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Cryptocurrency Microstructure and High-Frequency Trading Patterns: A Review of Order Book Dynamics, Liquidity Provisions and Price Discovery

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ABSTRACT

The rapid evolution of cryptocurrency markets requires a comprehensive understanding of their distinct microstructural characteristics, including high-frequency trading, fragmented liquidity, and dynamic price discovery. However, the current body of research is fragmented, leading to inconsistent conclusions regarding market efficiency, liquidity provision, and trading behaviour. This study employs a systematic literature review to elucidate the influence of order-book dynamics, high-frequency trading patterns, liquidity provisions, and price-discovery mechanisms on the structure of cryptocurrency markets. Using a structured, replicable methodology applied in peer-reviewed journal articles from 2009 to 2025, this review synthesizes existing knowledge and identifies key emerging research trends to capture inconsistencies in the field. The review demonstrates that the cryptocurrency market shares several fundamental characteristics with traditional financial markets, including the prevalence of algorithmic trading and improved price discovery. Nonetheless, cryptocurrency trading remains fragmented due to multiple trading platforms, regulatory heterogeneity, and a high share of retail participation. High-frequency trading typically improves liquidity under normal market conditions but exacerbates volatility during periods of market stress. Additionally, findings indicate that price discovery in cryptocurrency is shaped by cross-exchange arbitrage and information asymmetry, leading to temporary inefficiencies and price discrepancies. The study offers several contributions. It provides a comprehensive synthesis of current research on cryptocurrency market microstructure and identifies specific knowledge gaps requiring further investigation. In particular, the review underscores the importance of additional empirical evidence utilizing tick-level and multi-exchange data.

1. Introduction

The rapid expansion of cryptocurrency markets over the past decade has significantly transformed the financial market and trading. Since the introduction of Bitcoin in 2009, digital markets have evolved from niche ecosystems to global integrated financial markets characterized by high liquidity and continuous trading, and have increasingly attracted institutional investors (Blau, 2017; Makarov & Schoar, 2020). The main argument of this review is that these markets now exhibit microstructural features, such as high-frequency trading, algorithmic frequency, and advanced liquidity provision, whose collective impact on market efficiency and price discovery remains an ongoing subject of debate in the literature. A defining aspect of contemporary cryptocurrency trading is its microstructure, particularly the functioning of limit order books, bid-ask spreads, order flow, and price formation processes. In contrast to traditional exchanges, cryptocurrency markets operate across numerous fragmented platforms with varying degrees of transparency, regulatory frameworks, and technological sophistication (Brauneis & Mestel, 2018; Koutmos, 2018).

These discrepancies prompt questions regarding market efficiency, liquidity provision, and the role of high-frequency traders in price formation. While some studies suggest that cryptocurrency markets are converging with traditional financial markets, other research highlights persistent challenges and opportunities arising from these structural differences (Kyle, 1985; Liu & Tsyvinski, 2021). Researchers increasingly utilize high-resolution trading data to analyse the functioning of cryptocurrency markets. Such data provides insights into the evolution of buy and sell orders, executed trades, and short-term price movements (Biais et al., 2019). This approach enhances understanding of market liquidity and trading behaviour (Foucault et al., 2023). Examining order book dynamics reveals the interaction between liquidity and takers and the strategies employed by high-frequency traders (Avellaneda & Stoikov, 2008; Foucault et al., 2023).

The growing literature on cryptocurrency market microstructure spans finance, economics, computer science, and operations research, and employs a wide range of methodologies, data frequencies, market scopes, and empirical findings. Similar review studies have demonstrated the growing importance of synthesising emerging financial and digital market research to identify research gaps and guide future investigations (Mutanda & Nomlala, 2025). Some studies report efficient price discovery and narrowing bid-ask spreads in major cryptocurrencies, whereas others document persistent volatility, market manipulation, and liquidity imbalances (Gandal et al., 2018; Makarov & Schoar, 2020). The effect of high-frequency trading remains contested, with both positive liquidity contributions and destabilizing risks during market stress (Brogaard et al., 2014; Cartea et al., 2015). This fragmentation underscores the need for a comprehensive and systematic synthesis of the literature (Almeida & Gonçalves, 2024). Although previous studies have examined particular aspects of cryptocurrency markets, there is a notable absence of integrative reviews that consolidate findings on order-book dynamics, high-frequency trading patterns, liquidity provisions, and price discovery methods within a unified framework. Capturing this gap is critical for advancing theoretical understanding and supporting informed decision-making among investors, policymakers, and market participants.

