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Do cryptocurrencies and gold hedge against market risks? A wavelet coherence analysis of ASEAN+2 and G5 countries

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ABSTRACT

Stock market volatility, economic shocks, and geopolitical tensions have intensified recently, resulting in heightened uncertainty and disruptions in global financial markets with ASEAN+2 and G5. Identifying reliable hedging and safe haven assets is therefore critical for risk management. Moreover, effective hedging and safe haven strategies are important to reduce the risk of a portfolio for investors and help keep the market stable by lowering market contagion and boosting investor confidence. Therefore, this study examines the hedge and safe-haven properties of various cryptocurrencies, Bitcoin, Bitcoin Cash, Cardano, Chainlink, Dogecoin, Ethereum, Ripple, and Tron, and gold against stock markets in ASEAN+2 (Indonesia, Malaysia, Singapore, Thailand, Vietnam, China, and Russia) and G5 countries (France, Germany, Japan, the United Kingdom, and the United States) over the period 2017–2024. The findings, derived from wavelet coherence analysis, reveal that these properties are not uniform but vary significantly by market, investment horizon (particularly beyond 128 days), and period (e.g., during crises vs. stability). This study underscores the limitation of static correlation-based methods and highlights the importance of wavelet coherence in revealing short-, medium-, and long-term correlations that traditional methods may overlook. The results provide crucial insights for investors and policymakers to enhance financial stability through better anticipation of market dynamics.

Contribution/ Originality: This study contributes to existing research by exploring the time-frequency correlation between eight cryptocurrencies and gold with the stock markets of ASEAN+2 and G5 countries through wavelet coherence analysis. It provides new insights into how these assets co-move with stock markets across different investment horizons and market regimes, thereby enhancing understanding of their hedging, diversification, and safe haven properties during periods of market turmoil and stability.

1. INTRODUCTION

Cryptocurrencies are digital assets that have grown in importance in the global investing scene. They have been claimed as digital gold and serve as an alternative to gold as a store of value due to their decentralized (Arnone, 2024). Even though cryptocurrencies are relatively new, people continue to use them to store wealth and hedge against portfolio risk (Singh, Singh, & Ansari, 2024). However, increasing market volatility and the magnification of financial shocks by various crises create a need to seek true assets that can mitigate investment risk (Manzli, Alnafisah, & Jeribi, 2024).

Liquidity risk always affects the stock market, impacting asset pricing and portfolio returns, especially during financial and health crises. Diversification remains a useful approach to reducing risk during such times (Demirci, Ferreira, Matos, & Sialm, 2022). Investors seek risk mitigation solutions against market downturns. Therefore, assessing whether cryptocurrency can protect against market declines, like gold, is crucial.

The outbreak of COVID-19 and the Russia-Ukraine war have both significantly affected the stock market by causing a sharp decline (Tarchella, Khalfaoui, & Hammoudeh, 2024). The COVID-19 pandemic has triggered the largest turbulence in global financial markets since the 1930s (Liu & Yuan, 2024; Tarchella et al., 2024). Investors seek to reduce their portfolio risk during market turbulence. Since then, scholars have continued to focus on this financial contagion (Matos, Costa, & Da Silva, 2021; Shen, Feng, & Sun, 2024). Likewise, cryptocurrencies and gold emerged as favored hedging and haven instruments during market turbulence (Riahi, Bennajma, Jahmane, & Hammami, 2024).

Cryptocurrencies have become popular investments owing to their decentralised nature and high return (Liu & Yuan, 2024). According to Yarovaya, Matkovskyy, and Jalan (2022), cryptocurrency recovered faster after a crisis than other financial assets, suggesting it may be a potential alternative investment during crises. However, debate exists on whether cryptocurrencies are investments or speculative assets (Liu & Yuan, 2024). Likewise, there are studies that concluded that gold does not exhibit safe haven characteristics (Cheema, Faff, & Szulczyk, 2022). Still, there are studies that have concluded that gold is still a better hedge in contrast to gold (Ameur, Jamaani, & Alfoul, 2024; Dutta, Das, Jana, & Vo, 2020; Long, Pei, Tian, & Lang, 2021). As such, it is vital to determine the potential of digital assets such as cryptocurrencies for diversification purposes (Cheema et al., 2022; Corbet, Hou, Hu, Oxley, & Xu, 2021).

Following the past literature, there are limited studies focusing on the correlation between cryptocurrencies and major stock indices (Singh et al., 2024). According to Bhuiyan, Mukherjee, Tarique, and Zhang (2025), most previous research concentrates on Bitcoin and developed stock markets. Therefore, this study will examine more cryptocurrencies beyond Bitcoin. Additionally, few studies focus on emerging financial markets such as ASEAN+2. Consequently, this research will include both emerging and advanced markets to offer a more comprehensive analysis. Furthermore, there is no consensus on the hedge and safe haven abilities of cryptocurrencies and gold in the stock market (Manzli et al., 2024; Stensås, Nygaard, Kyaw, & Treepongkaruna, 2019). The hedge and safe haven abilities of cryptocurrencies and gold are found to be time-varying and market-dependent (Kakinuma, 2022; Karim, Abdul-Rahman, Hwang, & Kadri, 2021; Ustaoglu, 2023). Additionally, cryptocurrencies are not homogeneous, and their hedging and safe haven abilities differ (Majumder, 2022). Overall, the properties of cryptocurrencies in the stock market are still debated. This study aims to contribute insights into this ongoing discussion, providing up-to-date information through 2024.

Additionally, most of the past literature has utilized regression models to determine the relationship between cryptocurrency and stocks without capturing the time-varying behavior of cryptocurrency and gold against the stock market. Given the time-varying nature of interactions between financial assets, it is imperative to utilize methods that can capture both the temporal dynamics and frequency-specific attributes of co-movement simultaneously. Wavelet coherence is especially appropriate for this objective, as it offers a localized assessment of correlation in the time-frequency domain and facilitates the investigation of scale-dependent relationships that conventional time series might miss. Likewise, the phase difference information from wavelet coherence allows the identification of lead-lag relationships, which are not available in conventional regression. Thus, this study will contribute insights into both the time-frequency domain, which is overlooked by conventional methods in previous studies.

This study offers several novel contributions to the existing literature. Firstly, it determines whether various cryptocurrencies share common power in the time-frequency space. Secondly, it compares cryptocurrencies with gold to inform better investment decisions. Thirdly, the study employs wavelet coherence to analyze the magnitude and strength of hedge and safe haven abilities of cryptocurrencies and gold against the stock market in ASEAN+2 and

G5 countries across different horizons and periods. This approach differs from traditional time series models, which are limited to stationary data and cannot jointly determine dynamic relationships in the time-frequency domain. Fourthly, the sample covers the period from 2017 to 2024, providing the latest insights. Consequently, investors and policymakers can adopt more effective financial strategies. Overall, the study investigates how cryptocurrencies interact with financial markets in ASEAN+2 and G5 countries using wavelet coherence analysis, revealing time-frequency patterns that highlight the hedge properties of cryptocurrencies and gold across various periods and horizons. The paper is organized into sections on the literature review, methodologies, results, discussions, and conclusions.

2. LITERATURE REVIEW

The prospect theory and flight to safety both guide the idea of a hedge and safe haven in a stock portfolio. Generally, prospect theory is a psychological theory proposed by Kahneman and Tversky (1979), who claimed that people make decisions based on perceived losses or gains. In cases of equal probability of loss and gain, people tend to prioritize securing their losses rather than maximizing gains. Likewise, the behavioral finance concept of "flight to safety" or "flight to quality" illustrates that investors tend to seek safe-haven assets during market downturns. Prospect theory explains the behavioral rationale of investors, while the flight to safety concept involves selecting assets to protect investments. Both theories indicate that investors are risk-averse during market downturns and tend to move their capital into hedge or safe-haven assets, which exhibit low or negative correlation with stocks during such periods. This underscores the importance of identifying appropriate hedge instruments to mitigate risks effectively.

Following past studies, both cryptocurrency and gold, which serve as potential hedges against the stock market, deserve interest for investors. Several previous studies revealed the hedge and safe haven abilities of cryptocurrencies against stock markets. Firstly, studies from Jana and Sahu (2025); Kayral, Jeribi, and Loukil (2023); Tan, Ling, Sim, and Ming (2023); Widarto, Muharam, Wahyudi, and Pangestuti (2022), and Bouri, Gkillas, and Gupta (2020) supported that the hedge and safe haven capabilities of cryptocurrencies against the stock market are time-varying, as some studies have revealed. These properties fluctuate over different periods, affecting their effectiveness as financial safeguards. For instance, Karim et al. (2021) agreed that cryptocurrencies possess diversification benefits in the ASEAN-5 stock market only in the short run. Jiang, Lie, Wang, and Mu (2021) discovered that Ethereum is the most effective diversifier in the short term. Garcia-Jorcano and Benito (2020) also concluded that the hedging abilities of Bitcoin are only effective in the short term. Kumar, Kumar, and Singh (2023) found that the role of cryptocurrencies is time-varying. Additionally, Korsah, Mensah, Osei, and Amewu (2026); Tarchella et al. (2024), and Tan et al. (2023) indicated that the hedging role of cryptocurrencies is reliant on the markets. Still, there is literature denying the hedge capability of cryptocurrencies (Conlon, Corbet, & McGee, 2020; Kakinuma, 2022; Lavelle, Yamamoto, & Kinnen, 2022; Thampanya, Nasir, & Huynh, 2020). Hereafter, the hedge and safe haven capabilities of different cryptocurrencies remain inconclusive.

Apart from that, there are several literatures indicating that gold is a strong hedge and safe haven against the stock markets (Kakinuma, 2022; Vieira, De Carvalho, Curto, & Laureano, 2023; Wen, Tong, & Ren, 2022; Yousaf, Bouri, Ali, & Azoury, 2021). Similarly, the hedge and safe haven ability of gold is found to be context and market-dependent (Bahloul, Mroua, & Naifar, 2023; Brayek, Ameur, & Alharbi, 2024; Thuy, Oanh, & Ha, 2024). Additionally, some studies have concluded that the hedge and safe haven ability of gold varies over time. For instance, Hossain, Ismail, Akter, and Hossain (2020) also stated that the hedging ability of gold is only short-lived. Baur and Lucey (2010) concluded that gold is short term hedge against the US and German stock markets, limited to 15 trading days. Gold is more appropriate as a long-term safe haven during COVID-19 (Xu & Kinkyo, 2023). Belhassine and Riahi (2025) showed that gold displayed hedge and safe haven capabilities in medium- and long-term horizons. Studies from Ameur et al. (2024) and Klose (2022) compared the hedge and safe haven abilities of cryptocurrencies and gold and

concluded that gold is a better hedge and safe haven in contrast to cryptocurrencies. Still, there are studies that denied the hedge and safe haven capability of gold in stock markets, for instance, Sinlapates, Sriwong, and Chancharat (2023), Kakinuma (2022), and Chemkha, Bensaida, Ghorbel, and Tayachi (2021).

In addition, there is a contextual gap that arises where the existing empirical studies focus only on the advanced financial markets from the US and Europe (Manzli et al., 2024; Tarchella et al., 2024; Xu & Kinkyo, 2023). Even though there is a vast volume of literature investigating the hedging and safe haven features of cryptocurrencies and gold during the last decades, there are limited studies focusing on emerging countries (Bhuiyan et al., 2025). Likewise, although gold has been extensively examined as a potential hedge and safe haven against the stock market, the empirical studies of the hedge and safe haven properties of various cryptocurrencies remain inconclusive and unexplored. Also, most of the past literature focuses on the pioneer cryptocurrency, Bitcoin, and the developing stock market (Bhuiyan et al., 2025). As the hedging and safe haven efficiency of cryptocurrencies and gold against the stock market are found to differ across countries and periods (Belhassine & Riahi, 2025; Brayek et al., 2024; Jiang et al., 2021; Korsah et al., 2026; Tarchella et al., 2024). A detailed examination of the hedging and safe haven capabilities of cryptocurrencies and gold is needed to address these empirical gaps. Additionally, past studies only covered the initial waves of COVID-19 (Ballis, Drakos, Kallandranis, Anastasiou, & Doan, 2025; Lamine, Jeribi, & Fakhfakh, 2024); Later waves, such as the Omicron variation (December 2022), are overlooked (Vo, 2023). The absence of empirical studies covering this wave creates a gap, as it remains uncertain whether gold and cryptocurrencies maintained their hedging role during this unique crisis phase.

Additionally, there is a methodological gap because most of this earlier empirical research generated findings primarily based on the coefficient results from classic regression, without fully examining the magnitude and strength of correlation across different horizons and periods. Although an asset may display a negative connection on average to lower overall portfolio risk, this does not necessarily translate to risk reduction from a time-frequency perspective. Traditional time series, which rely on the stationarity assumption, fail to capture the time-frequency-dependent relationship between assets and overlook the time-varying correlation across different time horizons (Rubbaniy, Khalid, Syriopoulos, & Samitas, 2022). Investors with different investment horizons might not gain practical insights.

Furthermore, although macroeconomic factors might affect hedge and safe haven behavior between asset classes, this study does not aim to explain all factors influencing crypto prices. Bivariate wavelet coherence provides sufficient visual and statistical insights into the direct pairwise interactions between primary assets over time and frequencies. Haq, Maneengam, Chupradit, and Huo (2023) stated that bivariate wavelet coherence can accurately capture relationships between two series. A multivariate model, which includes more variables, complicates interpretation and may dilute the focus of this study. Similarly, the studies from Hu and Si (2021) and Hu and Si (2016) both clarified that increasing the number of variables is not beneficial in explaining the relationship if the variables are cross-related. Likewise, there are studies from Ali, Sargon, and Hadi (2024); Jana, Pandey, and Sahu (2024); Kumah, Odei-Mensah, and Baaba Amanamah (2022), and Nkrumah-Boadu, Owusu Junior, Adam, and Asafo-Adjei (2022) employed the use of the bi-wavelet technique to study the hedge, safe haven, and diversification for stock markets.

3. METHODOLOGY

3.1. Data

This study covered a period of observations from 10 November 2017 until 31 December 2024, encompassing the COVID-19 pandemic and the Russia-Ukraine war, which brought unprecedented volatility, structural breaks, and shifts in market dynamics. It extended beyond the initial waves of COVID-19, reaching the later phase marked by the emergence of the Omicron variant in early December 2021, a period often overlooked by past studies (Vo, 2023). Therefore, the critical phase of COVID-19 in this study covered from 1 January 2020 until 31 December 2021, as referenced in studies by Khan, Fifield, and Power (2024) and Ghorbel, Loukil, and Bahloul (2024). The period of the Russia-Ukraine war is defined from 24 February 2022 to 31 December 2022, in line with the studies from Gheorghe

and Panazan (2023) and Tanase (2023), who considered this time frame as a comprehensive time series for analysis. 24 February 2022 is widely known as the beginning of the full-scale invasion of Ukraine by Russia (Chumachenko, Dudkina, Chumachenko, & Morita, 2023; Hilmar, 2025), while ending the timeframe on 31 December 2022 establishes a clear analytical boundary encompassing the first year of invasion, capturing the immediate epidemiological effect. The remaining periods are regarded as periods of stability. Incorporating both events is critically important to reveal how different systemic risks affect the time-frequency relationship between the cryptocurrency or gold and the stock market.

Besides, all the daily closing prices are converted to USD to ensure consistency and enable comparability across countries and cryptocurrencies before calculating log returns. Additionally, since the stock market closes during weekends, cryptocurrency prices are removed for those days to align the dataset with the same trading days, consistent with studies by Kumah et al. (2022) and Junior, Kwaku Boafo, Kwesi Awuye, Bonsu, and Obeng-Tawiah (2018). This removal prevents the underestimation of correlation caused by non-synchronous data. As wavelet coherence is robust to non-stationary data (Boamah, Opoku, & Zamore, 2024; Matar, Al-Rdaydeh, Ghazalat, & Eneizan, 2021; Rubbaniy et al., 2022), it helps to preserve the original time-frequency structure without distorting the true frequency nature, and hence, no data preprocessing was conducted (Amewu, Akosah, & Armah, 2024; Chavez & Cazelles, 2019). Mishra and Debasish (2022) also agreed that preprocessing is unnecessary, as the wavelet transform embraces the non-stationarity characteristic of raw data to provide meaningful time-frequency patterns.

