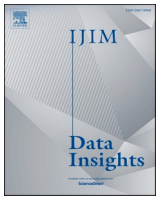
International Journal of Information Management Data Insights 4 (2024) 100240

Contents lists available at ScienceDirect

International Journal of Information Management Data Insights

journal homepage: www.elsevier.com/locate/jjimei



Cryptocurrency trading: A systematic mapping study

Duy Thien An Nguyen, Ka Ching Chan *

School of Business, University of Southern Queensland, Springfield, Queensland, Australia

ARTICLE INFO

Keywords:
Cryptocurrency trading
Cryptocurrency market
Market influential factors
Trading technologies
Input features

ABSTRACT

Cryptocurrency's unique features – decentralisation, anonymity, and diversification – have propelled it into the spotlight, attracting both investors and researchers despite its relative youth compared to traditional markets. This study utilizes a systematic mapping approach to examine the current state of cryptocurrency trading research. We are particularly interested in influential variables and technologies involved in cryptocurrency trading systems. By summarizing key findings on data, technology compatibility, and future research directions, this study serves as a starting point for new research activities in the field of cryptocurrency trading.

Abbreviations

ESG	Environmental-Societal and Governance
ML	machine learning
NN	neural network
RQs # (#=1, 2,…,n)	Research Questions #
IEEE	Institute of Electrical and Electronics Engineers
ACM	Association for Computing Machinery
EC	Exclusive Criteria
IC	Inclusive Criteria
Bitcoin	BTC
FTX	FTX Trading Ltd
ICEA	Index of Cryptocurrency Environmental Attention
AI	Artificial Intelligence

Introduction

Cryptocurrency has been making headlines in the finance world for the past decade. The digital currency, built on blockchain and cryptography, in theory, offers the promise of transparent and anonymous transactions. Unlike traditional currencies, cryptocurrency is decentralized, operating 24/7 and independently of central banks or physical assets (Frankenfield, 2023). Its unique features coupled with the rise of Fintech, Virtual Reality, and Metaverse have drawn significant interest from investors and financial institutions.

While cryptocurrency has some unique characteristics, the digital currency is known for its exceptional volatility. Cryptocurrency value can change dramatically within a short period, making cryptocurrency an extremely high-risk investment. The global cryptocurrency market capitalisation reached $3 Trillion USD in December 2021, just 3 years from the launch of Bitcoin (BTC) in 2009. However, by the end of July 2022, the cryptocurrency market had dropped below $1 trillion USD (CoinMarketCap, 2023). The exceptional volatility presents both risks and opportunities for investors.

These interesting characteristics of cryptocurrency trading have attracted the attention of researchers. A growing body of research has been dedicated to cryptocurrency trading, exploring various aspects of the market in recent years. For instance, Market Efficiency theory has been utilized to examine the long memory, market persistence, and other unique patterns of the cryptocurrency market. The theory is well-known in financial economics (Caporale et al., 2018; López-Martín et al., 2021; Omane-Adjepong et al., 2019; Sigaki et al., 2019). Other characteristics such as inter-correlation, (Co)Explosive, volatility clusters, chaotic structures, tail-dependence, and bubble-like (overaction) behaviours have been examined through different statistical and other economic models (Ahn, 2022; Blau et al., 2020; Caporale & Plastun, 2019; Pietrych et al., 2021). The influence of external factors studies (such as traditional assets, investor sentiment, environmental considerations, social impacts, and regulatory frameworks) offer another avenue to understanding cryptocurrency market fluctuations. (Ahn, 2022; Ahn & Kim, 2021; Cao & Xie, 2022). Beyond theoretical explorations, researchers have investigated into the mainstream financial market acceptance of cryptocurrency and trading strategies. This body of work examines market capitalization, potential investment opportunities, risk assessment, and trading platforms for digital assets. To navigate the market's volatility, various predictive models have been

* Corresponding author.
E-mail address: kc.chan@usq.edu.au (K.C. Chan).

https://doi.org/10.1016/j.jjimei.2024.100240

Available online 1 May 2024

proposed, including technical analysis, statistical time series forecasting, machine learning (ML), neural networks (NN), and other trading algorithms. (Corbet et al., 2019; Hansun et al., 2022; Lahmiri & Bekiros, 2021).

Cryptocurrency trading is a complex subject that requires expertise in a variety of fields, including finance, economics, and computer science. It can be challenging for new researchers to navigate due to the complexity and cross-disciplinary nature of cryptocurrency trading. Therefore, there is an urgent need for a comprehensive understanding of these rapidly evolving domains to help researchers gain a better understanding of cryptocurrency trading. Previous studies have explored the literature on cryptocurrency trading. For instance, Fang et al. (2022) conducted a survey of 146 papers on cryptocurrency trading, providing insights into the distribution of research within the field. Khedr et al. (2021) and Sattaru et al. (2022) studied the application of machine learning in market price prediction. de Oliveira Monteiro, de Souza, Batista, & Zaparoli, 2019 conducted a mapping review to explore cryptocurrency trading. However, the mapping review was based on the screening of only 17 papers, which might not be sufficient to discover all the main research themes.

This study aims to investigate the current state of research in cryptocurrency trading – by examining the key research areas, the systems technologies utilized, and the potential future research directions for cryptocurrency trading. To achieve this, we conducted a systematic mapping review. A mapping study offers a high-level view of the research area, spanning multiple disciplines and a diverse range of studies (Petersen et al., 2008). This study not only offers a comprehensive overview of current trends but also provides detailed information about the components of the cryptocurrency trading system. This information can be leveraged to help researchers and developers develop a cryptocurrency trading system, or a digital advisor platform (Robot--advisor) for trading cryptocurrencies- distinguishing our approach from previous literature reviews.

This study contributes to the existing literature by (1) providing the current and comprehensive overview of research trends, (2) identifying and categorising key research themes (3) examining the common trading strategies, exploring both the influential factors and trading technologies employed, (4) and proposing essential components needed to automate cryptocurrency trading or to develop a digital investment advisor, leveraging current research advancements.

Driven by these motivations, we investigate the methodology employed to address the research questions. The following section details the data collection and analysis methods used in our mapping study.

Methodology

Systematic mapping aims to provide a comprehensive understanding of the current state of research on a particular topic. Through descriptive analysis, primary areas of study are identified and classified into a systematic structure (Petersen et al., 2015). As noted by Riaz et al. (2015), the distinction between Systematic mapping and literature reviews lies in the scope of the research questions (RQs) and the data analysis methods employed. The RQs in systematic mapping are designed to have a broader scope, with a focus on the current state of research on a particular topic, thus assisting researchers with evidence in identifying the starting point for their study. Campbell et al. (2023) suggested the aim is not to synthesise but to *identify, describe, and catalogue findings. They aim to answer the questions "What do we know about a topic? What and where research exists in a particular area?"*.

Our systematic mapping study strictly adhered to the methodology and framework presented by Petersen et al. (2015) and aimed to explore the existing literature on cryptocurrency trading through a series of research questions. We separated the process into three phases: (1) the research planning and preparation phase, (2) collecting and selecting relevant publications (3) describing and classifying the accepted literature (Fig. 1).

Preparation phase

The systematic mapping study was guided by research questions (RQs) outlined in Table 1. These RQs, alongside the selection criteria detailed in Tables 3 and 4, were developed based on Campbell et al. (2023) recommendations.

The findings for RQ1.1 to RQ1.3 provided descriptive information about the research and practices in the field of cryptocurrency trading, including research trends and publication demographics. Research questions RQ2.1 and RQ2.2 identified existing areas of research focus, enabling researchers and investors to navigate to the desired starting point for their work. In the series of RQ3 (RQ3.1 to RQ3.4), the focus is on the technical side of cryptocurrency trading systems, focusing on artifacts and technologies related to cryptocurrency trading. The motivation behind RQ3 was to assist researchers and practitioners in understanding the building blocks of a trading system.

Guided by the research questions, we began to identify search keywords for database search. We followed Petersen et al. (2015) suggestion for defining keywords. Using well-defined research questions to determine search keywords is essential to avoid biased data collection and ensure comprehensive coverage of the chosen area of study. Additionally, the result from the query should be feasible within the established timeframe for the research. With the study goals in mind, the pilot searches were conducted. We began our search with simple keywords such as "cryptocurrency trading", "cryptocurrency markets" on Google Scholar. Based on our trial findings, we refined our keywords. The finalised result was the combination of search strings defined below (Table 2).

The string of keywords was then combined with the inclusion criteria (Table 3) to generate the search query for the four selected databases (Scopus, Web of Science, IEEE Access, and ACM Full-Text Collection). The databases were chosen based on their indexing and multidisciplinary coverage to ensure quality data for our study.

Selection phase

The search was performed on the 25th of September 2022 across four databases, returning a total of 1083 articles including journal and conference papers. Duplicate removal using Zotero (a bibliographic management tool), and manual screening resulted in a final set of 722 papers.

After screening titles and abstracts of 722 papers against the exclusion criteria detailed in Fig. 4, potentially ineligible studies were flagged for the second review. During this secondary review, we re-examined the flagged papers and retained those deemed relevant to our research focus, resulting in the final collection.

We established four exclusion criteria (EC) to ensure the selected papers were: (1) accessible for review (EC1), (2) thematically relevant to cryptocurrency trading (EC2), and (3) impactful or offering valuable insights into the field (EC3). We used the SCImago quartile rank database as the primary measure to assess the quality of the selected journal articles. Any journal paper lacking a quartile ranking was manually reviewed to determine its relevance to this study. To maintain methodological transparency and capture potentially relevant papers outside the Scopus ecosystem (the primary source for SJR), unranked articles underwent manual review for thematic fit. The same procedure was applied to conference papers. Any conference papers that were not included in ACM and IEEE conference proceedings were manually reviewed. These inclusive/exclusive criteria and the review procedure were put in place to ensure that our mapping study is reproducible.

