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LONG-TERM EQUILIBRIUM RELATIONSHIPS BETWEEN THE STOCK AND CRYPTOCURRENCIES MARKETS

ДОВГОСТРОКОВІ РІВНОВАЖНІ ВЗАЄМОЗВ'ЯЗКИ МІЖ ФОНДОВИМИ РИНКАМИ ТА РИНКАМИ КРИПТОВАЛЮТ

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This study investigates the long-term equilibrium relationships between the stock market, represented by the Dow Jones Industrial Average (DJIA), and a comprehensive range of 401 cryptocurrencies traded on Binance. Employing Johansen cointegration tests on data from January 2018 to May 2024, we examine pairwise relationships between 30 DJIA components and cryptocurrencies across various categories. Our findings reveal varying degrees of integration, with some stocks like Visa and Walt Disney Company showing strong cointegration with numerous cryptocurrencies. Sector-specific patterns emerge, such as significant links between technology stocks and platform tokens, and between financial services and DeFi tokens. Platform tokens exhibit the highest overall integration with stocks, followed by DeFi and NFT/Gaming domains. Notably, some cryptocurrencies, including major ones like Ethereum and Bitcoin, show high levels of cointegration, while others display independence. Stablecoins demonstrate strong cointegration with all stock prices. These results provide nuanced insights into the complex interactions between traditional and digital finance, contributing to our understanding of market integration, diversification strategies, and the evolving financial ecosystem.

Keywords: cryptocurrency, stock market integration, cointegration analysis, cross-market analysis, sector-specific cointegration, crypto-stock relationships.

У цьому дослідженні розглядаються довгострокові рівноважні зв'язки між фондовим ринком і широким набором криптовалют, з огляду на потребу в глибшому вивченні взаємодії між традиційними фінансовими ринками і простором цифрових активів. Використовуючи коінтеграційний аналіз Йохансена на основі повного набору даних з 401 криптовалюти та 30 компонентів промислового індексу Доу-Джонса за період з січня 2018 року по травень 2024 року, ми дослідили ступінь та характер ринкової інтеграції між різними категоріями криптовалют та секторами фондового ринку. Отримані дані свідчать про різний ступінь коінтеграції між різними акціями та криптовалютами, причому деякі пари демонструють сильні довгострокові зв'язки, в той час як інші – незалежність. Виявилися специфічні для кожного сектору закономірності: акції технологічних та фінансових компаній продемонстрували особливо сильні зв'язки з токенами платформ і токенами DeFi, відповідно. Платформні токени продемонстрували найбільшу кількість коінтеграцій з акціями, в той час як домени DeFi та NFT/Геймінг також продемонстрували значні рівні інтеграції. Слід зазначити, що деякі криптовалюти, включаючи основні монети, такі як Ethereum і Bitcoin, продемонстрували високий рівень коінтеграції з фондовими цінами, тоді як інші не показали жодної коінтеграції на будь-якому рівні значущості. Основні стейблкоіни продемонстрували повну коінтеграцію з усіма 30 фондовими цінами, що відображає їхню унікальну роль в криптовалютній екосистемі. У сукупності ці висновки підкреслюють складні та різнобічні зв'язки між ринком криптовалют і традиційним фондовим ринком. Виявлені коінтеграції свідчать про те, що в той час як деякі сегменти ринку криптовалют стають все більш інтегрованими з традиційними фінансовими системами, інші зберігають окремі траєкторії розвитку. Відмінності в рівнях інтеграції дозволяють отримати цінну інформацію про динаміку ринку та потенційні ризики або перспективи для інвесторів, які цікавляться як традиційними акціями, так і цифровими активами. Дане дослідження є внеском у зростаючу базу літератури про інтеграцію криптовалют і традиційних фінансових ринків, надаючи більш детальний і всебічний аналіз, ніж це було представлено в попередніх дослідженнях. Аналіз конкретних секторів і галузей дає більш глибоке розуміння того, як різні типи криптовалют взаємодіють з різними сегментами традиційного фінансового ринку.

Ключові слова: криптовалюти, інтеграція фондового ринку, коінтеграційний аналіз, міжринковий аналіз, галузева коінтеграція, взаємозв'язки між криптовалютами та фондовим ринком.

