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AI-Driven Investors Behaviour in Gold Market: A Review

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Abstract

The aim of this study is to examine and synthesize the literature produced by AI-enabled gold bullion market investor's behaviour. This study explored the influential authors, sources and themes in the research of AI-led investment decisions. The research methodology adopted was a hybrid methodology which includes biblioshiny and systematic review from the Scopus database from 2012-2024. The results showed that Resource Policy is a major outlet for academics and plays a major part in the diffusion of research followed by Expert Systems with Applications and emerging theme is forecasting gold prices in financial markets. China tops the world in research output and the average citation rate is 24.40, showing both volume and highly influential work. Gold has the highest frequency of 20, followed by financial markets, gold prices, forecasting, and commerce at a frequency of 15. The review outcomes show that machine learning, neural networks and artificial intelligence tools are capable of handling complex datasets in predicting the investors' behavior in the gold bullion market. Most of the studies used algorithms like Fuzzy Rough Quick Reduct, Extreme Learning Machines and Neural Networks. The results paved that the GRU, CNN, RNN and NLP methods will be adopted for further research studies.

Keywords: Artificial Intelligence, Bibliometrix, Gold, Investors Behaviour, R-studio, Systematic Review.

Introduction

Precious metals: gold, palladium, platinum and silver, oil and currency rates have attracted the interest of investors, traders, producers, and regulators alike, Gold is replicated as a leader in the precious metals market as rises in the price seem to lead to similar movements in the prices of other precious metals (1). A key component of the global economy is gold and it is one of the most significant commodities in the financial market (2). Due to its widespread use as a strategic economic resource and a tool for regulating prices gold makes up a major portion of central bank reserves (3). Gold is a precious commodity that many investors view as a safe haven for their money, which may be used to protect against price inflation and other monetary hazards (4). The US is a protruding participant in the gold mining industry, having fashioned 230 tons of the metal, employing it third in terms of production after China and Australia (5). The gold and oil markets serve as the main representative segments of the commodities market, accordingly, variations in the price of oil can predict variations in the price of gold (6, 7). Gold investment in India is primarily driven by family traditions and cultural customs, with more than 70% of investor purchasing gold for occasions like weddings and

festivals (8). Human behaviour considers the three factors like Financial Literacy, Financial Risk Tolerance and Investor Behaviour (9). Investment choice in which each investor selects from a range of other options the best investment portfolio (10). The investor's ultimate investing decision is based on their personal observations and experiences and it concludes with a belief in the portfolio's future performance (11). Hence, the technological revolution, along with the interaction between traditional investment preferences and modern financial strategies, creates a unique context for studying investor behaviour in the gold bullion market (12). Investors have been drawn to gold because it is easy to carry, has a long-term appreciation and functions as a hedge and longterm basis for an investment portfolio, a secure, reliable investment outlet (13, 14). Trends in the stock market and price projections are crucial elements for both marketers and new investors (15, 16). As per CAPM hypothesis, the market is the only source of risk and the agents have homogeneous investing behaviour, another risk source is commodity prices as well, since the oil shocks of the 1980s, various studies especially highlight the links between financial markets and

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oil prices (10, 17-20). A behavioural hypothesis that suggests agents have homogeneous investing behaviours is highlighted in the discussion of asset pricing models, this hypothesis states that agents share a common investment horizon and make similar investment decisions, in order to provide a more nuanced view of portfolio allocation and price dynamics, a Behavioural Asset Price Model which takes into account elements like cognitive biases, belief heterogeneity and investor attention - is introduced in a lot of literature to overcome this shortcoming (21-26). Individual economic behaviour frequently concentrates on a particular area (27, 28). Various methods and strategies like statistical and technical analysis are used to forecast the market trends and future (29). Secure investment, expected higher returns and traditional values are the factors of gold investment (30). Gold investments have outperformed many other investment options for individual and institutional investors. Among all, the gold bullion market is an emerging instrument as a gold exchange-traded fund (GETF), gold coins, physical gold and so on. Investors' decisions have a significant impact on financial market dynamics, influencing not only their personal wealth but also the overall stability of the market (31). Highlighted the distinct approaches and decision-making processes, underscoring the importance of tailored strategies for each type of investor in Southern India (32). The Time-Frequency Multi-Betas Model, Standard Multi-Betas Model and CAPM, make CAPM adequate for short-term investors whereas as long run the model proved more useful for fundamental investors by revealing significant differences across time horizons especially in sensitivity to oil, gold and Fama-French factors enhanced risk differentiation and investment

decision-making over longer periods (33). Though investors frequently aim to lower the risk associated with changes in asset prices a financial market crisis might further undermine these efforts, inferred that a large number of investors are risk averse since they take advantage of every opportunity to increase returns and lower risk (34). The predictions are derived from a dataset of gold price rates using ensemble-based machine learning techniques like Linear Regression, ARIMA model and Random Forest Regression, the machine learning prediction model for gold price forecasting offers more precise metrics for comparing actual and expected gold rate values (35). The study investigated the learning algorithm for single hidden layered feed-forward neural networks called Extreme Learning Machine (ELM), this algorithm demonstrated a strong learning capacity to forecast future gold prices from four commodities: historical data on gold, silver, and crude oil prices and Deep Q-network (DQN) and Double DQN (DDQN) algorithms for investors but also complicates the learning process, the DDQN outperforms benchmarks in return, risk and riskadjusted return on gold coin futures contracts (36). Artificial Neural Network models have been widely employed in banking and economics over the past ten years, especially for time series forecasting and performance evaluation (37). Therefore, gold plays a vital role in shaping investors' behavior serving as reliable safe-haven asset, in the short term its price fluctuations impact market sentiment and drive speculative activity, over the long term factors like inflation, oil prices, interest rates, and exchange rate movements influence investment strategies (38). The gold prices in India as shown in Figure 1.