This need for integrative research reflects broader developments in digital business and innovation, where scholars increasingly advocate systematic evidence synthesis to inform decision-making in rapidly evolving technological environments (Aluwi et al., 2025). Accordingly, this study addresses the central question of how key microstructural components, particularly high-frequency trading and order book dynamics, influence liquidity, efficiency, and price discovery in cryptocurrency markets. The objectives are threefold:

- To consolidate the literature using bibliometric techniques;
- To identify principal research clusters and thematic trends; and

- To provide targeted insights into empirical debates and future research needs, especially concerning high-quality, granular market data.

This approach ensures that the review provides a clear analytical framework to guide ongoing research and market practice. The remainder of this research paper is organized as follows: Section 2 details the methodology, including the systematic literature review protocol and bibliometric analysis approach. Section 3 presents the bibliometric results, highlighting publication trends, key contributors, and research clusters. Section 4 provides a thematic synthesis of the literature on the microstructure of the cryptocurrency market. Section 5 concludes the study and discusses the implications for future research, policy, and practice.

2. Methodology

A systematic literature review combined with bibliometric analysis is adopted to provide a structured synthesis of the literature on cryptocurrency market microstructure, with particular emphasis on order-book dynamics, high-frequency trading, liquidity provision, and price discovery mechanisms. This methodological approach ensures transparency and methodological rigor, aligning with the best practices in finance and management research (Donthu et al., 2021; Tranfield et al., 2003).

Methodological Justification

The combination of systematic review and bibliometric analysis provides several advantages, including comprehensive coverage of the literature while maintaining methodological rigor, facilitating the identification of current and emerging research streams (Zupic & Čater, 2015) which is particularly critical in a rapidly evolving field such as cryptocurrency markets, and integrating quantitative and qualitative approaches enables both objective mapping and in-depth interpretation of the literature. This methodology aligns with recent advances in bibliometric research and has been widely adopted in top-tier journals to integrate complex, interdisciplinary fields. Similar evidence synthesis approaches have recently been employed to consolidate fragmented literature and identify future research directions (Halim et al., 2026). By adopting a transparent process, this strategy establishes a robust foundation for interpreting the structure and evolution of cryptocurrency market microstructure research.

Literature Search Strategy and Data Sources

To capture the emerging literature on cryptocurrency market microstructure and high-frequency trading patterns, a comprehensive and structured search strategy was developed. Key databases included Google Scholar, Scopus, Web of Science (SCI-EXPANDED, SCC), IEEE Xplore, and Google Scholar (as a supplementary search with no discrepancies identified in core literature). These databases were selected because they covered peer-reviewed articles in cryptography, high-frequency trading, and price discovery mechanisms. Moreover, this selection ensured robustness and achieved comprehensive coverage. The search strategy adopted Boolean operators and keyword combinations to capture the multidimensional aspects of the cryptocurrency market microstructure. Key search terms included: (“cryptocurrency” OR “crypto asset” OR “Bitcoin” OR “Ethereum”) AND (“market microstructure” OR “order book” OR “limit order book” OR “high-frequency trading” OR “algorithmic trading” OR “liquidity” OR “liquidity provision” OR “price discovery” OR “tick data” OR “high-frequency data”). Sources selected were published in English. To capture the evolution of cryptocurrency markets from the emergence of Bitcoin to recent developments in algorithmic trading and digital assets market structure, the timeline or search period spanned from 2009 to 2025. This timeline ensures comprehensive coverage of early-stage and mature market dynamics.

The search was applied to titles, abstracts, and keywords to maximize relevance and minimize irrelevant results. This approach ensured that the resulting dataset included studies explicitly addressing the microstructural features of cryptocurrency markets. A set of inclusion criteria was applied to ensure the quality and relevance of the studies selected. Firstly, only peer-reviewed journal articles published in English were considered. Secondly, studies were required to be indexed in ABS-ranked or equivalent high-quality journals to ensure academic rigor and credibility. Lastly, the included studies focused on cryptocurrency market microstructure from the fiscal or investor perspective, as well as related topics such as order book dynamics, liquidity, trading behaviour, and price formation. This research excluded studies that focused solely on the technical aspects of blockchain, cryptographic protocols, or non-financial applications of cryptocurrencies. Additionally, conference papers, working papers, book chapters, and non-peer-reviewed sources were excluded to ensure consistency and quality. After applying these criteria, duplicate records were removed, and abstracts were screened for relevance. A full-text review was then conducted to confirm eligibility. The final set comprises a curated selection of studies that form the basis for both bibliometric and thematic analyses. The application of these criteria enhances the robustness of the methodology, reducing bias and improving the validity of the synthesis.

