2.50%	2016	29	3.81%
2003	18	2.37%	2017	37	4.86%
2004	19	2.50%	2018	28	3.68%
2005	23	3.02%	2019	31	4.07%
2006	30	3.94%	2020	48	6.31%
2007	21	2.76%	2021	25	3.29%
2008	37	4.86%	2022	32	4.20%
2009	23	3.02%	2023	47	6.18%
2010	43	5.65%	2024	28	3.68%
2011	27	3.55%	2025	50	6.57%
2012	27	3.55%	2026	5	0.66%
2013	27	3.55%			

Table 4 demonstrates the trend of publication from 2000 to January 2026 indicates that there is a long-term growth trend with observable stages of growth and stabilization. In the early period (2000–2006), the number of publications remained relatively low and stable with the range which between 14 to 30 articles per year (1.84% – 3.94%), representing a formative phase in the research filed where methodological grounds are access to data were still emerging. A prominent upward trend is visible from 2007, with periodic highs in 2008 (37 publications, 4.86%) and 2010 (43 publications, 5.65%). The trend suggests the growing academic interest in the topic, which is probably enhanced by the growth of computational power, the availability of large volumes of data, and the rising focus on quantitative and data-driven approaches. The stable production of the period between 2011 and 2014, which was always above 3.5%, is an indicator that it has been passed through the stage of emergent field and is now an established field with a stable presence of scholarly works.

The growth of publication has been even stronger since 2017 when the number of publications was 48 publications (6.31%), 47 publications (6.18%) and 50 publications (6.57%) for 2020, 2023 and 2025 respectively, the most productive years in the whole period. Such acceleration may be attributed to methodological enhancement, policy and industry relevance and the global movement toward evidence-based decision-making. The significant increase in the rate towards 2020 is also probably due to the increased number of research activities during global disruption, when forecasting and analysis tools assumed critical importance. The reduction in 2026 (5 publications, 0.66%) does not indicate a decline in the field but is likely due to the fact that only publications up to January 2026 are included in the data set, and to the fact that in bibliometric studies only partial-year data are captured. The overall result is a powerful

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confirmation of the continuous and progressive evolution of the field, and thus underscoring the maturity, relevance, and attractiveness of the subject throughout the considered period.

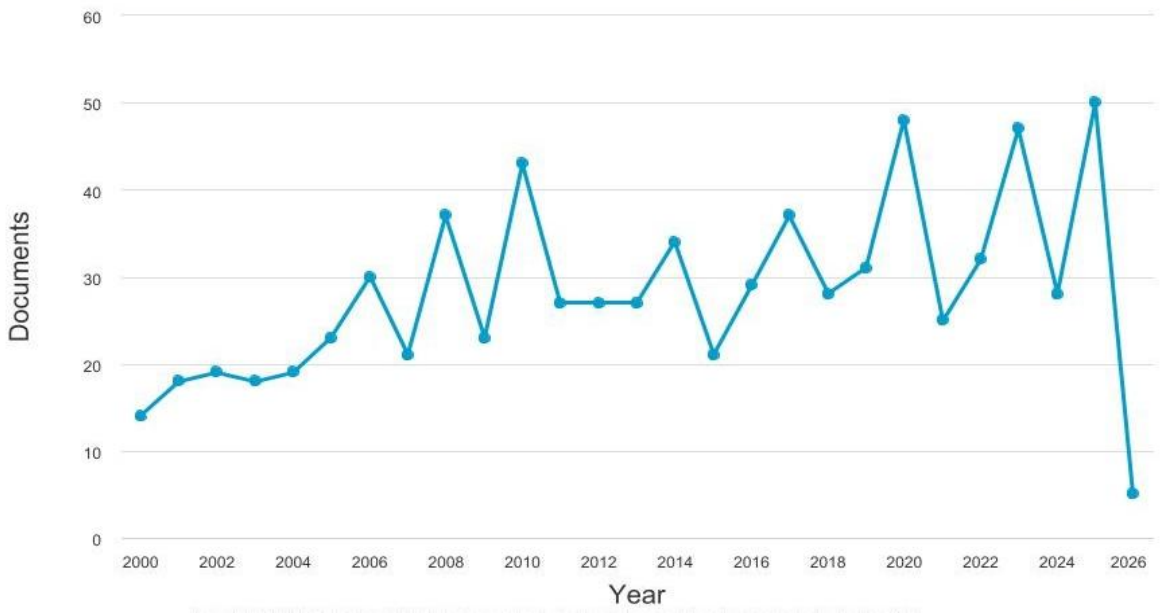

Figure 1: Trend of Research in Time Series Forecasting and Parameter Estimation Analysis by Years

RO2: To Identify and Evaluate The Most Influential Publications in The Field Based on Citations Impact and Scholarly Visibility.