Problem Statement. The rapid evolution and increasing complexity of the global financial ecosystem, particularly with the emergence and growth of the cryptocurrency market, has created a pressing need for a deeper understanding of the relationships between traditional financial markets and cryptocurrency markets. This study addresses this gap by examining the long-term equilibrium relationships between the stock market, represented by the Dow Jones Industrial Average (DJIA), and a broad spectrum of cryptocurrencies traded on one of the world's largest digital asset exchanges, Binance.

The cryptocurrency market has experienced exponential growth and diversification since the introduction of Bitcoin in 2009. The emergence of new domains such as decentralised finance (DeFi) tokens, non-fungible tokens (NFTs), and layer-2 scaling solutions has further complicated the landscape. This rapid evolution has created a complex and dynamic financial ecosystem that interacts with traditional markets in ways that are not yet fully understood.

Understanding the relationships between cryptocurrencies and traditional stocks is crucial for several reasons:

1. It informs effective diversification strategies and risk management for investors and financial institutions.
2. It provides insights into market efficiency, price discovery mechanisms, and potential spillover effects across asset classes.
3. It aids policymakers and regulators in developing appropriate frameworks for financial stability and innovation.

This study employs cointegration analysis on a comprehensive dataset of 401 cryptocurrencies and all 30 DJIA components to detect long-term equilibrium relationships. This approach offers valuable insights into the structural links between these markets, which may not be apparent in short-term analyses.

Literature review. Early research in this area primarily focused on Bitcoin, given its status as the first and most prominent cryptocurrency. Ciaian et al. [3] examined the interdependence between Bitcoin and traditional financial assets, finding evidence of long-term relationships between Bitcoin prices and certain macroeconomic variables. This study laid the groundwork for exploring the integration of cryptocurrencies with traditional financial markets.

As the cryptocurrency market expanded beyond Bitcoin, researchers began to explore a broader range of digital assets. Corbet et al. [4] investigated the relationships between three popular cryptocurrencies (Bitcoin, Ripple, and Litecoin) and a variety of traditional financial assets. Their findings suggested that cryptocurrencies may offer diversification benefits for investors, as they found limited evidence of spillovers between cryptocurrencies and traditional assets.

The emergence of more sophisticated econometric techniques has allowed for more nuanced analyses of market relationships. Mensi et al. [6] employed a time-varying approach to examine the correlations between Bitcoin and regional financial markets. Their study highlighted the dynamic nature of these relationships, emphasising the need for flexible modelling approaches when analysing cryptocurrency markets.

As the cryptocurrency ecosystem has grown more complex, researchers have begun to explore sector-specific relationships. Caporale et al. [1] examined linkages between cryptocurrencies and various traditional asset classes, including stocks, bonds, and commodities. Their findings revealed sector-specific patterns in these relationships, suggesting that different types of cryptocurrencies may interact differently with traditional markets.

The rapid growth of decentralised finance (DeFi) has opened up new avenues for research. Schär [7] provided a comprehensive overview of the DeFi ecosystem, highlighting its potential to reshape traditional financial services. This work underscores the need for research that considers the unique characteristics of different cryptocurrency categories and their potential impacts on traditional finance.

Similarly, the rise of non-fungible tokens (NFTs) has introduced new dynamics to the cryptocurrency market. Wang et al. [9] explored the economics of NFTs, uncovering unique price dynamics and market behaviours. Their work highlights the need for research that considers the heterogeneity within the cryptocurrency market and its implications for relationships with traditional assets.

Despite recent advancements in cryptocurrency research, several gaps remain in the literature. These include a lack of comprehensive analyses considering a broad range of cryptocurrencies, limited granular analysis of individual stocks and sector-specific relationships, insufficient research on long-term equilibrium relationships, and minimal examination of how relationships vary across different cryptocurrency categories.

Our study aims to address these gaps by providing a comprehensive analysis of long-term relationships between a wide range of cryptocurrencies and individual stocks. We employ cointegration analysis on a large, multi-year dataset to offer a more nuanced understanding of the evolving interactions between traditional and digital finance.