Following an initial screening phase that identified 616 suitable papers, 107 papers were marked for revision. After the second revision was completed, 6 papers were re-added back to our collection. This resulted in a final selection of 622 papers from the initial pool of 722. A

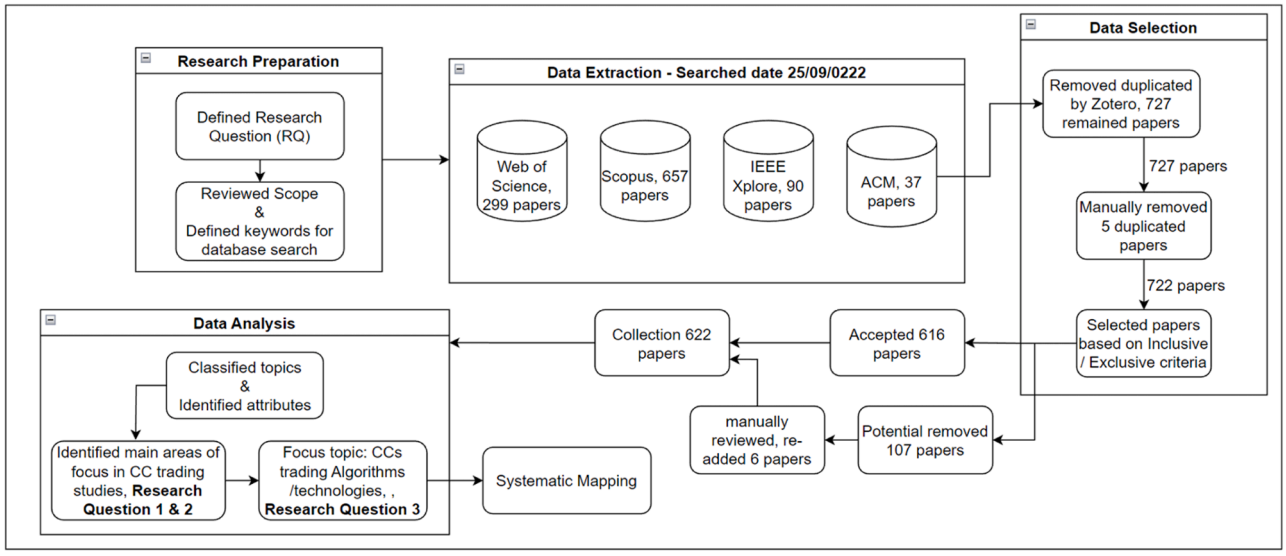


Fig. 1. Mapping flow chart for cryptocurrency trading study. The collection of papers can be found at Mendeley Data, titled Nguyen, Duy Thien An (2023), "Cryptocurrency Trading: A Systematic Mapping Study", DI: 10.17632/6frg6fd3kb.1.

Table 1
Research questions.

Research Questions
● RQ 1: What are the current trends and demographics of publications in the field of cryptocurrency trading market?
– RQ 1.1: How many peer-reviewed articles have been published over the years?
– RQ 1.2: How is the quality of publications in cryptocurrency trading?
– RQ 1.3: Which countries are the most productive in cryptocurrency trading research? To what extent does international collaboration contribute to these publications?
– RQ 1.4: Who are the most productive authors? Which academic journals or conferences are the most popular for publishing cryptocurrency trading research?
● RQ 2: What are the primary focus areas in cryptocurrency trading research?
– RQ 2.1: What are the popular keywords used in cryptocurrency trading publications?
– RQ 2.2: What are the main focuses of study in the field of cryptocurrency trading?
– RQ 2.3: How do these focuses change over the years?
● RQ 3: What type of systems or technologies are utilized in cryptocurrency trading?
– RQ 3.1: What are the main categories of systems/technologies in cryptocurrency trading?
– RQ 3.2: What are the typical inputs used in information systems for cryptocurrency trading?
– RQ 3.3: Which inputs are frequently used in conjunction with each other in information systems for cryptocurrency trading?

Table 2
String of search keywords.

Search Keywords
("crypto" OR "cryptocurrency" OR "cryptocurrencies") AND ("trade" OR trading" OR "invest" "investing" OR "market" OR "forecast" OR "forecasting" OR "predict" OR "prediction")

Table 3
Inclusive criteria table.

Inclusive Criteria	Description
IC1 - Topic	The subject of the papers is related to cryptocurrency trading, such as the cryptocurrency market, cryptocurrency trading algorithms, and cryptocurrency forecasting.
IC2 - Academic articles	The papers are academic journal articles or conference papers that have undergone a peer-review process.
IC3 – Language English	The papers must be written in English.

detailed breakdown of the selection process can be found in Fig. 1. Bibliographic data, including abstracts, for these 622 papers were then exported to an Excel spreadsheet for further analysis.

Classification scheme

We applied Garousi et al. (2013) mapping strategy to identify and categorise the research themes in cryptocurrency trading. By analysing objectives and keywords, we assigned topic categories to the articles. Recognizing the multifaceted nature of cryptocurrency trading research, we allowed articles to belong to multiple categories if their study objectives spanned different areas. To ensure a comprehensive classification scheme, we iteratively reviewed new articles. This process involved creating new categories for previously uncategorized information and refining existing categories for improved accuracy. This process continued until all papers were assigned relevant categories. We then employed the same method to classify the technologies and data inputs utilized within cryptocurrency trading systems.

The second author repeated the classification process to validate the finding. Any variation in classification would be discussed to reduce any misclassification, mitigate decision bias in performing selection.

Table 4
Exclusive criteria table.

Exclusive Criteria	Description	Number of Removed Papers
EC1 – Availability & Appropriate Materials Criterion	The abstract either lacks enough information or is not provided at all, or the full text of the paper is not available.	32
EC2 - Relevance Criterion	The paper is not focused on cryptocurrency applications or blockchain technology; or contains irrelevant research materials.	59
EC3 – Excessive Recycling Criterion	The paper has excessive recycled content by the same authors, or from other authors, duplicated papers; or an abridged version of an extended paper.	7
EC4 – Quality Criterion	Journal articles without SCImago quartiles or non-IEEE/ACM conference papers are manually re-examined for quality and relevance criteria.	3
	Total	**101**

Trend analysis

To investigate research trends in cryptocurrency trading, we analysed publication attributes including author demographics, publisher information, and SCImago ranking metrics. Data was extracted from Zotero and exported in a tabular format. We employed descriptive statistics, including frequency distribution tables and histograms, to explore the data's characteristics.

Result

In this section, we reported the answers to the RQs.

RQ 1: What is the current trend and demographics of publications in the field of the cryptocurrency trading market?

RQ 1.1: How many peer-reviewed articles have been published over the years?

Fig. 2 illustrates the trend in publication activity in cryptocurrency trading over the year. The total number of research papers increased from 54 in 2019 to 152 in 2021, suggesting a substantial growth in research output. The publication activity surged between 2019 and 2022, with publications doubling year-over-year at one point. Since 2021, the field has stabilized at around 150 articles annually. We found Journal articles were the most common publication type between 2015 and 2022. The number of journal articles was three times higher than the number of conference papers, with 473 and 148 study published, respectively.

RQ 1.2: How is the quality of publications in cryptocurrency trading?

Fig. 3 provides insight into the quality of publications in the field of cryptocurrency trading between 2015 and 2022. Journal publications in Q1 and Q2 accounted for 78 % of the total number of journal papers, indicating a prominent level of quality. Likewise, 53 % of conference papers were published in IEEE and ACM conference proceedings, which are renowned for their esteemed standing in the discipline.

RQ 1.3: Which countries are the most productive in cryptocurrency trading research? To what extent does international collaboration contribute to these publications?

Out of the total publications, 147 papers were the result of international collaborations, making up 32 %.

Fig. 4 shows the top 5 countries that contributed the most to research on cryptocurrency trading - China, UK, US, India, and Turkey. These countries collectively contributed almost half of the total publications, with 302 out of 622 papers. China consistently led in the number of publications, showing a strong upward trend. The total publications for China increased from 6 in 2017 to 31 in 2023. India has seen a notable increase in publications, with a total of 59 in 2023 compared to 5 in 2015. The USA and UK steady increases over the years, contributing to the overall upward trend. Germany, France, and Russia showed varying publication counts, with some fluctuations.

RQ 1.4: Who are the most productive authors? Which academic journals or conferences are the most popular for publishing cryptocurrency trading research?

Fig. 5 presents a list of the top authors who have published a minimum of 6 papers on cryptocurrency trading between 2015 and 2022. The number of publications of these authors varied from 6 to 12 papers, with most authors having published 6 papers, and two authors with 7 papers. It is worth noting Bouri. E had the most significant impact with a total of 12 papers published during this period.

All publications by the top authors comprised exclusively journal articles, with 85 % appearing in Q1 and Q2 journals (Fig. 5). This proportion of Q1 and Q2 publications is in line with the 78 % of all journal papers included in the study (Fig. 3). Table 5 shows the most popular publishing outlets, along with their corresponding number of publications and SJR Score in 2021.

RQ 2: What are the primary focus areas in cryptocurrency trading research?

RQ 2.1: What are the popular keywords used in cryptocurrency trading publications?

We examined keywords to understand the research objectives of the selected papers. These keywords come in two forms: Indexed keywords and Author keywords. Indexed keywords are assigned by the database

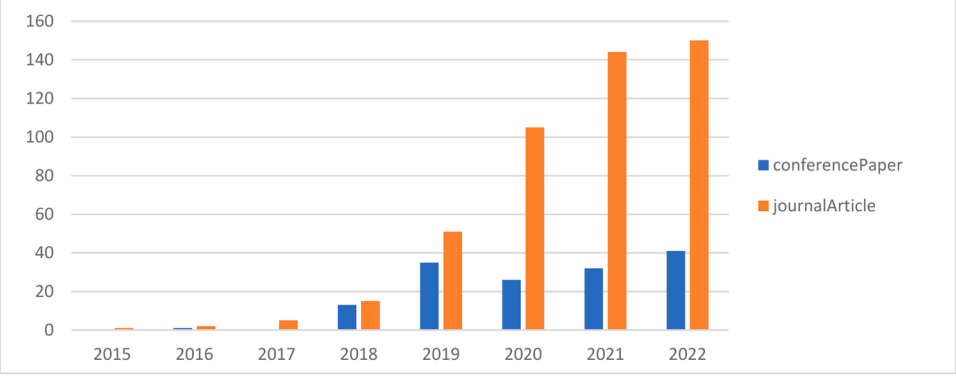


Fig. 2. Distribution of journal and conference papers in cryptocurrency trading.