Figure 1: Gold Rate in India from 2016 to 2024 (39)

The graph depicts the trend of gold rates in India, measured in Indian Rupees per 10 grams, over several years from 2016 to 2024. The data shows a clear upward trajectory in gold prices, starting at approximately 30,000 INR in 2016. Initially, the rate experienced gradual growth but by 2019 and 2020, there were noticeable fluctuations. These fluctuations coincide with significant global events, particularly the onset of the COVID-19 pandemic, which had a profound impact on global markets and investor sentiments. As a result, by 2020, the price of gold exceeds 50,000 INR, reflecting a sharp rise that can be attributed to both market conditions and broader economic factors such as uncertainty and inflation. Building on this momentum, the upward trend continues sharply in 2021, where prices peak, reaching nearly 70,000 INR by mid-2023, driven by increasing demand for gold as a safe-haven asset during periods of economic instability. The persistent demand for gold is further underscored by ongoing inflation concerns and fluctuating global financial markets. Looking ahead, the forecast for 2024 suggests that this high pricing level will likely be maintained, although minor fluctuations in rates may still occur. Overall, the chart illustrates not only the rising value of gold in India but also the evolving investment trends and economic sentiments shaping the market over the years. As per the continuous price increases, gold is seen as a trustworthy store of value that draw in long-term investors. Market responses to inflation, geopolitical events, and economic uncertainty are reflected in periods of volatility, which are characterized by sudden price spikes and corrections and have an impact on investment choices. When there is financial instability, demand for gold rises because investors frequently see it as a safe-haven asset. The persistent price increase may also encourage herd behavior, in which investors follow market trends out of past performance bias or fear of missing out. Gold is a desirable investment option in the Indian market because of this tendency, which highlights the influence of psychological and economic elements on investor emotion. SLR is common in information systems research and helps understand previous work on a specific area and like trying to find the latest data on a specific area to see how things stand at the moment. In order to present reliable findings that are repeatable and

auditable the primary objective of a SLR is to gather and evaluate the body of literature that is available on the study question or topic of interest (40). A SLR is an extensive methodological study of find the findings that aim to help specialists in the field create evidence-based recommendations in addition to helping to categorize earlier studies on the subject (41). To demonstrate that the work is original to the body of existing knowledge the results of a SLR should also ascertain the degree of expertise with respect to the research issue (42). The researchers went through a rigorous peer review process before being published which was chosen from "Article" or "Review" and the works also contain all the metadata required to do bibliometric analysis like authors, references, citation counts and publication dates (43). Notably, the rise of scientific databases like Scopus and Web-of-Science has made it easier to obtain vast amounts of bibliometric data and bibliometric software such as Gephi, Leximancer and VOSviewer makes it possible to analyze such data in a very practical manner, as result, bibliometric analysis has recently attracted more scholarly attention, in fact, the bibliometric approach has been used in business strategy as well as other business study domains (44), commerce in electronics (45), finance (46-48), marketing (49-55), human resources (56) and management (57, 58). Using statistical and mathematical methods bibliometric analysis is a quantitative analysis of academic publications to generate measures of scientific activity and research production (59). In bibliometric analysis a number of popular databases including Scopus, Web-of-Science and Google Scholar are used nevertheless, Scopus performs better than Web-of-Science and Google Scholar in terms of journal coverage and citation analysis (59, 60). Information from multiple bibliographic databases including Web-of-Science, Scopus and Google Scholar is needed for the bibliometric analysis (61). However, Scopus can perform the same search operations as Web-of-Science and was primarily designed for bibliographic endeavors and citation analysis making it a valuable alternative to Web-of-Science (62). Behavioural intention (BI) of gold bullion market investment is measured with five dimensions perceived behaviour control, social influence, financial literacy, financial standard and attitude (measured with four psychological factors

interest in the financial issues, anxiety, risk avoidance, precautionary) (63-65), whereas social influence is measured by family and peer (66). The study critically maps the connectedness of commodity markets focusing on literature from the Web of Science and highlights intra and crosscommodity market connectedness influenced by global financial crises, a review of 144 articles (1990-2021) reveals significant conceptual clusters in terms of market behavior, statistical analysis and global collaborations (67). Gold ETFs provide diversification, inflation protection and currency hedging, especially for emerging markets and they outperform other precious metal ETFs offer liquidity and act as a safe haven in downturns, despite limited awareness of alternatives like E-Gold, Gold ETFs deliver higher returns and less variability than physical gold and negative correlation with equity ETFs making them an effective equity risk hedge (68).

The study focused on the influence of indexing strategies, especially smart beta indices on investor behaviour and asset pricing through agent-based modeling and found that smart beta strategies can be effective even with a small number of initial investors and more investors adopt smart beta strategies, market behaviour shifts showed that investor composition and strategy mix significantly impact trading volume and asset prices and it offered insights into how different investment strategies affect market efficiency and investor decision-making (69). Test whether the Consumer Price Index (CPI) can predict gold price returns by using a newly developed predictive regression estimator that tests the null hypothesis of no predictability and the in-sample predictability test results revealed that CPI can predict gold price returns for only 10 countries namely, Australia, Canada, Germany, India, Sweden, Switzerland the UK, Uruguay, the US, Zimbabwe taken with 54 sample countries (70).

The study explored the link between gold pricesdowry and gender-based discrimination in India, analyzed how fluctuations in international gold prices and integral part of the dowry, influence son-preference behaviors leading to higher female mortality and reduced investments in surviving daughters and showed that when gold prices rise neonatal mortality for girls increases relative to boys and that prenatal sex-selective practice (female foeticide) became more common after the introduction of ultrasound technology in the mid-1980's (71).