Objectives. The primary objectives of this study encompass several key areas of investigation. We aim to measure and analyse the extent of long-term equilibrium relationships (cointegration) between individual stocks, stock market sectors, and various categories of cryptocurrencies, providing a more granular understanding of market integration than previous aggregate-level analyses. Our research also seeks to investigate how these relationships vary across different cryptocurrency categories and stock market sectors, offering insights into the evolving nature of market integration and identifying patterns that may inform investment strategies and policy decisions.

Furthermore, we intend to analyse how different sectors of the stock market interact with various categories of cryptocurrencies, potentially uncovering synergies or conflicts between traditional industries and emerging blockchain-based technologies. We also aim to determine the most influential factors driving long-term relationships between stocks and cryptocurrencies, such as market capitalization, trading volume, and technological features, to provide insights into the underlying mechanisms of market integration.

By addressing these objectives, this study aims to provide a comprehensive and nuanced understanding of the complex interactions between the stock market and the cryptocurrency ecosystem.

Methodology. This study analyses an extensive dataset from January 2018 to May 2024, covering 401 cryptocurrencies from the Binance exchange and all 30 components of the Dow Jones Industrial Average (DJIA). The cryptocurrency data includes various categories such as Stablecoins, DeFi, Metaverse Tokens, and others, selected based on the trading pairs available with USDT on Binance. The stock market data, sourced from the investor.com historical data repository, covers 10 sectors including Healthcare, Consumer Goods, and Technology. This comprehensive dataset aims to capture a broad spectrum of both the cryptocurrency and stock markets.

To explore long-term relationships between stock and cryptocurrency markets, we use the Johansen cointegration test, suitable for detecting multiple cointegrating relations within time series. Our study conducts pairwise tests between each of the 30 DJIA components and 401 cryptocurrencies, totalling 12,030 Johansen tests. Each pair is first confirmed to be integrated of order one, I(1), via unit root tests. The Johansen test, underpinned by the Vector Error Correction Model (VECM), involves a series of equations to determine the dynamics between the time series, involving long-run and short-run impact matrices, and constants. We utilize both the trace test and maximum eigenvalue test to ascertain the number of cointegrating relationships, testing the null hypothesis of no cointegration against the alternative hypothesis at significance levels of 10%, 5%, and 1%.

Following the pairwise cointegration tests, we conduct a comprehensive statistical analysis of the results to identify patterns and draw meaningful conclusions. This analysis encompasses several key aspects: frequency analysis to calculate the proportion of cointegrating relationships for each DJIA component and cryptocurrency domain; sector-based analysis to aggregate cointegration results by stock market sectors; and cryptocurrency domain analysis to examine cointegration patterns across different cryptocurrency categories.

Additionally, we perform a strength of cointegration analysis, examining the cointegrating coefficients and adjustment speeds in the error correction models for pairs that exhibit cointegration. We also conduct a cross-sectional analysis to explore whether stocks or cryptocurrencies with certain characteristics (e.g., market capitalization, trading volume) are more likely to exhibit cointegration.

This comprehensive methodology allows us to not only identify the existence of long-term equilibrium relationships between the stock market and cryptocurrency market but also to characterize the nature and patterns of these relationships across different sectors and cryptocurrency domains.

Results. The results of our cointegration tests revealed varying degrees of long-term relationships across different stocks and cryptocurrencies. For instance, IBM stocks exhibited cointegration with 230 cryptocurrencies at the 90% significance level, 174 at the 95% level, and 109 at the 99% level. This gradation in cointegration counts across significance levels

was consistent across most stocks analysed, indicating a nuanced relationship between stock prices and cryptocurrency valuations.

Notably, certain stocks demonstrated particularly strong cointegration with the cryptocurrency market. Visa and Walt Disney Company showed the highest number of cointegrating pairs at the most stringent 99% significance level, with 201 and 232 cryptocurrencies respectively. This suggests that these companies' stock prices may have a more robust long-term relationship with cryptocurrency market movements compared to other Dow components.