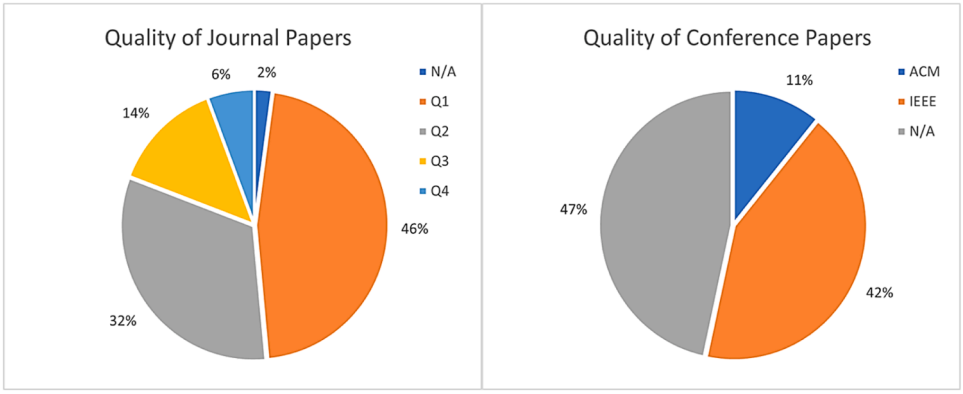
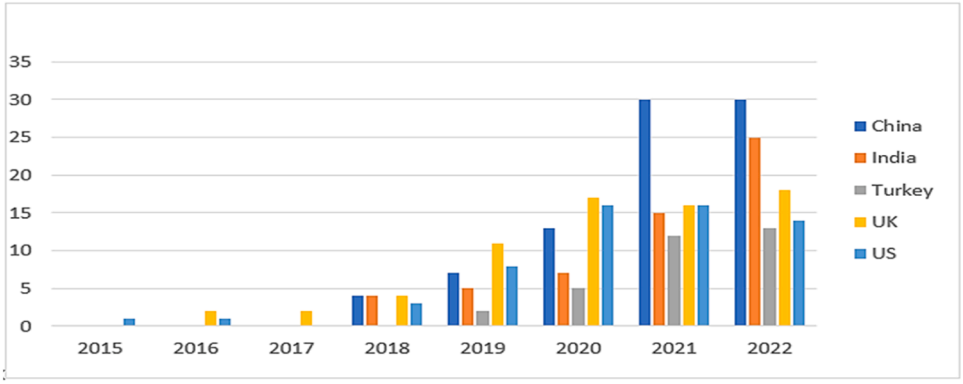


Fig. 3. Quality of journal and conference papers in cryptocurrency trading.



Countries	conference Paper	journal Articles	Total
China	21	63	84
UK	7	63	70
US	21	39	60
India	21	35	56
Turkey	4	28	32

Fig. 4. Distribution of research papers across the top productive countries (countries =5).

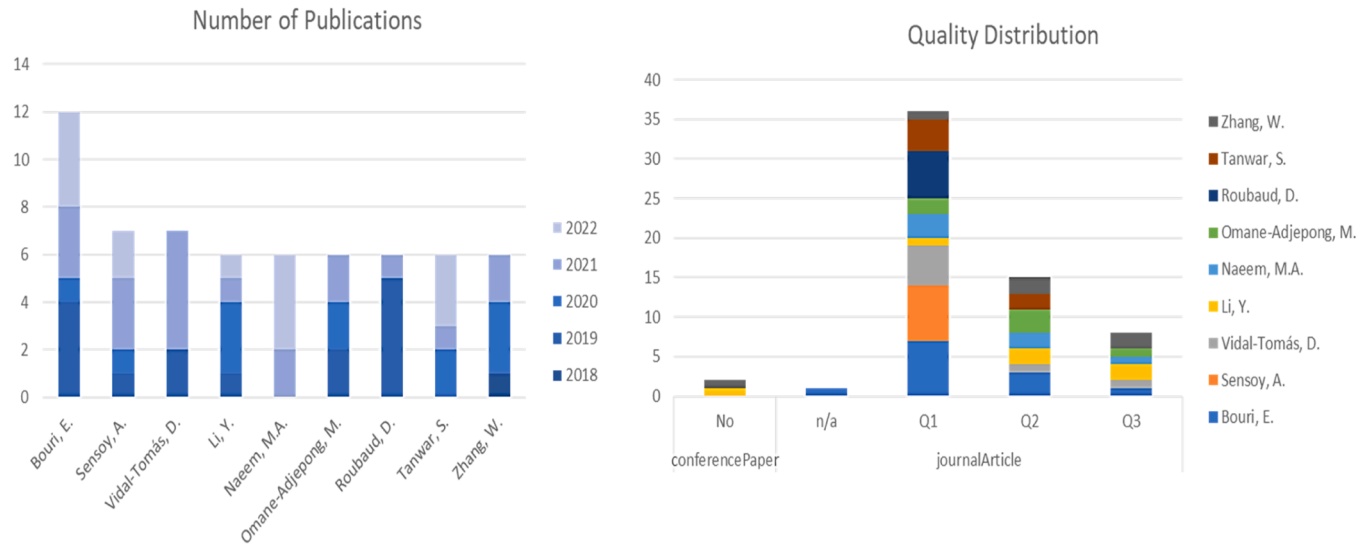


Fig. 5. Top Productive authors in cryptocurrency trading research.

Table 5
Popular publishers for cryptocurrency trading research papers.

Publications	Distinct Count of Key	Max of SIR Score2021
Finance Research Letters	47	2.007
Research in International Business and Finance	21	1.043
Physica A: Statistical Mechanics and Its Applications	20	0.891
International Review of Financial Analysis	16	1.833
Journal of International Financial Markets, Institutions, and Money	12	1.31
IEEE Access	11	0.93
North American Journal of Economics and Finance	11	0.71
Financial Innovation	10	0.94
Mathematics	10	0.54
Applied Economics Letters	8	0.4

system based on the paper's content.[1]; while author keywords are selected by the authors themselves. In our study, we prioritized author keywords because they likely best reflect the authors' intent. When author keywords were not available, indexed keywords were then utilized.

In Fig. 6, the Word Cloud diagram displays the frequency of keywords that occurred at least 10 times in the pool of articles. The size of each word in the diagram corresponds to its number of occurrences. Based on the visualisation, the main themes of cryptocurrency trading can be grouped into four categories. The first group shows the popular cryptocurrencies in the cryptocurrency market ("Cryptocurrencies", "Bitcoin", "Ripple"). The second group, which includes words "Machine Learning", "Predictive Models", "Cryptocurrency Market", "Market Efficiency", and "Time series Analysis", was related to cryptocurrency market analysis and trading activity. The third group consists of terms related to the dynamics of cryptocurrency pricing, such as "Liquidity," "Volatility," and "Herding Behaviour.". The final group includes external

Fig. 6. Author's keywords cloud words (nfrent >= 10 times).

[1] How do Author keywords and Indexed keywords work? https://service.elsevier.com/app/answers/detail/a_id/21730/supporthub/scopus/.

factors associated with the cryptocurrency pricing market, such as "Covid-19″ and "Stock Market".

RQ 2.2: What are the main focuses of study in the field of cryptocurrency trading?

The classification method outlined in Section 2.3 was deployed to investigate the current research themes in cryptocurrency trading. We screened articles in two stages. First, we sorted them into "market study" or "trading system" categories based on titles and the study objectives found in the abstracts. Then, in the second screening, we further divided them into seven sub-categories, as detailed in Fig. 7.

Our screening results revealed the most studied area in cryptocurrency trading research focused on market analysis, titled "Cryptocurrency Pricing Theories" in this study (208 publications). This theme explored the unique characteristics of the cryptocurrency market, with an emphasising volatility, market efficiency and the co-movement of the market price and return (Table 6). Researchers primarily used financial models and time series analysis to understand these dynamics.

The second major theme, "Influential Factors" (165 publications), investigated variables that potentially impact cryptocurrency prices. These factors could be internal (e.g., blockchain technology, trading activity) or external (e.g., traditional assets, investor sentiment, world events, regulations) (Table 7).

A significant remaining portion of research addressed Market Forecasting and Trading & Portfolio, accounting for 119 papers and 76 of the collected papers. These studies aimed to develop methods for predicting the cryptocurrency market, automating trading, and optimising portfolio. The models used included machine learning, time series analysis, and economic models (Table 8). Predictive models were utilized to forecast or predict market movement. The predictive models can be further divided into two categories: (1) classification models for detecting price movement and market trends, and (2) regression models for predicting the market value. To automate trading or portfolio optimization, algorithmic trading techniques such as reinforcement learning, and fuzzy algorithms were used to automate the decision-making process.

Beside Market Forecasting and Trading & Portfolio groups, the remaining papers covered a range of topics from cryptocurrency Market Evolution, Acceptance, and Regulations (65 papers), Risk evaluation & Anomaly Detection (54 papers), to Trading Platforms (10 papers). The common research topics among these groups were the volatility risk of the cryptocurrency market, the investment opportunities of the market from different jurisdictions, and the analysis of legislative framework for this newly emerged market (Table 7).

RQ 2.3: How have these focuses changed over the years?

Fig. 8 shows illustrates the shifting in research focus in cryptocurrency trading from 2015 to 2022. While initial interest (2015–2018) centered on market acceptance and evolution, a shift towards market movements emerged in 2018, particularly in Cryptocurrency Pricing Theories. Publications in this area surged after 2018, peaking in 2021 before stabilizing in 2022 (46 papers). Notably, "Forecasting" and "Influence Factors" studies also saw a significant rise from 2019 onwards, with "Influence Factors" surpassing "Cryptocurrency Pricing Theories" as the most researched area by 2022. "Forecasting" publications also climbed steadily, nearing "Cryptocurrency Pricing Theories" by 2021.

RQ 3: What type of systems or technologies are utilized in cryptocurrency trading?

To address RQ3, we primarily focused on research papers that are in the "Forecasting" and "trading algorithms" themes.

RQ 3.1: What are the main categories of systems/technologies in cryptocurrency trading?

Fig. 9 and Table 8 categorize and illustrate the distribution of cryptocurrency trading technologies used between 2017 and 2022. We classified these technologies into three key groups: (1) Decision-Making, (2) Portfolio Optimization, and (3) Trading Model.

