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IS BITCOIN TIED TO BRICS MARKETS? A DEEP DIVE INTO COINTEGRATION AND WAVELET COHERENCE

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Abstract: *This study explores the dynamic relationship between Bitcoin and BRICS stock markets using cointegration and wavelet coherence analyses. We used daily Bitcoin and BRICS stock market indices from 01 January, 2013 to 31 March, 2024. The findings of the study reveal valuable insights into Bitcoin's utility as an investment asset in emerging markets and its role in financial portfolios. The independence of Bitcoin from traditional markets, particularly in emerging economies like the BRICS nations, has significant implications for portfolio diversification, risk management, and financial stability.*

Keywords: *Bitcoin, BRICS, Cointegration, Cryptocurrency, Wavelet Coherence*

INTRODUCTION

The global economy is transitioning toward a digital ecosystem, and cryptocurrency has emerged as one of the most innovative developments in digital payments. As a decentralized form of electronic cash, cryptocurrency enables transactions directly between parties without the need for financial intermediaries (Corbet et al., 2019). This innovation has led to a growing interest among investors who seek high returns in alternative investment vehicles, moving away from traditional low-yield options. Among cryptocurrencies, Bitcoin stands out with the largest market capitalization and is now widely included in investment portfolios alongside traditional assets like stocks, gold, and oil. Attracted by its high liquidity,

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low transaction costs, and quick transaction times, institutional investors such as banks, investment firms, and hedge funds have also started participating in the cryptocurrency market.

Bitcoin's increasing popularity and market value present both opportunities and challenges for the global financial system, particularly in banking, financial markets, and public financing. Investors globally consider Bitcoin a viable investment vehicle due to its potential as a portfolio diversifier and hedge. However, this growth raises questions about Bitcoin's potential to affect traditional financial markets and impact asset allocation strategies.

A significant focus in recent research has been the relationship between Bitcoin and stock markets in emerging economies, specifically the BRICS nations- Brazil, Russia, India, China, and South Africa. These markets play pivotal roles in the global economy due to their active involvement in trade, financing, and economic activities. Despite being vibrant and offering diversification opportunities, BRICS stock markets are susceptible to shifts in global economic conditions and risk perceptions. Investigating the long-term connections between Bitcoin and BRICS stock markets, along with the wavelet coherence analysis, is therefore essential for understanding potential dependence and independence in these economies.

This study employed the Engle-Granger cointegration test to investigate the long-term relationship between Bitcoin and the stock markets of BRICS countries. The findings reveal that there is no cointegration between Bitcoin prices and the stock markets of BRICS countries. We also conducted a wavelet coherence analysis on Bitcoin and stock market pairs, and the results validate and support the findings of the cointegration study. The absence of cointegration confirms Bitcoin's structural independence from BRICS stock markets, while the wavelet analysis reveals only sporadic short-term synchronization. These findings emphasize Bitcoin's role as a speculative, uncorrelated asset with significant diversification potential but limited utility as a hedge or safe haven for BRICS investors.

1. Review of Previous Literature

The cryptocurrency market, led by Bitcoin, is often perceived as speculative and highly volatile. Bitcoin lacks a fundamentalist segment and is dominated by speculators, noise traders, trend chasers, and short-term investors, making it more of an investment asset than a stable currency (Kristoufek, 2013). As (Özdemir, 2022) emphasizes, the extreme volatility in Bitcoin's price undermines its role as a medium of exchange and unit of account,

especially when compared with more stable global currencies (Yermack, 2013). This volatility, while challenging for traditional currency functions, presents unique opportunities and risks for investors (Bruhn & Ernst, 2022).

Numerous studies highlight the spillover effects and connections between cryptocurrency and stock markets, particularly during times of economic turbulence. (Maitra et al., 2022) found that Bitcoin and Ethereum's spillover effects on stock markets grew significantly during the COVID-19 pandemic. This relationship, explored using copula models, demonstrated increased interconnectedness before and after the pandemic. Similarly, studies by (Ghorbel et al., 2022) using the NARDL model showed a positive asymmetric impact on stock prices by cryptocurrencies like Bitcoin, Litecoin, and Maker. This finding suggests that stock markets respond more intensely to negative shocks from cryptocurrency than to positive ones. These spillover effects extend beyond local markets, with international indices such as the S&P 500 and Dow Jones influencing Bitcoin prices in the short term (Van Wijk, 2013; Gozbasi et al., 2021). Ciaian et al. (2016) and Lamothe-Fernández et al. (2020) discovered a positive relationship between Bitcoin's price and the Dow Jones Index. In contrast, (Zhu et al., 2017) identified a long-term inverse effect of the Dow Jones Index on Bitcoin, showing the potential for diverse impacts from traditional financial markets on Bitcoin. The S&P 500 Index's influence on Bitcoin has been widely examined, with findings indicating a positive association with Bitcoin prices, as well as synchronous movement with Bitcoin returns (Bakas et al., 2022; Jareño et al., 2020; Nguyen, 2022). The Chinese Stock Market Index has similarly shown a significant positive impact on Bitcoin prices (Bouoiyour & Selmi, 2015). Additionally, (Panagiotidis et al., 2018) demonstrated that the Nikkei index positively influenced Bitcoin returns.