The top ten articles demonstrate a clear dominance of contributions to methodology that is not limited to only one of the application domains. This is likely the explanation for their high citation impact. The study by Wagenmakers et al. (2004) (Wagenmakers et al., 2004), which addresses 1/fα noise in human cognition and has gathered 320 citations to date, and Karagiannis et al. (2004) (Karagiannis et al., 2004), which addresses the long range dependence in Internet traffic has already received 261 citations to date, represent seminal research that formalizes the statistical structure of persistence. The high citation impact is likely because these studies are theoretically applicable to a wide range of domains. Similarly, seminal methodological papers such as Hillebrand (2005), which concern parameter instability of GARCH models, or Brandt and Jones (2006), which concerns range-based EGARCH models, receive large citation numbers since they consider one of the most significant shortcomings of the volatility models: structural change and information efficiency.

The second prominent pattern is the dominance of research in the fields of energy and commodity prices, with a focus on Energy Economics, which comprises half of the most frequently cited papers. The highly cited papers by Zhang et al. (2009) (X. Zhang et al., 2009), Álvarez-Ramírez et al. (2008) (Álvarez-Ramírez et al., 2008), Gong and Lin (2017)(Gong & Lin, 2017), Hou and Suardi (2012) (Hou & Suardi, 2012), and Mei et al. (2020) can be explained by the strong demand for effective forecasting and volatility modeling tools in the context of crude oil markets, where prices are driven by extreme events, geopolitical factors, and asymmetric uncertainty. These papers are frequently cited because they incorporate new techniques such as EMD, DFA, HAR, MIDAS, and nonparametric GARCH in a context that

is economically meaningful. Modelingusion of the paper by Montanari et al. (2000) on the topic of seasonal fraction ARIMA in hydrology also supports the idea that long-range and fraction modeling techniques form a unifying backbone for all the research fields, which explains the persistence of the above papers in bibliometric paths. The above details are summarized in Table 5.

Table 5: Most Cited Author

No	Authors	Title	Year	Source title	Cited by
1	Wagenmakers, E.J. et al. (Wagenmakers et al., 2004)	Estimation and interpretation of 1/fα noise in human cognition	2004	Psychonomic Bulletin and Review	320
2	Karagiannis, T. et al. (Karagiannis et al., 2004)	Long-range dependence: Ten years of internet traffic modeling	2004	IEEE Internet Computing	261
3	Zhang, X. et al. (X. Zhang et al., 2009)	Estimating the impact of extreme events on crude oil price: An EMD-based event analysis method	2009	Energy Economics	242
4	Álvarez-Ramírez, J. (Álvarez-Ramírez et al., 2008)	Short-term predictability of crude oil markets: A detrended fluctuation analysis approach	2008	Energy Economics	216
5	Hillebrand, E. (Hillebrand, 2005)	Neglecting parameter changes in GARCH models	2005	Journal of Econometrics	213
6	Mei, D. et al. (Mei et al., 2020)	Geopolitical risk uncertainty and oil future volatility: Evidence from MIDAS models	2020	Energy Economics	209
7	Gong, X.; Lin, B. (Gong & Lin, 2017)	Forecasting the good and bad uncertainties of crude oil prices using a HAR framework	2017	Energy Economics	174
8	Brandt, M.W.; Jones, C.S. (Brandt & Jones, 2006)	Volatility forecasting with range-based EGARCH models	2006	Journal of Business and Economic Statistics	170
9	Montanari, A. et al. (Montanari et al., 2000)	A seasonal fractional ARIMA model applied to the Nile River monthly flows at Aswan	2000	Water Resources Research	163
10	Hou, A.; Suardi, S. (Hou & Suardi, 2012)	A nonparametric GARCH model of crude oil price return volatility	2012	Energy Economics	161

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RO3: To analyze the contribution of countries and regions to the field in terms of publication productivity, citation performance, and research collaboration.