The Decision-Making group included publications explored trading strategies and technologies that were used to assist investors in

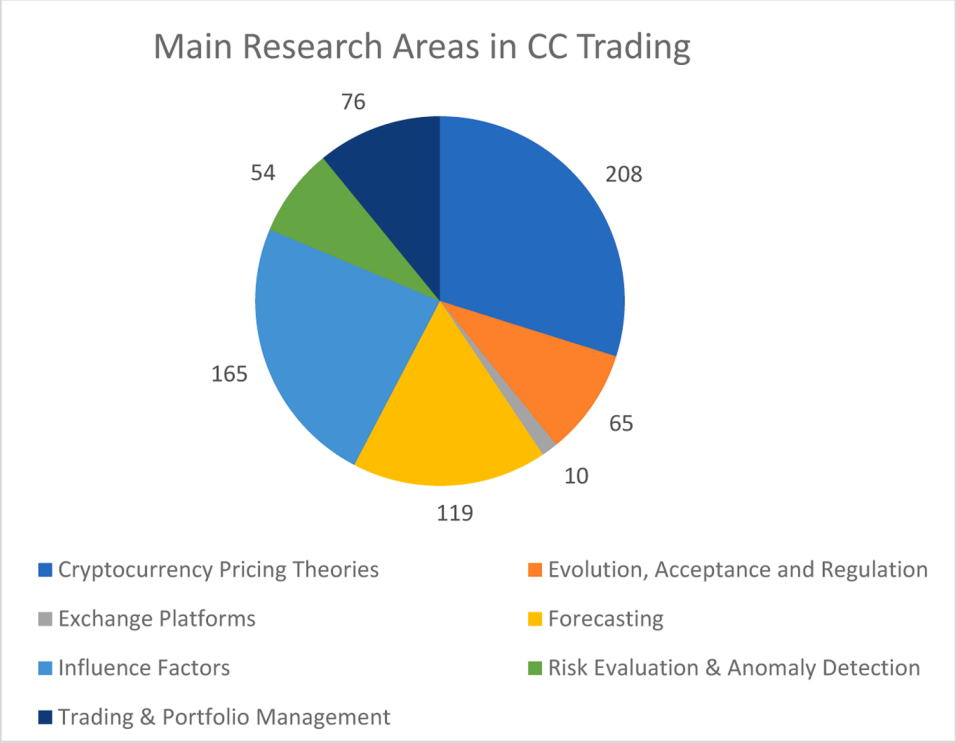


Fig. 7. Focus Studies on cryptocurrency trading.

Table 6
Sub-topics in cryptocurrencies pricing theories theme.

Sub-topics in Cryptocurrency Pricing Theories	Characteristics of the market	Number of Papers
Inter-connectedness of the cryptocurrencies within the cryptocurrency market	Co-Explosivity, Contagion, Spill Over, Tail Risk Dependence, Co-Jump, Co-Movement, correlation	62
Marke Efficiency	Volatility Persistence, Long Memory, Multifractal Behaviour, Predictability, Market Theories (e.g. Weak, Adaptive), Information Asymmetry Effect	40
Other return / Price Volatility studies	Bubbles, Tail-risk, Volatility Convergence, Leverage Effect / Asymmetric Volatility Effect, Lottery Like Momentum / Max Effect, Momentum / Reversal / Contrarian Effect, Return [Price] & Trading Activity, Volatility cluster, Market Structure, Investor Behaviour (e.g. Overaction, herding, Overconfident, Peer Pressure, motivation, intention), Disposition Effect / Contagion Effect, liquidity related topics.	106

identifying opportunities for entering or exiting the market. These papers accounted for 64 % of the papers within the "Forecasting" and "Trading Algorithms" themes. The primarily focus of these papers was to explore prediction models that were used to analyse the future trends of the market or to predict future market value, utilizing machine learning (ML), mathematical/statistical time-series models, technical analysis (TA), and hybrid models. In the machine learning group, the models were classified into two categories: Neural Networks (NNs) and traditional machine learning models (MLs). Additionally, feature selections and optimization models, such as Principal Component Analysis (PCA), Exploratory Data Analysis (EDA), Akaike Information Criterion (StepAIC), Particle Swarm Optimization, Genetic Algorithm, were often employed to enhance the trading system performance.

NNs and MLs emerged as the leading choice for forecasting and automated trading, while statistical time-series analysis dominated portfolio optimization. Interestingly, despite being less popular than NNs and MLs, time-series analysis showed an upward trend in recent research. Our mapping specifically identified Long Short-Term Memory (LSTM), Recurrent Neural Network (RNN), Gated Recurrent Unit (GRU), and Convolutional Neural Network (CNN) as the most prevalent technologies, followed by popular traditional models (MLs) like Random Forest, Support Vector Machine, and Gradient Boost.

Table 9 summarizes the top 20 models and their common roles.

The remaining publications focused on automated trading system and portfolio construction models, accounted for 20 % and 16 % of the total papers, respectively. Reinforcement Learning and Fuzzy Logic were identified as the primary methods for automating trading decisions, while time-series analysis proved most popular for portfolio construction. This approach facilitates analysing historical data alongside external factors to build effective trading or investment strategies.

RQ 3.2: What are the typical inputs used in information systems for cryptocurrency trading?

Table 10 presents the six primary categories of data inputs for the cryptocurrency trading system. The most frequently used input was Cryptocurrency Market Information (Historical Cryptocurrency Market, Trading Activity, and Book Order data), found in 217 studies. The Engineered Features group, including Technical Indicators, Economic/Macroeconomic variables, and other Engineered Features, was the second most popular input with 60 studies. The Sentiment group, with 45 studies, has also gained popularity in recent years. The remaining input falls into the Time-Series Features/Special Event Timelines and Expert Knowledge categories.

RQ 3.3: Which inputs are frequently used in conjunction with each other in information systems for cryptocurrency trading?

Approximately 75 % of the cryptocurrency trading systems that used multiple inputs were found through the mapping process, 217 out of 362 studies in the Forecasting and trading area.

Table 7
Sub-topics from other themes.

Primary Topics	Example of Sub-topics	Number of Papers
Evolution, Acceptance, and Regulation	Market Acceptance; Market Evolution; Market Function, Market Structure, Market Simulation; Market Overview/ Performance / Trend; Recommendation & Regulation, Investment Opportunity, Social Impact	65
Exchange Platforms	Exchange Platforms; Market Marker; Platform Simulation; Investment Models for Market Platforms; Platform Design; Hot Wallets	10
Forecasting	Forecasting Price Movement; Forecasting Trading Volume; Price Prediction; Market Liquidity (Bid-ask spread) Prediction	119
Trading & Portfolio Management Algorithms	Algorithmic trading; Trading Strategy - Arbitrage / Pairs Trading; Trading Strategy - Technical Trading / MLs; Hedging / Portfolio Management	76
Influence Factors / Features	**Cryptocurrencies Market Info** (Historical Cryptocurrencies Market / Historical Cryptocurrencies Market); **Blockchain** Specification; **Traditional Assets** (Stock, Bonds, Commodities, Real Estate, Forex prices, and Indexes); **Event Time-Series** (Calendar Features, Disaster, and other extraordinary events); **Sentiment** (Social Network Sentiment, Investor Attention, and Developers Influence); **Technical Indicators; Economic / Macroeconomic** Variables; Expert Knowledge; Other Engineered Features.	165
Risk Evaluation & Anomaly Detection	Anomaly Detection; Deceptive Cryptocurrencies / Untrusted Investor Detection; Liquidity Risk; Detection; Pump&Dumb Detection; Risk Evaluation & Management; Risk Forecasting; Sandwich Attack; Short & Distort Detection	54

In examining the primary technologies employed in cryptocurrency trading, including Machine Learning (ML), Neural Networks (NN), Mathematical/Statistical models, and others; we analysed the distribution of input classes (Table 11). It was evident that historical cryptocurrency market data, encompassing price history, order book dynamics, and trading activity, served as a key feature for many trading technologies. In addition, Social Sentiment data emerged as a significant factor leveraged by Neural Networks, Machine Learning, and Hybrid models, underscoring a growing dependence on sentiment analysis derived from sources like social media platforms to shape trading decisions. Also, conventional Mathematical/Statistical Models frequently relied on technical indicators to devise trading strategies, emphasizing the paramount importance of quantitative analysis in cryptocurrency trading. Nevertheless, certain input categories, such as "Expert Knowledge" and "Transaction Fees," were underutilized across all trading models, hinting at a diminished reliance on these factors in shaping cryptocurrency trading strategies.

Discussion

In this section, a thematic discussion of the finding results and future directions of study in the field of cryptocurrency trading are discussed.

Publication demographics, key contributors, and publishing outlets

RQ 1 shows the trends and demographics of publications in cryptocurrency trading research, suggesting that cryptocurrency trading was an active research area with a sizable number of quality publications produced in the area. A high percentage of journal papers (approximately 80 %) were published in Q1 and Q2; many conference papers were in IEEE and ACM conference proceedings. The increased market acceptance, regulation, and trading modeling also indicate a growing interest in the market.

Table 8
Cryptocurrency trading technologies.

Model Classes	Example Technologies	Freq
Traditional Machine Learning	Random Forest (RF); Decision Tree Regression; Support Vector Machine (SVM); Support Vector Regression (SVR); Extreme Gradient Boosting (XGBoost); K-Means; k-Nearest Neighbor (KNN); Logistic Regression; Support Vector Regression (SVR); Naive Bayes; Lasso Regression; Stochastic gradient descent	40
Neural Network / Deep Learning	Convolutional Neural Networks (CNN); Attention Long Short Term Memory (ALSTM); Multilayer Perceptron (MLP); Long Short-Term Memory (LSTM); Bidirectional Long Short-Term Memory (BiLSTM); Stochastic Neural Networks; Gated recurrent units (GRUs); Deep Q-Learning Network; Transformer; Deep Reinforcement Learning (DRL) + Self-Attention (Transformer-based); Deep Feed Forward Neural Network (DFFNN); Levenberg–Marquardt artificial neural network (LMANN); Conjugate Gradient Approach (NN+conjugate gradient algorithm); Bayesian regularization artificial neural network (BRANN); ResNet + LSTM (RSLSTM- Actor)	59
Mathematics / Statistical Models & Technical Analysis	**Mathematics / Statistical Models:** Generalized autoregressive conditional heteroskedasticity models (GARCH); generalized additive model (GAM); Autoregressive moving-average (ARM); VaR Mean-Variance Portfolio Optimization; Conditional Variance Estimates (DCC-GARCH); Copula Approach **Technical Analysis:** Moving Average (MA); Moving Average Convergence Divergence (MACD); Exponential Moving Average (EMA); Moving Average Crossovers (MAC); Variable Moving Average (VMA); Oscillator; Fibonacci retracements + Crossover Trading; Candlestick patterns; Triangular Arbitrage parity (TAP); Average true range (ATR); Support Resistance Rule; Breakout (BO); On Balance; Trading Range Break (TRB) Volume (OBV); Support Resistance Rule	65
Hybrid Models / Ensembles Methods	**Fuzzy Logics+NN/ML**: Neuro-Fuzzy Inference System (ANFIS); Fuzzy Volatility Forecasting **NN+ML / NN+NN / ML+Mathematics models**: Binary Auto Regressive Tree (CART+Autoregressive Integrated Moving average); Deep Reinforcement Learning (DRL) + Self-Attention (Transformer-based); LSTM + CNN; LSTM + Transformer; LSTM + GRU	33
Fuzzy Logics & Other Trading Algorithms	SK-MOEFS (SciKit-Multi Objective Evolutionary Fuzzy System); Evolving Fuzzy Granular Predictor (Fuzzy Rule-Based); High Level Fuzzy Petri Net (HLFPN); Evolution-Ending Algorithm (EEA); Bellman-Ford-based negative cycle detection (NCD) algorithm; Price Action Algorithm (SPA)	12
Features Selection / Optimization	Principal component analysis (PCA); Analysis of Variance (ANOVA); Akaike Information Criterion (StepAIC); Exploratory Data Analysis (EDA); Genetic Algorithm; Genetic Filter; Genetic Wrapper; GMDH-Based Algorithms; Multi-Stage Variable Selection; Particle Swarm Optimization; Rao algorithms (QORA)	18