Studies by (Ha & Nham, 2022), who used a time-varying parameter vector autoregression (TVP-VAR) model, highlighted that the stock and gold markets are net recipients of shocks transmitted from cryptocurrencies, with spillovers into traditional assets like WTI crude oil. Bampinas & Panagiotidis (2024) further observed cross-market linkages during crisis periods, noting how the East Asian markets led contagion towards cryptocurrencies during COVID-19, while the U.S. stock market played this role during the Russian invasion of Ukraine. Studies such as those by Agrawal (2024) and Isah & Ekeocha, (2024) also emphasize Bitcoin's bidirectional relationship with major indices like Nasdaq and S&P 500, showing the interdependency and mutual predictive power between cryptocurrency and stock markets.

The influence of Bitcoin on various regional markets has been discussed in the previous studies. (Handika et al., 2019) suggest that the Asian stock market remains largely unaffected by Bitcoin, while (Hachicha & Hachicha, 2021) show that the cryptocurrency market is still linked with certain global indices, emphasizing the European and U.S. markets. Hung (2024) found a weak correlation between Bitcoin and the Asia-Pacific markets at higher frequencies, but this dependence increases at lower frequencies, indicating an evolving relationship over time. These results are aligned with findings of Mei-jun & Guang-xi (2024), which documented asymmetric cross-correlations between cryptocurrencies and both G7 and E7 stock markets.

Bitcoin's potential as a hedge and safe-haven asset has been a widely debated topic. Feder-Sempach et al. (2024) and Frikha et al. (2024) documented Bitcoin's role as a weak safe haven for indices like the S&P 500 and FTSE 100 during financial distress. Manzli & Jeribi (2024) extended this perspective, showing that Bitcoin (alongside gold) serves as a strong safe-haven asset during crises such as the COVID-19 pandemic and the Russia-Ukraine conflict. These findings align with Ali et al. (2024), who identified green cryptocurrencies as receivers of return and volatility spillovers from G7 markets, particularly during times of market stress and uncertainty. A number of studies demonstrate the significant, often asymmetric impact of major indices like NASDAQ, DAX, and S&P 500 on stock market returns in both developed and emerging markets. (Lahiani et al., 2021) found that these indices play dominant roles in forecasting stock returns, particularly within the BRICS and G7 nations. Within the BRICS markets, Brazil's stock market was the most effective predictor of stock market returns, while India's BSE 30 showed some predictive strength for cryptocurrency returns, they also explored that Ethereum has the leading role in predicting cryptocurrencies and stock market returns followed by Bitcoin.

While prior research has shed light on short-term volatility, spillovers, and speculative trading within the cryptocurrency market, there remains a significant gap in understanding the long-term relationships between Bitcoin and the BRICS stock markets. Existing studies are predominantly focused on developed markets (G7, S&P 500, Nasdaq), with limited emphasis on emerging markets, particularly BRICS nations. With the growing influence of BRICS countries in global finance and trade, their market dynamics have increasingly intertwined with Bitcoin, yet the depth and durability of these connections remain underexplored. Given that Bitcoin adoption rates in emerging economies have been rising- especially as an investment and remittance vehicle- understanding its long-term relationship with BRICS stock markets is

critical. This study aims to bridge this gap, exploring whether Bitcoin exhibits a stable, long-term relationship with BRICS markets and how this could impact global financial integration and investment strategies.

2. Data and Research Methodology

This study is characterised by an analytical approach. We obtained daily closing prices of Bitcoin and BRICS stock market indices, covering the period from 01 January 2013, to 31 March 2024. The abbreviations and sources for each variable in the dataset are shown in **Table.1**. Since Bitcoin is traded every day, including weekends and holidays, there was a non- synchronization with the stock market indices. To address this issue, weekends and holidays were excluded from the dataset.