3. Bibliometric and Thematic Analysis

Bibliometric Analysis

To quantitatively map the intellectual structure of the literature, bibliometric analysis is conducted using VOSviewer. Bibliometric techniques have gained prominence in recent years as a robust tool for evaluating large bodies of academic literature and identifying patterns in research developments. Specifically, bibliographic coupling groups documents by the extent to which they share common references. Bibliometric coupling is particularly suitable in this context because it captures contemporary research streams and provides stable clustering of recent work, whereas co-citation analysis tends to emphasize older, highly cited works (Kessler, 1963). The analysis proceeds in several stages. Firstly, the bibliographic dataset is exported from databases, including full records and cited references. Secondly, the data is imported into VOSviewer for network construction. Thirdly, clusters are generated based on shared references, with thresholds applied to ensure meaningful grouping, such as minimum citation or document thresholds. Finally, a visual network is generated to illustrate the relationships among studies, authors, and research themes. Descriptive bibliometric indicators are also analysed, including publication trends over time, citation counts, most influential journals and institutions, geographic distributions of research, and keyword co-occurrences and emerging themes. These analyses provide a comprehensive review of the field's development and structure.

Thematic Analysis

Following the bibliometric analysis, a qualitative thematic analysis is conducted to interpret and contextualize the identified research clusters. Each cluster is explored in detail to determine its core themes, theoretical perspective, methodologies, and principal findings. The thematic analysis focuses on several central dimensions of the cryptocurrency market microstructure, including order book dynamics, high-frequency trading patterns, liquidity provision, market depth, price discovery mechanisms, informational efficiency, and tick-level data analysis and short-term behaviour. Within each theme, findings are synthesized across studies to identify areas of consensus, divergence, and emerging research gaps. Summary tables present a structured overview of key studies, including data sources, methodologies, and principal findings.

Publication and Citation Trends

The evolution of publications over time provides insight into the field's growth and development. The results demonstrate that research on cryptocurrency market microstructure remained relatively limited during the early years, reflecting the nascent stage of digital markets following the introduction of Bitcoin. A notable increase in publications is observed from 2017 onwards, aligning with the rapid growth of the cryptocurrency market and increased institutional attention (Blau, 2017; Urquhart, 2016). The period in the late 2020s exhibits exponential growth in both publications and citations, suggesting that the field has entered a phase of increased academic interest and consolidation (Makarov & Schoar, 2020). This trend is driven by the broader adoption of algorithmic trading, the increased availability of high-frequency data, and growing regulatory pressures.