Moreover, all the variables used in this study are sourced from reliable databases such as Investing.com and the World Gold Council. Cryptocurrencies such as Bitcoin, Bitcoin Cash, Cardano, Chainlink, Dogecoin, Ethereum, Ripple, and Tron are chosen based on top market capitalization and were founded before 2018. A comparison with gold provides meaningful insights to evaluate whether cryptocurrencies truly function as a modern hedge or safe haven. The study also covers emerging stock markets from ASEAN+2 (Indonesia, Malaysia, Singapore, Thailand, Vietnam, China, and Russia) and the advanced stock market G5 (France, Germany, Japan, the United Kingdom, and the United States). Analyzing both developing and developed stock markets is crucial due to their differences in volatility, investor behavior, and regulatory frameworks. Understanding the unique characteristics of each market ensures reliable assessments of the hedging and safe haven capabilities of cryptocurrencies and gold across different stock markets. Table 1 shows the summary of variables used in this study.

Table 1. Summary of variables.

Variables	Descriptions	Sources
BTC	Logarithm Return of Bitcoin	Investing.com
BCH	Logarithm Return of Bitcoin Cash	Investing.com
ADA	Logarithm Return of Cardano	Investing.com
LINK	Logarithm Return of Chainlink	Investing.com
DOGE	Logarithm Return of Dogecoin	Investing.com
ETH	Logarithm Return of Ethereum	Investing.com
XRP	Logarithm Return of Ripple	Investing.com
TRX	Logarithm Return of Tron	Investing.com
G	Logarithm Return of Gold	World Gold Council
JKSE	Logarithm Return of Jakarta Stock Exchange Composite Index	Investing.com
KLCI	Logarithm Return of FTSE Bursa Malaysia KLCI Index	Investing.com
STI	Logarithm Return of Straits Times Index	Investing.com
SETI	Logarithm Return of Stock Exchange of Thailand Index	Investing.com
VN	Logarithm Return of Vietnam Index	Investing.com
SSEC	Logarithm Return of Shanghai Stock Exchange Composite Index	Investing.com
IMOEX	Logarithm Return of MOEX Russia Index	Investing.com
FCHI	Logarithm Return of CAC 40 Index	Investing.com
GDAXI	Logarithm Return of Deutscher Aktienindex Index	Investing.com
N225	Logarithm Return of Nikkei 225 Index	Investing.com
FTSE	Logarithm Return of Financial Times Stock Exchange Index	Investing.com
SPX	Logarithm Return of Standard & Poor 500 Index	Investing.com

3.2. Wavelet Coherence – Continuous Wavelet Transform (WC-CWT)

The wavelet coherence is a non-parametric method that does not rely on the normality, linearity, and stationarity assumptions. Unlike conventional methods such as bivariate cross-quantilogram, DCC-GARCH, and rolling window approaches, these methods ignore the frequency dependencies of the data in estimations (Rubbaniy et al., 2022). Using wavelet coherence allows simultaneous capture of both time and frequency dimensions. This study is motivated to use wavelet coherence for several reasons. Firstly, wavelet coherence can deal with non-stationary behaviour (Matar et al., 2021; Rubbaniy et al., 2022), which is prevalent in financial data. Financial data, such as the return of cryptocurrencies, gold, and stocks, are inherently non-stationary and exhibit time-varying co-movements. Second, wavelet coherence provides insights into the time-frequency relationship between assets, capturing both the magnitude and directions of correlation across different investment horizons simultaneously. Third, wavelet coherence is especially useful for capturing asset relationships during times of structural change (Fruehwirt, Hochfilzer, Weydemann, & Roberts, 2021), such as the COVID-19 pandemic and the Russia-Ukraine war, where the relationship between the assets might vary across the horizons. Likewise, there are also existing studies such as Kumah et al. (2022), Abdul-Rahim, Khalid, Karim, and Rashid (2022), and Rubbaniy et al. (2022) that study the hedge and safe haven properties of assets through wavelet analysis. Due to wavelet coherence's advantages over other methods, this study employed it to investigate the comovement of cryptocurrency and gold with stocks. The following describes wavelet coherence in detail.

The wavelet coherence is computed through the continuous wavelet transform. As the discrete wavelet transform is only applicable to stationary data (Ming, Shen, Yang, Zhu, & Zhu, 2020), continuous wavelet transforms, which are designed specifically to treat the non-stationary data, therefore favour this study. In the case of two time series i and j, the cross-wavelet spectrum as shown in Equation 1.

$$W_X(\tau,s) = \frac{1}{\sqrt{s}}\int_{-\infty}^{+\infty} x(t)\psi^*\left(\frac{t-\tau}{s}\right)dt \qquad (1)$$

$$W_{i,j}(\tau,s) = W_i(\tau,s)W_j^*(\tau,) \qquad (2)$$

Where $x(t)$ denotes the time series, the input signal is to be analysed, while * denotes the conjugation.

Later, the wavelet coherence, $R^2(\tau,s)$ proposed by Torrence and Compo (1998) computes the cross-wavelet power to show the area with higher covariance between two time series at each scale, as shown in Equation 3.

$$R_{ij}^2(\tau,s) = \frac{\left|S'\left(s^{-1}W_{ij}(\tau,s)\right)\right|^2}{S'(s^{-1}|W_i(\tau,s)|^2)S'\left(s^{-1}|W_j(\tau,s)|^2\right)} \qquad (3)$$

Where S' is a smoothing operator in both time τ and scale s stabilize the coherence measure, $W_{ij}(\tau,s)$ is the cross wavelet transform combines the wavelet transform of time series i and j. The resulting value should lie between 0 and 1. For the interpretation, the higher the value, the higher the co-movement between the two-time series.

However, it fails to reveal the negative and positive co-movement between two time series. Therefore, Torrence and Compo (1998) suggested using the phase difference between the time series i and j, $\emptyset_{ij}(\tau,s)$ as defined in Equation 4.

$$\emptyset_{ij}(\tau,s) = tan^{-1}\left(\frac{lm\left\{S\left(s^{-1}W^{ij}(\tau,s)\right)\right\}}{Re\left\{S(s^{-1}W^{ij}(\tau,s)\right\}}\right) \qquad (4)$$

Where lm and Re the imaginary and real parts of the smoothed cross wavelet transform, respectively. The wavelet coherence is computed through a Monte Carlo simulation with 1,000 randomizations to robustly assess the significance of the coherence produced.

The strength and magnitude of the hedge and safe haven of cryptocurrencies and gold are therefore interpreted based on the arrow, colour, and horizons on the wavelet coherence heatmap. According to Rubbaniy et al. (2022), the right-pointing arrow, "←" in the wavelet coherence plot indicates a negative relationship, while the left-pointing arrow, "→" indicates a positive relationship. The upward-rightward-pointing arrow, "↗", indicates a leading effect of the first time series, while the downward-leftward-pointing arrow, "↙", indicates a leading effect of the second series.

The downward-rightward-pointing arrow, "↘", indicates a positive relationship with the leading effect of the second time series, while the upward-leftward-pointing arrow, "↖", indicates a negative relationship with the leading effect of the first time series.

Likewise, the warmer the colour in the wavelet coherence heatmap, the higher the coherence between the two-time series. The colour ranges from dark blue (0, weak correlation) to red (1, strong correlation). According to Abdul-Rahim et al. (2022), a negative co-movement with a value approaching -1.0 (hot red colour with arrow ←) represents a strong safe haven, while a positive co-movement with a value approaching 1.0 (hot red colour with arrow →) represents a diversifier. The value between 0.2 and 0.6 (light blue to greenish area) denotes a hedger, while a value less than 0.2 (dark blue area) indicates a weak safe haven. Additionally, the black contours in the diagram show regions where wavelet coherence is statistically significant at the 5% level. The white bell-shaped line in the wavelet coherence plots is the cone of influence.

Furthermore, the investment horizon is further interpreted according to short-term, medium-term, and long-term. The definitions of these terms are clarified as referring to the article proposed by Phillips and Gorse (2018). The short term is defined as a 2-to-8-day period. The medium term refers to an 8-to-32-day period, while the long term denotes a 32-to-256-day period. The upper limit of 256 days was chosen to represent one year of trading, aligning with previous financial studies (Kumah et al., 2022; Rehman, Khan, Abbas, & Alhashim, 2023; Sahabuddin et al., 2022) and to avoid reducing the reliability of findings at larger scales, the continuous wavelet transform uses information from neighboring data sets at any point. Therefore, areas at the beginning and end of the samples should be viewed cautiously (Rehman et al., 2023).

Later, as motivated by Su, Wang, Lobonţ, and Qin (2023) and Ming et al. (2020), the robustness of the wavelet coherence heatmap is validated through comparison of heatmaps generated from datasets at different frequencies. In this study, the wavelet coherence heatmap is computed from daily datasets and compared with those from weekly datasets. This approach verifies whether the coherence results differ across dataset frequencies. If the wavelet coherence heatmaps from both daily and monthly datasets show consistent coherence overall, the findings are considered robust.

Table 2. Descriptive statistics of variables.

Variables	Mean	Min.	Max.	σ	Skewness	Kurtosis
BTC	0.00	-0.52	0.25	0.04	-0.95	17.07
BCH	-0.00	-0.60	0.41	0.07	0.03	12.54
ADA	0.00	-0.53	0.88	0.07	2.35	30.91
LINK	0.00	-0.68	0.49	0.07	-0.01	11.33
DOGE	0.00	-0.50	1.47	0.08	4.23	68.29
ETH	0.00	-0.60	0.35	0.06	-0.78	14.24
XRP	0.00	-0.54	0.62	0.07	1.25	20.96
TRX	0.00	-0.57	0.97	0.07	2.66	39.93
G	0.00	-0.05	0.05	0.01	-0.31	7.01
JKSE	-0.00	-0.10	0.11	0.01	-0.58	15.64
KLCI	-0.00	-0.06	0.06	0.01	-0.13	9.90
STI	0.00	-0.08	0.09	0.01	-0.22	18.08
SETI	-0.00	-0.12	0.07	0.01	-1.43	21.39
VN	0.00	-0.07	0.05	0.01	-0.99	7.38
SSEC	0.00	-0.09	0.08	0.01	-0.37	9.40
IMOEX	-0.00	-0.45	0.19	0.02	-3.97	76.25
FCHI	0.00	-0.14	0.09	0.01	-0.66	14.56
GDAXI	0.00	-0.14	0.11	0.01	-0.42	15.12
N225	0.00	-0.12	0.10	0.01	-0.38	11.39
FTSE	0.00	-0.13	0.10	0.01	-0.94	18.97
SPX	0.00	-0.13	0.09	0.01	-0.84	18.35

Note: BTC-Bitcoin, BCH-Bitcoin Cash, ADA-Cardano, LINK-Chainlink, DOGE-Dogecoin, ETH-Ethereum, XRP-Ripple, TRX-Tron, G-Gold, JKSE-Indonesia, KLCI-Malaysia, STI-Singapore, SETI-Thailand, VN-Vietnam, SSEC-China, IMOEX-Russia, FCHI-France, GDAXI-Germany, N225-Japan, FTSE-United Kingdom & SPX-United States.

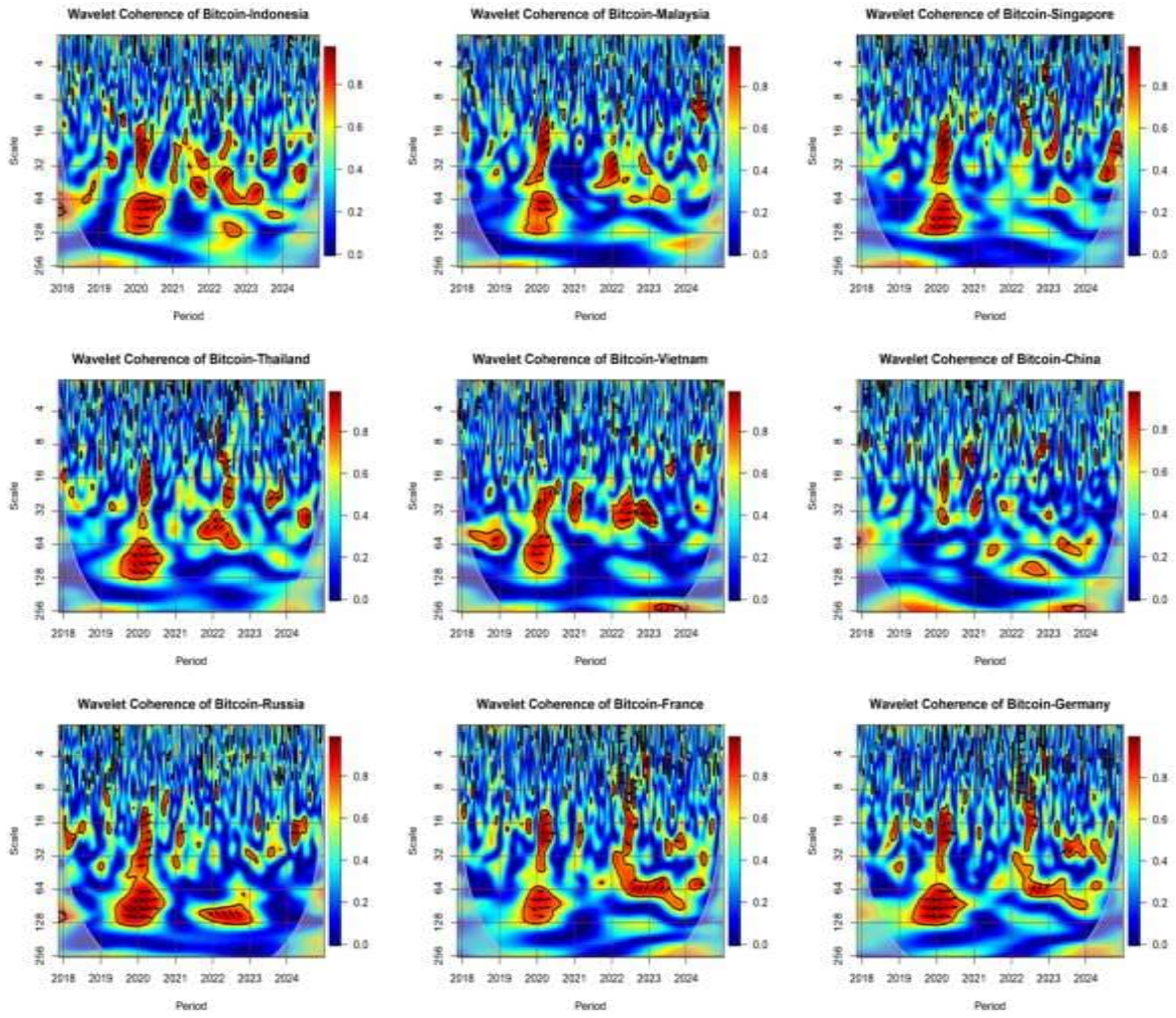
4. RESULTS AND DISCUSSIONS

4.1. Descriptive Statistics

The descriptive statistics of the variables used in this study are presented in Table 2. Overall, the average return of all cryptocurrencies, gold, and stocks is positive, except for Bitcoin Cash, Indonesia (JKSE), Malaysia (KLCI), and Russia (IMOEX). The return of gold has a lower standard deviation compared to all cryptocurrencies, implying that gold is less volatile than cryptocurrencies. Additionally, all cryptocurrency returns showed higher standard deviations than stock markets, indicating that cryptocurrencies are more volatile than stocks. Dogecoin, which exhibited the largest standard deviation, suggests it is the most volatile asset. Most cryptocurrencies and gold demonstrated high skewness, indicating that these assets exhibit more negative returns than positive returns, except for Bitcoin Cash, Cardano, Dogecoin, Ripple, and Tron. Likewise, high kurtosis observed across all assets indicates fat tails, sharp peaks, and asymmetry, suggesting non-linearity. This justifies the use of the wavelet transform to model the returns and analyze their correlation over time.

4.2. Wavelet Coherence

This section discusses the wavelet coherence heatmap of cryptocurrencies and gold with the ASEAN+2 and G5 stock markets, as shown in Figures 1 to Figure 9. The study found that short-term co-movement of cryptocurrency-stocks and gold-stocks pairs is unpredictable, with random movements observed.