Table.1 Description of variables

Abbreviation	Full Name	Market/ Asset	Source
Bitcoin	Bitcoin	Cryptocurrency	coinmarketcap.com
BVSP	Bovespa Index	Brazilian Stock Market Index	finance.yahoo.com
MOEX	MOEX Russia Index	Russian Stock Market Index	finance.yahoo.com
BSE SENSEX	BSE SENSEX	Indian Stock Market Index	finance.yahoo.com
SSEC	Shanghai Composite Index	Chinese Stock Market Index	finance.yahoo.com
FTSE JSE	FTSE/JSE All Share Index	South African Stock Market Index	investing.com

Source: Authors' construction

Level data was used to test the cointegration among variables. We calculated the log returns of Bitcoin and BRICS's stock market indices for wavelet analysis. The calculation of the log return is presented below:

$$Log\ Return = \log(P_t / P_{t-1})$$

$$P_t = Price\ at\ the\ time\ t$$

$$P_{t-1} = Price\ at\ the\ time\ t-1$$

Engle-Granger cointegration test

The Engle-Granger cointegration test is a statistical method used to analyse the presence of a long-term equilibrium relationship between two non-stationary time series. The method follows a two-step procedure. First, the individual series are tested for stationarity using a unit root test, such as the Augmented Dickey-Fuller (ADF) test, to verify that they are non-stationary at levels and integrated of the same order, typically I (1). In the latter step, an ordinary least squares (OLS) regression is conducted, and the residuals from

this regression are tested for stationarity using another unit root test. If the residuals are found to be stationary, it indicates the presence of cointegration, suggesting that the variables maintain a stable long-term relationship despite short-term deviations.

Wavelet coherence

To provide a thorough explanation of wavelet coherence, it is necessary to first define cross-wavelet transform and cross-wavelet power. The cross-wavelet transform of the two time series $x(t)$ and $y(t)$ is defined as follows:

$$W_{xy}(u,s) = W_x(u,s)W_y^*(u,s)$$

where, $W_x(u,s)$ is continuous wavelet transform of $x(t)$ and $W_y(u,s)$ is continuous wavelet transform of $y(t)$

Wavelet coherence analysis examines the interconnection between two variables and the dynamics of lead-lag relationship over several time and frequency domains. This technique can be employed for both linear and non-linear time series (Torrence & Compo, 1998). A coherence score of 1 signifies absolute coherence, whereas a score of 0 denotes entire incoherence. The coherence coefficient is determined by squaring the local correlation coefficient derived from data of two time series. A wavelet phase difference is employed to ascertain the phase disparity between two time series to reveal their lead-lag relationship. The mathematical expression is as follows:

$$R^2(u,s) = \frac{\left|S\left(s^1 W_{xy}(u,s)\right)\right|^2}{S(s^{-1}|W_x(u,s)|^2)S\left(s^{-1}\left|W_y(u,s)\right|^2\right)}$$

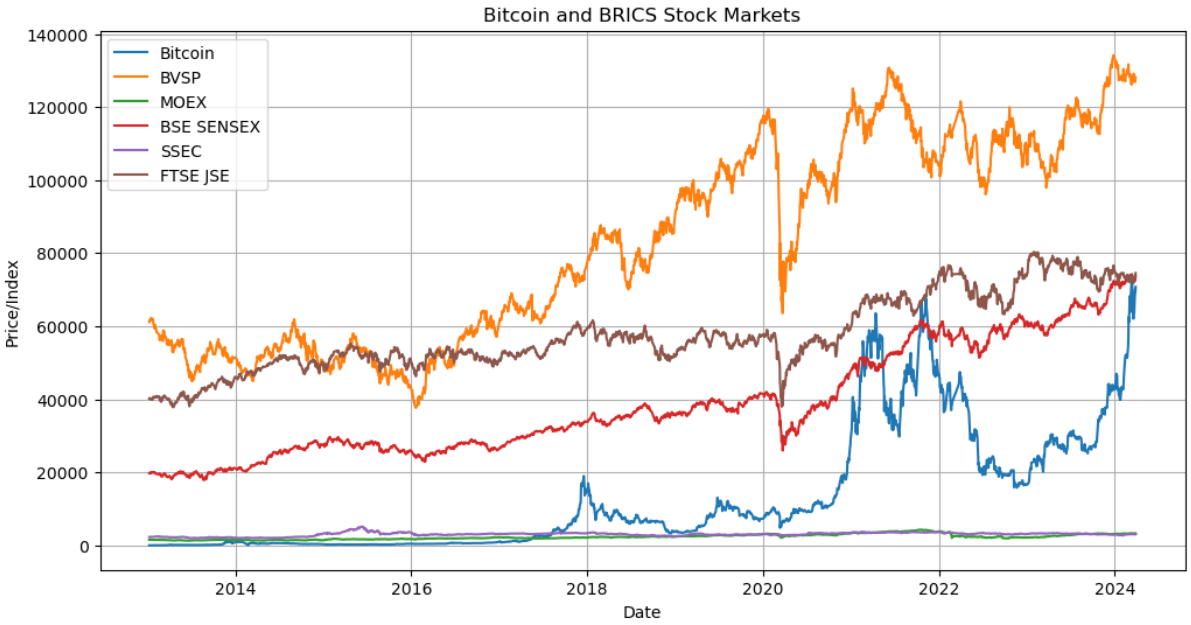
We also use wavelet coherence phase differences in the study. The wavelet coherence phase difference equation is given as follows:

$$\Phi_{xy}(u,s) = \tan^{-1}\left(\frac{\mathrm{Im}\left\{S\left(s^{-1}W^{xy}(u,s)\right)\right\}}{\mathrm{Re}\left\{S\left(s^{-1}W^{xy}(u,s)\right)\right\}}\right)$$

3. Results and Discussion

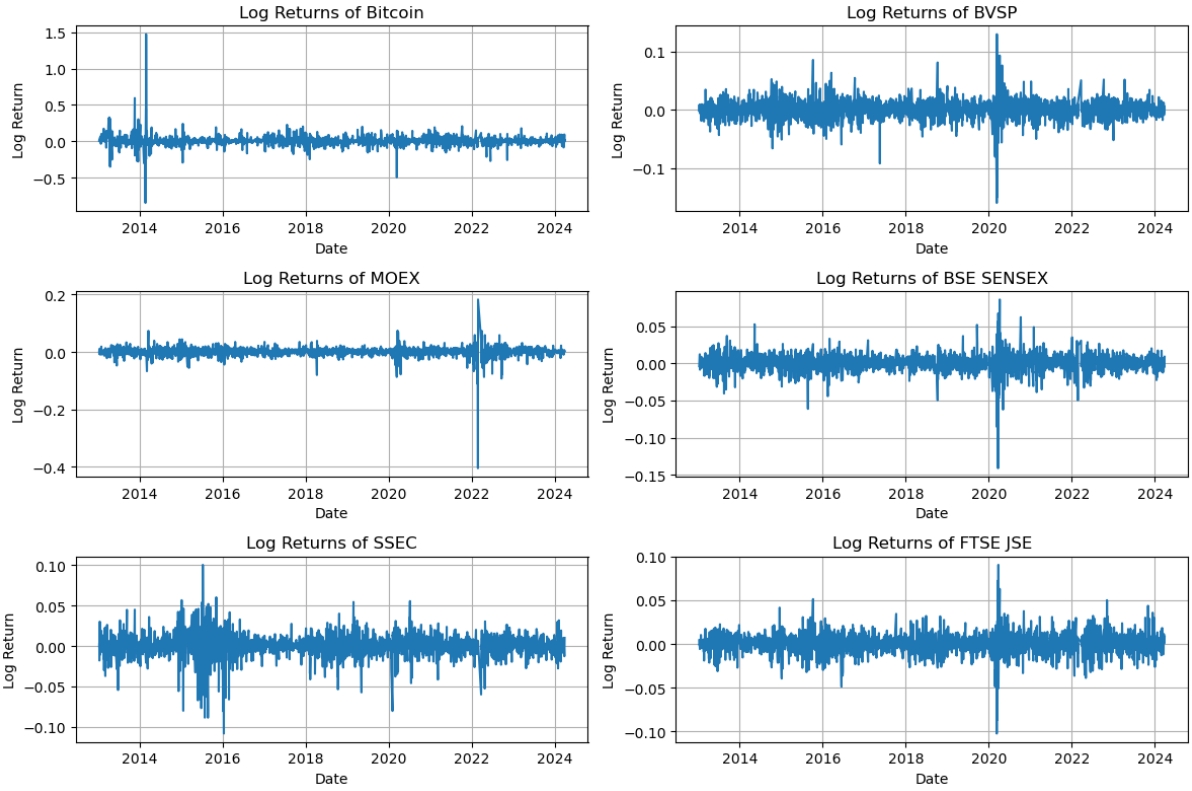
The daily prices of Bitcoin and BRICS stock market indices are exhibited in **Fig.1**, while **Fig.2** displays their respective daily log returns.