The country-level publications count provides a clear indication of concentration of research in a small number of scientifically advanced countries, with the US on the top (199 publications, 26.15%). Such a position can be attributed to the US's well-developed research system, its steady support for research in quantitative and applied economics, and its leading universities and journals publishing articles on time-series models, forecasting techniques and applied statistical methods. The UK and China share the second position (86 publications, 11.30%) and contribute to productivity in different ways: The UK with its tradition in econometrics and statistical theory, and China with rapid growth in research capacity across the country with funding from national research councils, big data, and growing interest in policy in market forecasting and risk assessment. The three countries represent almost half of the publications, reflecting their key role in shaping the research agenda and standards in the field.

The inclusion of European countries (France, Spain, Germany and Italy) in the top ten accounts for a substantial share of the publications and is indicative of a strong regional interest in econometric modelling and forecasting in energy, finance and environmental sciences, and techniques dealing with long memory processes and fractals. The strong position of France (9.07%) can be traced back to the strong schools of statistical physics and applied mathematics, while Spain and Germany are part of a strong research community and EU funding programs. Australia and Canada are consistent performers in the top ten as applied market modelling and forecasting in resource markets and finance continue to be their research strengths, while the appearance of Brazil in the top ten is indicative of the growing prominence of emerging countries, especially in the field of commodity and agricultural pricing. In summary, the country distribution gives strong evidence that publication leadership is associated with a combination of research funding, capacity building, data availability and economic significance and that methods development is led by countries with a combination of quantitative expertise and forecasting needs.

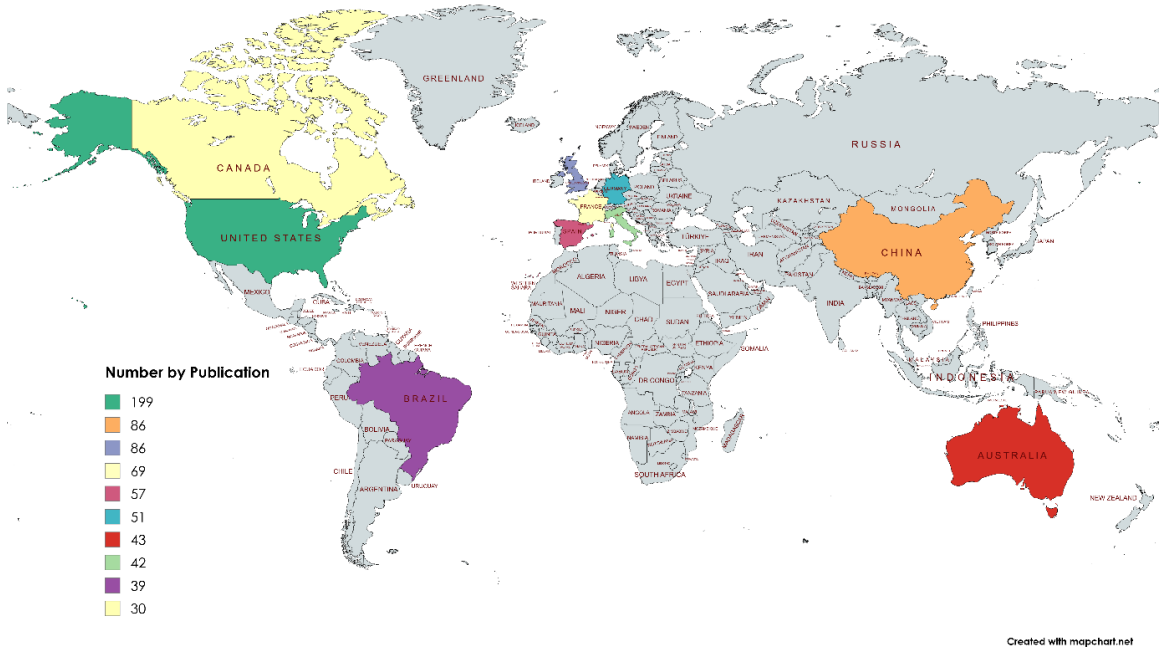

Figure 2: Top 10 Countries Based on Number of Publication

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RO4: To Investigate the Intellectual Structure of The Field by Identifying Dominant, Evolving, and Emerging Research Themes Through Author Keyword Co-Occurrence Analysis.