Methodology Search Strategy

The bibliometric analysis and Systematic Mapping work (SMS) a scholarly approach that is wellknown in the realm of scientific surveys were employed in this work, Systematic Review (SR) is another term for the Systematic Mapping Study, in this approach sequential actions that involve completing a number of independent tasks lead to the final objective and the purpose of the SMS task is mainly to collect and examine scientific papers related to a particular topic in order to provide answers to predefined questions (72). The SMS approach was implemented in the study using the recommendations (73, 74). The study employed bibliographic mapping techniques to visualize bibliometric data and findings from a systematic literature review and it only used the Scopus database to perform a systematic literature review in a repeatable and scientific manner (75). The four activities listed below are completed in order to carry out this research: research goal; document extraction; selection criteria and findings.

Research Goal

The world witnessed that the gold bullion market has long been a vital part of global financial systems, acting as a protect against economic volatility as well as an investment vehicle. Artificial Intelligence (AI) has developed into a significant force in this industry in recent years, providing new tools for data analysis, gold price prediction, operational efficiency and investor behavior. Nowadays industries, organizations, and exchange-traded funds require artificial intelligence to identify capabilities regarding gold investment decisions because of quickly increasing technology, but not all of them can be used to access the gold bullion market investors' behavior. The lack of studies that address all elements of investors' behavior in the Indian gold bullion market and diversity comprise а of implementation strategies, neural networks and algorithms. To fill this gap, the study has set out this research to identify investors' decisions in the Indian gold bullion market, their associate algorithms, and neural networks that go with investors' decisions in the Indian gold bullion

market. Besides, the study investigates the role and importance of artificial intelligence in the area of gold bullion market investors' behavior using AI and investigates its potential applications for investors' behavior using AI. So that the study presents a clear data view to other researchers in this domain through SLR and bibliometric analysis. This research aims to explore the key contributors in the field of gold bullion investment by most influential identifying the authors, documents, and sources. It seeks to provide a clear overview of the main themes and focus areas within the existing literature on gold bullion market investment and investor behaviour.

Document Extraction

2400 documents were found in the initial search by using keywords, and then 200 documents were found by refining the search with "Artificial Intelligence", then 182 documents were found by document type with "Article" and "Conference paper" Then further search used subject area Science", "Economics, which is "Computer Econometrics and Finance", "Business Management and Accounting" 158 documents were found, published documents period between 2012-2024, 143 documents found, finally 25 documents were selected through selective review approach from Scopus database to conduct Systematic Review in a replicable and scientific fashion and bibliographic mapping approaches to visualize bibliometric information and findings from a systematic literature review (75). The search query was used to retrieve the relevant document from Scopus database is (TITLE-ABS-KEY ("investors behaviour" OR "Gold market")) AND (artificial AND intelligence) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp")) AND (LIMIT-TO (SUBJAREA, "COMP") OR LIMIT-TO (SUBJAREA, "ECON") OR LIMIT-TO (SUBJAREA, "BUSI")).

Inclusion and Exclusion Criteria

The study splits a set of criteria into those that are highly relevant scientific documents and those that are irrelevant or somewhat relevant.

The Inclusion Criteria (IC) is as follows:

IC1: The focused this particular study is the use of Artificial Intelligence by investors in the gold bullion market.

IC 2: This research focused on empirical studies and experimental designs.

IC 3: The study gives priority to the entire text.

IC 4: This article is from computer science, economics econometrics and finance, business management and accounting.

IC 5: The study focused on peer-reviewed journal articles and conference papers.

Similarly, the following are the Exclusion Criteria (EC):

EC 1: The study excluded redundant studies or ones that present the same data without novel insights.

EC 2: Studies that lack statistical rigor, have little sample numbers, or have poor research designs are excluded.

EC 3: The study excluded the workshop, book chapters.

EC 4: The study excluded the video content articles.

EC 5: Papers written in a language other than English.

The methodology of selected documents is presented in Figure 2.The Scopus database was chosen for this study because of its extensive collection of high-quality, peer-reviewed literature across various disciplines. One of the biggest abstract and citation databases, it offers access to books, conference proceedings, and respected academic journals, guaranteeing the selection of reliable sources.

Results

Most Influential Authors, Articles, Sources and Countries

This section addresses the RQ1 concerning the prominent authors, articles, sources and countries in the area of gold bullion market investors behavior using AI. It summarizes the most influential authors' production over time with total citations of articles.



Figure 2: Butterfly Blooming Process of Number of Articles Subjected to Analysis Note(s): *Subject Area: Computer Science, Economics Econometrics and Finance, Business Management and Accounting, *TA – Total Analysis, IA – Impact Factor Analysis, SR – Systematic Review.



Figure 3: Represents Authors' Production over Time Regarding Document



Figure 4: Represents Most Relevant Affiliations Regarding Articles

Figure 3 depicts various authors' publication output and corresponding citation activity over time. CI B has produced one article with 7.5 total citations in the year of 2020, as indicated by the larger dots, followed by CHANDAR SK has 5 total citations per year with light dot. Others like Abolade OC, Acharjya B, Ayinde To, Balakumar S, Chen Y, Chenyang W and Chew LM has only 2.5 total citations per year of their documents. Though significant authors published articles from relevant affiliations are depicted in Figure 4.