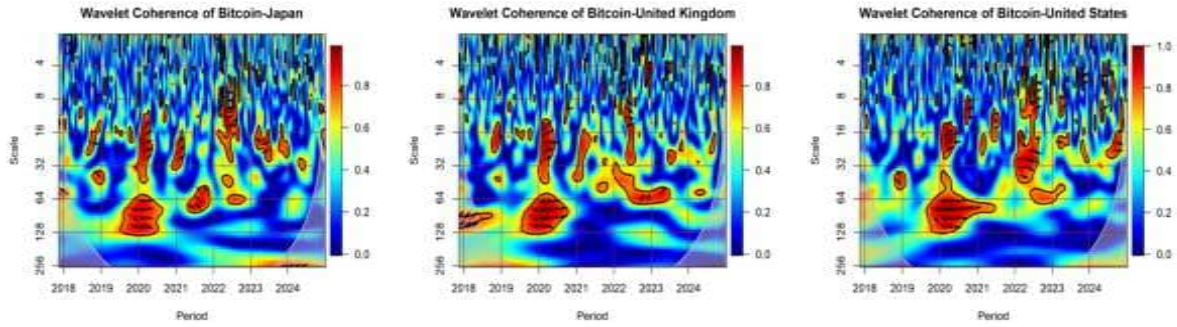
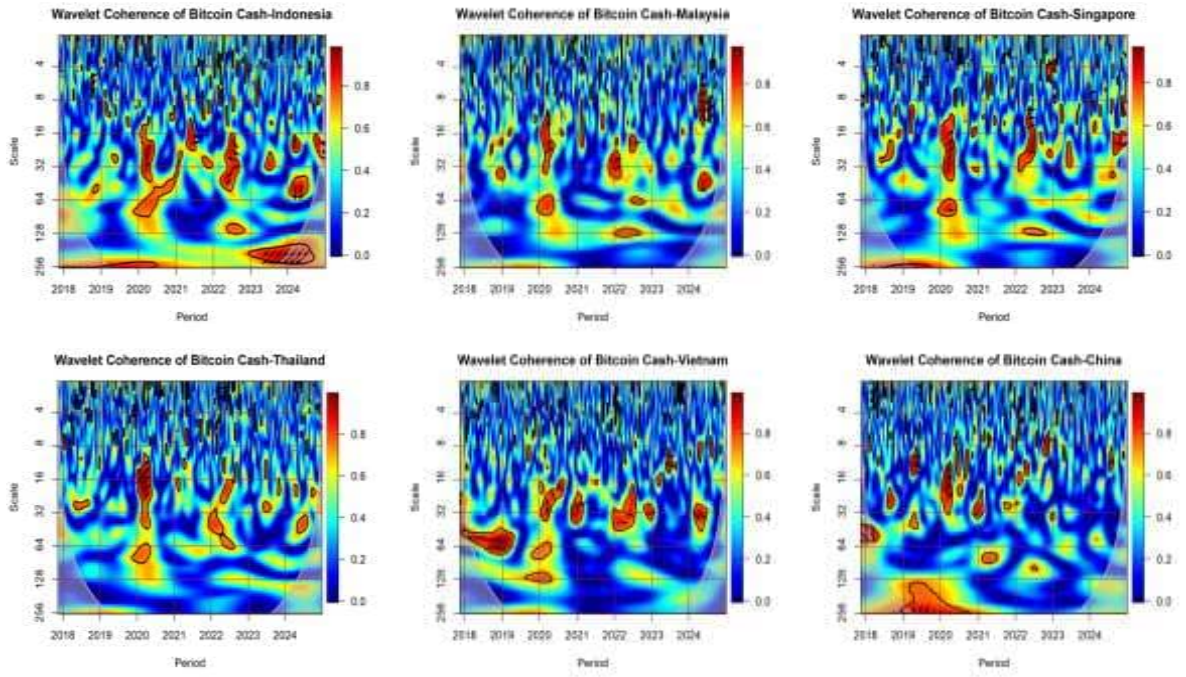


Figure 1. Wavelet Coherence Heatmap of Bitcoin-Stock Pairs.

Note: Indonesia-JKSE, Malaysia-KLCI, Singapore-STI, Thailand-SETI, Vietnam-VN, China-SSEC, Russia-IMOEX, France-FCHI, Germany-GDAXI, Japan-N225, United Kingdom-FTSE & United States-SPX, Periods of COVID-19:1 January 2020 until 31 December 2021, Periods of Russia-Ukraine War: 24 January 2022 until 31 December 2022.

Based on Figure 1, Bitcoin is considered merely a weak hedge or diversifier for up to 256 days before the stock market, before COVID-19. Yet, during the early outbreak of COVID-19, there was significant positive coherence observed in the medium-long term (8 to 128 days), implying that Bitcoin acted as a diversifier during that period and horizon, consistent with findings in Abdul-Rahim et al. (2022). Overall, Bitcoin showed no safe haven ability against the stock markets of ASEAN+2 and G5 during the pandemic. Later in 2022, Bitcoin was merely a diversifier against the ASEAN+2 and G5 stock markets during the Russia-Ukraine war across all investment horizons up to 128 days, supported by the study from Ustaoglu (2023). Only the Bitcoin-Russia pair showed a significant negative coherence in the long term (100 to 128 days), implying that Bitcoin is a strong safe haven against Russia's stock market during this period, especially during the Russia-Ukraine war, when Bitcoin is found to lead Russia's stock market. Although Kayral et al. (2023) concluded that Bitcoin is a safe haven against G7 countries, this study found that Bitcoin only exhibited weak safe haven properties against Thailand, Russia, and the United States during the war. During 2023 and 2024, most Bitcoin-stock pairs are dominated by areas of red to yellowish across the horizons; little greenish to blue color is observed, indicating Bitcoin serves mainly as a diversifier against the stock markets of ASEAN+2 and G5 during this period. Still, Bitcoin demonstrated a strong hedge in the long term (>128 days) in Singapore and the United Kingdom.



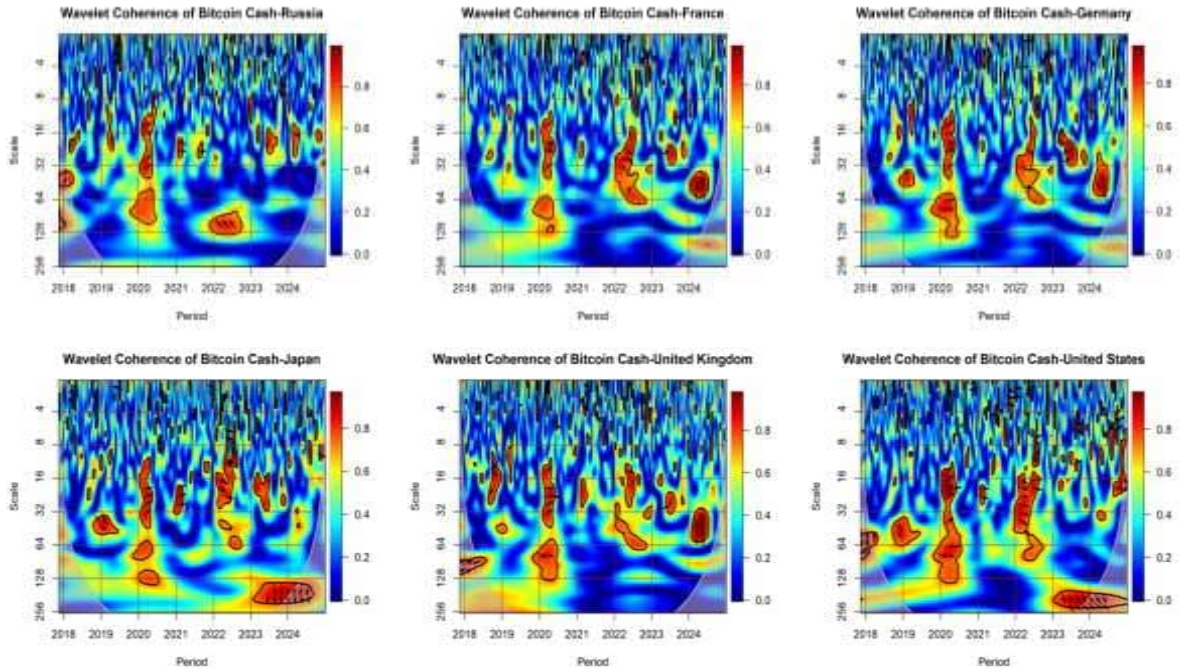
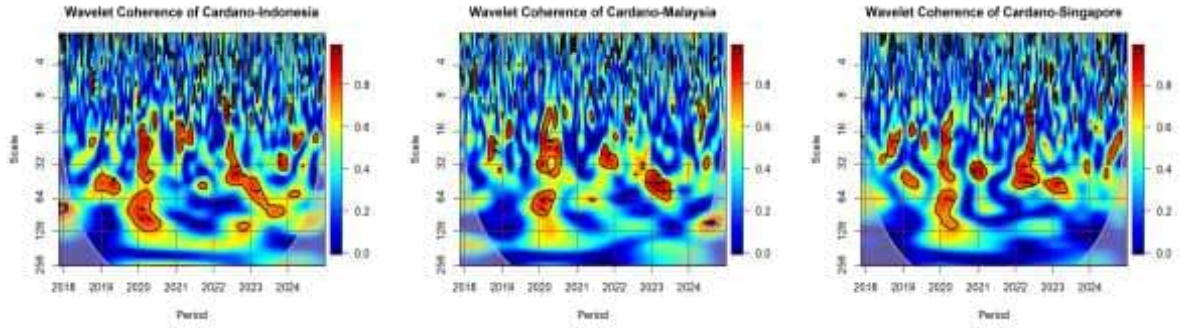


Figure 2. Wavelet coherence heatmap of Bitcoin Cash-stock pairs.

Note: Indonesia-JKSE, Malaysia-KLCI, Singapore-STI, Thailand-SETI, Vietnam-VN, China-SSEC, Russia-IMOEX, France-FCHI, Germany-GDAXI, Japan-N225, United Kingdom-FTSE, United States-SPX. Periods of COVID-19: 1 January 2020 until 31 December 2021. Periods of the Russia-Ukraine War: 24 January 2022 until 31 December 2022.

Refer to Figure 2, none of the Bitcoin Cash-stock pairs showed persistent hedges before COVID-19. However, significant positive coherence was found during 2020 in the medium to long term (8 to 128 days) for all Bitcoin Cash-stock pairs, implying that Bitcoin Cash does not hedge the stock market of ASEAN+2 and G5 in the respective period and horizon. Additionally, Bitcoin Cash only demonstrated a strong safe haven against the Vietnam stock market during the early outbreak of COVID-19 in the medium term, between 16 and 32 days, leading Vietnam's stock market. However, this hedging effect faded later in 2021. During 2022, most Bitcoin Cash stock pairs served only as diversifiers across various time horizons. Only Bitcoin Cash-Russia demonstrated a strong safe haven in the long term (100 to 128 days) during the Russia-Ukraine war, with Bitcoin Cash leading the Russian stock market. Similarly, Bitcoin Cash showed weak safe haven properties only against France and Germany in the long term (> 128 days) during the political conflict. Moreover, Bitcoin Cash-Indonesia, Bitcoin Cash-Malaysia, Bitcoin Cash-Singapore, Bitcoin Cash-Vietnam, Bitcoin Cash-Russia, and Bitcoin Cash-United Kingdom also exhibited hedging properties in 2023 and 2024 in the long term (> 128 days).



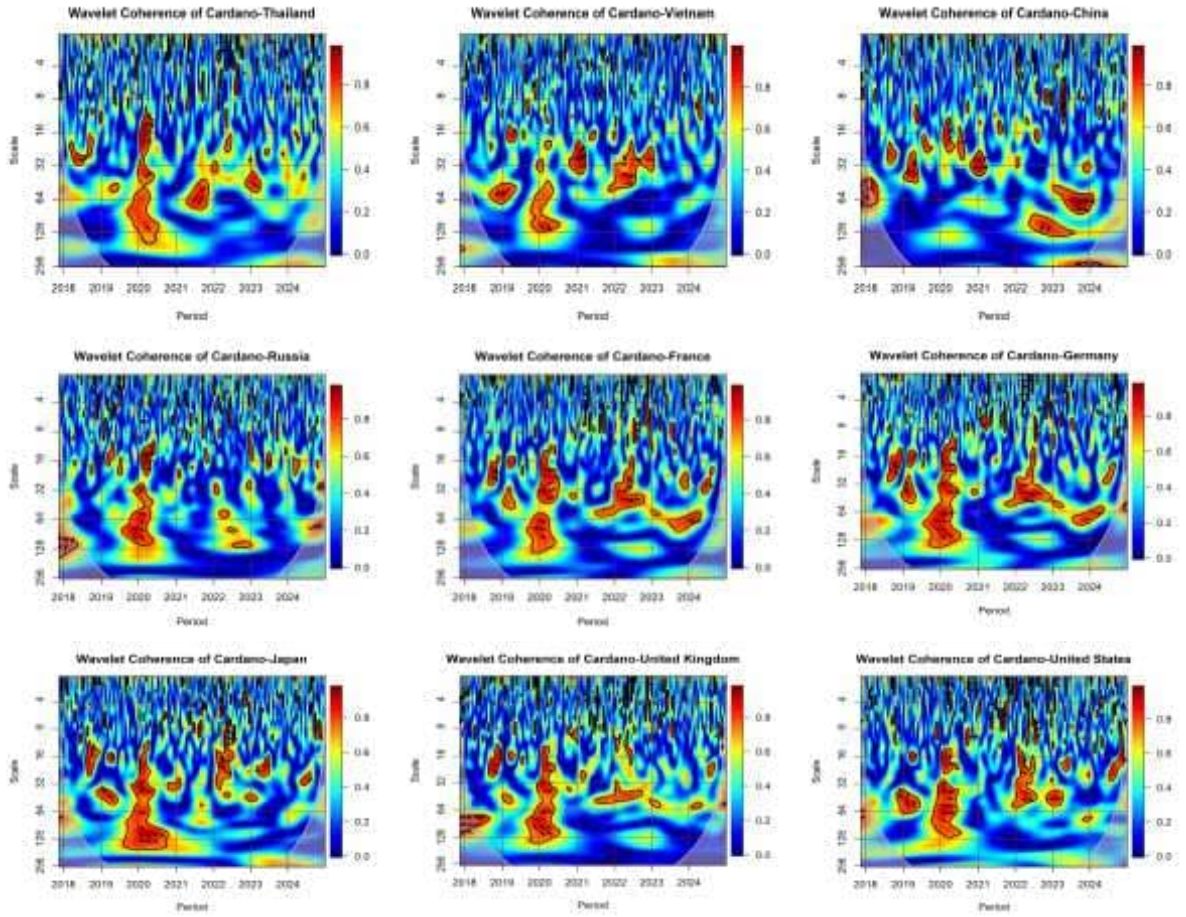
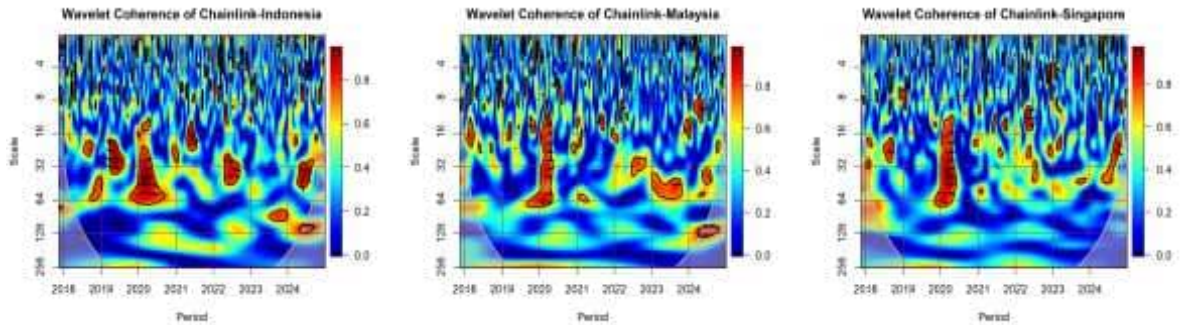


Figure 3. Wavelet Coherence Heatmap of Cardano-Stock Pairs.

Note: Indonesia-JKSE, Malaysia-KLCI, Singapore-STI, Thailand-SETI, Vietnam-VN, China-SSEC, Russia-IMOEX, France-FCHI, Germany-GDAXI, Japan-N225, United Kingdom-FTSE, United States-SPX. Periods of COVID-19: 1 January 2020 until 31 December 2021. Periods of the Russia-Ukraine War: 24 January 2022 until 31 December 2022.