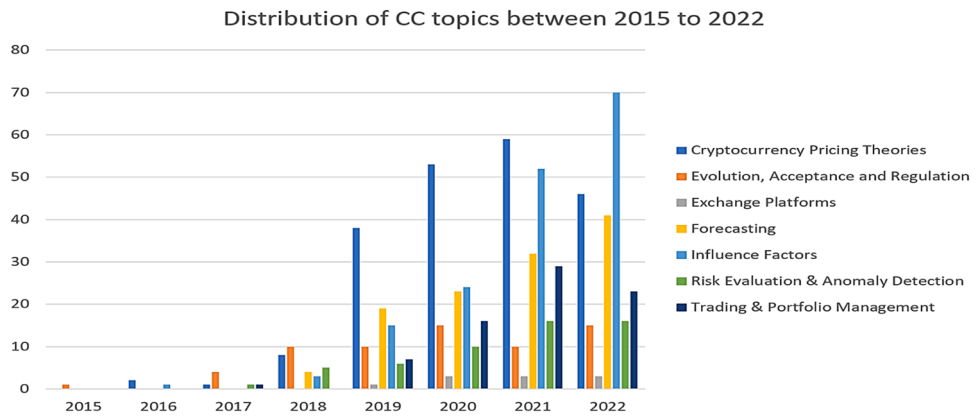


Fig. 8. Main research areas in cryptocurrency trading between 2015 and 2022.

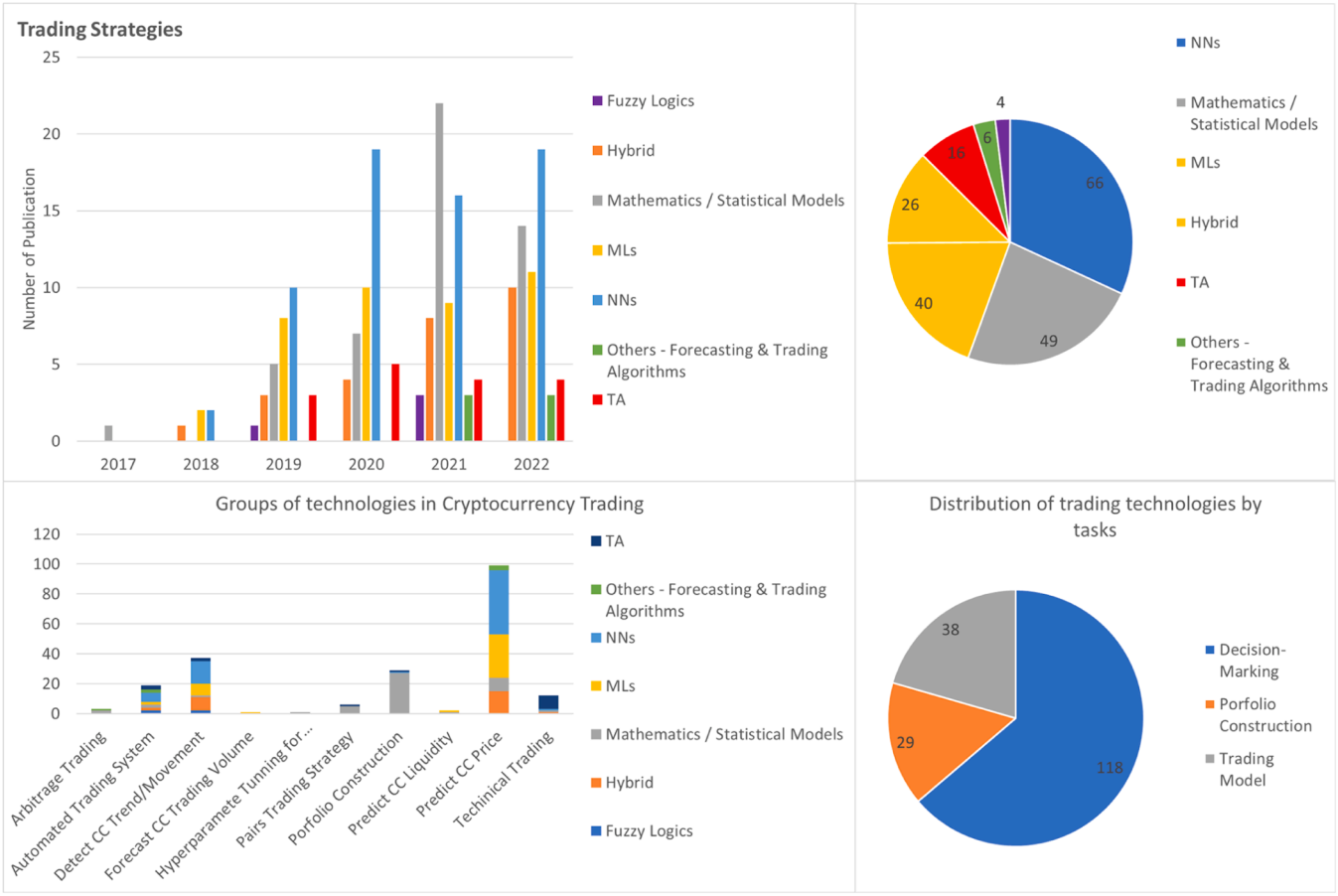


Fig. 9. Type of technologies and their functions in cryptocurrency trading systems.

- The field has witnessed significant growth, with a marked increase in the number of publications between 2019 and 2022. The dominance of journal articles over conference papers underscores a focus on quality, with Q1 and Q2 journals contributing significantly to the overall quality of publications.
- The examination of international collaboration reveals that 32 % of total publications result from collaborations, indicating a global effort in advancing cryptocurrency trading research. The top five countries contributing to research (China, UK, US, India, and Turkey) collectively contribute almost half of the total publications, showcasing a global distribution of research productivity.
- Key publishing outlets include 'Finance Research Letters,' 'Research in International Business and Finance,' and 'Physica A: Statistical Mechanics and Its Applications,' highlighting the diversity of platforms contributing to this research field. The identification of the most productive authors and popular publishing outlets highlights Elie Bouri (Bouri et al., 2019, 2020, 2019, 2021; Qureshi et al., 2020; Shahzad et al., 2022; Wen et al., 2022; Yousaf et al., 2021), Ahmet Sensoy (Akyildirim et al., 2020; Aslan & Sensoy, 2020; Corbet et al., 2019; Wang et al., 2022b; Yao et al., 2021, Yao, Sensoy, Nguyen, & Li, 2024), and David Vidal-Tomás (David, 2021; Kurt Gümüş et al., 2019; Vidal-Tomás, 2021; Vidal-Tomás et al., 2019a, 2019b, 2021)

Table 9
Top 20 popular models for trading strategies.

Models	Trend/ Movement Detection	Trading Vol Prediction	Liquidity Prediction	Price Prediction
LSTM	9			22
Support Vector Machine (SVM)	5			11
Random Forest (RF)	5			6
CNN	3			4
k-Nearest Neighbor (KNN)	1		1	5
MultiLayer Perceptron (MLP)	3			4
Extreme Gradient Boosting (XGBoost)	1			4
GRU				5
Linear Regression (LR)				5
Optimal Portfolio Weights				
ARIMA				4
Copula Approach				
Decision Tree				4
GARCH			1	2
Gradient Boosting				4
Linear Specification of the Market (LMM)				4
Support Vector Regression (SVR)		1		4
Artificial Neural Network (ANN)	1			2
LSTM + GRU				3

are significant contributors to shaping the landscape of cryptocurrency trading research.

Primary focus areas and trend of research focus in cryptocurrency trading research

Valuable insights were gained from studying market movements, aiding in the research of cryptocurrency trading systems. Our observations revealed a significant shift from theoretical study of the dynamics of the cryptocurrency market to trading systems. Between 2017 and 2022, there was a noticeable increase in the number of research studies in the areas of trading strategies and automated trading systems. Although market forecasting research has been dominant in the field, the study of automated trading systems has started to gain popularity. We also noted a growing interest in the study of external influencing factors, as the emergence of AI, ML, Big Data, and Cloud technologies has had a significant impact on the cryptocurrency trading field. The analysis of keywords and focus areas reveals four main thematic categories: dynamics of cryptocurrency pricing, cryptocurrency trading analysis, cryptocurrency market analysis, and external factors affecting the cryptocurrency market.

- The classification of research papers into seven focus areas indicates a predominant interest in cryptocurrency pricing theories (Agosto & Cafferata 2020; Gong & Huser 2022; Li et al., 2021; López-Martín et al., 2021; Tran & Leirvik 2020), followed by influential factors (Agosto et al., 2022; Jeris et al., 2022; Smales, 2022; Wu et al., 2021), forecasting, trading strategies and portfolio management algorithms (Evrim Mandaci & Cagli 2022; Lahmiri & Bekiros 2021; Lahmiri et al., 2022; Li et al., 2022; Makarov & Schoar 2020; Müller et al., 2022; Ortu et al., 2022; Ustaoglu, 2022).

Table 10
Inputs in cryptocurrency trading systems.