Fig. 1 Daily Bitcoin Price and BRICS's Stock Market Indices



Source: Authors' graph

Fig. 2 Log Return of Bitcoin Price and BRICS's Stock Market Indices



Source: Authors' graph

Table. 2 presents the descriptive statistics of daily returns for Bitcoin and five stock indices: BVSP, MOEX, BSE SENSEX, SSEC, and FTSE JSE. Bitcoin demonstrates the highest mean return (0.00364) and standard deviation (0.06839), indicating superior average performance and significant volatility relative to traditional markets. SSEC exhibits the lowest mean return (0.00012), accompanied by moderate volatility (0.01394). Skewness and kurtosis values show how a distribution is spread out. Bitcoin has a high positive skewness (3.36) and an extreme kurtosis (108.15), which means that there are a lot of large positive outliers. In contrast, MOEX displays a pronounced negative skewness (-6.27) and exceptionally high kurtosis (163.01), indicating severe negative outliers. Traditional indices typically exhibit reduced skewness and kurtosis, signifying more stable and symmetric distributions. The FTSE JSE is the most similar to normality. This points to the significant differences in risk and return characteristics between cryptocurrencies and traditional equity markets.

Table. 2 Descriptive statistics of Bitcoin and BRICS stock market returns

Basic Statistics	Count	Mean	Std Dev	Min	Max	Skewness	Kurtosis
Bitcoin	2343	0.00364	0.06839	-0.84883	1.47418	3.359504	108.1545
BVSP	2343	0.00031	0.01673	-0.15993	0.130223	-0.70641	12.69151
MOEX	2343	0.00033	0.01653	-0.40467	0.18262	-6.26781	163.005
BSE SENSEX	2343	0.00056	0.01143	-0.14102	0.085947	-1.09572	16.8871
SSEC	2343	0.00012	0.01394	-0.10832	0.100453	-0.85936	8.622791
FTSE JSE	2343	0.00026	0.01171	-0.10227	0.090484	-0.33407	8.111996

Source: Authors' calculation

Table. 3 Augmented-Dickey Fuller test for stationarity

Stationarity test	Level series		Log differenced series	
	ADF test	Stationarity	ADF test	Stationarity
Bitcoin	-0.2884 (0.9271)	Not stationary	-20.1817 (0.0000)	Stationary
BVSP	-1.0137 (0.7483)	Not stationary	-8.8864 (0.0000)	Stationary
MOEX	-1.3004 (0.6290)	Not stationary	-9.8313 (0.0000)	Stationary
BSE SENSEX	0.5812	Not stationary	-12.1841	Stationary

	(0.9871)		(0.0000)	
SSEC	-2.5600 (0.1016)	Not stationary	-10.0568 (0.0000)	Stationary
FTSE JSE	-1.6025 (0.4823)	Not stationary	-17.5265 (0.0000)	Stationary

Source: Author Calculation

The first step in the analysis involves testing for the stationarity of the individual series using the Augmented Dickey-Fuller (ADF) test. **Table. 3** exhibits the ADF test results. The results indicate that all series are non-stationary at levels but achieve stationarity upon first differencing. Since all variables are non-stationary at level and integrated of the same order, I (1), this satisfies the prerequisite for conducting a cointegration test, allowing us to explore potential long-term equilibrium relationships between Bitcoin and the BRICS stock market indices. This analysis examines the pairwise cointegration relationships between Bitcoin and the BRICS stock market indices, utilizing the Engle-Granger cointegration test. We conducted an ordinary least squares (OLS) regression for each pair in the initial step. In the second step, we tested the stationarity of the regression residuals using the Augmented Dickey-Fuller (ADF) test. **Table. 4** presents the results of the pairwise Engle-Granger cointegration test. The results demonstrate that none of the examined pairs, which include Bitcoin and the BRICS stock indices (BVSP, MOEX, BSE SENSEX, SSEC, and FTSE JSE), show a cointegrating relationship. The ADF test statistics for the residuals across all pairs do not reject the null hypothesis of a unit root, indicating non-stationarity of the residuals. This indicates the absence of a long-term equilibrium relationship between Bitcoin and the traditional stock indices in BRICS nations.