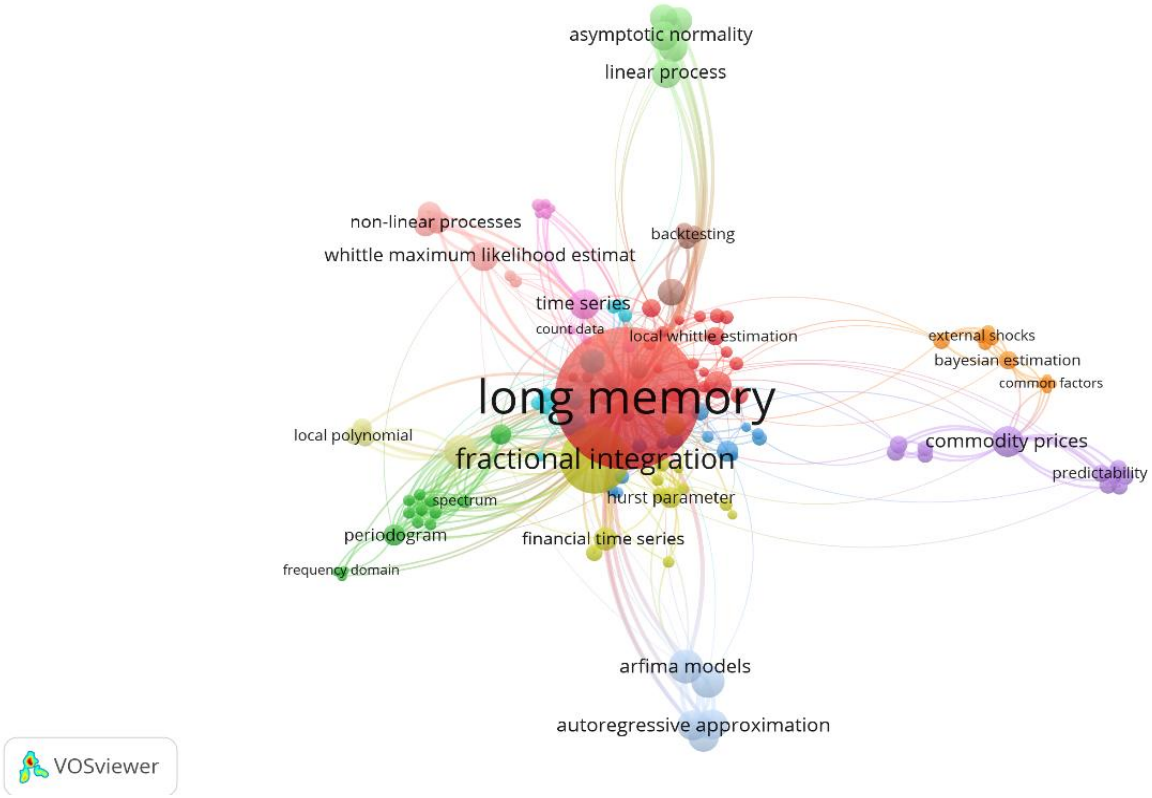

Figure 3: Network Visualization Map of Keywords' Co-occurrence

Author keywords co-occurrence analysis of VOSviewer is a bibliometric method that aims to map the conceptual landscape of a research domain by analysing co-occurrences of keywords in the same publications. The basic premise is that words that frequently occur together are conceptually related, reflecting common theories, methods or application areas. In the present study, network analysis not only represents the dominance of individual topics via the frequency (occurrences) of keywords but also their connectedness via total link strength, which is a measure of the strength of association of a keyword with all other keywords in the data set. The "long memory" (454 occurrences, 1198 total link strength) and "fractional integration" (126 occurrences, 302) are the core concepts in the literature, as identified by the keywords analysis. The tight interlinkages between words like ARFIMA models, forecasting, spectral density, Whittle likelihood, and non-stationary processes, suggest a well-developed methodological framework that covering theoretical aspects, estimation methods and empirical applications.

The network of co-occurrence was constructed by using the full counting method, where every occurrence of a keyword was assigned an equal weight, regardless of the total number of keywords in a document. This approach is appropriate for describing the wide variety and complexity of a methodologically rich field where several methods are discussed at once. In order to minimize noise from rarely used terms or idiosyncratic terms, the minimum threshold of the number of occurrences was set at 5, which reduced the analysis from 1142 keywords to 133 keywords. To ensure that all terms of interest were included, a minimum cluster size of