Data Classes	Feature Types	Number of Papers	Examples of Inputs
Cryptocurrencies Market Info	Historical Cryptocurrencies Market Data	194	Cryptocurrencies Price/Return; Open-High-Low-Close of Cryptocurrencies price & trading volume (OHLC-V) CCi30 index, Bloomberg Galaxy Cryptocurrency Index BGCI, CRIX index, Market Cap
	Book Order & Trading Activity Data	23	Quoted Bid–Ask spread; Dollar trading volumes of Bid–Ask; Trading Fees, …
Cryptocurrencies Specification	Blockchain Info	10	Mining difficulty, mining profits, and harsh rate; Block size; cryptocurrency life span …
Traditional Assets	Prices and Indexes Stock; Bonds; Commodities; Real Estate; Forex	28	Market stock prices from technology, energy, and other sectors; Stock Indexes … Government Bond Index (GBI-EM); S&P Green Bond Index; Treasury Bills … Oil Price (WTI; BRENT Crude Oil prices; …); precious metals (Gold futures; silver; aluminium; Commodity Channel Index (CCI) … MSCI Emerging Foreign Exchange Index (MSCI EM FX)
Time-Series Features & Special Events	Calendar Features	1	Day-of-the-week; Saturday and Sunday; Month of Year; Turn-of-the-month; Initial Coin Offerings & Disappear Timeline; Seasonal Pattern; Month of Ramadan …
	Disaster Events data and timeline	5	COVID-19; Cyber-Attacks; Terrorist Attack related data and timeline (Infectious Disease Equity Market Volatility (EMV), Covid19 fatality number …)
	Other Special Events data and timeline	7	Futures trading activities: Initial Coin Offerings & Disappear Timeline; Stable Coins launch. Regulatory events data (U.S. Senate hearing on Facebook's Libra; China Cryptocurrencies trading ban; Law enforcement action …) News Announcements; Bull/Bear Periods …
Sentiment	Investor Attention	11	The number of cryptocurrency-related searches on search engines (Google Search Index; Search Trend) …

(*continued on next page*)

Table 10 (*continued*)

Data Classes	Feature Types	Number of Papers	Examples of Inputs
			The number of cryptocurrency-related blogs, posts, forums, and Wikipedia page views (word count of the Reddit post; topic distribution of Reddit posts) …
	Developers Influence	0	Developer activity from GitHub, Reddit
	Social Network Sentiment	34	Sentiment extracted from popular social network media such as Facebook, Twitter; Reddit, Weibo, IRC, Cryptocurrencies related blogs, forums, and News platforms (VADER Tweets polarity sentiment, Thomson Reuters Marketpsych Index TRMI …) …
Engineered Features	Technical Indicators	41	Candlesticks graph Info such as: ***Momentum indicators*** (Moving Average (MA); Moving Average Convergence Divergence (MACD); Relative Strength Index (RSI); Chaikin Money Flow (CMF), …) ***Trend strength Indicators*** (Average Directional Index ADX; Moving Average Oscillator MAO; Ichimoku Cloud (IC), …) ***Oscillator indicators*** (Stochastic Oscillator; Williams%R; Psychological Line (PSY), Stochastic D% (SD); Stochastic K% (SK), …)
	Economic / Macroeconomic Variables	6	Monetary Policy; Geopolitical Risk (GPR); Federal Reserve Economic Data (FRED); Interest Rate; Small Granular Sentimental Divergence Index (SGSDI); Inflation Rate … Thomson Reuters Marketpsych Index TRMI; Economic Policy Uncertainty (EPU) Index
	Other Engineered Features	13	Realised volatility; Annualized returns (AR); Centrality Measures Features (Degree Centrality, Node Strength, Betweenness Centrality, Closeness Centrality, Eigenvector Centrality); …
Others	Expert Knowledge	1	Hand-collected Dataset containing bullish, neutral, and bearish predictions for Bitcoin

- The temporal analysis of research focus areas depicts a shift from market acceptance and revolution towards the dynamics of cryptocurrency pricing theories after 2018.
- Notably, forecasting, and influential factors have gained prominence in recent years, reflecting the evolving priorities and interests of researchers in the cryptocurrency trading domain.

Technological aspects, data inputs and their interconnections in cryptocurrency trading

Our mapping revealed 75 % of cryptocurrency trading systems used multiple inputs, discussed in R3.3. Past research solely relied on analysing historical patterns and indicators to understand market movements, but the latest research has expanded to include external factors such as social sentiments, traditional financial market movements, and blockchain technical data. By incorporating these a range of factors, experts can make more informed predictions about the fluctuations in the ever-evolving cryptocurrency market. These systems utilize advanced algorithms to outperform the current market trend. The trading systems consist of two main components: market signal triggers and trading execution algorithms. Some of the common trading strategies leveraged these systems included Trend Trading, Mean Reversion, and Buy/Sell at given market conditions. Another commonly used trading system involves arbitrating price differences between different crypto exchange platforms. This is made possible by the existence of 24/7 exchange platforms in various jurisdictions worldwide. These basic building blocks highlight the current works in the cryptocurrency trading field.

- The exploration of technologies in cryptocurrency trading research highlights three main categories: market forecasting modellings, portfolio optimization, and automated trading systems.
- Neural Network and Deep Learning models emerge as the most popular among trading algorithms, with reinforcement learning and fuzzy logic prominent in automated trading systems.

Future directions

Further investigation is necessary to develop novel economic metrics aimed at gauging the enduring value of the cryptocurrency market. The collaborative efforts from researchers and experts spanning diverse knowledge domains would be required to overcome the multi-disciplinarity problem. This will overcome the challenge due to unfamiliarity with technology, economic implications of Fintech, and legal and regulatory frameworks.

In addition, it can be difficult to have a comprehensive understanding of the influential actors within the cryptocurrency market, given the potentially vast number of entities driving the market. Breidbach and Tana (2021) suggested firm was not the only actor shaping cryptocurrency market. They identified the four different actors within the cryptocurrency market. They can be categorised into Freshman (public with interest in cryptocurrencies), Trail-Blazer (Traders, Investors, and Miners), Idealist (Academics, Students, Blockchain Enthusiast, IT Professionals), and Fortune Hunter (Communal Entrepreneurs) classes within cryptocurrency market through ethnography analysis. Authors further studied their unique roles and resources that they can contribute to the shaping of the market. Lucchini et al. (2020) showed the role of developers/coders in shaping the cryptocurrency market. The study found around 4 % of developers participated in coding two or more cryptocurrencies. They contribute an average of 10 % of all the coding. Researchers suggested there was a correlation between the return time series of two co-developed cryptocurrencies increased after the collaboration. Bowden and Gemayel (2022) research found a link between the cryptocurrency trading community sentiment on Reddit and individual traders' actions. Positive Reddit sentiment led to bigger trades and increased deposits into cryptocurrency exchange

Table 11
Matrix table of input and cryptocurrency trading models.

Input Groups	Fuzzy Logics	Hybrid Models	Mathematics / Statistical Models (included Technical Analysis)	Traditional Machine Learning	Neural Network	Other Models
Blockchain & Mining Info		3	2	4	4	
Book Order & Trading Activity	1	5	3	7	6	
CC Index		1	6	1	1	
CCs Market Info	4	26	64	4	66	5
Economic variables		1	3	1	1	
Expert Knowledge						1
Investor Attention		5	1	2	5	
Others Engineered Features		2	2	3	7	1
Social Sentiment		4	1	9	22	1
Special Event Time-Series		1	9			
Technical Indicators	2	8	19	12	14	4
Traditional Assets		4	17	3	1	
Transaction Fees		1	3		1	

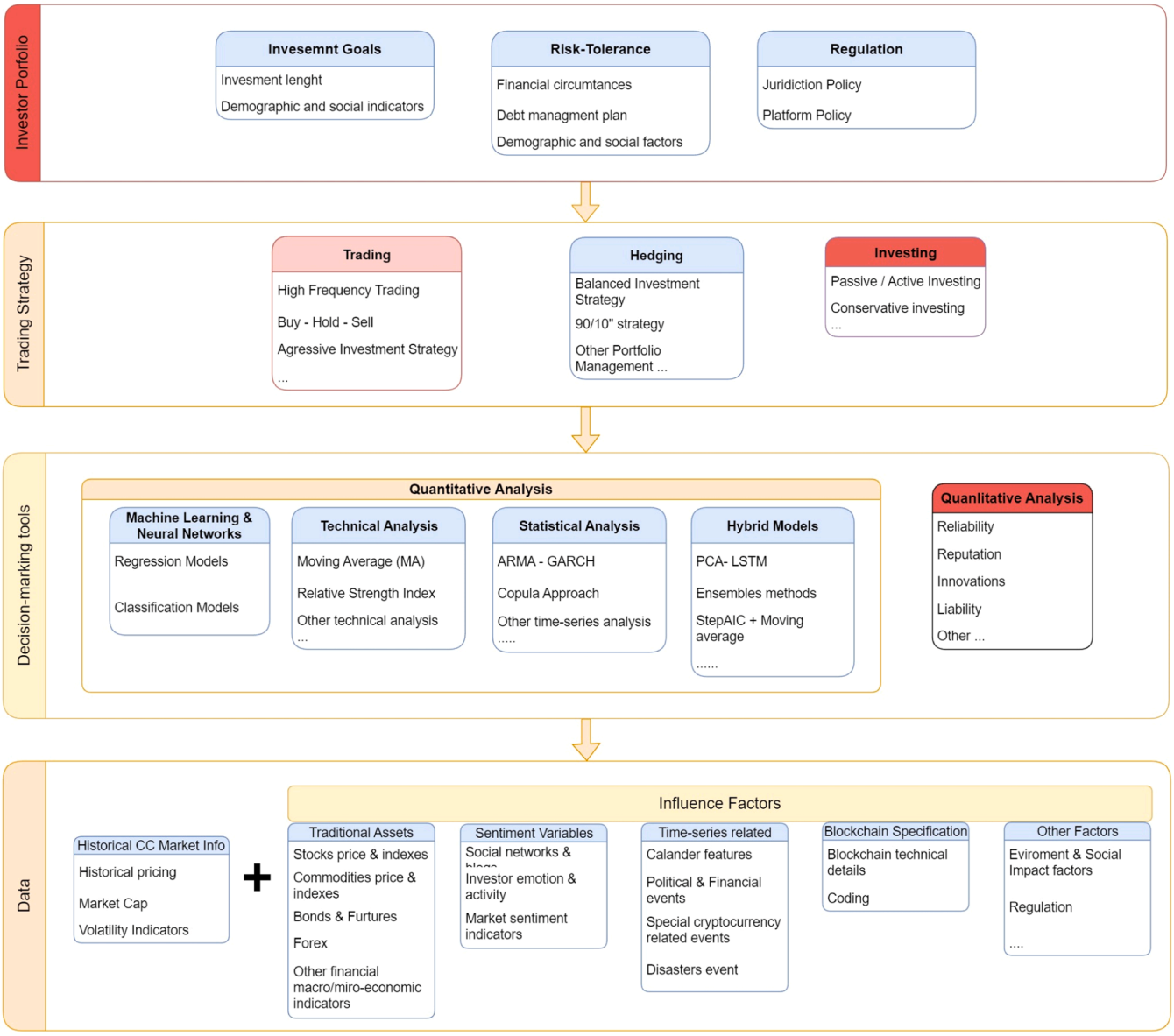


Fig. 10. Robot-Advisor Building Blocks for cryptocurrency trading.

accounts during periods of market positivity. Further research on these actors' roles is necessary to understand their impact on the market's growth and evolution.