As shown in Figure 3, only Cardano-Indonesia and Cardano-China pairs exhibited hedging properties before COVID-19 across various horizons. During COVID-19, significant areas of red to yellowish colors appeared in the medium and long term across all Cardano-stock pairs, indicating that Cardano functions primarily as a diversifier against the stock market in ASEAN+2 and G5 regions in the medium to long term (8 to 128 days). None of the Cardano-stock pairs demonstrated safe-haven properties during the pandemic. Later, during the Russia-Ukraine war, all Cardano stock pairs showed positive coherence in the medium to long term (8 to 128 days), suggesting no hedge or safe haven within this period and horizon. The long-term (>128 days) analysis revealed weak safe-haven properties of Cardano in the stock markets of Singapore and Russia. During 2023 and 2024, Cardano only demonstrated hedging properties against the stock markets of Indonesia, Malaysia, Singapore, Russia, France, Germany, and the United Kingdom in the long term (>128 days).



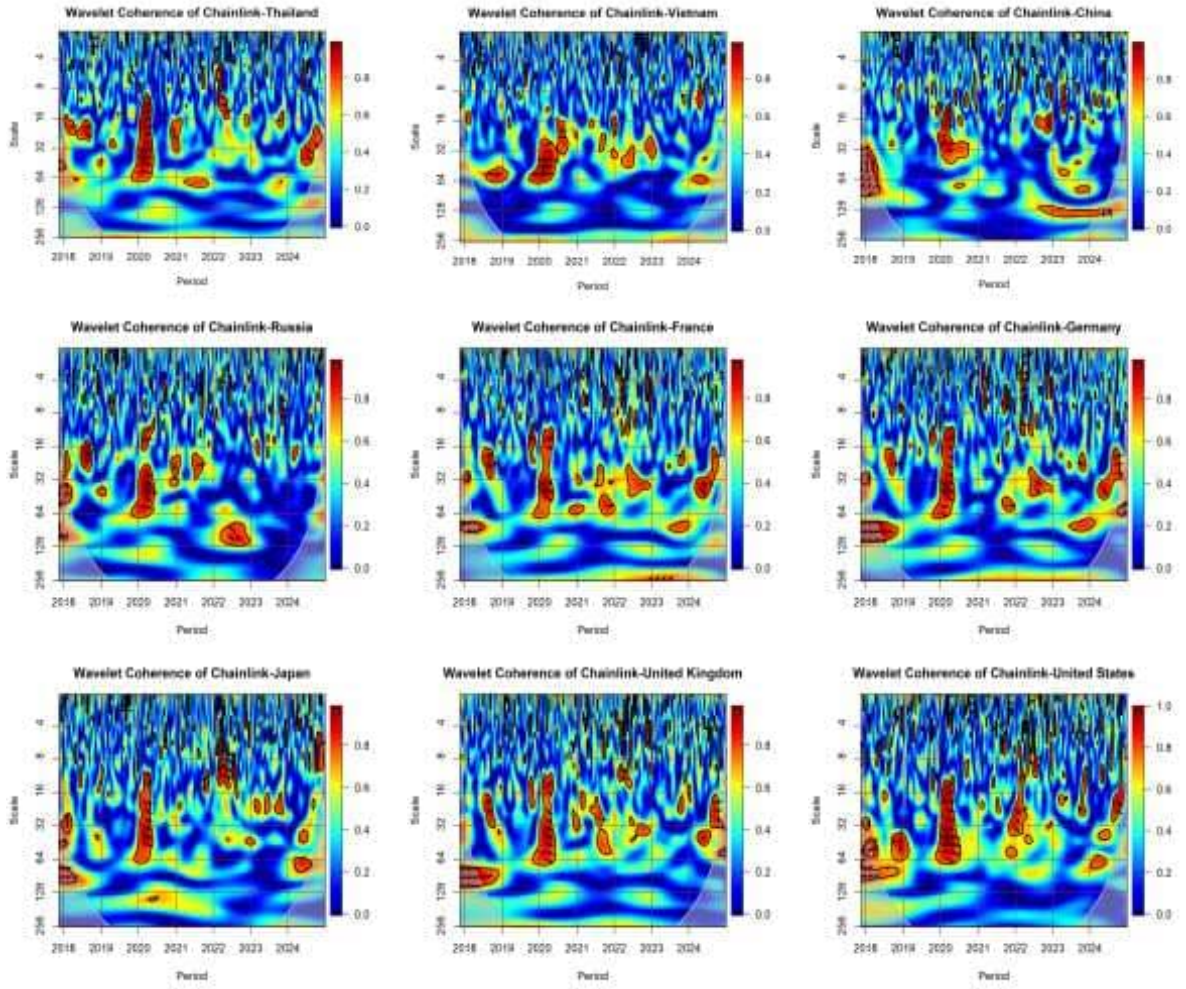


Figure 4. Wavelet Coherence Heatmap of Chainlink-Stock Pairs.

Note: Indonesia-JKSE, Malaysia-KLCI, Singapore-STI, Thailand-SETI, Vietnam-VN, China-SSEC, Russia-IMOEX, France-FCHI, Germany-GDAXI, Japan-N225, United Kingdom-FTSE & United States-SPX, Periods of COVID-19:1 January 2020 until 31 December 2021, Periods of Russia-Ukraine War: 24 January 2022 until 31 December 2022.

Apart from that, according to Figure 4, there is no pronounced hedge observed in the short and medium term before the health crisis. Chainlink only exhibits hedging properties against the French market before COVID-19 in the long term (>128 days). Similarly, all Chainlink-stock pairs showed positive co-movement in the medium to long term (up to 128 days), indicating that Chainlink failed as a safe haven against the stock market up to 128 days during the early outbreak of COVID-19. Moreover, during the Russia-Ukraine war, none of the Chainlink stock pairs exhibited any hedging properties in the short to medium term. However, the Chainlink-Russia pair exhibited a robust safe haven in the long term (64 to 128 days) during the war. During 2023 and 2024, Chainlink showed hedging properties against Singapore, Russia, Japan, the United Kingdom, and the United States stock markets in the long term (>128 days). There is no significant hedge observed in the short and medium term during 2023 and 2024.

Moreover, as illustrated by Figure 5, before the year 2020, Dogecoin only showed hedging properties in the long term (> 128 days), particularly in Indonesia, Malaysia, Singapore, Thailand, China, and France. During COVID-19, a strong positive coherence was observed in the medium to long term (8 to 128 days), indicating that Dogecoin failed as a safe haven against all the stock markets of ASEAN+2 and G5. Only Dogecoin-Vietnam and Dogecoin-United Kingdom exhibited weak safe haven properties in the long term (> 128 days) during the pandemic. Later, during 2022, a positive coherence was observed during the early outbreak of the Russia-Ukraine war, signifying that Dogecoin failed as a safe haven for all ASEAN+2 and G5 stock markets in the medium to long term (8 to 128 days).

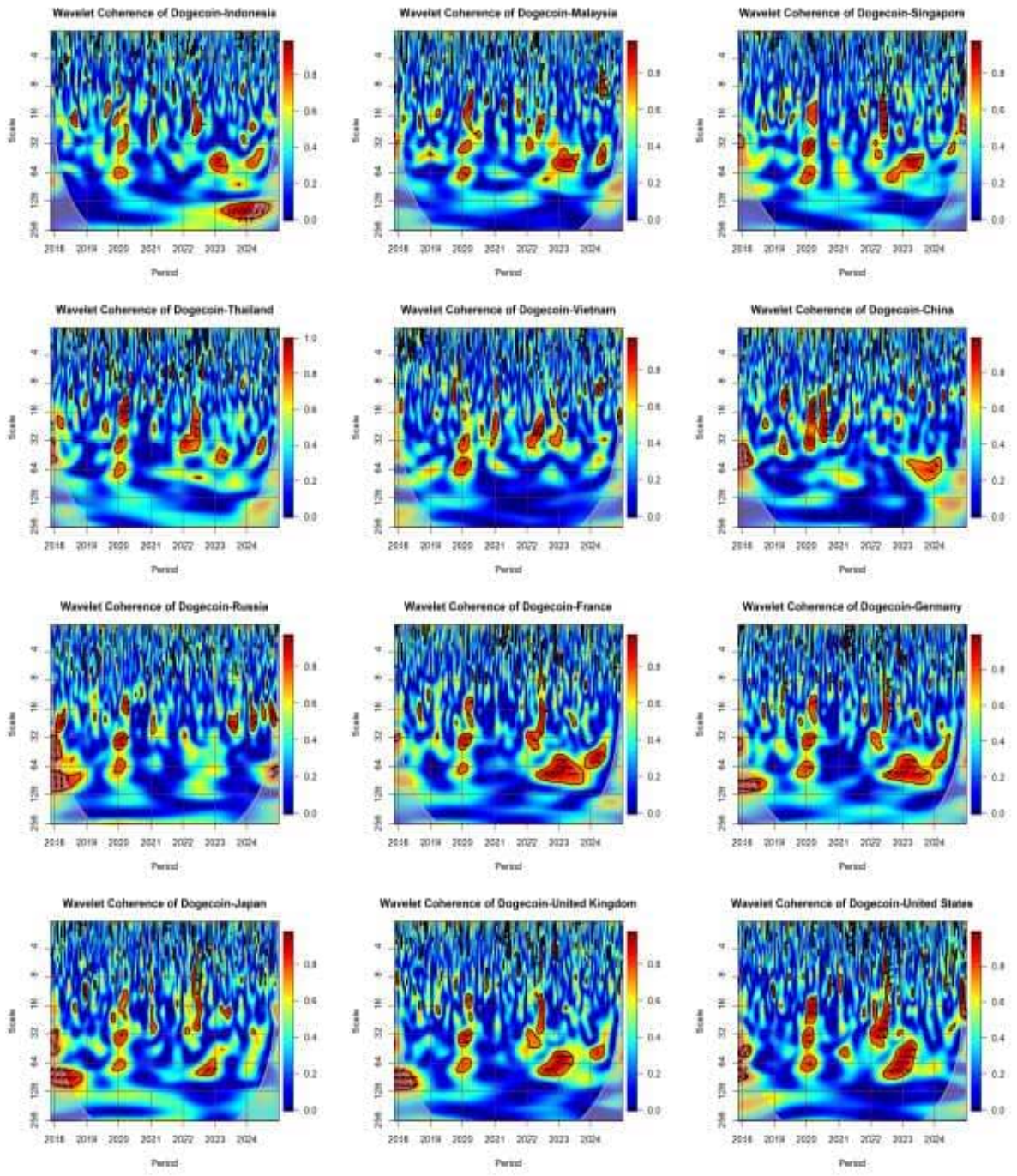


Figure 5. Wavelet coherence heatmap of dogecoin-stock pairs.

Note: Indonesia-JKSE, Malaysia-KLCI, Singapore-STI, Thailand-SETI, Vietnam-VN, China-SSEC, Russia-IMOEX, France-FCHI, Germany-GDAXI, Japan-N225, United Kingdom-FTSE & United States-SPX, Periods of COVID-19:1 January 2020 until 31 December 2021, Periods of Russia-Ukraine War: 24 January 2022 until 31 December 2022.

However, Dogecoin showed weak safe haven properties in the long term (> 128 days) against the stock markets of Malaysia, Vietnam, China, and the United States during the war. Later, during 2023 and 2024, Dogecoin showed hedging properties in the long term (> 128 days) against the stock markets of Indonesia, Singapore, Russia, Germany, Japan, and the United Kingdom. Overall, only Dogecoin-Indonesia and Dogecoin-Singapore showed persistent hedges in the long term (> 128 days) throughout the observation period.

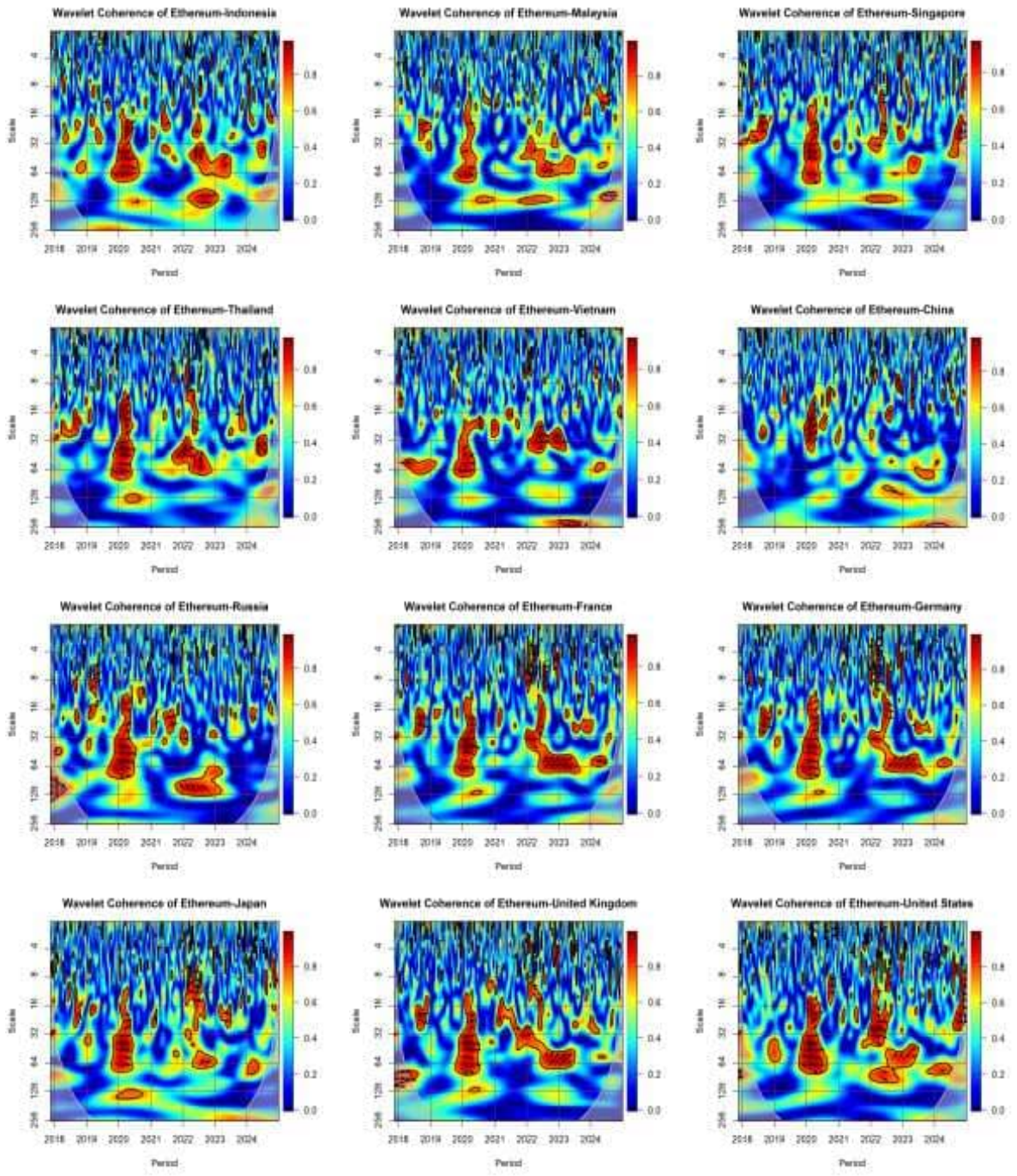


Figure 6. Wavelet coherence heatmap of Ethereum stock pairs.

Note: Indonesia-JKSE, Malaysia-KLCI, Singapore-STI, Thailand-SETI, Vietnam-VN, China-SSEC, Russia-IMOEX, France-FCHI, Germany-GDAXI, Japan-N225, United Kingdom-FTSE, United States-SPX. Periods of COVID-19: 1 January 2020 until 31 December 2021. Periods of the Russia-Ukraine War: 24 January 2022 until 31 December 2022.

Moreover, as depicted in Figure 6, only Ethereum-Thailand exhibited hedging properties in the long term (> 128 days) before the pandemic. During COVID-19, Ethereum did not exhibit strong safe haven properties against any of the stock markets of ASEAN+2 and G5 across the horizons, aligning with findings from Abdul-Rahim et al. (2022); Yuhanitha and Robiyanto (2021), and Conlon et al. (2020). Later, positive coherence was observed in the medium to long term (8 to 128 days) for Ethereum-stock pairs, indicating no hedge or safe haven in those periods in 2022. However, Ethereum showed a strong safe haven against the Russian stock market in the long term (100 to 128 days) during the Russia-Ukraine war, with Ethereum leading the Russian stock market. It also showed a weak safe haven against Russia in the long term (> 128 days) during the war. In 2023 and 2024, Ethereum demonstrated hedging properties against Singapore in the long term (> 128 days).