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one was set and 18 clusters were obtained, covering the two core themes and emerging or specialized research areas. The results bring to the literature a clear indication that the literature focuses on the modelling of long memory and fractional processes, with ARFIMA, Hurst parameter, spectral methods, and Whittle estimation forming a coherent methodological backbone. Meanwhile, there are other significant methodological clusters associated with the nonlinearity, nonstationarity and high-frequency characteristics of data. This is demonstrated in important focal points on volatility modelling such as GARCH, stochastic volatility, realized volatility, forecasting and predictability, and frequency-domain and wavelet-based approaches. With application-oriented keywords like commodity prices, crude oil prices, agricultural commodity prices, foreign exchange, stock returns, and internet traffic are closely related to the practical problem of forecasting and risk management, which is a testament that the development of theory is closely connected to the practice of forecasting and risk management. Some of the emerging themes that reflect a change towards hybrid, time varying and uncertainty-aware modelling frameworks are the Bayesian estimation, the Kalman filter, the state-space models, the ideas of MIDAS, the events of extreme and the external shocks, such as signals. Overall, the co-occurrence structure shows a field that is theoretically focused and empirically responsive and long-memory dynamics remain central while new interdisciplinary and advanced modelling approaches continue to evolve. The evolution of methodological keywords reflects the changing statistical challenges encountered in agricultural and commodity price forecasting. Earlier studies focused primarily on linear stochastic processes and fractional integration to model persistence and long-memory behaviour. More recent studies increasingly adopt hybrid forecasting approaches, Bayesian estimation, state-space models, and time-varying parameter frameworks to accommodate structural breaks, nonlinear dynamics, and external market shocks. This progression suggests that methodological development has shifted from improving statistical estimation toward constructing adaptive forecasting systems capable of handling highly volatile and nonstationary market environments.

RO5: To Explore International Research Collaboration Patterns and Examine the Global Knowledge Network Through Country-Level Co-Authorship Analysis.

Co-authorship by country analysis in VOSviewer is a bibliometric method that can be used to identify and measure global research collaboration by looking at the co-authorship patterns between authors from different countries. The nodes represent countries, and when there is a link between two countries, they have co-authored at least one publication. The thickness of links, measured by total link strength, refers to the strength of collaboration measured by volume and frequency of collaboration, not just publications. In this sense, this analysis captures the social and structural dimensions of knowledge production, demonstrating the movement of ideas, methods and data between countries.

The co-authorship network was generated using the full counting methods, whereby each co-authored publication contributed equally to every participating country regardless of the number of authors or affiliations. This is an inclusive setting that best captures the collaborative effort of each country. The analysis used a minimum of five documents per country to exclude countries that participate at very low levels, bringing the total down from 77 to 38 countries that satisfy a minimum level of participation. The minimum cluster size of one ensured that all countries were included in the network, even if they were part of small clusters or had weak connections. Using these settings, we identified eight clusters that represent groups of countries collaborating more strongly with each other than with the rest of the network. The results reveal

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that the US is the most central and dominant country with the largest number of documents (202), citations (5,426) and total link strength (125), establishing it as the main international hub for collaboration. Its connections with the United Kingdom, France, China, Australia and other leading research economies indicate that methodological and agenda-setting leadership in the field is primarily coordinated through the US-based collaboration networks.