Future study can also investigate the environmental and social impact factors. The energy consumption and carbon footprint generated by cryptocurrency are challenging current regulations. While the decentralized nature of cryptocurrency may enhance traditional financial operations, it also raises concerns about illicit trading activities. A fundamental rating system that integrates these factors, as well as credibility and technical specifications, can determine the potential value of cryptocurrencies. This information can help determine the long-term pricing of the market. Wang et al. (2022a) presented the index of cryptocurrency environmental attention (ICEA) to capture the media attention concerning the impact of cryptocurrencies on the environment. In examining the cryptocurrency market under the Environmental, Social, and Governance (ESG) framework, Rabbani et al. (2021) found that it did not meet the standards of the framework. The ESG rating is a business standard used to evaluate the environmental and social impact, as well as the effectiveness of company management in overseeing them. While investors' sentiment was well studied, we found other factors were not well received.

Limited research on trading platforms surprised us, considering the market's reputation for risk. High-profile incidents like the FTX collapse (Reiff, 2023), Binance's money laundering fine (Singh, 2023), and Deribit's hot wallet hack (Knight, 2022) have eroded public trust. Unfortunately, the socio-technical underpinnings of these platforms—operations, personnel, culture, and technology—remain shrouded in secrecy. While future research in this area will be challenging, it is crucial for fostering market maturity.

Our review revealed a shift in research focus from market analysis to trading applications, suggesting a future dominated by trading research. However, while trading technologies have shown promise in aiding cryptocurrency investors, they often neglect to incorporate personal financial circumstances or a customer-centric approach in model development. Future study can explore digital advisor platforms for cryptocurrency trading. Boreiko and Massarotti (2020) suggested the use of robo-advisors could be appealing to both researchers and investors due to their customer-centric approach, lack of cognitive bias, and competitive pricing. These AI-powered systems use algorithms that can recognize an investor's financial situation and making portfolio recommendations that comply with financial regulations. Fig. 10 illustrates a potential physical resources abstraction that can leverage to help constructing an automated cryptocurrency trading Robot-Adviser, based on current research (green and purple blocks) and future directions (red blocks). This Robot-advice framework is based on the big-data decision-making framework proposed by Rhyn and Blohm (2019).

This mapping focused on analysing the models employed within cryptocurrency trading. However, it is important to acknowledge the significance of the underlying technological infrastructure. Real-time data streaming, efficient data collection, and robust data management systems are fundamental building blocks for any trading platform. Additionally, complex models with extensive data inputs necessitate high processing speeds and significant computing power. Future research should encompass the entire cryptocurrency trading ecosystem, including these crucial technological aspects, to ensure a comprehensive understanding of this evolving field.

We recommended utilizing this study as foundational navigation guidance for future research endeavors in this field. As our literature mapping is to map the key themes within cryptocurrency trading, a systematic literature review is essential for thorough investigation of specific themes. Such themes may encompass diverse subjects, including experiences with cryptocurrency trading systems and legal considerations across various global jurisdictions.

Conclusion

Our systematic mapping revealed a thriving and dynamic field of cryptocurrency trading research. This is further evidenced by the high concentration (80 %) of papers published in top Q1, Q2, ACM, and IEEE conferences.

Future research should concentrate on the creation of novel metrics to assess the "intrinsic value" of cryptocurrencies, identifying influential factors that play a pivotal role in shaping the cryptocurrency landscape. This includes a comprehensive exploration of the roles various actors assume within the cryptocurrency market and the functioning of cryptocurrency exchange platforms. Several crucial mentioned issues remain insufficiently studied, presenting prime opportunities for investigation. The development of an intelligent trading advisory system represents a promising avenue for further exploration in enhancing the efficiency of trading cryptocurrency.

By summarizing the features and compatibility of various technologies, this review stands as a valuable guide for researchers venturing into cryptocurrency trading research, especially in the conceptualization and design of intelligent trading systems. We recommend using this study as a starting point for further research in this area. Conducting a systematic literature review on a particular topic can provide in-depth knowledge on a theme that researchers found interesting during the mapping review.

CRediT authorship contribution statement

Duy Thien An Nguyen: Writing – review & editing, Writing – original draft, Validation, Project administration, Methodology, Investigation, Conceptualization. **Ka Ching Chan:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization.

Declaration of competing interest

There is no conflict of interest.

References

Agosto, A., & Cafferata, A. (2020). "Financial Bubbles: A study of co-explosivity in the cryptocurrency market". *Risks, 8*(2). https://doi.org/10.3390/risks8020034

Agosto, A., Cerchiello, P., & Pagnottoni, P. (2022). 'Sentiment, Google queries and explosivity in the cryptocurrency market'. *Physica A: Statistical Mechanics and its Applications*, 605.

Ahn, Y. (2022). "Asymmetric tail dependence in cryptocurrency markets: A Model-free approach". *Finance Research Letters, 47*, Article 102746. https://doi.org/10.1016/j.frl.2022.102746. Part B.

Ahn, Y., & Kim, D. (2021). "Emotional trading in the cryptocurrency market". *Finance Research Letters, 42*, Article 101912. https://doi.org/10.1016/j.frl.2020.101912

Akyildirim, E., Goncu, A., & Sensoy, A. (2020). 'Prediction of cryptocurrency returns using machine learning'. *Annals of Operations Research, 297*(1–2), 3–36.

Aslan, A., & Sensoy, A. (2020). "Intraday efficiency-frequency nexus in the cryptocurrency markets". *Finance Research Letters, 35*, Article 101298. https://doi.org/10.1016/j.frl.2019.09.013

Blau, B., Griffith, T., & Whitby, R. (2020). "Comovement in the cryptocurrency market". *Economics Bulletin, 40*(1), 448–455. https://digitalcommons.usu.edu/econ_facpubs/944/.

Boreiko, D., & Massarotti, F. (2020). 'How risk profiles of investors affect robo-advised portfolios'. *Frontiers in Artificial Intelligence, 3*, 60.

Bouri, E., Gupta, R., & Vo, X. V. (2020). 'Jumps in Geopolitical risk and the cryptocurrency market: The singularity of Bitcoin'. *Defence and Peace Economics, 33*(2), 150–161.

Bouri, E., Lau, C. K. M., Lucey, B., & Roubaud, D. (2019b). 'Trading volume and the predictability of return and volatility in the cryptocurrency market'. *Finance Research Letters, 29*, 340–346.

Bouri, E., Shahzad, S. J. H., & Roubaud, D. (2019a). 'Co-explosivity in the cryptocurrency market'. *Finance Research Letters, 29*, 178–183.

Bouri, E., Vo, X. V., & Saeed, T. (2021). 'Return equicorrelation in the cryptocurrency market: Analysis and determinants'. *Finance Research Letters, 38*.

Bowden, J., & Gemayel, R. (2022). 'Sentiment and trading decisions in an ambiguous environment: A study on cryptocurrency traders'. *Journal of International Financial Markets, Institutions and Money, 80*, Article 101622.

Breidbach, C. F., & Tana, S. (2021). 'Betting on Bitcoin: How social collectives shape cryptocurrency markets'. *Journal of Business Research, 122*, 311–320.

Campbell, F., Tricco, A. C., Munn, Z., Pollock, D., Saran, A., Sutton, A., et al. (2023). 'Mapping reviews, scoping reviews, and evidence and gap maps (EGMs): The same but different—The "Big Picture" review family'. *Systematic Reviews, 12*(1), 45.

Cao, G., & Xie, W. (2022). "Asymmetric dynamic spillover effect between cryptocurrency and China"s financial market: Evidence from TVP-VAR based connectedness approach'. *Finance Research Letters, 49*, Article 103070. https://doi.org/10.1016/j.frl.2022.103070

Caporale, G. M., Gil-Alana, L., & Plastun, A. (2018). 'Persistence in the cryptocurrency market'. *Research in International Business and Finance, 46*, 141–148.

Caporale, G. M., & Plastun, A. (2019). 'Price overreactions in the cryptocurrency market'. *Journal of Economic Studies, 46*(5), 1137–1155.

CoinMarketCap. (2023). *Global Cryptocurrency Charts*. CoinMarketCap, viewed 23 February 2023, <> https://coinmarketcap.com/charts/.

Corbet, S., Eraslan, V., Lucey, B., & Sensoy, A. (2019). 'The effectiveness of technical trading rules in cryptocurrency markets'. *Finance Research Letters, 31*, 32–37.

de Oliveira Monteiro, A. H., de Souza, A. D., Batista, B., & Zaparoli, M. (2019). *Market Prediction in Criptocurrency: A Systematic Literature Mapping* (p. 800). Cham: Springer. https://doi.org/10.1007/978-3-030-14070-0_85

Evrim Mandaci, P., & Cagli, E. C. (2022). 'Herding intensity and volatility in cryptocurrency markets during the COVID-19'. *Finance Research Letter, 46*, Article 102382.

Fang, F., Ventre, C., Basios, M., Kanthan, L., Martinez-Rego, D., Wu, F., & Li, L. (2022). "Cryptocurrency trading: A comprehensive survey". *Financial Innovation, 8*(1), 1–59.

Frankenfield, J. (2023). *Cryptocurrency explained with pros and cons for investment*, Investopedia, viewed 23 February 2023.

Garousi, V., Mesbah, A., Betin-Can, A., & Mirshokraie, S. (2013). 'A systematic mapping study of web application testing'. *Information and Software Technology, 55*(8), 1374–1396.

Gong, Y., & Huser, R. (2022). 'Asymmetric tail dependence modeling, with application to cryptocurrency market data'. *The Annals of Applied Statistics, 16*(3), 1822–1847.

Hansun, S., Wicaksana, A., & Khaliq, A. Q. M. (2022). "Multivariate cryptocurrency prediction: Comparative analysis of three recurrent neural networks approaches". *Journal of Big Data, 9*(1), Article 50. https://doi.org/10.1186/s40537-022-00601-7

Jeris, S. S., Ur Rahman Chowdhury, A., Akter, M. T., Frances, S., & Roy, M. H. (2022). 'Cryptocurrency and stock market: Bibliometric and content analysis'. *Heliyon, 8*(9), e10514.

Khedr, A. M., Arif, I., El-Bannany, M., Alhashmi, S. M., & Sreedharan, M. (2021). 'Cryptocurrency price prediction using traditional statistical and machine-learning techniques: A survey'. *Intelligent Systems in Accounting, Finance and Management, 28*(1), 3–34.