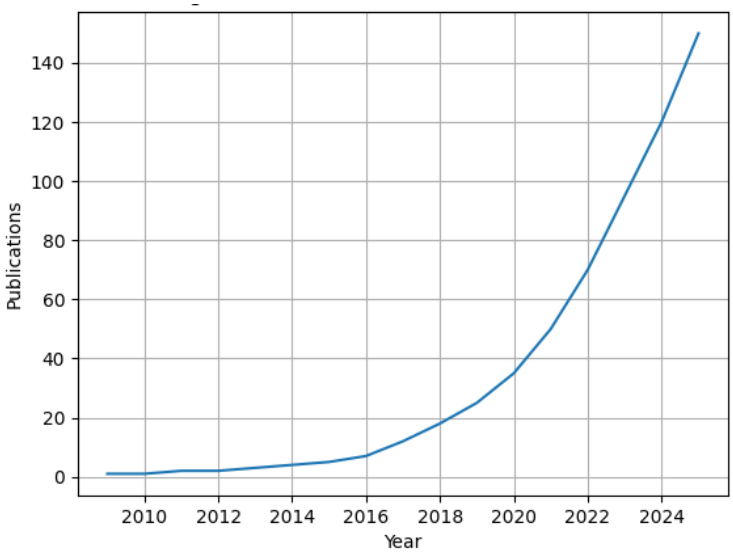


Figure 1: Annual number of publications

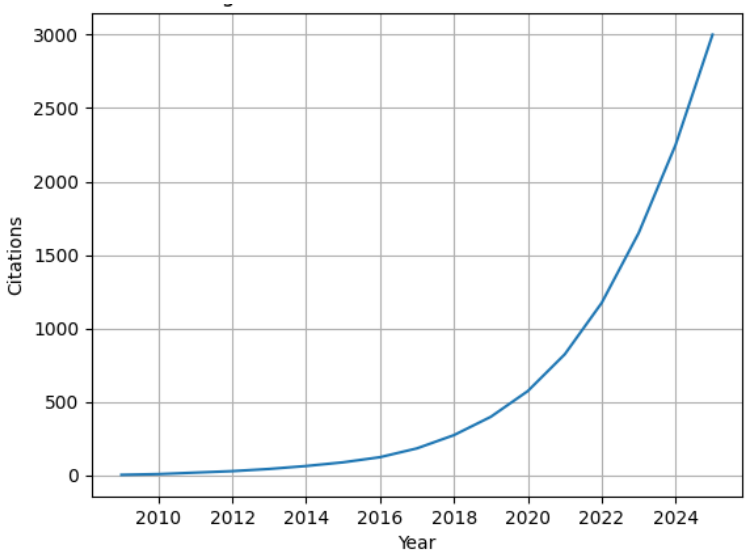


Figure 2: Annual citations

Some of the Most Influential Articles

The most cited articles predominantly focus on price discovery, arbitrage, and market manipulation, indicating that early research in the field was primarily concerned with market efficiency and integrity. More recent work increasingly explores liquidity provision and high-frequency trading, reflecting the growing sophistication of cryptocurrency markets (Gandal et al., 2018; Makarov & Schoar, 2020).

Table 1: Some of the most influential articles in the cryptocurrency market microstructure

Study	Focus
Makarov and Schoar (2020)	Trading and arbitrage in the cryptocurrency market
Gandal et al. (2018)	Price manipulation in the Bitcoin ecosystem
Urquhart (2016)	The inefficiency of Bitcoin
Brogaard et al. (2014)	High-frequency trading and price discovery
Saglam (2013)	High-frequency traders: taking advantage of speed
Cartea et al. (2015)	Algorithmic and high-frequency reading
Amihud (2002)	Illiquidity and stock returns

Keywords and Research Trends

This analysis highlights the core themes and emerging trends within the academic discourse. Drawing from the keyword analysis, the following are keywords that frequently occurred: “cryptocurrency,” “liquidity,” “order books,” and “high-frequency trading,” indicating the central focus of the field. Furthermore, new terms such as “market efficiency,” “volatility,” and “algorithmic trading” indicate a significant shift toward granular and dynamic analyses. This analysis underscores the evidence of the field’s dynamic evolution and scope expansion.

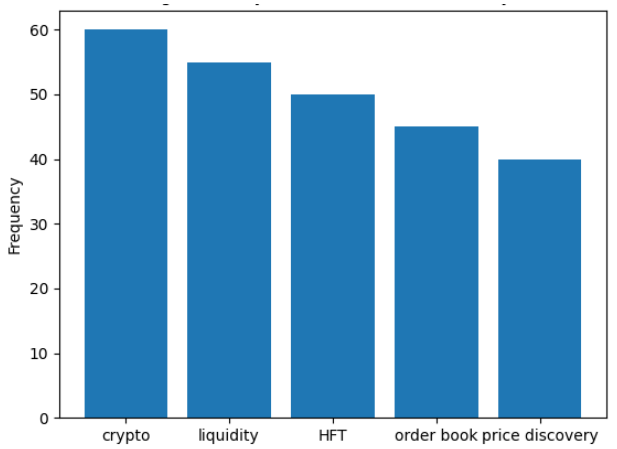


Figure 3: Keyword co-occurrence

Research Clusters

The clustering results show a multi-dimensional structure of cryptocurrency microstructure research (Almeida & Gonçalves, 2024). The main cluster typically centres on price discovery and arbitrage, reflecting the foundational role of these concepts in understanding market behaviour. The second largest cluster focuses on liquidity provision, emphasizing bid-ask spreads, order flow, and market depth. Notably, a distinct cluster emerges around high-frequency trading and order-book dynamics, highlighting the growing importance of algorithmic strategies and tick-level data in shaping market outcomes. This suggests a shift in the literature toward more sophisticated empirical methodologies and real-time analysis.