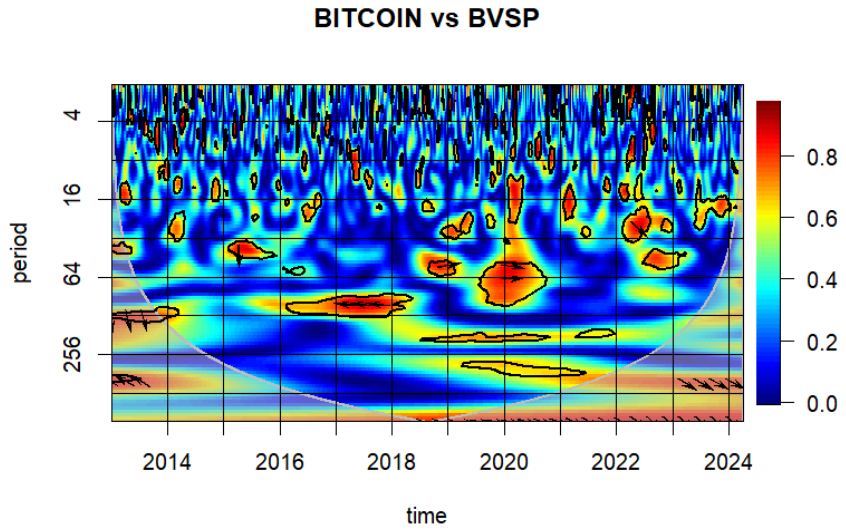
Table. 4 Pairwise Engle-Granger cointegration result

Cointegration relationships	**ADF test statistics of residuals**	**H0: a = 1** *(Residuals have unit roots)*	**Cointegration/ No cointegration**
Bitcoin- BVSP	-1.0137 (0.7483)	Failed to Reject	No cointegration
Bitcoin- MOEX	-1.3004 (0.6290)	Failed to Reject	No cointegration
Bitcoin- BSE SENSEX	0.5812 (0.9871)	Failed to Reject	No cointegration
Bitcoin- SSEC	-2.5600 (0.1016)	Failed to Reject	No cointegration
Bitcoin- FTSE JSE	-1.6025 (0.4823)	Failed to Reject	No cointegration

Source: Author Calculation

We employed wavelet coherence analysis, alongside cointegration analysis, to examine the relationships between Bitcoin and BRICS stock markets across different time and frequency domains. Using a biwavelet approach, we analysed the co-movement and phase differences between these markets. The wavelet coherence plots use a colour spectrum ranging from dark blue to red to illustrate the intensity of coherence between each pair. Colours from yellow to red indicate high coherence, while blue denotes low coherence. The y-axis of the plot represents the frequency domain, where high frequencies correspond to shorter periods and low frequencies to longer periods, while the x-axis represents time.

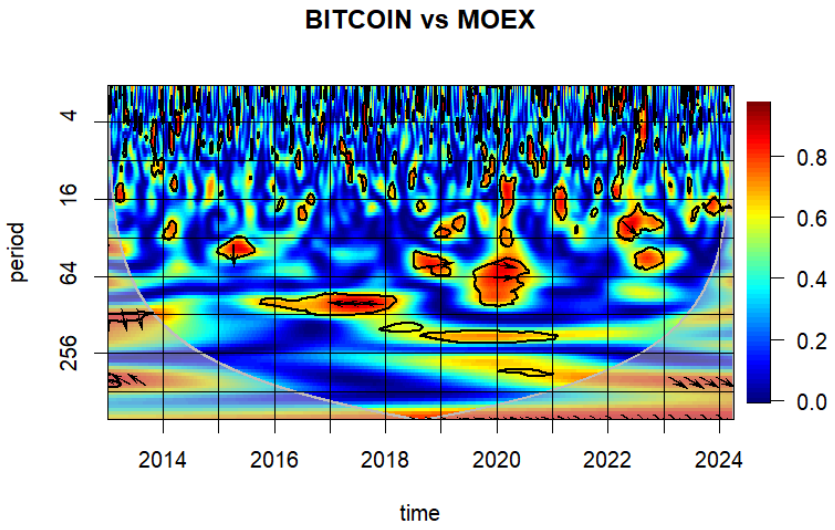
Fig. 3 Wavelet coherence among Bitcoin and BVSP



Source: Authors' graph

Fig. 3 depicts the wavelet coherence between Bitcoin and Brazil's stock market index (BVSP). Blue shades dominate the plot, indicating a lack of coherence between the two markets. We reported instances of coupling effects, particularly between 2016 and 2018, at extended time scales (128-256 periods). During 2019-2020, a notable "red island" appears in the medium-frequency range (16-64 periods), coinciding with the COVID-19 pandemic and the resultant global crisis. Post-2020, a discernible reduction in coherence indicates a decoupling trend between Bitcoin and BVSP.