Our analysis also revealed sector-specific patterns in cointegration relationships. The technology sector, as can be observed on the Table 1, displayed a significant degree of cointegration with platform tokens, with 58% (399 out of 686 observations) and 44% (304 out of 686 observations) showing cointegration at the 90% and 95% significance levels respectively. This finding suggests a strong interaction between technological stocks and cryptocurrencies that serve as foundational platforms for blockchain-based services.

In the financial services sector, we observed notable interactions with decentralised finance tokens. Specifically, 52% (217 out of 420 tests) of the DeFi domain cryptocurrencies showing cointegration with financial services stocks at the 95% significance level, as shown in Table 1. This observation points to the growing integration of traditional financial services with innovative blockchain-based financial technologies.

The energy sector showed varying levels of interaction with notable cointegration observed in several areas, as depicted in Table 1. Interoperability tokens exhibited a strong cointegration rate of 75% (6 out of 8 tests), suggesting a possible connection between energy companies and cross-chain technologies, which may facilitate more efficient energy transactions and data sharing. NFT/Gaming tokens also demonstrated substantial cointegration at 68.97% (20 out of 29 tests), reflecting the potential influence of digital assets and blockchain-based gaming in energy markets. Stablecoins showed a cointegration rate of 57.69% (15 out of 26 tests), indicating a growing interest in using stable, cryptocurrency-backed solutions within the energy sector.

Table 1

Johansen Cointegration Analysis by Cryptocurrency Category and Consumer Goods, Energy, Entertainment, Financial Services and Technology Sectors

Rows represent cryptocurrency categories; columns represent stock sectors. Intersections indicate the percentage of tests with results exceeding the 95% confidence level.

Sector	Consumer Goods	Energy	Entertainment	Financial Services	Technology
DeFi	0.65	0.55	0.81	0.52	0.48
Exchange Tokens	0.64	0.33	0.75	0.55	0.44
Interoperability Tokens	0.67	0.75	0.63	0.35	0.41
Layer 2 Tokens	0.83	0.50	1.00	0.65	0.46
Leverage Tokens	0.61	0.45	0.59	0.56	0.49
Mainstream	0.60	0.44	0.75	0.54	0.53
Meme Coins	0.50	0.00	0.50	0.20	0.21
Metaverse Tokens	1.00	1.00	1.00	1.00	1.00
NFT/Gaming	0.68	0.69	0.72	0.62	0.61
Oracle Tokens	0.72	0.50	0.83	0.40	0.19
Payment Tokens	0.70	0.55	0.82	0.64	0.56
Platform Tokens	0.70	0.40	0.86	0.52	0.44
Privacy Coins	0.56	0.40	0.73	0.53	0.43
Stablecoins	0.71	0.58	0.81	0.62	0.58
Storage Tokens	0.43	0.14	0.71	0.23	0.18
Utility Tokens	0.72	0.45	0.84	0.57	0.51

These interactions highlight the increasing relevance of blockchain technologies and digital assets in enhancing operational efficiencies and financial transactions in the energy industry.

Interestingly, the consumer goods sector showed substantial links with platform tokens, where 70% (205 out of 294) tests displayed cointegration at the 95% significance level, as evident in Table 1. This unexpected finding suggests significant interactions between consumer goods companies and foundational cryptocurrency platforms, potentially indicating the increasing relevance of blockchain technologies in consumer-oriented business models.

The entertainment sector exhibited more significant interactions, as shown in Table 1, most notably with platform tokens, where 85.71% (84 out of 98) of tests indicated cointegration at the 95% significance level. This finding suggests a strong connection between the entertainment industry and foundational cryptocurrency platforms, possibly highlighting the growing integration of blockchain technologies within entertainment business models. Similarly, payment tokens showed an 81.82% (9 out of 11) cointegration rate, reflecting the sector's openness to cryptocurrency payments.

The industrial sector demonstrated significant cointegration with cryptocurrency domains, as shown in Table 2, indicating a substantial interaction between industrial activities and digital assets. Payment tokens showed a high cointegration rate of 63.64% (28 out of 44 tests), suggesting a possibility of strong alignment with industrial operations, likely due to the adoption of cryptocurrency payments for enhancing transaction efficiency. Platform tokens also exhibited notable cointegration at 54.59% (214 out of 392 tests), reflecting the sector's reliance on foundational blockchain technologies to improve logistics, supply chain management, and other industrial processes. Similarly, NFT/Gaming tokens had a cointegration rate of 59.48% (69 out of 116 tests), highlighting the integration of blockchain-based digital assets in the industrial sector.