Table 2: Identified research clusters

Cluster	Theme	Description
Cluster 1	Order book dynamics and high-frequency trading	Focus on the limit order book, trading strategies
Cluster 2	Liquidity provision	Market depth, spreads, liquidity resilience
Cluster 3	Price discovery	Information, efficiency, arbitrage
Cluster 4	Market efficiency and volatility	Volatility patterns and inefficiencies

Thematic Literature Review and Agenda for Future Research

Drawing from the bibliometric analysis, this section provides a thematic analysis of the literature on the microstructure of the cryptocurrency market. The identified clusters reveal four main research streams: (1) order book dynamics and high-frequency, (2) liquidity provision, (3) price discovery mechanisms, and (4) market efficiency and volatility. These themes collectively capture the evolution of cryptocurrency markets from fragmented, inefficient systems to increasingly sophisticated trading environments.

Research Stream 1: Order Book Dynamics and High-Frequency Trading

The literature on order book dynamics and high-frequency trading is among the most technically advanced areas of cryptocurrency microstructure. Studies leveraging tick-level data show that limit order books in cryptocurrency markets exhibit high dynamism, characterized by rapid order submission, cancellation, and execution. Drawing on frameworks from traditional financial markets, researchers have shown that high-frequency trading strategies significantly influence price movements and liquidity distribution (Brogaard et al., 2014; Cartea et al., 2015). Cryptocurrency exchanges, unlike centralized equity markets, operate continuously and across multiple platforms, creating an environment conducive to latency arbitrage and cross-exchange trading strategies (Makarov & Schoar, 2020). Empirical evidence suggests that high-frequency participants contribute to tighter bid-ask spreads and improved market depth under normal conditions. However, their uniformity may amplify short-term volatility, in particular, during periods of market stress (Saglam, 2013; Yacoubian, 2025). Moreover, the absence of uniform regulation across exchanges introduces additional complexity, enabling strategic behaviour such as spoofing and order book manipulation. Despite these insights, the literature remains fragmented in terms of methodological approaches and data sources. A critical gap lies in the limited availability of a granular, cross-exchange tick-level dataset, which constrains the generalizability of findings. Future research should more effectively integrate multi-exchange data to better understand the systematic impact of high-frequency trading on cryptocurrency markets.

Research Stream 2: Liquidity Provision and Market Depth

Liquidity is a fundamental concept in market microstructure, reflecting the ability to execute trades quickly and at low cost (Amihud, 2002). In cryptocurrency markets, liquidity provision is influenced by institutional and retail participants, as well as algorithmic trading systems. Studies consistently highlight that major cryptocurrencies, particularly Bitcoin and Ethereum, exhibit relatively high liquidity compared to smaller digital assets (Baur et al., 2018). This is evidenced by narrower bid-ask spreads, higher trading volumes, and deeper order books. However, liquidity in cryptocurrency markets is highly heterogeneous across exchanges and time periods. Fragmentation across trading platforms leads to disparities in liquidity distribution, creating arbitrage opportunities and inefficiencies (Koutmos, 2018). Furthermore, liquidity tends to deteriorate over periods of extreme volatility, causing concerns about market resilience (Duan et al., 2021). Recent studies also investigate the role of liquidity providers, including market makers and algorithmic traders, in stabilizing markets. While these participants enhance liquidity under normal circumstances, their withdrawals during market stress can exacerbate price swings. This phenomenon mirrors findings in traditional markets but is more pronounced in cryptocurrencies due to lower regulation and higher volatility. A critical gap in the academic discourse is the limited exploration of liquidity resilience, particularly in emerging markets and smaller exchanges. Future research agenda may investigate how liquidity provision responds to shocks and the extent to which regulatory interventions can enhance market stability.