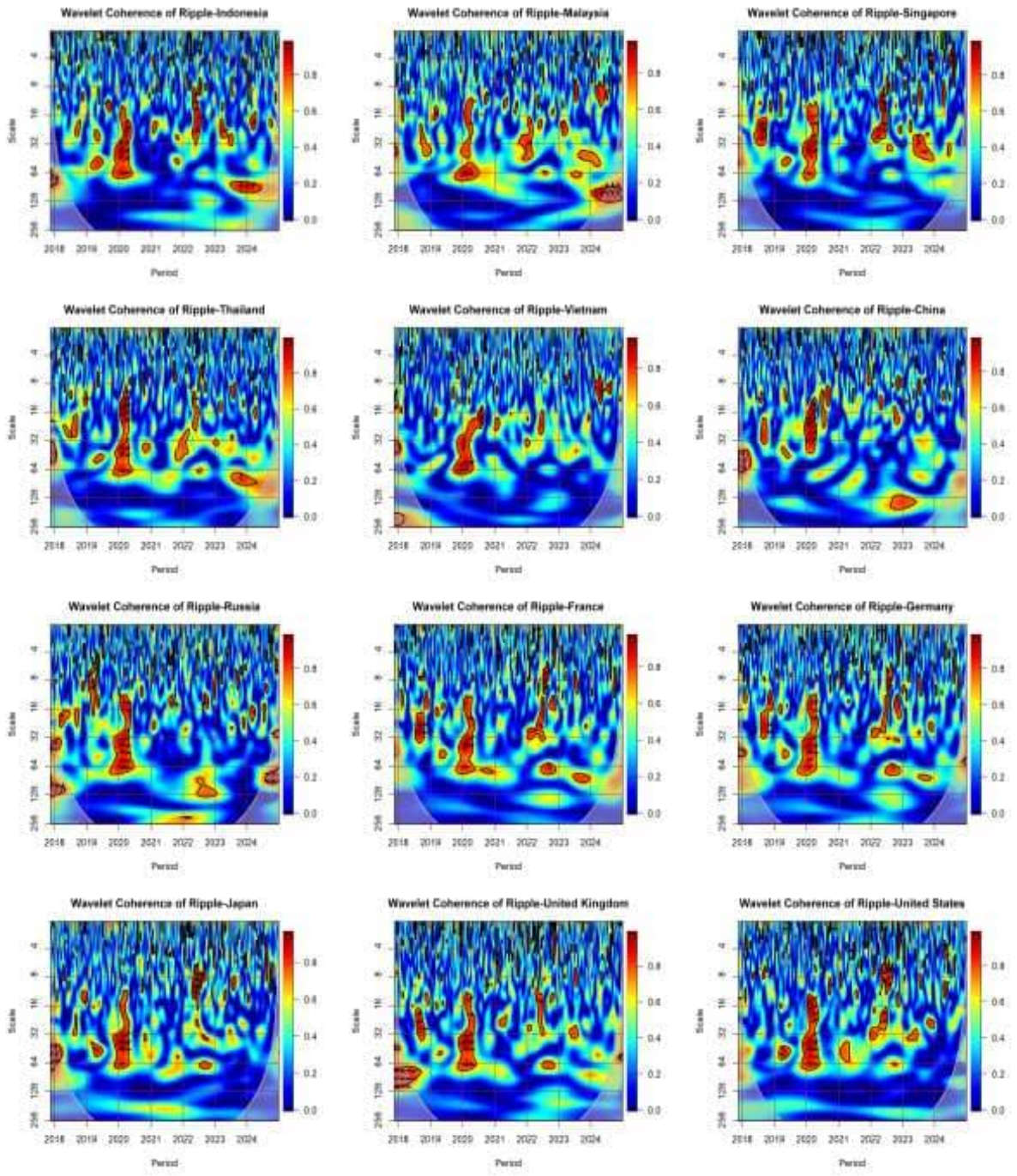


Figure 7. Wavelet coherence heatmap of ripple-stock pairs.

Note: Indonesia-JKSE, Malaysia-KLCI, Singapore-STI, Thailand-SETI, Vietnam-VN, China-SSEC, Russia-IMOEX, France-FCHI, Germany-GDAXI, Japan-N225, United Kingdom-FTSE & United States-SPX, Periods of COVID-19:1 January 2020 until 31 December 2021, Periods of Russia-Ukraine War: 24 January 2022 until 31 December 2022.

Looking into the Ripple-stock pairs as shown in Figure 7, Ripple showed a hedging property against all the ASEAN+2 and G5 markets in the long term (> 128 days), except for Vietnam and Russia prior to COVID-19. During COVID-19, positive coherence was observed in the medium to long term (8 to 128 days), indicating that Ripple failed as a safe haven in the stock markets of ASEAN+2 and G5. In line with the study by Yuhanitha and Robiyanto (2021). Ripple also failed as a safe haven against the Indonesian stock market. A weak safe haven was found in the long term (> 128 days) during the COVID-19 pandemic for Ripple-Malaysia, Ripple-Vietnam, Ripple-China, Ripple-France, and Ripple-United Kingdom. Later, in 2022, positive coherence was observed in the medium to long term (8 to 128 days) for Ripple-stock pairs, suggesting the absence of a viable hedge or safe haven during that period and horizon. Only the Ripple-Thailand pair showed a weak safe haven in the long term (> 128 days) during the war. Additionally, Ripple

demonstrated hedging properties in the long term (> 128 days) against Singapore, Vietnam, Germany, Japan, and the United States during 2023 and 2024. Overall, only Ripple-Singapore, Ripple-Germany, and Ripple-United States showed persistent hedges in the long term (> 128 days) throughout the observation period.

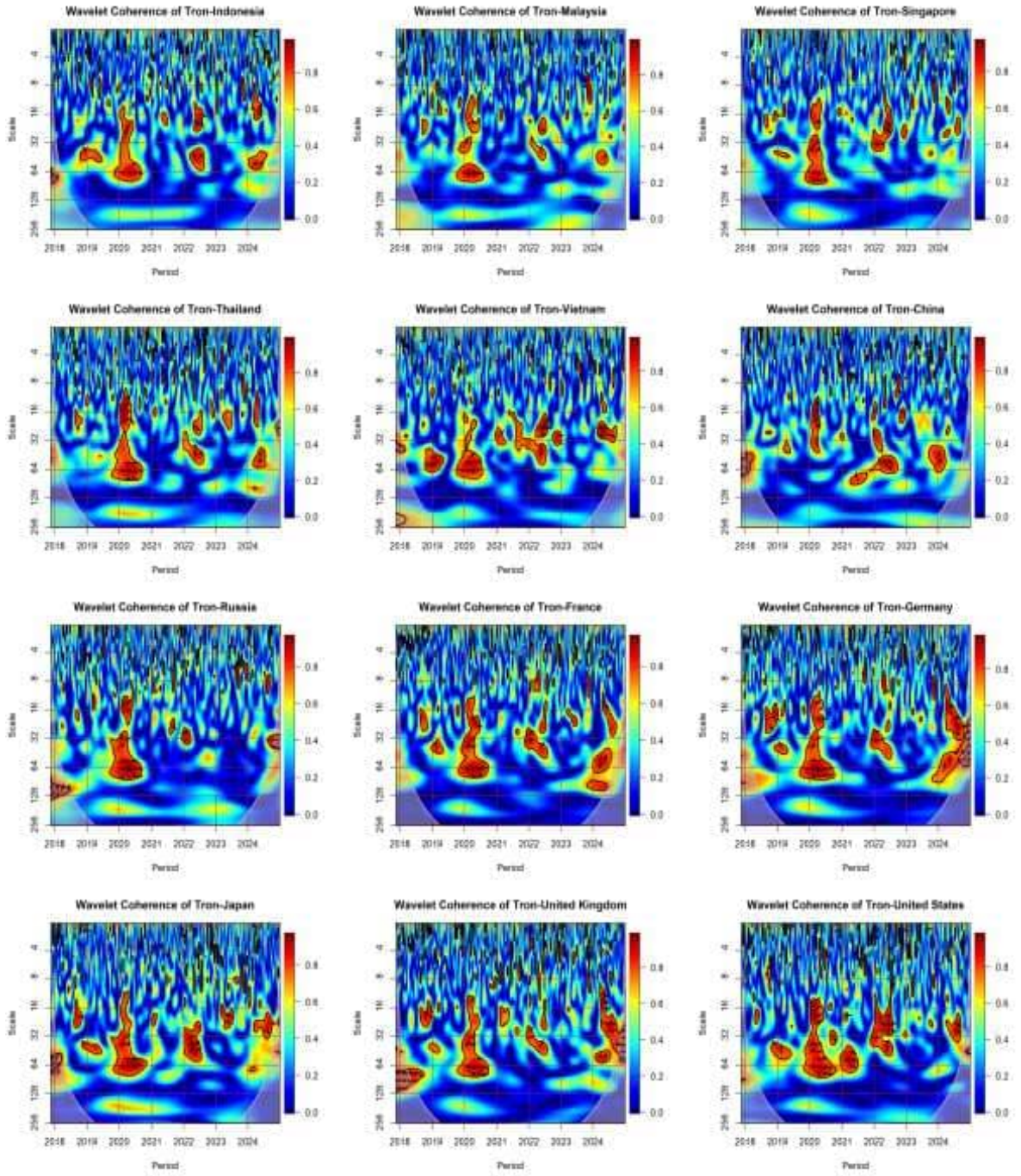


Figure 8. Wavelet coherence heatmap of tron-stock pairs.

Note: Indonesia-JKSE, Malaysia-KLCI, Singapore-STI, Thailand-SETI, Vietnam-VN, China-SSEC, Russia-IMOEX, France-FCHI, Germany-GDAXI, Japan-N225, United Kingdom-FTSE & United States-SPX, Periods of COVID-19:1 January 2020 until 31 December 2021, Periods of Russia-Ukraine War: 24 January 2022 until 31 December 2022.

Drawing from Figure 8, before COVID-19, only Tron-China showed hedging properties in the long term (> 128 days). Also, positive coherence was observed in the medium to long term (8 to 128 days) during COVID-19, indicating that Tron failed as a safe haven for the stock markets of ASEAN+2 and G5. However, Tron did not demonstrate safe haven properties against these markets of ASEAN+2 G5 during the COVID-19 pandemic. During the first half-year of the Russia-Ukraine war, Tron showed a strong safe haven against the Indonesian and Chinese stock markets in

the long term (32 to 64 days), with Tron leading both markets. Still, a weak safe haven is observed in the long term (> 128 days) for Singapore, France, Germany, Japan, and the United Kingdom during the Russia-Ukraine war. In 2023 and 2024, Tron showed hedging ability except for Malaysia, China, and Russia in the long term (> 128 days).

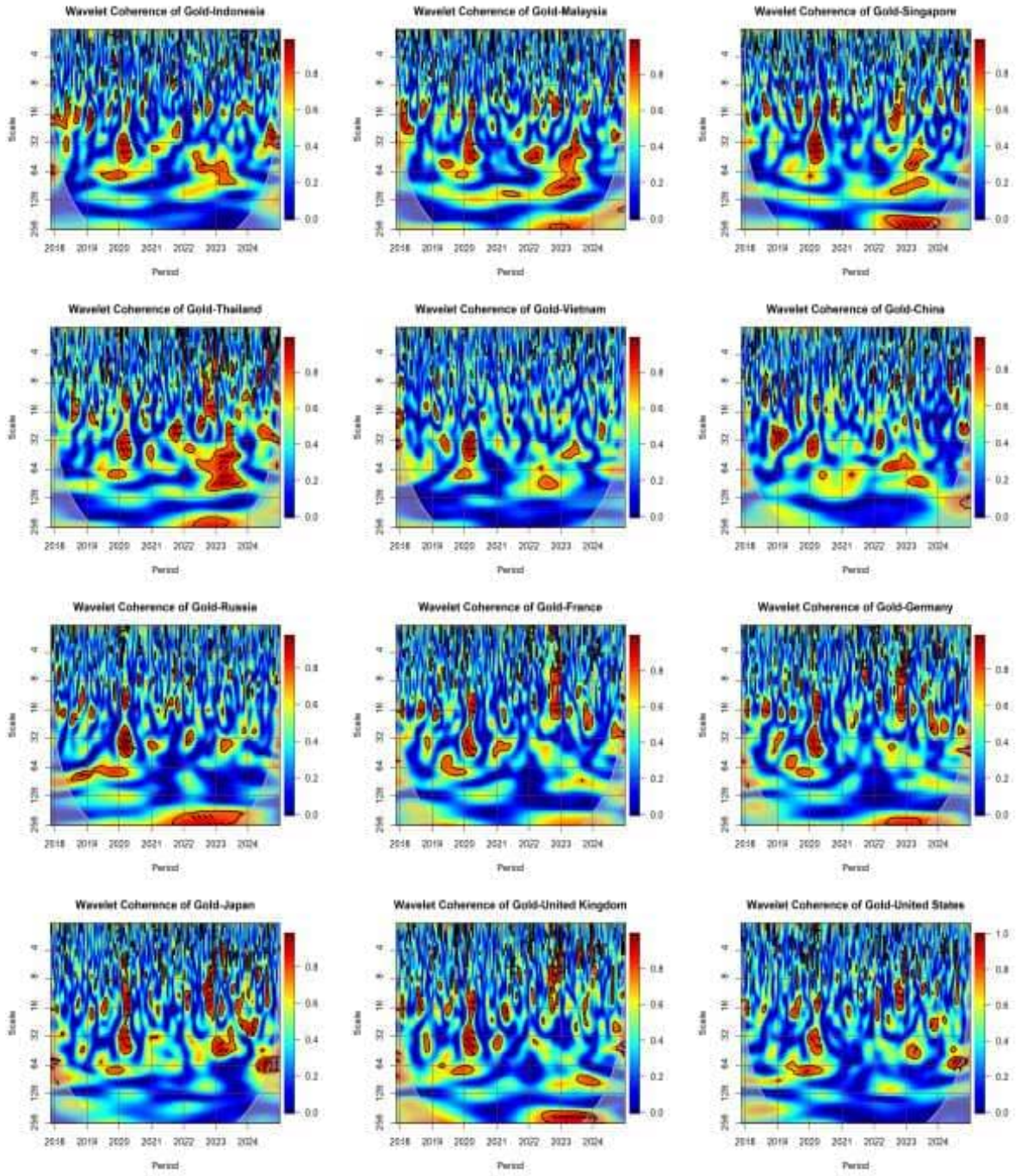


Figure 9. Wavelet coherence heatmap of gold-stock pairs.

Note: Indonesia-JKSE, Malaysia-KLCI, Singapore-STI, Thailand-SETI, Vietnam-VN, China-SSEC, Russia-IMOEX, France-FCHI, Germany-GDAXI, Japan-N225, United Kingdom-FTSE & United States-SPX, Periods of COVID-19:1 January 2020 until 31 December 2021. Periods of the Russia-Ukraine War: 24 January 2022 until 31 December 2022.

Considering Figure 9, although the short-term co-movement of gold and stocks is difficult to predict, more areas of negative coherence are observed in the short term compared to cryptocurrency-stock pairs. No significant hedge was found prior to 2020. During COVID-19, a positive coherence appeared in the medium to long term (8 to 128 days), indicating that gold did not serve as a safe haven for ASEAN+2 and G5 stock markets. In 2022, a strong safe haven was observed in the gold-Russia pair in the long term (>128 days), with gold leading the Russian stock market,

supported by Ustaoglu (2023). Similarly, gold showed a weak safe haven in the long term (>128 days) during the war in Indonesia, Vietnam, China, and the United States stock markets. From 2023 to 2024, gold demonstrated hedging properties only in Vietnam, Japan, and the United States stock markets in the long term (>128 days).

4.3. Robustness

Lastly, Figure A1 (see Appendix A) demonstrates that the wavelet coherence heatmap resulting from different frequency data (monthly datasets) shows that both the daily and monthly datasets generate the same key trend of coherence. Minor differences in intensity and timing are expected due to different frequency aggregation, but the overall patterns remain unchanged. This suggests that our findings are robust across different data frequencies.