Figure 4 depicts various affiliations against corresponding "Activity" levels to show how relevant they are. There is a distinct hierarchy seen in the figure, with the most important affiliation clearly at the top, denoted by the largest bubble,

signifying its dominant impact and the highest "Activity" score of 4 of Nanjing University of Aeronautics and Astronautics, University of International Business and Economics, University of Reading and Wuhan Donghu University are the most relevant affiliations of gold bullion market investors behavior using AI, there are a few more associations that have an "Activity" score of 3 which indicates that they are moderately important of Academy of Mathematics and Systems Science, Dongbei University of Finance and Economics, Islamic Azad University, Multimedia University and Universitas Ciputra Surabya affiliations. Significant affiliations of selected articles have been published in the most relevant sources which are projected in Figure 5.







Figure 6: Most Cited Countries with Citations



Figure 7: Most Global Cited Documents with Citations

Choosing the most active source was an intriguing part of the bibliometric study. The top ten sources that published gold bullion market investor behavior using AI. The Resource Policy was the top journal with 4 publications. The Expert Systems with Applications from the United Kingdom were second with 2 publications. Following them the Advances in 2023 11th International Conference on Information, Intelligent Systems and Computing, Applied Economics, Energy Economics, Forum Scientiae Oeconomia and other sources have been published with 1 document as shown in figure 5. Following Figure 6 represents the most cited countries with citations of selected documents. The total citations (TC) and average article citations for the top most 5 countries -China, Hong Kong, India, Iran and the US are contrasted in the below Figure 6, with a substantial total of 220 citations, China tops the world in research output and average citation rate per publication is 24.40, showing both volume and highly influential work. Hong Kong comes in second with 37 total citations and a little higher average citation rate of 37.00, India ranks third in terms of total citations 34, indicating that its output is lower overall but its level of influence per piece is similar to that of Hong Kong. Iran, with a total of 30 citations, 15.00 citations on average of 1.00 citations per document. Although China leads in volume Hong Kong and India have more influence per article, which speaks to the calibre and significant of their research. Finally, Figure 7 represents most global cited selected documents of gold bullion market investors' behavior using AI.

Figure 7 shows that a comparison of globally cited documents across 3 metrics for each paper one normalized total citations which represents blue bars, total citations per year indicates orange bars and total citations looks grey bars. Energy Econ's Dai X (2020) has the most citations overall 69, indicating a considerable influence, although having a moderate normalized citation rate 13.80, followed by Resource Policy, Zhang P (2020) is particularly noteworthy with 56 total citations and a marginally elevated normalized rate 11.20, although their yearly citation increase is slower, papers like Yang J-H (2012) and Zhou S (2012) have amassed 45 and 41 citations, respectively, demonstrating substantial influence over time. With 11 citations and a high yearly rate of 2.75, He C (2021) in Appl Econ shows a rapidly expanding impact in a short amount of time. Despite having less citations, Mousapour Mamoudian M (2023) and Jia Z (2023) have high normalized scores 15.00 and 15.50, indicating that they are becoming more influential. Other and more noteworthy publications with consistent increase over time are Reboredo JC (2015) and Chandar SK (2016) with 4.50 and 3.78 citations, respectively. Recent publications are quickly garnering attention and despite the proven influence of older papers, their high normalized citation rates indicate their increasing relevance in their respective disciplines. Most Dominating Themes in Research

on Gold Bullion Market

In response to RQ2, concerning the word tree map, trend topics and word cloud regarding gold bullion

market investors' behaviour using AI. Words which are visualization that provides a hierarchical view of data, used by different authors in their publications are following Figure 8.

The tree-map Figure 8 shows the relative shares of different study themes within a dataset 15% of the entire area is occupied by the largest part, which stands for gold and emphasizes its importance to the research topic. Forecasting follows, covering 7%, demonstrating that predictive analysis is another prominent area of research. The importance of studies relating to economics and market is demonstrated by the proportions of commerce and financial markets, which are 6% and 5% respectively. The fact that both gold prices and investments account for 5% highlights the importance of financial and investment-related matters. Both the costs and the gold bullion market account for 4%, which illustrates their importance in economic studies. Regression analysis, machine learning and artificial intelligence each account for 3% of the topics, indicating their growing application in financial and economic modelling. At 2%, time series analysis, neural networks and predictions are also included, emphasizing the use of sophisticated computational techniques. A few minor subjects such forecasting the price of gold, price dynamics, exchange rates and random forests account for 1% of the total, suggesting that these are important but specialized fields of research. The figure indicates a wide concentration on predicting, new AI techniques and financial markets, with a preponderance of study on gold. From the word tree map which are the most trend words used by the authors represents in the Figure 9. The Figure 9, which focuses on subjects like financial markets, gold prices, forecasting, crisis, commodities and the gold bullion market, shows

the frequency of financial phrases across time. Interestingly, the word "gold" has highest frequency of 20 between 2021-2023 followed by "financial markets", "gold prices", "forecasting", "commerce" at a frequency of 15 between 2021-2023, the term namely "gold market" and "costs" notably at a frequency of 10 between 2017 to 2023. The global financial disruptions in 2020 coincide with the emergence of a crisis with notable spikes, while commodity interest is low and peaks around five in 2019. The gold bullion market is still talked about less frequently - up to five times a year. Word cloud is used to find the centre point of written text (76), in bibliometric studies, the use of a word cloud to evaluate the most prevalent words indicates that most of the work is concentrated in those areas. Words in smaller letters indicate potential study directions (77). The following Figure 10 signifies words which are not done more studies in the area of gold bullion market investors' behaviour using AI.