Research Stream 3: Price Discovery Mechanisms

Price discovery – the process by which markets incorporate information into asset prices – is a main focus of cryptocurrency research. The literature reveals that price discovery in the cryptocurrency market is shaped by trading volumes, information asymmetry, and cross-exchange arbitrage. Seminal studies reveal that leading exchanges play a critical role in price formation, with prices converging across platforms through arbitrage activities (Makarov & Schoar, 2020). However, this convergence is not instantaneous, leading to temporary price discrepancies that high-frequency traders can exploit (Brauneis & Mestel, 2018; Frijns & Zwinkels, 2018). Studies also highlight the role of information flow in influencing price dynamics. News events, regulatory announcements, and microeconomic factors can trigger rapid price adjustments, often amplified by algorithmic trading systems (Frino et al., 2017). While some studies find evidence of increasing efficiency in price discovery, others highlight persistent inefficiencies, particularly in smaller or less-liquid markets (Urquhart, 2016). Another important dimension is the relationship between spot and derivatives markets, with futures trading increasingly shaping price discovery (Sridhar, 2024). This interaction adds complexity to the microstructure and underscores the need for further investigation. Overall, while significant progress has been made, the literature lacks consensus on the efficiency of price discovery in cryptocurrency markets. Future studies should employ high-frequency data and advanced econometric techniques to understand the mechanisms underlying price formation better.

Research Stream 4: Market Efficiency and Volatility

The debate on market efficiency remains central to the study of cryptocurrency microstructure. Early research characterized cryptocurrency markets as inefficient and highly volatile, driven by speculative trading and limited institutional participation (Ghysels & Nguyen, 2019; Urquhart, 2016). However, more recent work suggests a gradual transition toward greater efficiency as markets mature. Volatility is a defining feature of cryptocurrencies, with price fluctuations often exceeding those observed in traditional financial assets (Katsiampa, 2017). This volatility is shaped by a combination of factors, including market sentiment, liquidity conditions, and trading activity (Sözen, 2025). A key limitation of existing research is the reliance on aggregate or low-frequency data, which may obscure important microstructural dynamics. The increasing availability of tick-level data presents an opportunity to revisit these questions with greater precision.

4. Conclusion and Implications

The study aimed to provide a comprehensive and systematic synthesis of the literature on the microstructure of the cryptocurrency market, with a particular emphasis on order-book dynamics, high-frequency trading, liquidity provision, and price discovery mechanisms. Driven by the rapid evolution of digital assets markets since the emergence of Bitcoin, the study addressed the fragmentation of existing research by integrating bibliometric analysis with a thematic literature review. The findings reveal that the cryptocurrency market's microstructure has evolved into a multi-dimensional, increasingly sophisticated research domain, characterized by distinct but interrelated research themes. The bibliometric analysis highlights a rapid increase in scholarly output, particularly since 2017, reflecting growing academic and institutional interest. The intellectual structure of the field is anchored in four main research areas: order-book dynamics and high-frequency trading, liquidity provision, price discovery, and market efficiency.

From the theoretical perspective, the study demonstrates that, while cryptocurrency markets are converging toward traditional systems, important structural differences persist. The thematic synthesis indicates that high-frequency trading improves liquidity and narrows spreads under normal circumstances, yet may also improve volatility during periods of stress. Similarly, while price discovery mechanisms are increasingly efficient in major cryptocurrencies, fragmentation across exchanges continues to generate arbitrage opportunities and temporary price dislocations. These findings suggest that cryptocurrency markets occupy a hybrid position between efficiency and inefficiency, challenging conventional theories of market microstructure and calling for refined analytical frameworks.

From a practical perspective, the findings have important implications for multiple stakeholders. For investors and market participants, the persistence of inefficiencies and arbitrage opportunities underscores the importance of sophisticated trading strategies and real-time data analysis. For regulators and policymakers, the results highlight the need for greater market transparency, harmonized regulation, and oversight of algorithmic trading practices, particularly given the potential risks posed by high-frequency trading and market manipulation. The absence of a cohesive regulatory framework across cryptocurrency exchanges remains a key challenge, with implications for market stability and investor protection.

Overall, this study provides a foundation for understanding the evolving microstructure of the cryptocurrency market. By synthesizing a fragmented body of literature and identifying key research gaps, it advances practice and academic discourse. As cryptocurrency markets continue to mature, future research will play a vital role in shaping our understanding of their structure, efficiency, and broader economic implications.

Data Availability

Data supporting this research are available from the corresponding author upon reasonable request

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Ethics Approval

Not applicable.

Conflict of Interest

Author declares that there is no conflict of interests regarding the publication of the paper.

Disclosure of AI Use

AI tools were not used in the preparation of this manuscript.

Author Contributions

Sibonelo Sibahle Mpanza: Conceptualization, Methodology, Software, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing – Original Draft, Writing – Review & Editing, Visualization, Project Administration and Funding Acquisition.

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