5. CONCLUSIONS

To sum up, this paper aims to discover the potential hedge and safe haven properties of various cryptocurrencies, Bitcoin, Bitcoin Cash, Cardano, Chainlink, Dogecoin, Ethereum, Ripple, and Tron, and gold against the stock markets of ASEAN+2 (Indonesia, Malaysia, Singapore, Thailand, Vietnam, China, and Russia) and G5 (France, Germany, Japan, the United Kingdom, and the United States) through wavelet analysis. The summary of important findings is presented in Table B1 (see Appendix B). Several conclusions are drawn from this study. Firstly, the study revealed that cryptocurrencies and gold do not show consistent co-movement with stocks across the horizons throughout the observation periods. Only limited cryptocurrency-stock pairs, such as Dogecoin-Indonesia, Dogecoin-Singapore, Ripple-Singapore, Ripple-Germany, and Ripple-United States, showed persistent hedges in the long term (> 128 days) over the period of observations. Secondly, short-run co-movements are difficult to predict, fitting a random behavior. Thirdly, cryptocurrencies and gold are found to fail as safe havens in the medium-long term at a scale of 8 to 128 days during the early outbreak of both COVID-19 and the Russia-Ukraine war. This mainly results from the common fear and flight to liquidity in the market during the early outbreak of the crisis, contributing to the temporary co-movement between cryptocurrencies, gold, and stocks. This scenario aligns with prospect theory, which states that investors are risk-averse; during both COVID-19 and the Russia-Ukraine war, investors showed panic selling, an irrational behavior to avoid potential loss, leading to temporary co-movement during the early crisis. Likewise, it is also evident that liquidity needs override demand for safe-haven assets during crises, and the flight to safety only rebounds after the crisis. Fourthly, some cryptocurrencies and gold showed a hedge and safe haven against stock markets in the long term over 128 days, but this is market-dependent. However, the limitation of gold as a safe haven across all stock markets casts doubt on its reliability as a universal safe haven.

Additionally, the findings indicate that the comovement between cryptocurrencies and gold with the stock markets of ASEAN+2 and G5 is very dynamic, fluctuating over time and frequency, which significantly impacts market stability and financial integration. For instance, a period of strong coherence implied a potential transmission of shocks from cryptocurrencies to stock markets, especially in emerging markets. Therefore, it emphasizes the limitations of static correlation-based methodologies and illustrates the importance of wavelet coherence in uncovering short-, medium-, and long-term correlations that conventional methods might overlook. Likewise, the results enhance the literature on cryptocurrencies by demonstrating that the hedge and safe-haven potential between cryptocurrencies and stock markets depends on investment horizons rather than remaining static over time.

Based on these findings, regulators gain insights into potential systemic risk spillovers at different investment horizons. Thereby, a comprehensive monitoring of these assets could help safeguard market stability. Also, securities commissions and regulators can improve market transparency and provide access to suitable hedging instruments during market turmoil, allowing market participants to manage their risk effectively. For investors, their choice of hedging instruments should align with their investment horizons. Investors with a medium-term investment horizon are not encouraged to use cryptocurrencies or gold as hedging instruments. Only investors with a longer investment horizon may consider these cryptocurrencies and gold as hedge or safe haven instruments against the stock market,

but they are market-dependent.

Since wavelet coherence analysis has a limitation in which high variability in data makes it difficult to detect stable movements in the short term, this study suggests that future research employ other methodologies that evaluate short-term hedge and safe haven properties in combination with wavelet coherence. Additionally, as our study focuses on the correlation between asset returns, future research should aim to quantify the downside risk of a portfolio including cryptocurrencies and gold across different horizons. Furthermore, the analysis could be extended through partial wavelet coherence methods by incorporating control variables, providing a more comprehensive understanding of the hedge and safe haven properties of cryptocurrencies and gold.

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Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Data Availability Statement: Upon a reasonable request, the supporting data of this study can be provided by the corresponding author.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

REFERENCES

Abdul-Rahim, R., Khalid, A., Karim, Z. A., & Rashid, M. (2022). Exploring the driving forces of stock-cryptocurrency comovements during COVID-19 pandemic: An analysis using wavelet coherence and seemingly unrelated regression. *Mathematics*, *10*(12), 2116. https://doi.org/10.3390/math10122116

Ali, D. J., Sargon, B., & Hadi, D. M. (2024). The impact of economy policy uncertainty and oil price shocks on G20 banks' stock performance: Wavelet coherence and non-parametric causality in quantiles approach. *Heliyon*, *10*(7), e28846. https://doi.org/10.1016/j.heliyon.2024.e28846

Ameur, H. B., Jamaani, F., & Alfoul, M. N. A. (2024). Examining the safe-haven and hedge capabilities of gold and cryptocurrencies: A GARCH and regression quantiles approach in geopolitical and market extremes. *Heliyon*, *10*(22), e40400. https://doi.org/10.1016/j.heliyon.2024.e40400

Amewu, G., Akosah, N. K., & Armah, M. (2024). African sovereign risk premia and international market assets: A relook under the COVID-19 outbreak. *Heliyon*, *10*(21), e40194. https://doi.org/10.1016/j.heliyon.2024.e40194

Arnone, G. (2024). *Navigating the world of cryptocurrencies*. Cham, Switzerland: Springer.

Bahloul, S., Mroua, M., & Naifar, N. (2023). Re-evaluating the hedge and safe-haven properties of Islamic indexes, gold and Bitcoin: Evidence from DCC–GARCH and quantile models. *Journal of Islamic Accounting and Business Research*, *14*(8), 1167-1181. https://doi.org/10.1108/JIABR-03-2022-0076

Ballis, A., Drakos, K., Kallandranis, C., Anastasiou, D., & Doan, V. A. (2025). The impact of COVID-19 first wave on cryptocurrencies and G7 stock markets. *Journal of Small Business and Enterprise Development*, *32*(3), 725–738. https://doi.org/10.1108/JSBED-12-2023-0582

Baur, D. G., & Lucey, B. M. (2010). Is gold a hedge or a safe haven? An analysis of stocks, bonds and gold. *Financial review*, *45*(2), 217-229. https://doi.org/10.1111/j.1540-6288.2010.00244.x

Belhassine, O., & Riahi, M. (2025). Searching for safe haven assets against American and European stocks during the Russo-Ukrainian War. *Studies in Economics and Finance*, *42*(2), 352-372. https://doi.org/10.1108/SEF-01-2024-0056

Bhuiyan, R. A., Mukherjee, T. C., Tarique, K. M., & Zhang, C. (2025). Hedge asset for stock markets: Cryptocurrency, cryptocurrency volatility index (CVI) or commodity. *Quantitative Finance and Economics*, *9*(1), 131-166. https://doi.org/10.3934/QFE.2025005

Boamah, N. A., Opoku, E., & Zamore, S. (2024). The integration of real estate investment trust: A wavelet coherency analysis. *China Finance Review International*, *14*(2), 332-351. https://doi.org/10.1108/CFRI-02-2023-0021

Bouri, E., Gkillas, K., & Gupta, R. (2020). Trade uncertainties and the hedging abilities of Bitcoin. *Economic Notes*, *49*(3), e12173. https://doi.org/10.1111/ecno.12173

Brayek, B. A., Ameur, H. B., & Alharbi, F. M. (2024). The importance of bitcoin and commodities as investment diversifiers in OPEC and non-OPEC countries. *Economies*, *12*(12), 351. https://doi.org/10.3390/economies12120351

Chavez, M., & Cazelles, B. (2019). Detecting dynamic spatial correlation patterns with generalized wavelet coherence and non-stationary surrogate data. *Scientific Reports*, *9*(1), 7389. https://doi.org/10.1038/s41598-019-43571-2

Cheema, M. A., Faff, R., & Szulczyk, K. R. (2022). The 2008 global financial crisis and COVID-19 pandemic: How safe are the safe haven assets? *International Review of Financial Analysis*, *83*, 102316. https://doi.org/10.1016/j.irfa.2022.102316

Chemkha, R., Bensaida, A., Ghorbel, A., & Tayachi, T. (2021). Hedge and safe haven properties during COVID-19: Evidence from Bitcoin and gold. *The Quarterly Review of Economics and Finance*, *82*, 71-85. https://doi.org/10.1016/j.qref.2021.07.006

Chumachenko, D., Dudkina, T., Chumachenko, T., & Morita, P. P. (2023). Epidemiological implications of war: Machine learning estimations of the Russian invasion's effect on Italy's COVID-19 dynamics. *Computation*, *11*(11), 221. https://doi.org/10.3390/computation11110221

Conlon, T., Corbet, S., & McGee, R. J. (2020). Are cryptocurrencies a safe haven for equity markets? An international perspective from the COVID-19 pandemic. *Research in International Business and Finance*, *54*, 101248. https://doi.org/10.1016/j.ribaf.2020.101248

Corbet, S., Hou, Y. G., Hu, Y., Oxley, L., & Xu, D. (2021). Pandemic-related financial market volatility spillovers: Evidence from the Chinese COVID-19 epicentre. *International Review of Economics & Finance*, *71*, 55-81. https://doi.org/10.1016/j.iref.2020.06.022

Demirci, I., Ferreira, M. A., Matos, P., & Sialm, C. (2022). How global is your mutual fund? International diversification from multinationals. *The Review of Financial Studies*, *35*(7), 3337-3372. https://doi.org/10.1093/rfs/hhab103

Dutta, A., Das, D., Jana, R., & Vo, X. V. (2020). COVID-19 and oil market crash: Revisiting the safe haven property of gold and Bitcoin. *Resources Policy*, *69*, 101816. https://doi.org/10.1016/j.resourpol.2020.101816

Fruehwirt, W., Hochfilzer, L., Weydemann, L., & Roberts, S. (2021). Cumulation, crash, coherency: A cryptocurrency bubble wavelet analysis. *Finance Research Letters*, *40*, 101668. https://doi.org/10.1016/j.frl.2020.101668

Garcia-Jorcano, L., & Benito, S. (2020). Studying the properties of the Bitcoin as a diversifying and hedging asset through a copula analysis: Constant and time-varying. *Research in International Business and Finance*, *54*, 101300. https://doi.org/10.1016/j.ribaf.2020.101300

Gheorghe, C., & Panazan, O. (2023). Effects of information related to the Russia-Ukraine conflict on stock volatility: An EGARCH approach. *Cogent Economics & Finance*, *11*(2), 2241205. https://doi.org/10.1080/23322039.2023.2241205

Ghorbel, A., Loukil, S., & Bahloul, W. (2024). Connectedness between cryptocurrencies, gold and stock markets in the presence of the COVID-19 pandemic. *European Journal of Management and Business Economics*, *33*(4), 466-487. https://doi.org/10.1108/EJMBE-10-2021-0281

Haq, I. U., Maneengam, A., Chupradit, S., & Huo, C. (2023). Are green bonds and sustainable cryptocurrencies truly sustainable? Evidence from a wavelet coherence analysis. *Economic Research-Ekonomska Istraživanja*, *36*(1), 807-826. https://doi.org/10.1080/1331677X.2022.2080739

Hilmar, T. (2025). Signifying the present in links to the past: Memory organizations react to the February 24, 2022, Russian full-scale invasion of Ukraine: T. Hilmar. *American Journal of Cultural Sociology*, 1-34. https://doi.org/10.1057/s41290-025-00267-7

Hossain, M. J., Ismail, M. T., Akter, S., & Hossain, M. R. (2020). *Which will serve better as a hedge or diversifier gold or bitcoin?* Paper presented at the 2020 International Conference on Decision Aid Sciences and Application (DASA).

Hu, W., & Si, B. (2021). Improved partial wavelet coherency for understanding scale-specific and localized bivariate relationships in geosciences. *Hydrology and Earth System Sciences*, *25*(1), 321-331. https://doi.org/10.5194/hess-25-321-2021

Hu, W., & Si, B. C. (2016). Multiple wavelet coherence for untangling scale-specific and localized multivariate relationships in geosciences. *Hydrology and Earth System Sciences*, *20*(8), 3183-3191. https://doi.org/10.5194/hess-20-3183-2016

Jana, S., Pandey, K. D., & Sahu, T. N. (2024). An application of ADCC-GARCH and wavelet coherence to explore connectedness between stock markets and cryptocurrencies. *International Journal of Electronic Finance*, *13*(2), 168-195. https://doi.org/10.1504/IJEF.2024.137634

Jana, S., & Sahu, T. N. (2025). A wavelet analysis of investing in cryptocurrencies in the Indian stock market. *International Journal of Emerging Markets*, *20*(8), 3229-3251. https://doi.org/10.1108/IJOEM-05-2023-0698

Jiang, Y., Lie, J., Wang, J., & Mu, J. (2021). Revisiting the roles of cryptocurrencies in stock markets: A quantile coherency perspective. *Economic Modelling*, *95*, 21-34. https://doi.org/10.1016/j.econmod.2020.12.002

Junior, O. P., Kwaku Boafo, B., Kwesi Awuye, B., Bonsu, K., & Obeng-Tawiah, H. (2018). Co-movement of stock exchange indices and exchange rates in Ghana: A wavelet coherence analysis. *Cogent Business & Management*, *5*(1), 1481559. https://doi.org/10.1080/23311975.2018.1481559

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, *47*(2), 263-292. https://doi.org/10.2307/1914185

Kakinuma, Y. (2022). Nexus between Southeast Asian stock markets, bitcoin and gold: Spillover effect before and during the COVID-19 pandemic. *Journal of Asia Business Studies*, *16*(4), 693-711. https://doi.org/10.1108/JABS-02-2021-0050

Karim, B. A., Abdul-Rahman, A., Hwang, J. Y. T., & Kadri, N. (2021). Portfolio diversification benefits of cryptocurrencies and ASEAN-5 stock markets. *The Journal of Asian Finance, Economics and Business*, *8*(6), 567-577.

Kayral, I. E., Jeribi, A., & Loukil, S. (2023). Are bitcoin and gold a safe haven during COVID-19 and the 2022 Russia–Ukraine war? *Journal of Risk and Financial Management*, *16*(4), 222. https://doi.org/10.3390/jrfm16040222

Khan, M. N., Fifield, S. G., & Power, D. M. (2024). The impact of the COVID 19 pandemic on stock market volatility: Evidence from a selection of developed and emerging stock markets. *SN Business & Economics*, *4*(6), 63. https://doi.org/10.1007/s43546-024-00659-w

Klose, J. (2022). Comparing cryptocurrencies and gold-a system-GARCH-approach. *Eurasian Economic Review*, *12*(4), 653-679. https://doi.org/10.1007/s40822-022-00218-4

Korsah, D., Mensah, L., Osei, K. A., & Amewu, G. (2026). Dynamic connectedness, hedge and safe-haven effects: Cryptocurrencies, precious metals and African stock markets. *International Journal of Emerging Markets*, *21*(1), 147-169. https://doi.org/10.1108/IJOEM-06-2024-1090

Kumah, S. P., Odei-Mensah, J., & Baaba Amanamah, R. (2022). Co-movement of cryptocurrencies and African stock returns: A multiresolution analysis. *Cogent Business & Management*, *9*(1), 2124595. https://doi.org/10.1080/23311975.2022.2124595

Kumar, S., Kumar, A., & Singh, G. (2023). Gold, crude oil, bitcoin and Indian stock market: Recent confirmation from nonlinear ARDL analysis. *Journal of Economic Studies*, *50*(4), 734-751. https://doi.org/10.1108/JES-01-2022-0007

Lamine, A., Jeribi, A., & Fakhfakh, T. (2024). Spillovers between cryptocurrencies, gold and stock markets: Implication for hedging strategies and portfolio diversification under the COVID-19 pandemic. *Journal of Economics, Finance and Administrative Science*, *29*(57), 21-41. https://doi.org/10.1108/JEFAS-09-2021-0173

Lavelle, B., Yamamoto, K. N., & Kinnen, M. (2022). Cryptocurrencies, correlations, and COVID-19: Diversifiers, hedge, or safe haven? *Review of Integrative Business and Economics Research*, *11*(2), 25-35.