Figure 10 highlights key terms relating to finance, the terms that stand out the most are "gold", "financial "forecasting", markets", and "commerce", indicating their importance in economic research and market dynamics. Significant "gold prices", "investment" and expenses also show how important gold is to commodities trading and financial decisionmaking. The expanding influence of modern technology in financial analysis and market forecasting is reflected in the words "machine learning", "artificial intelligence" and "neural The employment of technical networks". approaches in market analysis is suggested by smaller phrases like "electronic trading", "price dynamics", "exchange rate" and "regression analysis".



Figure 8: Represents Word Map Tree of Selected Documents



Figure 9: Represents Trend Topics of Selected Documents



Figure 10: Represents Word Cloud of Selected Documents

Table 1: Review of Selected Articles

S.	Article title	Author	Year	DOI	Journal	Cite	Author	Outcomes	Limitations/Future
No					Name	d by	Keywords		Direction
1.	A Fuzzy Rough Feature Selection Framework for Investors Behavior Towards Gold Exchange-Traded Fund (78)	Acharjya B, Natarajan S	2019	10.4018/IJB AN.2019040 103	International Journal of Business Analytics	6	Behavioral Finance; Dependency; Fuzzy Indiscernibility; Fuzzy Rough Quick Reduct; Rule Generation	Identifying key variables like perceived behavioural control and financial competence. The FRQR algorithm highlighted the most critical factors influencing decisions and emphasized the need to raise GETF awareness in India.	Explore subjective norms influencing GETF investments while incorporating financial knowledge, focus on diverse demographics for improved generalizability, with advanced analytical techniques and longitudinal studies.
2.	Downside/upside price spillovers between precious metals: A vine copula approach (79)	Reboredo JC, Ugolini A	2015	10.1016/j.na jef.2015.08.0 01	North American Journal of Economics and Finance	45	Downside/upsi de risk; Precious metals; Spillover; Vine copula	Vine copula model to examine the multivariate dependence structure between four precious metals – gold, silver, palladium and platinum – revealing that they do not behave as a single asset class, which has important implications for trading, risk management and hedging strategies in portfolio containing these metals.	Explore alternative models, consider macroeconomic and geopolitical factors include more metals like rhodium or iridium and analyse different investor types through longitudinal studies.

3.	Hybrid neural network-based metaheuristics for prediction of financial markets: a case study on global gold market (80)	Mousapour Mamoudan M, Ostadi A, Pourkhodabakh sh N, Fathollahi-Fard AM, Soleimani F	2023	10.1093/jcd e/qwad039	Journal of Computation al Design and Engineering	30	Bidirectional gated recurrent unit; convolutional network; firefly algorithm; moth-flame optimization algorithm; precious metals market; prediction	The hybrid model in the study outperformed conventional techniques with 96% accuracy, though its precision and F1-score were slightly lower compared to MFO, while robustness was enhanced by using an extensive dataset and ANOVA, F-test for feature selection	Developing new indicators for academics and investors, explore finer time intervals, apply multi-criteria decision-making theories, time series algorithms and fuzzy approaches and powerful metaheuristic algorithms (lion-inspired optimization, red deer, etc.)
4.	Correlation between Shanghai crude oil futures, stock, foreign exchange and gold markets: a GARCH- vine-copula method (81)	He C, Li G, Fan H, Wei W	2021	10.1080/000 36846.2020. 1828566	Applied Economics	11	Backtesting; GARCH-vine- copula model; Shanghai crude oil futures market; Value at Risk	GARCH-vine-copula approach to investigate interdependence between the Shanghai crude oil futures market and others found strong tail dependencies and a dominant influence of the crude oil market	Incorporate stock markets and higher-frequency data for deeper insights, explore alternative copula models.
5.	Trend Detection in Gold Worth Using Regression (82)	Rashidi Sf, Parvin H, Nejatian S	2017	10.1007/978 -3-319- 62434-1_24	Lecture Notes in Computer Science	0	Gold worth; Mapping chase autoregression; Predict shape	THE MCAF technique was applied to the daily value of gold, with experimental results showing that it outperforms the BPNN technique, particularly in stability when handling large datasets from 2008 to 2013, thus benefiting investors by enhancing decision-making and risk reduction	New hybrid models for predicting future data with larger sample sizes, which will assist depositors in making informed decisions and achieving better asset allocation and portfolio diversification.

6.	Research on the relationship between Covid-19 epidemic and gold price trend based on Linear Regression Model (83)	Jianyi Y, Chenyang W, Yupeng H, Zicheng L	2020	10.1109/ITA IC49862.202 0.9338828	IEEE Joint International Information Technology and Artificial Intelligence Conference (ITAIC)	3	Covid-19; Gold price trend; Linear regression model; World economy	The selected datasets, which encompass gold price trends, daily cumulative confirmed cases, cumulative deaths and cumulative recoveries from Jan 22 to Sept 23, underscore the extensive impact of the ongoing epidemic on various market aspects.	Expand the data collection to include datasets for both gold prices and COVID-19 statistics, additional economic indicators, non- linear models, machine learning, longitudinal studies.
7.	A Two-Stage Deep Fusion Integration Framework Based on Feature Fusion and Residual Correction for Gold Price Forecasting (84)	Qiu C, Zhang Y, Quan X, We C, Lou J, Chen Y, XI Y, Zhang W, Gong Z	2024	10.1109/AC CESS.2024.3 408837	IEEE Access	0	Feature fusion; integration model; price forecast; residual correction	Combining CNN, BP and LSTM improves gold market forecasting by addressing the limitations of each individual model through feature fusion to capture complex patterns and residual correction for better predictions, while VMD enhances accuracy and computing efficiency.	Focus on adaptive algorithms as a primary topic to enhance the management of real-time market volatility.
8.	Multi-Scale Dependence Structure and Risk Contagion Between Oil, Gold and US Exchange Rate: A Wavelet-Based Vine- Copula Approach (85)	Dai X, Wang Q, Zha D, Zhou D	2020	10.1016/j.en eco.2020.10 4774	Energy Economics	69	Dependence structure; Oil price; Risk contagion; Vine-copula model; Wavelet decomposition	Intricate, time-varying linkages among oil, gold and the US dollar with the US dollar-gold relationship driving asymmetrical risk contagion, especially during medium-term horizons and financial crises, which can aid investors in enhancing portfolio management and risk mitigation techniques.	Long-term relationships among oil, gold and US FX to capture extended market dynamics, while incorporating variables like interest rates and inflation, machine learning to better capture non-linear interactions, geopolitical events and investor behaviour along with comparative regional studies.