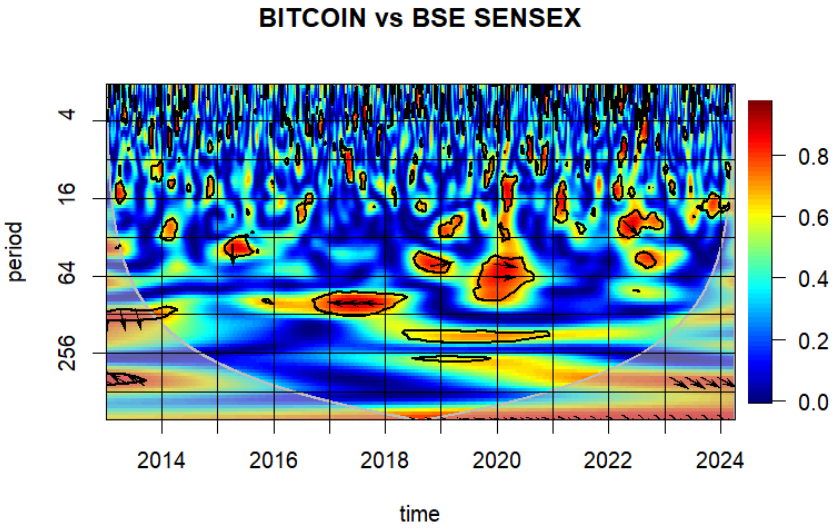
Fig. 4 Wavelet coherence among Bitcoin and MOEX



Source: Authors' graph

Fig. 4 illustrates the wavelet coherence between Bitcoin and the Russian stock market index. Blue regions largely dominate the plot, indicating weak overall coherence. Nonetheless, several red areas are apparent, indicating intervals of significant coherence, especially at long time scales before 2020. We observed significant co-movement across both short and medium time periods between 2020 and 2022. This timeframe aligns with significant global events such as the COVID-19 pandemic, geopolitical conflicts involving sanctions against Russia, and the volatility of oil prices due to Russia's invasion of Ukraine. Following 2022, the coupling effect weakened, signifying a separation between Bitcoin and the Russian stock market.

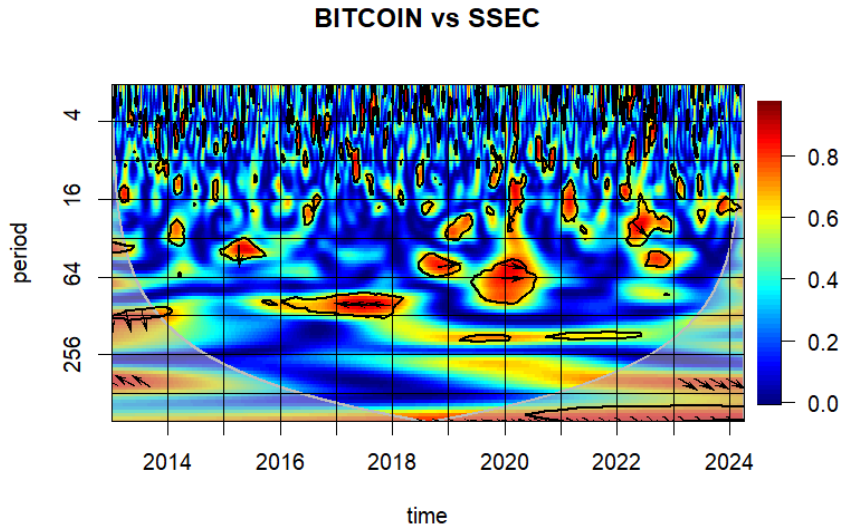
Fig. 5 Wavelet coherence among Bitcoin and BSE SENSEX



Source: Authors' graph

Fig. 5 displays the wavelet coherence between Bitcoin and the BSE Sensex. Prior to 2017, weak coherence is evident. Afterwards, we observe coherence on long and medium-time scales. Post-2020, there is a noticeable decline in coherence. In 2022, coherence emerges in medium and short time frames, only to dissipate shortly thereafter.