Liu, P., & Yuan, Y. (2024). Is Bitcoin a hedge or safe-haven asset during the period of turmoil? Evidence from the currency, bond and stock markets. *International Review of Financial Analysis*, *96*, 103663. https://doi.org/10.1016/j.irfa.2024.103663

Long, S., Pei, H., Tian, H., & Lang, K. (2021). Can both Bitcoin and gold serve as safe-haven assets?—A comparative analysis based on the NARDL model. *International Review of Financial Analysis*, *78*, 101914. https://doi.org/10.1016/j.irfa.2021.101914

Majumder, B. S. (2022). Searching for hedging and safe haven assets for Indian equity market–a comparison between gold, cryptocurrency and commodities. *Indian Growth and Development Review*, *15*(1), 60-84. https://doi.org/10.1108/IGDR-10-2021-0131

Manzli, S. Y., Alnafisah, H., & Jeribi, A. (2024). Safe haven ability of energy and agricultural commodities against G7 stock markets and banking indices during COVID-19, Russia–Ukraine War, and SVB collapse: Evidence from the wavelet coherence approach. *Discrete Dynamics in Nature and Society*, *2024*(1), 2587000. https://doi.org/10.1155/ddns/2587000

Matar, A., Al-Rdaydeh, M., Ghazalat, A., & Eneizan, B. (2021). Co-movement between GCC stock markets and the US stock markets: A wavelet coherence analysis. *Cogent Business & Management*, *8*(1), 1948658. https://doi.org/10.1080/23311975.2021.1948658

Matos, P., Costa, A., & Da Silva, C. (2021). COVID-19, stock market and sectoral contagion in US: A time-frequency analysis. *Research in International Business and Finance*, *57*, 101400. https://doi.org/10.1016/j.ribaf.2021.101400

Ming, L., Shen, Y., Yang, S., Zhu, S., & Zhu, H. (2020). Does gold serve as a hedge for the stock market in China? Evidence from a time-frequency analysis. *Emerging Markets Finance and Trade*, *56*(3), 659-672. https://doi.org/10.1080/1540496X.2019.1677225

Mishra, S., & Debasish, S. S. (2022). Exploring relationship between crude oil price volatility and stock indices movement using wavelet analysis: Evidence from India and China. *Vilakshan-XIMB Journal of Management*, *19*(1), 69-86. https://doi.org/10.1108/XJM-11-2020-0204

Nkrumah-Boadu, B., Owusu Junior, P., Adam, A., & Asafo-Adjei, E. (2022). Safe haven, hedge and diversification for African stocks: cryptocurrencies versus gold in time-frequency perspective. *Cogent Economics & Finance*, *10*(1), 2114171. https://doi.org/10.1080/23322039.2022.2114171

Phillips, R. C., & Gorse, D. (2018). Cryptocurrency price drivers: Wavelet coherence analysis revisited. *PloS One*, *13*(4), e0195200. https://doi.org/10.1371/journal.pone.0195200

Rehman, M. Z., Khan, S., Abbas, G., & Alhashim, M. (2023). Novel COVID-19 outbreak and global uncertainty in the top-10 affected countries: Evidence from wavelet coherence approach. *Sustainability*, *15*(6), 5556. https://doi.org/10.3390/su15065556

Riahi, R., Bennajma, A., Jahmane, A., & Hammami, H. (2024). Investing in cryptocurrency before and during the COVID-19 crisis: Hedge, diversifier or safe haven? *Research in International Business and Finance*, *67*, 102102. https://doi.org/10.1016/j.ribaf.2023.102102

Rubbaniy, G., Khalid, A. A., Syriopoulos, K., & Samitas, A. (2022). Safe-haven properties of soft commodities during times of Covid-19. *Journal of Commodity Markets*, *27*, 100223. https://doi.org/10.1016/j.jcomm.2021.100223

Sahabuddin, M., Hassan, M. F., Tabash, M. I., Al-Omari, M. A., Alam, M. K., & Islam, F. T. (2022). Co-movement and causality dynamics linkages between conventional and Islamic stock indexes in Bangladesh: A wavelet analysis. *Cogent Business & Management*, *9*(1), 2034233. https://doi.org/10.1080/23311975.2022.2034233

Shen, Y., Feng, Q., & Sun, X. (2024). Stability and risk contagion in the global sovereign CDS market under Russia-Ukraine conflict. *The North American Journal of Economics and Finance*, *74*, 102204. https://doi.org/10.1016/j.najef.2024.102204

Singh, V. V., Singh, H., & Ansari, A. (2024). Bitcoin as a distinct asset class for hedging and portfolio diversification: A DCC-GARCH model analysis. *NMIMS Management Review*, *32*(1), 7-13. https://doi.org/10.1177/09711023241260967

Sinlapates, P., Sriwong, T., & Chancharat, S. (2023). Risk spillovers between Bitcoin and ASEAN+ 6 stock markets before and after COVID-19 outbreak: A comparative analysis with gold. *Journal of Risk and Financial Management*, *16*(2), 103. https://doi.org/10.3390/jrfm16020103

Stensås, A., Nygaard, M. F., Kyaw, K., & Treepongkaruna, S. (2019). Can Bitcoin be a diversifier, hedge or safe haven tool? *Cogent Economics & Finance*, *7*(1), 1593072. https://doi.org/10.1080/23322039.2019.1593072

Su, C.-W., Wang, K.-H., Lobonţ, O.-R., & Qin, M. (2023). Continuous wavelet transform of time-frequency analysis technique to capture the dynamic hedging ability of precious metals. *Mathematics*, *11*(5), 1186. https://doi.org/10.3390/math11051186

Tan, C.-C., Ling, P.-S., Sim, S.-L., & Ming, K. L. Y. (2023). Hedge and safe-haven properties of Cryptocurrencies: evidence in east asia-5 market. *Cogent Economics & Finance*, *11*(1), 2183640. https://doi.org/10.1080/23322039.2023.2183640

Tanase, T. (2023). Online communication strategy of world political leaders during the Ukraine crisis (February 24-December 24, 2022). Comparative case study: Joe Biden, Ursula von der Leyen and Jens Stoltenberg. *Technium Social Sciences Journal*, *39*(1), 207-219. https://doi.org/10.47577/tssj.v39i1.8220

Tarchella, S., Khalfaoui, R., & Hammoudeh, S. (2024). The safe haven, hedging, and diversification properties of oil, gold, and cryptocurrency for the G7 equity markets: Evidence from the pre-and post-COVID-19 periods. *Research in International Business and Finance*, *67*, 102125. https://doi.org/10.1016/j.ribaf.2023.102125

Thampanya, N., Nasir, M. A., & Huynh, T. L. D. (2020). Asymmetric correlation and hedging effectiveness of gold & cryptocurrencies: From pre-industrial to the 4th industrial revolution☆. *Technological Forecasting and Social Change*, *159*, 120195. https://doi.org/10.1016/j.techfore.2020.120195

Thuy, L. T. V., Oanh, T. T. K., & Ha, N. T. H. (2024). The roles of gold, US dollar, and bitcoin as safe-haven assets in times of crisis. *Cogent Economics & Finance*, *12*(1), 2322876. https://doi.org/10.1080/23322039.2024.2322876

Torrence, C., & Compo, G. P. (1998). A practical guide to wavelet analysis. *Bulletin of the American Meteorological society*, *79*(1), 61-78. https://doi.org/10.1175/1520-0477(1998)079%3C0061:APGTWA%3E2.0.CO;2

Ustaoglu, E. (2023). Diversification, hedge, and safe-haven properties of gold and bitcoin with portfolio implications during the Russia–Ukraine war. *Resources Policy*, *84*, 103791. https://doi.org/10.1016/j.resourpol.2023.103791

Vieira, D. S., De Carvalho, P. V., Curto, J. D., & Laureano, L. (2023). Gold's hedging and safe haven properties for European stock and bond markets. *Resources Policy*, *85*, 103817. https://doi.org/10.1016/j.resourpol.2023.103817

Vo, D. H. (2023). Volatility spillovers across sectors and their magnitude: A sector-based analysis for Australia. *PloS One*, *18*(6), e0286528. https://doi.org/10.1371/journal.pone.0286528

Wen, F., Tong, X., & Ren, X. (2022). Gold or Bitcoin, which is the safe haven during the COVID-19 pandemic? *International Review of Financial Analysis*, *81*, 102121. https://doi.org/10.1016/j.irfa.2022.102121

Widarto, A. R., Muharam, H., Wahyudi, S., & Pangestuti, I. R. D. (2022). ASEAN-5 and crypto hedge fund: Dynamic portfolio approach. *SAGE Open*, *12*(2), 21582440221094612. https://doi.org/10.1177/21582440221094612

Xu, L., & Kinkyo, T. (2023). Hedging effectiveness of bitcoin and gold: Evidence from G7 stock markets. *Journal of International Financial Markets, Institutions and Money*, *85*, 101764. https://doi.org/10.1016/j.intfin.2023.101764

Yarovaya, L., Matkovskyy, R., & Jalan, A. (2022). The COVID-19 black swan crisis: Reaction and recovery of various financial markets. *Research in International Business and Finance*, *59*, 101521. https://doi.org/10.1016/j.ribaf.2021.101521

Yousaf, I., Bouri, E., Ali, S., & Azoury, N. (2021). Gold against Asian stock markets during the COVID-19 outbreak. *Journal of Risk and Financial Management*, *14*(4), 186. https://doi.org/10.3390/jrfm14040186

Yuhanitha, N., & Robiyanto, R. (2021). Cryptocurrencies as a hedge and safe haven instruments during Covid-19 Pandemic. *JASF: Journal of Accounting and Strategic Finance*, *4*(1), 13-30. https://doi.org/10.33005/jasf.v4i1.129

APPENDIX A. Wavelet Coherence Heatmap of Cryptocurrencies-Stock and Gold-Stock Pairs (Weekly Data).

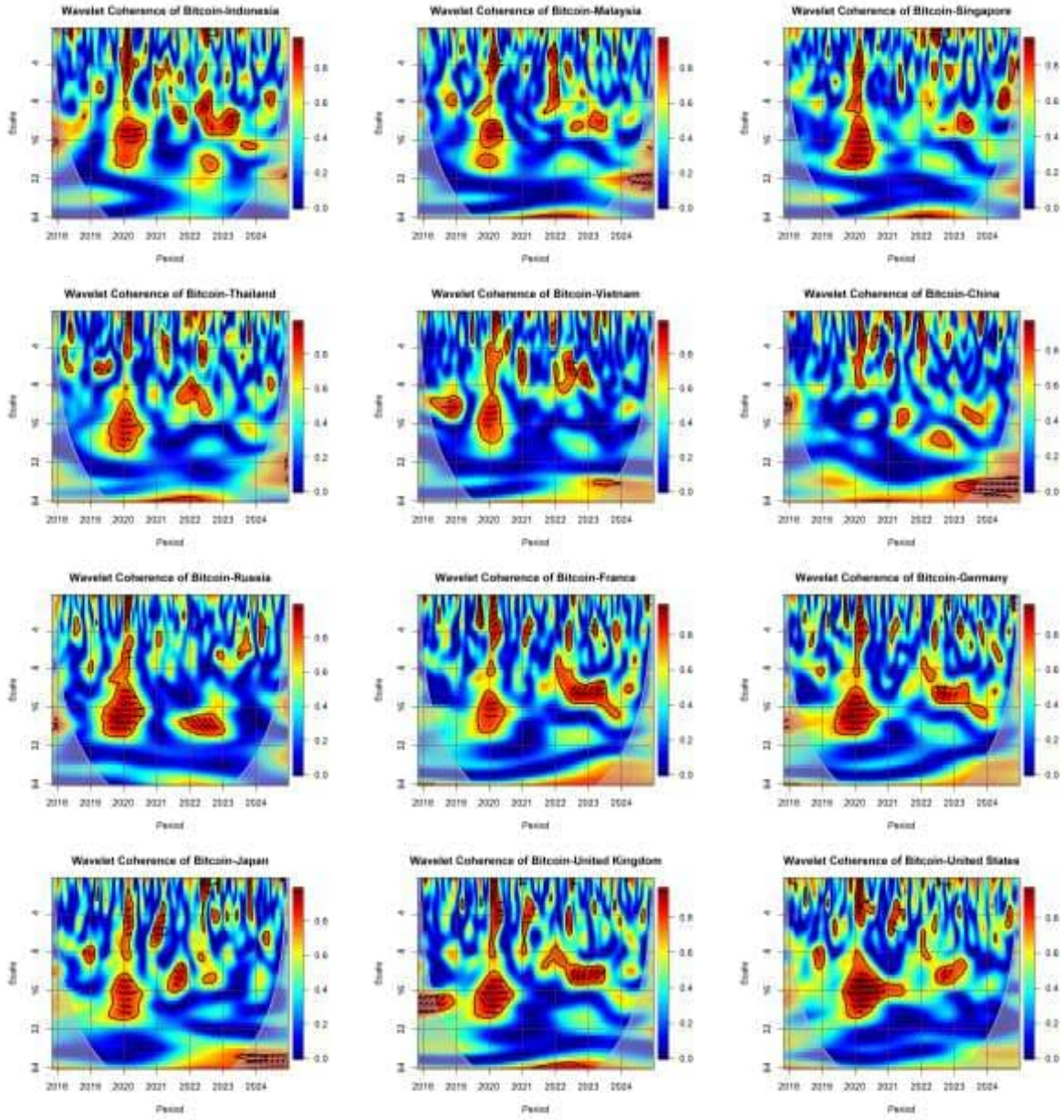
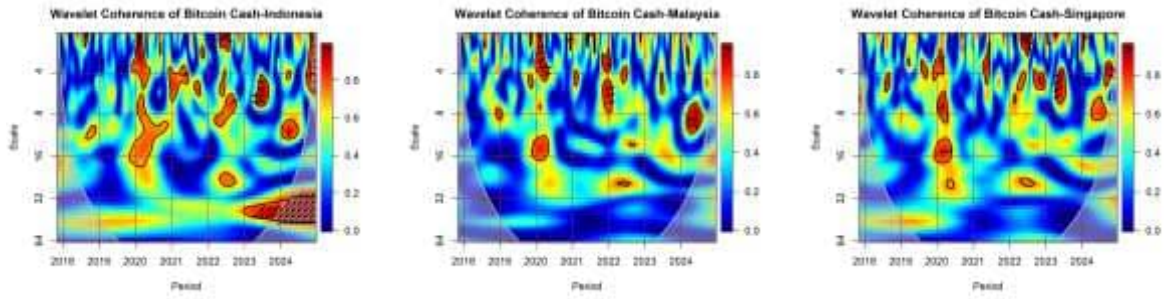


Figure A1. Wavelet Coherence Heatmap of Bitcoin-Stock Pairs (Weekly Data).

Note: The vertical axis of scale 1 to 64 here refers to weeks, Indonesia-JKSE, Malaysia-KLCI, Singapore-STI, Thailand-SETI, Vietnam-VN, China-SSEC, Russia-IMOEX, France-FCHI, Germany-GDAXI, Japan-N225, United Kingdom-FTSE & United States-SPX. Periods of COVID-19:1 January 2020 until 31 December 2021, Periods of Russia-Ukraine War: 24 January 2022 until 31 December 2022.

Figure A2 illustrates the wavelet coherence heatmap of Bitcoin Cash-Stock Pairs based on weekly data.