The healthcare sector also exhibited noteworthy relationships with the DeFi domain, as evident in Table 2, with 57% (193 out of 336) tests showing cointegration at the 95% significance level. This finding suggests that healthcare-related stocks might be significantly

Table 2

Johansen Cointegration Analysis by Cryptocurrency Category and Chemical, Healthcare, Industrial, Retail and Telecommunications Sectors

Rows represent cryptocurrency categories; columns represent stock sectors. Intersections indicate the percentage of tests with results exceeding the 95% confidence level.

Sector	Chemical	Healthcare	Industrial	Retail	Telecommunications
DeFi	0.69	0.57	0.58	0.58	0.38
Exchange Tokens	0.42	0.50	0.44	0.44	0.33
Interoperability Tokens	0.25	0.47	0.41	0.50	0.25
Layer 2 Tokens	0.75	0.31	0.56	0.67	0.25
Leverage Tokens	0.53	0.54	0.52	0.52	0.63
Mainstream	0.53	0.53	0.56	0.54	0.44
Meme Coins	0.50	0.13	0.25	0.33	0.00
Metaverse Tokens	1.00	1.00	1.00	1.00	1.00
NFT/Gaming	0.55	0.64	0.59	0.79	0.45
Oracle Tokens	0.83	0.38	0.63	0.39	0.33
Payment Tokens	0.73	0.66	0.64	0.67	0.64
Platform Tokens	0.55	0.44	0.55	0.59	0.33
Privacy Coins	0.73	0.48	0.53	0.67	0.27
Stablecoins	0.69	0.62	0.59	0.71	0.62
Storage Tokens	0.57	0.14	0.46	0.33	0.00
Utility Tokens	0.65	0.59	0.60	0.63	0.42

influenced by, or are themselves influencing, the decentralised finance sector, pointing to potential intersections between healthcare innovation and blockchain-based financial solutions.

When examining cointegration from the perspective of cryptocurrency domains, we found that platform tokens exhibited the highest number of cointegrations with stock prices. Specifically, 52% (1534 out of 2940) of tests showed cointegration at the 95% significance level. This suggests a significant interaction between stocks and cryptocurrencies that offer a platform for building other blockchain-based services, potentially indicating the growing importance of these foundational cryptocurrencies in the broader financial ecosystem.

The DeFi domain also showed substantial levels of cointegration, with 55.6% (1403 out of 2519) of tests indicating cointegration at the 95% significance level. This highlights the increasing relevance of decentralised financial services in relation to traditional stock market activities and suggests a growing interconnectedness between these two financial spheres.

Notably, the NFT/Gaming domain showed strong cointegration, particularly at the 99% significance level, with 47% (410 out of 870) of tests indicating a relationship. This robust connection between the NFT/gaming sector and the broader stock market may be driven by increased investor interest and growing market capitalization in this emerging area of the cryptocurrency market.

Our analysis of individual cryptocurrencies revealed that several, including ECPX, SLP, and MOB, showed complete cointegration with all 30 stock prices at all significance levels. This suggests a strong and consistent linkage between these specific cryptocurrencies and the stock market. Major cryptocurrencies such as Ethereum and Bitcoin also displayed high levels of cointegration, indicating their significant interaction with traditional financial markets.