9.	Improved prediction of global gold prices: An innovative Hurst- reconfiguration-based machine learning approach (86)	Yang M, Wang Rm Zeng Z, Li P	2024	10.1016/j.re sourpol.202 3.104430	Resources Policy	0	Decomposition and ensemble; Gold price forecasting; Hurst exponent; Swarm intelligence optimization	Multifractal-based model, with lower prediction errors and a negative correlation with the Hurst exponent, enhances investor and regulatory understanding of gold market dynamics and broader applications.	Investigate other decomposition techniques, incorporate calendar features for better forecasting accuracy, develop statistical tests for nonlinearity and expand to multi-step forecasting models.
10.	Viral decisions: unmasking the impact of COVID-19 info and behavioural quirks on investment choices (87)	Rehman Wu, Saltik O, Jalil F, Degirmen S	2024	10.1057/s41 599-024- 03011-7	Humanities and Social Sciences Communicati ons	0	Investors behavior, COVID-19, investment decisions	Explored decisions during the pandemic are significantly driven by emotional biases, overconfidence and herding behavior, particularly among young, lower-income investors, with COVID-19 amplifying these effects, as demonstrated through an agent-based model and K- means clustering.	Institutional behaviours, incorporate more behavioural factors, expand to global markets and provide qualitative data and open-source code for collaborative research to advance behavioural finance models.
11.	A dynamic meta- learning rate-based model for gold market forecasting (88)	Zhou S, Lai KK, Yen J	2012	10.1016/j.es wa.2011.11. 115	Expert Systems with Applications	37	BPNN; EMD; Forecasting; Meta-learning	The study proposed an improved EMD meta- learning rate-based model for gold price forecasting, demonstrating strong performance with 2,636 observations, balancing convergence speed and accuracy for enhanced predictions in the gold market.	Suggesting future research on global meta-learning rates to explore potential relationships between MAE and data samples.

12.	Asymmetric nexus between Bitcoin, gold resources and stock market returns: Novel findings from quantile estimates (89)	Jai Z, Tiwari S, Zhou J, Farooq Mu, Fareed Z	2023	10.1016/j.re sourpol.202 3.103405	Resources Policy	31	Bitcoin; Chinese economic structure; Gold price; Quantile and quantile; Stock market returns	Bitcoin outperformed both the stock market and gold in average returns, while exhibiting mild positive correlations with the stock market and strong positive e correlations with gold, indicating intricate relationships that could impact China's economic growth and policy regarding cryptocurrencies and market dynamics.	Incorporate data from both pre and during COVID-19 period to gain deeper insights, while also exploring the impact of Bitcoin exchange rates across various countries and their relationships with stock market, commodities, and foreign exchange rate.
13.	Evaluation of business strategies based on the financial performance of the corporation and investors behavior using D-Critic and fuzzy MULTI-MOORA techniques: A real case study (90)	Ghaenu-Zadeh N, Eghbali- Zarch M	2024	10.1016/j.es wa.2024.123 183	Expert Systems with Applications	1	Business strategies; D- CRITIC; Decision- making; Financial performance; Fuzzy theory; MULTI- MOORA; Principal component analysis (PCA); Uncertainty	Tehran Stock Exchange (2017-2021) indicate that the medium analyser strategy, the fuzzy MULTI- MOORA approach to handle uncertainty, most favourable for corporations and investors, the integration of PCA and a correlation heatmap for visualization demonstrates the proposed framework effectiveness in identifying optimal business strategies	Understanding of strategic dynamics by integrating both financial and non- financial factors, expand global data collection, advanced statistical and machine learning methods, and longitudinal studies.
14.	Gold Prices Forecasting Using Bidirectional LSTM Model Based on SPX500 Index, USD Index, Crude Oil Prices and CPI (91)	Chew LM, NGU Chuan YI, Yeng OL	2023	10.1109/ICo ICT58202.20 23.1026248 1	2023 11 th International Conference on Information and Communicati on Technology, ICOICT	0	Bidirectional LSTM; Consumer Price Index; Crude Oil Prices; Gold Prices Forecasting; SPX500 Index; Time-series analysis; USD Index	Significant impacts of the CPI and SPX500 Index on market dynamics; weak correlations between the USD and crude oil prices.	Focus on exploring deep learning architectures such as GRUs and CNNs, features engineering and hyperparameter optimization techniques, macroeconomic factors, market sentiment.