Knight, O. (2022). *Crypto exchange deribit Loses $*28M *in Hot wallet hack, pauses withdrawals*, viewed 20/12/2023.

Kurt Gümüş, G., Gümüş, Y., & Çimen, A. (2019). *Herding behaviour in cryptocurrency market: CSSD and CSAD analysis*, vol. PartF1.

Lahmiri, S., & Bekiros, S. (2021). 'Deep Learning forecasting in cryptocurrency high-frequency trading'. *Cognitive Computation, 13*(2), 485–487.

Lahmiri, S., Bekiros, S., & Bezzina, F. (2022). "Complexity analysis and forecasting of variations in cryptocurrency trading volume with support vector regression tuned by Bayesian optimization under different kernels: An empirical comparison from a large dataset". *Expert Systems with Applications, 209*, Article 118349. https://doi.org/10.1016/j.eswa.2022.118349

Li, D., Shi, Y., Xu, L., Xu, Y., & Zhao, Y. (2022). "Dynamic asymmetric dependence and portfolio management in cryptocurrency markets". *Finance Research Letters, 48*, Article 102829. https://doi.org/10.1016/j.frl.2022.102829

Li, Y., Urquhart, A., Wang, P., & Zhang, W. (2021). "MAX momentum in cryptocurrency markets". *International Review of Financial Analysis, 77*, Article 101829. https://doi.org/10.1016/j.irfa.2021.101829

López-Martín, C., Benito Muela, S., & Arguedas, R. (2021). 'Efficiency in cryptocurrency markets: New evidence'. *Eurasian Economic Review, 11*(3), 403–431.

Lucchini, L., Alessandretti, L., Lepri, B., Gallo, A., & Baronchelli, A. (2020). "From code to market: Network of developers and correlated returns of cryptocurrencies". *Science Advances, 6*(51). https://doi.org/10.1126/sciadv.abd2204

Makarov, I., & Schoar, A. (2020). 'Trading and arbitrage in cryptocurrency markets'. *Journal of Financial Economics, 135*(2), 293–319.

Müller, F. M., Santos, S. S., Gössling, T. W., & Righi, M. B. (2022). "Comparison of risk forecasts for cryptocurrencies: A focus on Range Value at Risk". *Finance Research Letters, 48*, Article 102916. https://doi.org/10.1016/j.frl.2022.102916

Omane-Adjepong, M., Alagidede, P., & Akosah, N. K. (2019). 'Wavelet time-scale persistence analysis of cryptocurrency market returns and volatility'. *Physica A: Statistical Mechanics and its Applications, 514*, 105–120.

Ortu, M., Uras, N., Conversano, C., Bartolucci, S., & Destefanis, G. (2022). "On technical trading and social media indicators for cryptocurrency price classification through deep learning". *Expert Systems with Applications, 198*, Article 116804. https://doi.org/10.1016/j.eswa.2022.116804

Petersen, K., Feldt, R., Mujtaba, S., & Mattsson, M. (2008). 'Systematic mapping studies in software engineering'. *12th International Conference on Evaluation and Assessment in Software Engineering (EASE), 12*, 1–10.

Petersen, K., Vakkalanka, S., & Kuzniarz, L. (2015). 'Guidelines for conducting systematic mapping studies in software engineering: An update'. *Information and Software Technology, 64*, 1–18.

Pietrych, L., Sandubete, J. E., & Escot, L. (2021). "Solving the chaos model-data paradox in the cryptocurrency market". *Communications in Nonlinear Science and Numerical Simulation, 102*, Article 105901. https://doi.org/10.1016/j.cnsns.2021.105901

Qureshi, S., Aftab, M., Bouri, E., & Saeed, T. (2020). "Dynamic interdependence of cryptocurrency markets: An analysis across time and frequency". *Physica A: Statistical Mechanics and its Applications, 559*, Article 125077. https://doi.org/10.1016/j.physa.2020.125077

Rabbani, M. R., Alshaikh, A., Jreisat, A., Bashar, A., & Moh'd Ali, M. A. (2021). Whether Cryptocurrency is a threat or a revolution? An analysis from ESG perspective. In *2021 International Conference on Sustainable Islamic Business and Finance* (pp. 103–108). Sakheer, Bahrain: IEEE. https://doi.org/10.1109/IEEECONF53626.2021.9686332

Reiff, N. (2023). *The Collapse of FTX: What went wrong with the crypto exchange?*, viewed 20/12/2023.

Rhyn, M., & Blohm, I. (2019)., 'Patterns of data-driven decision-making: How decision-makers leverage crowdsourced data'.

Riaz, M., Breaux, T., & Williams, L. (2015). 'How have we evaluated software pattern application? A systematic mapping study of research design practices'. *Information and Software Technology, 65*, 14–38.

Sattaru, N. C., Umrao, D., Ramachandran, K., Karthick, K., Tiwari, M., & Kumar, S. (2022). Machine learning as a predictive technology and its impact on digital pricing and cryptocurrency markets. In *2022 2nd International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE)* (pp. 1077–1080). Greater Noida, India: IEEE. https://doi.org/10.1109/ICACITE53722.2022.9823734

Shahzad, S. J. H., Bouri, E., Ahmad, T., & Naeem, M. A. (2022). "Extreme tail network analysis of cryptocurrencies and trading strategies". *Finance Research Letters, 44*, Article 102106. https://doi.org/10.1016/j.frl.2021.102106

Sigaki, H. Y. D., Perc, M., & Ribeiro, H. V. (2019). "Clustering patterns in efficiency and the coming-of-age of the cryptocurrency market". *Scientific reports, 9*(1), 1440. https://doi.org/10.1038/s41598-018-37773-3

Singh, K. (2023). *US court approves order for Binance to pay $2.7 bln to CFTC*, Reuters, viewed 20/12/2023.

Smales, L. A. (2022). "Investor attention in cryptocurrency markets". *International Review of Financial Analysis, 79*, Article 101972. https://doi.org/10.1016/j.irfa.2021.101972

Tran, V. L., & Leirvik, T. (2020). "Efficiency in the markets of crypto-currencies". *Finance Research Letters, 35*, Article 101382. https://doi.org/10.1016/j.frl.2019.101382

Ustaoglu, E. (2022). "Safe-haven properties and portfolio applications of cryptocurrencies: Evidence from the emerging markets". *Finance Research Letters, 47*, Article 102716. https://doi.org/10.1016/j.frl.2022.102716. Part B.

Vidal-Tomás, D. (2021b). 'The entry and exit dynamics of the cryptocurrency market'. *Research in International Business and Finance, 58*, Article 101504. https://doi.org/10.1016/j.ribaf.2021.101504

Vidal-Tomás, D. (2021a). 'An investigation of cryptocurrency data: The market that never sleeps'. *Quantitative Finance, 21*(12), 2007–2024.

Vidal-Tomás, D., Ibáñez, A. M., & Farinós, J. E. (2019a). 'Herding in the cryptocurrency market: CSSD and CSAD approaches'. *Finance Research Letters, 30*, 181–186.

Vidal-Tomás, D., Ibáñez, A. M., & Farinós, J. E. (2019b). 'Weak efficiency of the cryptocurrency market: A market portfolio approach'. *Applied Economics Letters, 26*(19), 1627–1633.

Vidal-Tomás, D., Ibáñez, A. M., & Farinós, J. E. (2021). 'The Effect of the Launch of Bitcoin Futures on the Cryptocurrency Market: An Economic Efficiency Approach'. *Mathematics, 9*(4), 1–14.

Wang, Y., Lucey, B., Vigne, S. A., & Yarovaya, L. (2022a). 'An index of cryptocurrency environmental attention (ICEA)'. *China Finance Review International, 12*(3), 378–414. https://doi.org/10.1108/CFRI-09-2021-0191

Wang, Y., Wang, C., Sensoy, A., Yao, S., & Cheng, F. (2022b). 'Can investors' informed trading predict cryptocurrency returns? Evidence from machine learning'. *Research in International Business and Finance, 62*, Article 101683. https://doi.org/10.1016/j.ribaf.2022.101683

Wen, Z., Bouri, E., Xu, Y., & Zhao, Y. (2022). "Intraday return predictability in the cryptocurrency markets: Momentum, reversal, or both". *The North American Journal of Economics and Finance, 62*, Article 101733. https://doi.org/10.1016/j.najef.2022.101733

Wu, W., Tiwari, A. K., Gozgor, G., & Leping, H. (2021). "Does economic policy uncertainty affect cryptocurrency markets? Evidence from Twitter-based uncertainty measures". *Research in International Business and Finance, 58*, Article 101478. https://doi.org/10.1016/j.ribaf.2021.101478

Yao, S., Kong, X., Sensoy, A., Akyildirim, E., & Cheng, F. (2021). "Investor attention and idiosyncratic risk in cryptocurrency markets". *The European Journal of Finance*, 1–19. https://doi.org/10.1080/1351847X.2021.1989008

Yao, S., Sensoy, A., Nguyen, D. K., & Li, T. (2024). "Investor attention and cryptocurrency market liquidity: A double-edged sword". *Annals of Operations Research, 334*, 815–856.

Yousaf, I., Ali, S., Bouri, E., & Dutta, A. (2021). "Herding on fundamental/Nonfundamental information during the COVID-19 outbreak and cyber-attacks: Evidence from the cryptocurrency market". *SAGE open, 11*(3). https://doi.org/10.1177/21582440211029911

Duy Thien An NGUYEN (Corresponding Author) Email: duyThienAn.Nguyen@usq.edu.au School of Business, University of Southern Queensland Duy Thien An Nguyen is currently pursuing Postgraduate study at the Business School of the University of Southern Queensland in Australia. He is also a member of the Data Surveillance and Support team for the Loddon Mallee Public Health Unit (Victoria, Australia). Nguyen's areas of expertise and interest include big data, data analytics, machine learning, and trading algorithms. He has received a graduate diploma in science with a focus on Data Science. Presently, Nguyen's project is centered around exploring cryptocurrency trading and digital investment advisors (robot advisors).

Ka Ching CHAN (Corresponding Author) Email: KC.Chan@usq.edu.au School of Business, University of Southern Queensland KC Chan is a Senior Lecturer at the University of Southern Queensland, an Honorary Senior Research Fellow at La Trobe University, and a Visiting Fellow at the University of New South Wales. He holds a BASc in Engineering Science and a MASc in Mechanical Engineering from the University of Toronto, Canada, and a PhD in Manufacturing Engineering from the University of New South Wales, Australia. Dr Chan is a Chartered Engineer with extensive industry experience in building technology companies at the Australian Technology Park.