Conversely, some cryptocurrencies, particularly newer or less mainstream ones like BNB Bull and NPXS, showed no cointegration

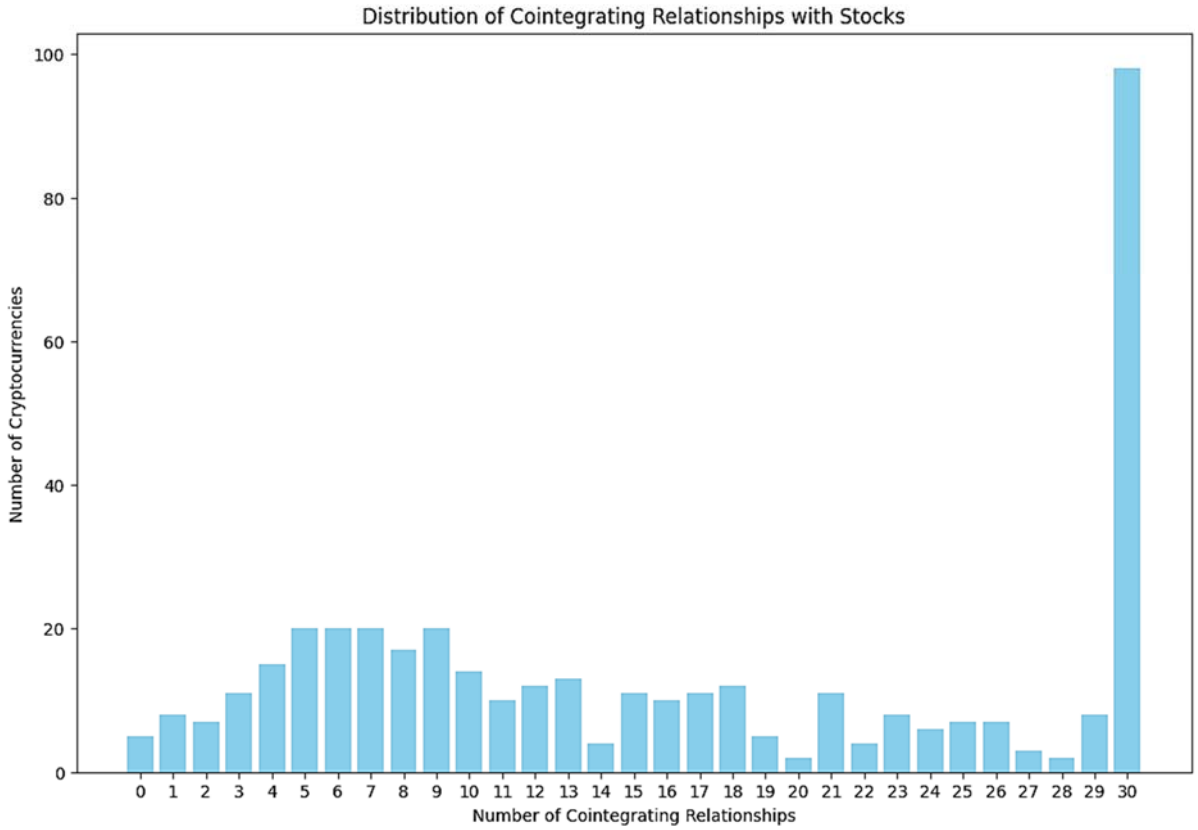

Figure 1. Distribution of Cointegrating Relationships

X-axis represents the number of cointegrating relationships that exceed the 95% significance level according to the Johansen test. Y-axis is the number of cryptocurrencies that have the respective level of cointegrating relationships

with stock prices at any significance level. This suggests independent price movements or less integration with the broader financial markets for these digital assets.

The distribution of cointegrating relationships indicates that while some cryptocurrencies have minimal to moderate integration with the stock market, a substantial number exhibit strong and widespread integration. The large concentration at Level 30 suggests that many cryptocurrencies are significantly influenced by stock market movements, reflecting a high degree of interconnectedness.

In examination of the top 25 cryptocurrencies by average trading volume, we found that stablecoins such as Binance USD and USD Coin showed complete cointegration with all 30 stock prices at all significance levels. This strong linkage with traditional financial markets is likely due to their pegged nature to fiat USD currency.

Emerging cryptocurrencies with significant market presence, such as STEPN (GMT) and Gala, also showed high levels of cointegration, pointing to their growing influence and integration within the broader financial ecosystem. Cryptocurrencies integral to developing blockchain ecosystems, like Polygon (MATIC) and Polkadot, exhibited notable cointegration, suggesting their increasing relevance to stock market movements.