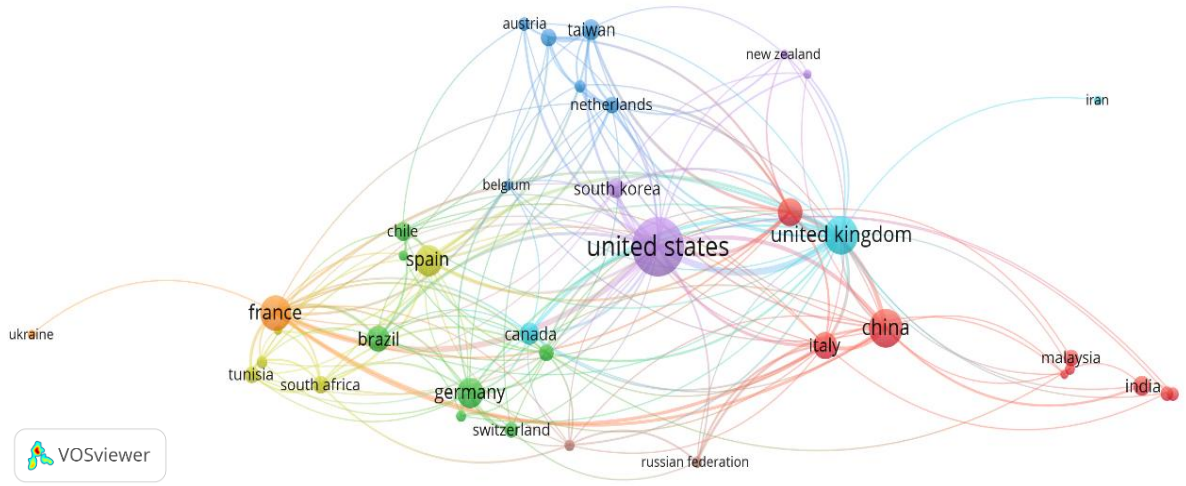

Figure 4 : Co-authorship by Countries' Collaboration

Despite having an equal number of documents as China (86 documents), the UK has a much higher total link strength, suggesting that it has more extensive collaborative links, especially with European and Commonwealth countries. This reveals the UK's bridging role between North American, European and some Asia-Pacific research communities. In terms of knowledge contribution, the co-authorship pattern reveals that high-impact research in this field is highly dependent on international collaboration, rather than national research. Countries like France, Australia, Italy, and the Netherlands display comparatively high citation counts and link strength relative to their publications, which suggests that their position in the collaboration network contributes to greater research impact. Middle- and emerging-economy nations such as Brazil, Malaysia, Tunisia, Chile, and South Africa are present but typically display lower total link strength, suggesting lesser involvement in the heart of global collaboration. However, their presence in the core clusters suggests growing engagement in global research collaborations, often with established hubs.

This finding supports claims that methodological and empirical progress are increasingly co-constructed through international collaboration, with advanced methods such as long memory modelling, volatility modelling, and state space models transferred from one application to another. The co-authorship network adds to knowledge by empirically validating that the advancement and dissemination of time series and forecasting approaches are influenced not only by national research capabilities, but also by the intensity and structure of international collaboration.

Conclusion

This study aimed to evaluate the growth, structure and thematical focus of time series forecasting and parameter estimation methods in the analysis of agricultural and commodity prices. The researchers used a bibliometric analysis to answer questions about publication

growth, highly cited scholarly works, prominent countries, research themes and global research networks. The results showed a sustained growth in research output for more than 20 years, suggesting a growing interest in the study of price volatility, long memory properties and forecasting uncertainty in commodity markets and an increasing methodological focus to tackle these issues. The results show a steady growth in publication activity, especially since 2010, which signifies the growing interest in forecasting and estimation methods in volatile agricultural and commodity markets.

Citation analysis shows that highly cited papers address fundamental methodological issues such as long memory, fractional integration, volatility modelling and robust estimation, implying that methodological and theoretical rigour is a factor of influence. Our analysis of keyword co-occurrence shows that the field covers major research themes such as long memory, ARFIMA models, volatility models and spectral estimation, with more recent themes such as hybrid models, Bayesian and state-space techniques, time-varying parameters and extreme events and market uncertainty.

Meanwhile, geographical analysis reveals that the impact and publication of research is highly concentrated in a few countries with high quantitative research capacity, while co-authorship analysis reveals the impact of international co-publication in the development of new methods and applications. Overall, this bibliometric analysis adds to the literature by synthesising dispersed knowledge and showing how methodological innovation has been driven by theoretical advances as well as forecasting demand. Beyond its academic contribution, this study provides practical value by identifying forecasting methodologies that have demonstrated sustained scholarly influence and by revealing emerging analytical directions suitable for increasingly volatile agricultural and commodity markets. A comprehensive synthesis of this fast-growing literature is essential to guide methodological development, to ensure that research does not be duplicated, and to provide a more consistent choice of models, and to accelerate the uptake of more sophisticated forecasting methods. The findings therefore provide a useful benchmark and reference for researchers, policymakers, agricultural producers, commodity traders, and financial institutions who are interested on finding suitable forecasting and parameter estimation methods under various market conditions. The observed trend toward hybrid forecasting model, Bayesian estimation, state-space models, and time-varying parameter models also indicates that future forecasting systems would benefit from flexibility, resilience, and the consideration of multiple sources of uncertainty.

Future studies could expand this research by incorporating the use of more than a single bibliographic database, an analysis of temporal trends in collaboration and citation patterns and associating bibliometric evidence with empirical forecasting accuracy. More importantly, future methodological research should be directed to the development of integrated forecasting frameworks that integrate long-memory processes, machine learning, Bayesian inference, and adaptive parameter estimation methods, while including external drivers like climate variability, geopolitical events, and macroeconomic uncertainty. Such developments are expected to strengthen forecasting accuracy and support more effective decision-making in agricultural production, commodity markets, and food security planning.

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