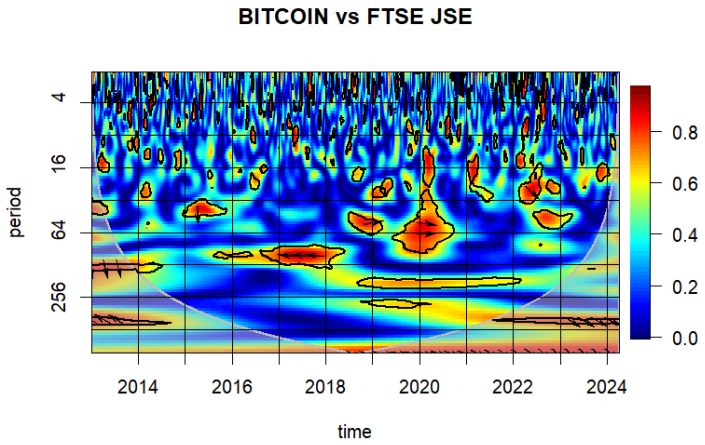
Fig. 6 Wavelet coherence among Bitcoin and SSEC



Source: Authors' graph

Fig. 6 portrays the wavelet coherence between Bitcoin and the Shanghai Composite Index. The plot primarily displays notable blue regions, especially prior to 2020 and following 2021, suggesting a general independence between Bitcoin and the Chinese stock market. Between 2018 and 2020, several regions exhibited moderate to high coherence at medium time scales.

Fig. 7 Wavelet coherence among Bitcoin and FTSE JSE



Source: Authors' graph

Fig.7 illustrates the coherence between Bitcoin and the Johannesburg Stock Exchange All Share Index. Significant blue regions are evident across various time scales during the early periods, particularly before 2018 and in certain areas after 2021. This indicates bitcoin's independence from the South African stock market during the specified periods. We identified regions exhibiting moderate to high coherence during the period from 2018 to 2020.

The lack of consistent arrows in all the wavelet coherence plots suggests a lack of a stable lead-lag relationship between bitcoin and the stock markets. Phase differences in the plots likely signify short-term synchronization rather than a sustained dynamic.

4. Conclusion

This study demonstrates Bitcoin's structural independence from BRICS stock markets, indicated by the lack of cointegration and the consistently low wavelet coherence observed across various time and frequency scales. The absence of cointegration suggests that Bitcoin does not maintain a stable, long-term relationship with BRICS indices, highlighting its function as an alternative asset class that operates independently of the economic dynamics influencing traditional equity markets. Speculative forces, technological adoption, and regulatory developments, rather than the economic fundamentals supporting BRICS stock markets, seem to primarily drive the price movements of Bitcoin. Bitcoin functions as a speculative, decentralized asset, offering notable diversification potential for portfolios primarily composed of BRICS equities, yet it has restricted effectiveness as a hedge or safe haven.

Wavelet coherence analysis indicates that Bitcoin and BRICS stock markets demonstrate intermittent, short-term synchronisation, predominantly during times of increased global financial stress. In times of crisis, Bitcoin often correlates with speculative market sentiment, reducing its utility as a hedge or safe haven. In contrast to conventional safe-haven assets like gold or government bonds, Bitcoin exhibits traits of a "risk-on" asset, rendering it more appropriate for speculative trading instead of acting as a dependable store of value or a safeguard against market fluctuations. The results indicate that Bitcoin may improve portfolio diversification in stable market environments; however, it does not provide the necessary stability for reliable protection during volatile times.

This study highlights the necessity for investors and policymakers to acknowledge Bitcoin's unique dynamics in comparison to traditional equity markets, especially in emerging economies such as BRICS. The decentralized, unregulated, and volatile

characteristics of Bitcoin highlight its detachment from BRICS markets, positioning it as a valuable component in diversified portfolios, particularly for investors interested in non-traditional assets. Nonetheless, its speculative characteristics require meticulous allocation and proactive risk management. The differing regulatory approaches of BRICS nations- spanning from stringent prohibitions in China to developing frameworks in India- underscore Bitcoin's separation from these markets. Future regulatory changes may affect short-term coherence; however, they are unlikely to facilitate long-term integration with traditional markets. Overall, Bitcoin's independence and speculative characteristics position it as a unique global asset that complements, rather than substitutes, traditional investment strategies.

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