In our analysis of the relationship between the number of cointegrating relationships and the average trading volume of cryptocurrencies, we observed no discernible pattern or consistent correlation. This lack of a clear relationship suggests that trading volume alone is not a reliable predictor of a cryptocurrency's integration with the traditional stock market.

Discussion. The high number of cointegrating pairs observed for companies like Visa and Walt Disney Company suggests that these stocks may have more robust long-term relationships with cryptocurrency market movements compared to other Dow components. This finding contributes to the growing body of literature on the integration of cryptocurrency and traditional financial markets, such as the work by Ciaian et al. [3], who found long-term relationships between Bitcoin and certain macroeconomic variables.

The gradation in cointegration counts across significance levels, consistently observed across most stocks analysed, indicates a nuanced relationship between stock prices and cryptocurrency valuations. This complexity in long-term relationships underscores the need for sophisticated modelling approaches when analysing the interplay between traditional and digital asset markets, as advocated by Mensi et al. [6] in their study of time-varying correlations between Bitcoin and regional financial markets.

Sector-specific patterns in cointegration relationships were particularly noteworthy. The strong interaction observed between technological stocks and platform tokens, as well as between financial services stocks and DeFi tokens, underscores the growing integration of traditional sectors with innovative blockchain-based technologies. These findings extend the work of Caporale et al. [1], who identified sector-specific linkages between cryptocurrencies and traditional assets.

The unexpected finding of substantial links between the consumer goods sector and platform tokens suggests significant interactions between consumer goods companies and foundational cryptocurrency platforms. This observation points to the increasing relevance of blockchain technologies in consumer-oriented business models, potentially indicating a shift in how consumer goods companies approach digital transformation. This finding contributes to the emerging literature on the adoption of blockchain technologies in supply chain management and consumer engagement, as discussed by Saberi et al. [8].

The notable relationships observed between the healthcare sector and the DeFi domain suggest potential intersections between healthcare innovation and blockchain-based financial solutions. This unexpected connection opens up new avenues for research into the application of decentralised finance principles in healthcare funding, insurance, and data management, extending the work of Mackey et al. [5] on blockchain applications in healthcare.

The high levels of cointegration exhibited by platform tokens across various stocks highlight the growing importance of these foundational cryptocurrencies in the broader financial ecosystem. This finding aligns with the increasing recognition of blockchain platforms as critical infrastructure for the future of finance, as discussed by Chen and Bellavitis [2] in their review of blockchain disruption and decentralised finance.

The strong cointegration observed in the DeFi domain underscores the increasing relevance of decentralised financial services in relation to traditional stock market activities. This growing interconnectedness between DeFi and traditional finance suggests a potential convergence

of financial systems, with implications for regulatory frameworks and market structures. This observation extends the work of Schär [7] on the potential of DeFi to reshape traditional financial services.

The robust connection between the NFT/Gaming sector and the broader stock market, particularly at high significance levels, reflects the growing mainstream acceptance and economic impact of digital collectibles and blockchain-based gaming. This finding contributes to the emerging literature on the economics of NFTs, such as the work by Wang et al. [9] on the interplay between NFT markets and traditional asset classes.

Conclusions. Our study expanded on previous research by examining the integration between individual stocks, stock market sectors, and various categories of cryptocurrencies. We found varying degrees of cointegration across different pairs, providing a more nuanced understanding of market integration. Additionally, we observed distinct patterns of cointegration across different stock market sectors, with technology and financial services showing strong links to platform tokens and DeFi tokens, respectively.

Analysis of different cryptocurrency categories revealed that platform tokens had the highest number of cointegrations with stocks, followed by DeFi and NFT/Gaming domains. Some cryptocurrencies showed complete cointegration with all 30 stock prices, while others showed none, highlighting the heterogeneity within the cryptocurrency market. Notably, stablecoins exhibited strong cointegration with stock prices, offering new insights into their role in the broader financial ecosystem.

While our study has made significant contributions to understanding the relationships between cryptocurrencies and traditional financial markets, several areas for future research remain. These include causality analysis to examine the direction of influence, investigation of structural breaks to understand the impact of specific events, and expansion to include global stock markets for a more comprehensive perspective.

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