15.	A New Hybrid VMD- ICSS-BiGRU Approach for Gold Futures Price Forecasting and Algorithmic Trading (92)	Li Y, Wang S, Wei Y, Zhu Q	2021	10.1109/TCS S.2021.3084 847	IEEE Transactions on Computation al Social Systems	41	Algorithmic trading; bidirectional gated recurrent unit (BiGRU); gold futures price forecasting; variational mode decomposition (VMD)	The hybrid forecasting approach expressively outperformed benchmarks, consistent better results when generalized to the spot gold market, providing practical guidance for minimizing investment risk and hedging strategies in the gold commodity market.	Explore GRU and CNN deep learning models, macroeconomic and sentiment data and external factors.
16.	Technology shocks – Gold market connection: Is the effect episodic to business cycle behaviour? (93)	Ayinde TO, Olaniran AO, Abolade	2023	10.1016/j.re sourpol.202 3.103771	Resources Policy	0	Business cycle; Forecasting analysis; GARCH-MIDAS; Gold market; Mixed data sampling; Predictability; Technology shock; Volatility	Study illustrates that Technology Shocks (TS) enhance the predictability of gold return volatility compared to conventional models using the GARCH- MIDAS model, with their influence being episodic and particularly pronounced during economic expansions.	Incorporate broader datasets, including emerging markets and geopolitical factors.
17.	Forecasting Gold Prices Based on Extreme Learning Machine (36)	Chandar SK, Sumathi M, Sivanada SN	2016	10.15837/ijc cc.2016.3.20 09	International Journal of Computers, Communicati ons and Control	34	Extreme learning machine; Feed forward neural networks; Gold price forecasting	The future gold price prediction becomes the warning system for the investors due to unforeseen risk in the market and the results proved that the ELM learning performs better than the other methods	Explore predicting gold prices using a variety of models beyond machine learning to enhance forecasting accuracy and comprehensiveness.

18.	Using Neural Network Architectures for Intraday Trading in the Gold Market (94)	Devarajula S, Milke V, Luca C	2023	10.5220/001 1794400003 393	International Conference on Agents and Artificial Intelligence	0	Algorithmic Trading; Artificial Intelligence; Forex; Intraday Trading; Machine Learning in Finance; Neural Network Computing	Study found that a 2-layer CNN outperformed LSTM in minute-level gold price prediction by achieving lower error rates (MSE, MAE and MAPE).	Focus on advanced systems like Transformers, broaden data sources including commodities cryptocurrencies and new sentiment.
19.	Deep belief network for gold price forecasting (95)	Zhang P, CI B	2020	10.1016/j.re sourpol.202 0.101806	Resources Policy	56	Deep belief network; Gold price forecasting; Neural network; Time series	Study found that the DBN model, trained on historical data from 1984- 2014, outperformed conventional models like BP, GA-BP and ARIMA in predicting gold prices, achieving the highest directional accuracy (D stat) and offering strong guidance for investment strategies	Incorporating diverse economic indicators, hybrid models and integrating real- time data, deep learning architectures like CNNs and RNNs to improve pattern recognition and extend forecasting to longer timeframes.
20.	Prediction of Gold Price based on WT- SVR and EMD-SVR model (96)	Yang J-H, Dou W	2012	10.1109/CIS. 2012.99	Proceedings of the 2012 8 th International Conference on Computation al Intelligence and Security CIS	9	Empirical mode decomposition; gold price; independent intrinsic mode functions; support vector regression; wavelet transform	EMD-SVR model outperforms the Wavelet Transform (WT) by effectively managing nonlinear, nonstationary data, leading to more accurate gold price predictions and aiding in financial decision-making.	Incorporate diverse variables, testing across different markets and periods, improve interpretability and compare effectiveness to deep learning model for applications.

21.	Investment Instruments: The Power of Neural Networks in Predicting Gold Price Trends (97)	Horak J, Vochozka M, Kaisler D	2024	10.23762/FS O_VOL12_NO 1_4	Forum Scientiae Oeconomia	0	Artificial intelligence; commodity market; gold; investing; prediction	Artificial neural networks have demonstrated the ability to accurately predict gold price trends by incorporating key political, economic and social factors that historically influence its development.	Expand the dataset, optimize parameters like time series delays, input data could enhance gold price prediction accuracy, compare the current neural network model with alternatives (LSTM, ARIMA, VAR).
22.	Gold Prices Time- Series Forecasting: Comparison of Statistical Techniques (98)	Maryati I, Christian, Paramita AS	2023	10.47738/ja ds.v4i4.135	Journal of Applied Data Sciences	0	Exponential Smoothing; Gold Prices; Linear Regression; Time Series	With a Mean Absolute Percentage Error of 7.12%, the study found single exponential smoothing most reliable for predicting gold prices, which remain stable during peaceful times but rise during political and economic unrest, with gold value as a hedge expected to increase over the next decade due to rising prices.	Respective of limitations focus on regional variations the impact of specific geopolitical or economic events on gold price volatility.
23.	Analysing the Influence of Indexing Strategies on Investors' Behavior and Asset Pricing Through Agent-Based Modeling: Smart Beta and Financial Markets (69)	Takahashi H	2016	10.1007/978 -3-319- 39883-9_27	Smart Innovation, Systems and Technologies	0	Agent-based model; Asset management business; Financial markets; Smart beta; Stock indices	Study found that smart beta strategies are effective even with a small initial number of investors and revealed a important relationship between the number of smart beta investors and trade-off volume, making the findings valuable from both practical and academic perspectives.	Explore indexing strategies beyond smart beta, longitudinal studies, incorporate diverse investor profiles, integrate behavioural finance and analysing market design to gain deeper insights into investor behavior and improve market efficiency.

24.	Gold Price Prediction using ARIMA model (35)	Nanthiya D, Gopal SB, Balakumar S, Harisankar M, Midhun SP	2023	10.1109/ViT ECoN58111. 2023.10157 017	Vitecon 2023 - 2nd IEEE International Conference on Vision Towards Emerging Trends in Communicati on And Networking Technologies , Proceedings	2	ARIMA Model; Linear Regression; Machine Learning; Multiple Linear Regression; Random Forest Regression	The ARIMA model demonstrated superior accuracy in predicting gold prices, with an RMSE of 0.046 and an MAE of 0.040, outperforming Random Forest and Linear Regression, the study also highlights the importance of ensemble learning for enhancing prediction stability and accuracy.	Use geopolitical events and economic indicators, real- time data analysis.
25.	The Structural Analysis of the World Gold Prices Dynamics (99)	Dzerjinsky RI, Pronina EN, Dzerzhinskaya MR	2020	10.1007/978 -3-030- 51971-1_29	Advances in Intelligent Systems and Computing	8	Hidden periodicity; Scaling; Self- similarity; Structure functions; World gold market	The structural analysis of world gold prices reveals three interrelated 30-year cycles, indicate that global production and price dynamics will fluctuate from 2017 to 2041, reflecting this cyclical tendency in market activity.	Focus on deep learning, algorithms of machine learning, neural networks to predict the gold prices.

Trends and Outcomes of Selected Documents

Table 1 presents a detailed summary of research studies on gold price forecasting, investor behaviour, and financial market dynamics. It explores various analytical techniques, including machine learning, statistical modelling, and behavioural finance, to identify key trends in gold prices, risk contagion, and investment strategies. Furthermore, the table highlights research gaps and future directions.

Discussion

In 2020, notable contributions were recognised through many citations, emphasizing the impact of individual researchers in this field, particularly (95). The analysis of financial behaviour has been consistently advanced through the use of neural networks and algorithms like the Extreme Learning Machine (ELM) (78, 93). These models have shown success in managing complex data structures thereby supporting more accurate market predictions. Together, these contributions form a solid foundation for modeling investor behaviour in fluctuating markets underscoring AI transformative potential. Institutions like the University of International Business and Economics and Nanjing University of Aeronautics and Astronautics, particularly in China are at the forefront of this research. China leadership in output and citations is notable, but despite having fewer publications, countries like Hong Kong and India display a higher impact per article. This demonstrates the global reach and importance of AI-driven financial research. High-impact studies, such as those Energy Economics and Resources Policy, reflect substantial influence with 56 to 69 citations, especially in topics like commodity interdependence and advanced predictive modeling, which are crucial for risk management. For instance, the Wavelet-Based Vine-Copula Approach study 69 citations explores relationships between commodities and currencies while the Deep Belief Network for Gold Price Forecasting 56 citations has shown effective prediction through machine learning applications. Recent research explored hybrid neural has network metaheuristics, as evidenced in the Journal of Computational Design and Engineering with 30 citations (80). Hybrid neural networks like CNN and LSTM have been shown to significantly outperform traditional models in predicting gold prices, achieving up to 95% accuracy (84). Despite performance challenges this high like hyperparameter optimization and generalizability persist, limiting widespread application. In contrast, copula models have been used to analyse asset interdependencies among precious metals, though their reliance on historical data limits their effectiveness in predicting future market movements (79, 85). This indicates a need for more sophisticated models capable of integrating real-time global data. A comparison between traditional statistical models and machine learning distinct techniques reveals performance differences. Traditional models like ARIMA perform well in stale market conditions but struggle to effectively capture non-linear patterns and respond to external shocks (83). On the other hand, machine learning models are better in adapting complex data and changing market conditions which leads to improved prediction accuracy (86, 92). Hybrid models combine the advantages of both statistical and machine learning methods, leading to improved performance (80). Research on the role of artificial intelligence in analysing the gold market highlights its increasing importance in tackling global economic uncertainty (36, 95). Institutions like the University of International Business and Economics are leading this charge, focusing on machine learning and neural networks to improve financial forecasting and decision-making, especially during crises like COVID-19. The shift toward data-driven approaches underscores AI's growing importance in financial markets.

Conclusion

The analysis has a growing reliance on advanced forecasting methods, including hybrid neural networks and machine learning to predict gold prices and understand investor behaviour, significantly improving accuracy over traditional models. Nonetheless, challenges like overfitting and data dependency hinder their application in volatile markets. In contract, while traditional statistical models are interpretable they struggle with non-linearity and volatility, which are increasingly common in today's markets. On the other hand, copula models effectively capture asset dependencies for risk management but are limited by historical data, restricting their adaptability to sudden market changes. Furthermore, hybrid models combine strengths for better performance but are computationally expensive leading to practical implementation challenges. Therefore, continued advancements in model robustness and broader data integration are essential for enhancing predictive capabilities in an everevolving financial landscape. It highlights a growing interest in forecasting, particularly during economic crises like that of 2020, where financial markets and gold prices became prominent areas of investigation. The study indicates that AI-driven research in financial markets, especially in commodities like gold, and precious metals are becoming more sophisticated and impactful.

Limitations and Future Research Scope However, the study only includes scopus database and excludes relevant studies indexed in other databases like Web-of-Science, IEEE, etc., to mitigate these limitations, future research could take place on additional databases to ensure a more comprehensive review. Additionally, Advanced deep learning techniques like CNN, LSTM and RNN alongside machine learning algorithms such as Random Forest and XGBoost to enhance gold market forecasting and investor behaviour analysis. These models can capture both short-term volatility and long-term trends while integrating real-time data for more accurate predictions. This integration of methodologies is crucial as it allows for a more nuanced understanding of market movements. Furthermore, adaptive deep learning algorithms and reinforcement learning can optimize decisionmaking, particularly during market disruptions. Additionally, using NLP to analyse market sentiment and investor psychology can complement these models, further enriching the predictive capabilities of AI, while deep learning can explore the relationship between gold and emerging assets like cryptocurrencies it also provides comprehensive tools for risk management and portfolio diversification.

Abbreviations

IA: Impact Factor Analysis, SR: Systematic Review, TA: Total Analysis.

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