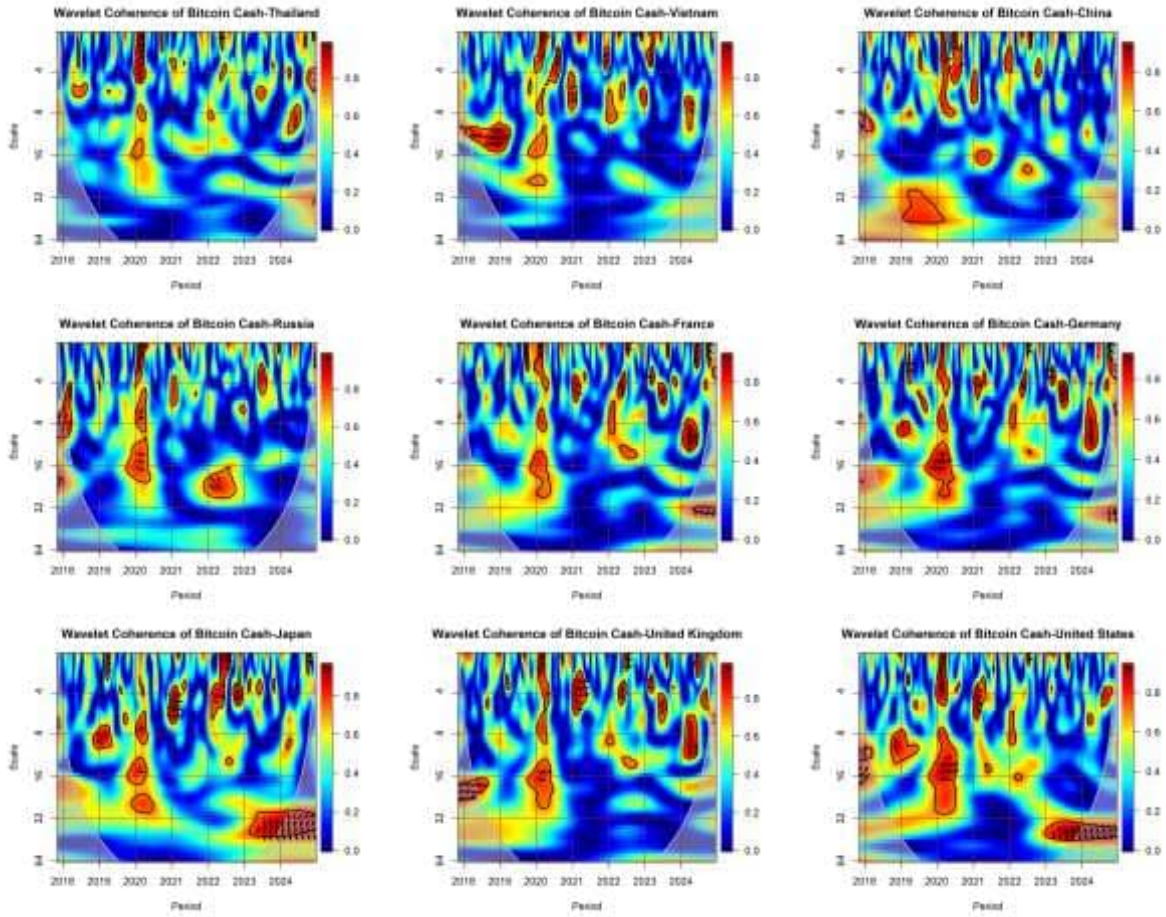
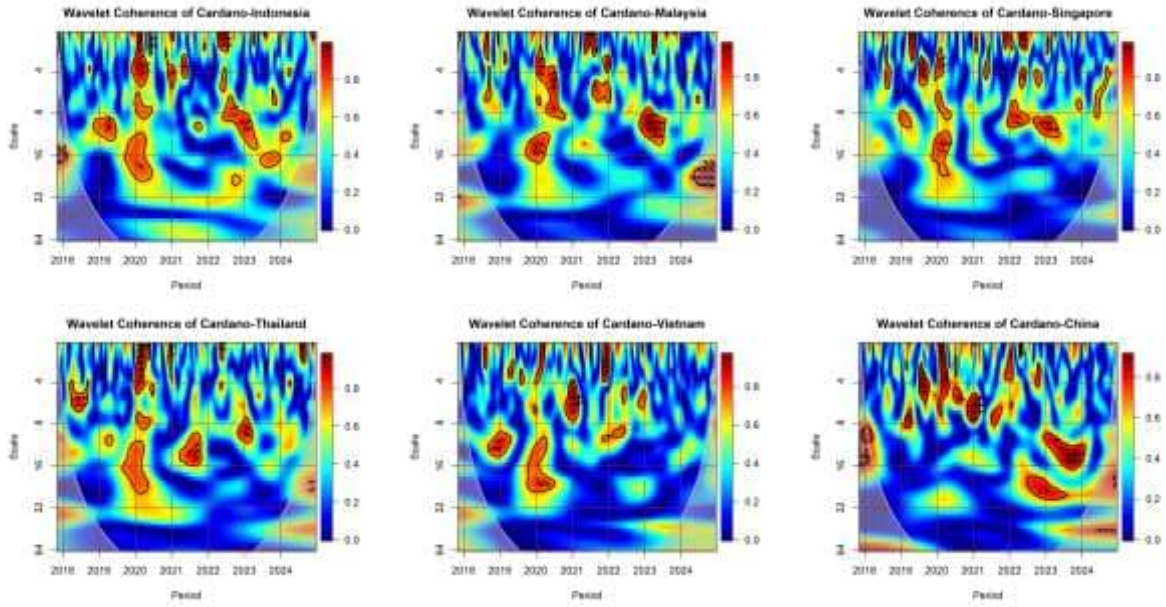


Figure A2. Wavelet Coherence Heatmap of Bitcoin Cash-Stock Pairs (Weekly Data).

Note: The vertical axis of scale 1 to 64 here refers to weeks, Indonesia-JKSE, Malaysia-KLCI, Singapore-STI, Thailand-SETI, Vietnam-VN, China-SSEC, Russia-IMOEX, France-FCHI, Germany-GDAXI, Japan-N225, United Kingdom-FTSE & United States-SPX. Periods of COVID-19:1 January 2020 until 31 December 2021, Periods of Russia-Ukraine War: 24 January 2022 until 31 December 2022.

Figure A3 illustrates the wavelet coherence heatmap of Cardano-Stock Pairs based on weekly data.



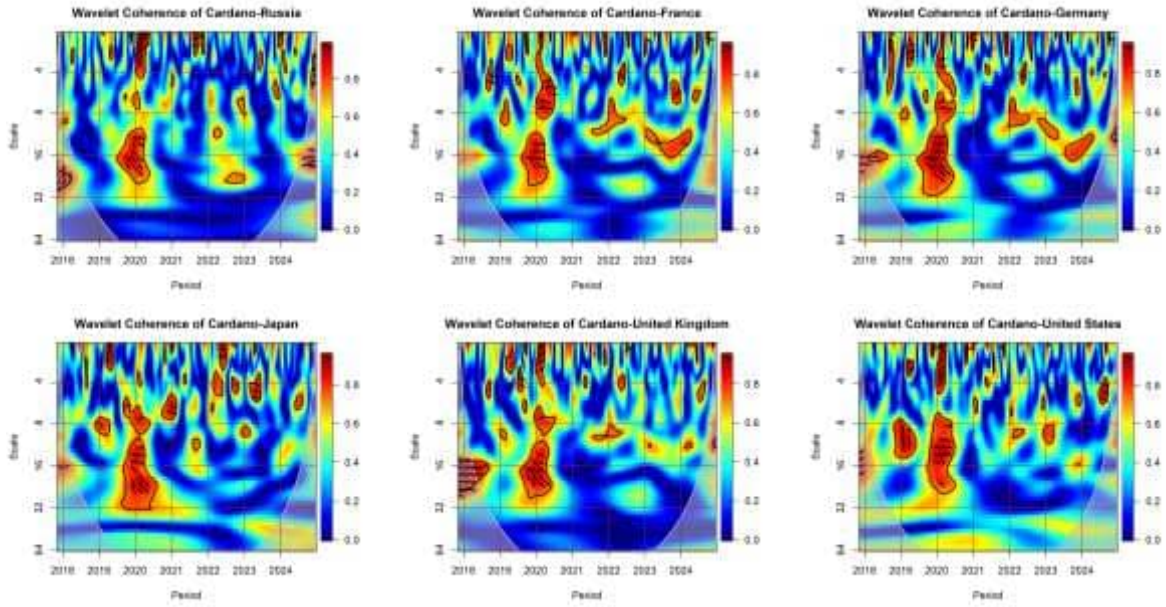
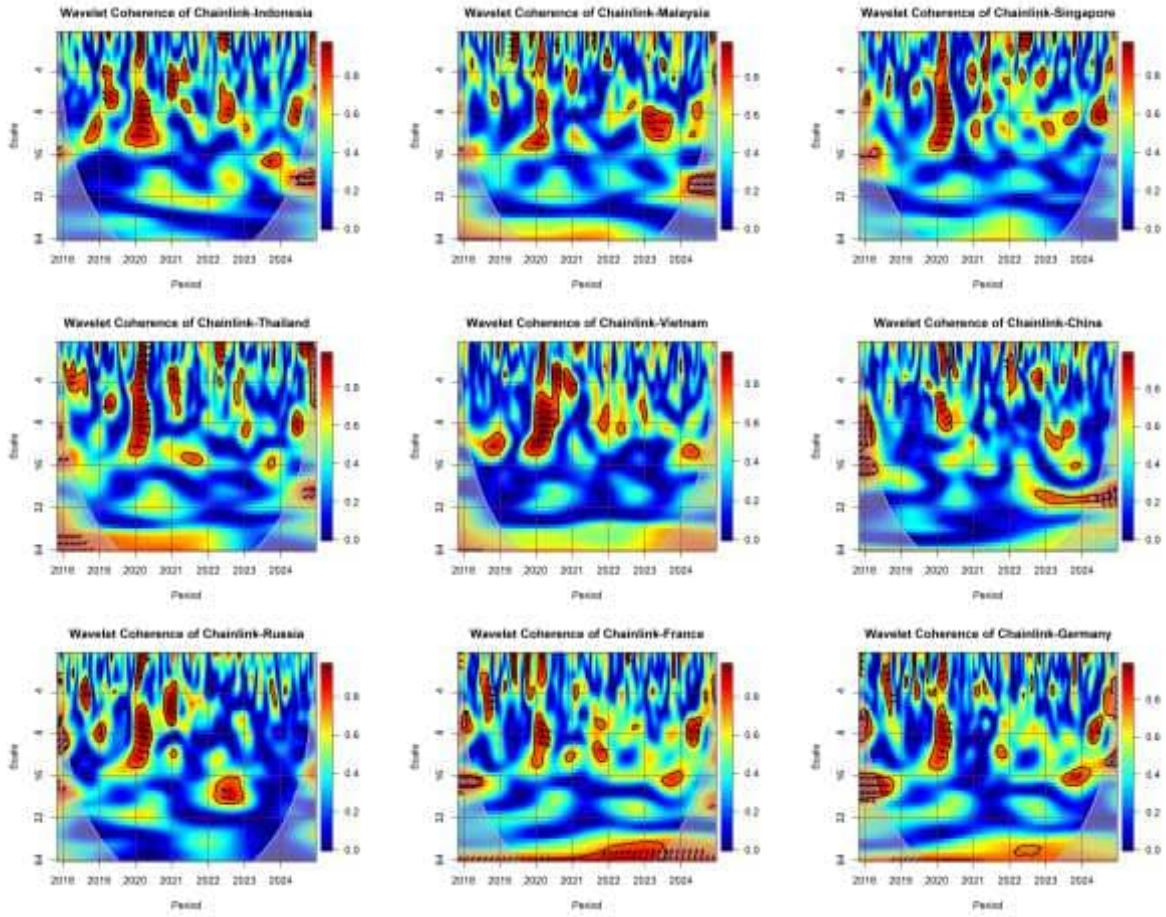


Figure A3. Wavelet Coherence Heatmap of Cardano-Stock Pairs (Weekly Data).

Note: The vertical axis of scale 1 to 64 here refers to weeks, Indonesia-JKSE, Malaysia-KLCI, Singapore-STI, Thailand-SETI, Vietnam-VN, China-SSEC, Russia-IMOEX, France-FCHI, Germany-GDAXI, Japan-N225, United Kingdom-FTSE & United States-SPX. Periods of COVID-19:1 January 2020 until 31 December 2021, Periods of Russia-Ukraine War: 24 January 2022 until 31 December 2022.

Figure A4 illustrates the wavelet coherence heatmap of Chainlink-Stock Pairs based on weekly data.



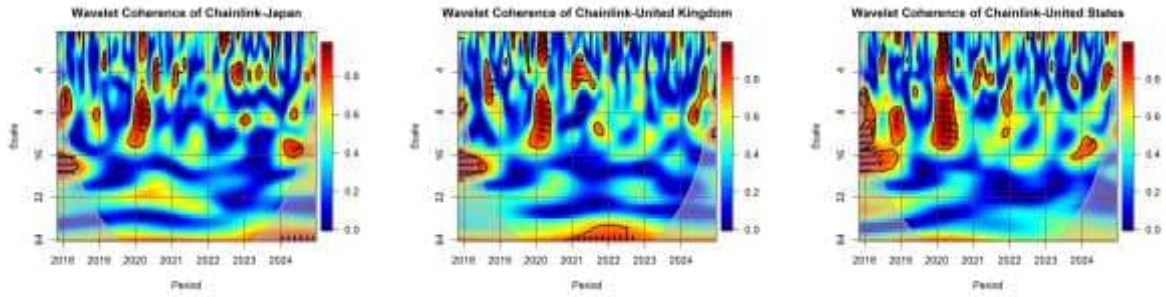


Figure A4. Wavelet Coherence Heatmap of Chainlink-Stock Pairs (Weekly Data).

Note: The vertical axis of scale 1 to 64 here refers to weeks, Indonesia-JKSE, Malaysia-KLCI, Singapore-STI, Thailand-SETI, Vietnam-VN, China-SSEC, Russia-IMOEX, France-FCHI, Germany-GDAXI, Japan-N225, United Kingdom-FTSE & United States-SPX. Periods of COVID-19:1 January 2020 until 31 December 2021, Periods of Russia-Ukraine War: 24 January 2022 until 31 December 2022.

Figure A5 illustrates the wavelet coherence heatmap of Dogecoin-Stock Pairs based on weekly data.

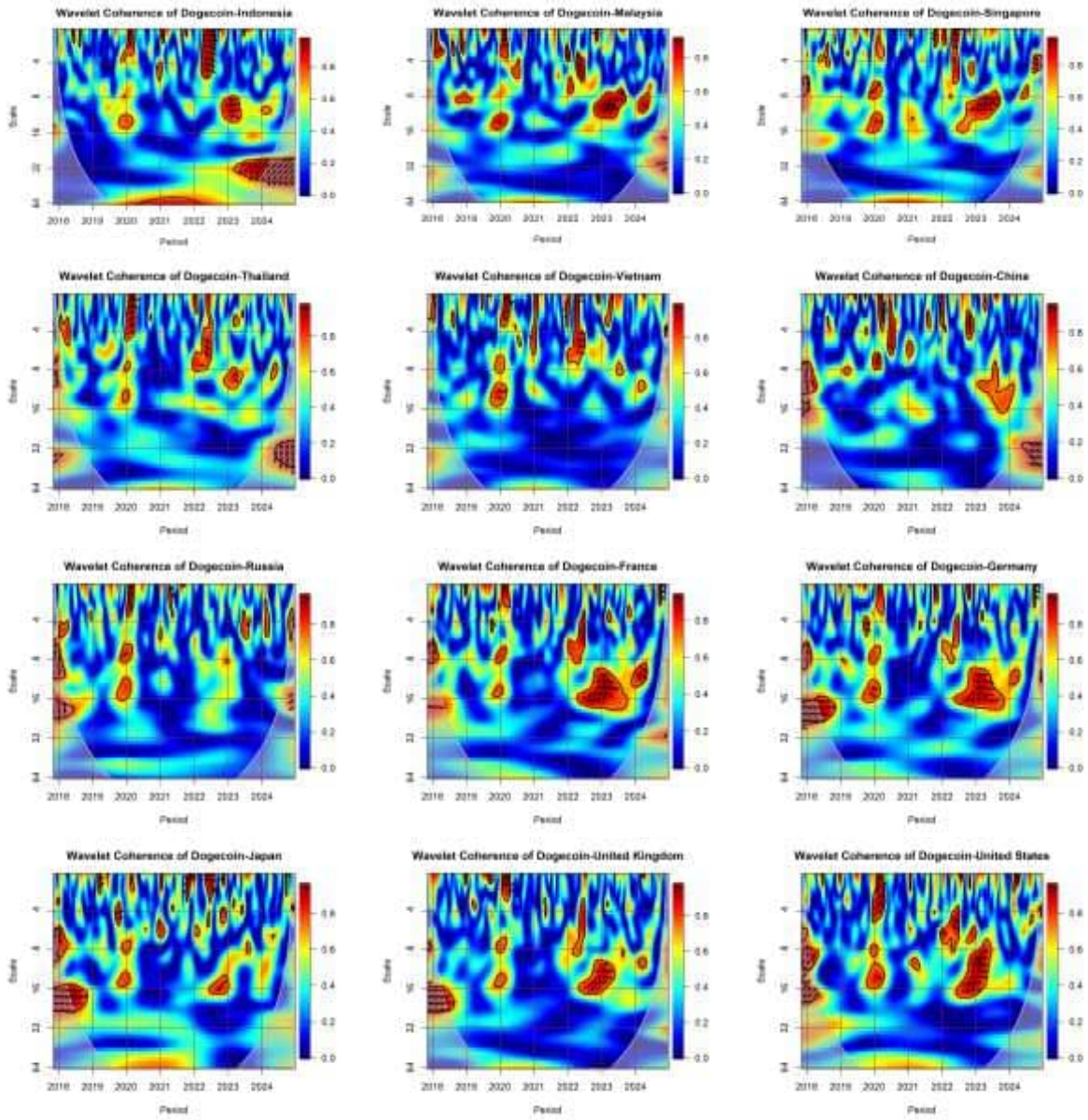


Figure A5. Wavelet Coherence Heatmap of Dogecoin-Stock Pairs (Weekly Data).

Note: The vertical axis of scale 1 to 64 here refers to weeks, Indonesia-JKSE, Malaysia-KLCI, Singapore-STI, Thailand-SETI, Vietnam-VN, China-SSEC, Russia-IMOEX, France-FCHI, Germany-GDAXI, Japan-N225, United Kingdom-FTSE & United States-SPX. Periods of COVID-19:1 January 2020 until 31 December 2021, Periods of Russia-Ukraine War: 24 January 2022 until 31 December 2022.

Figure A6 illustrates the wavelet coherence heatmap of Ethereum-Stock Pairs based on weekly data.

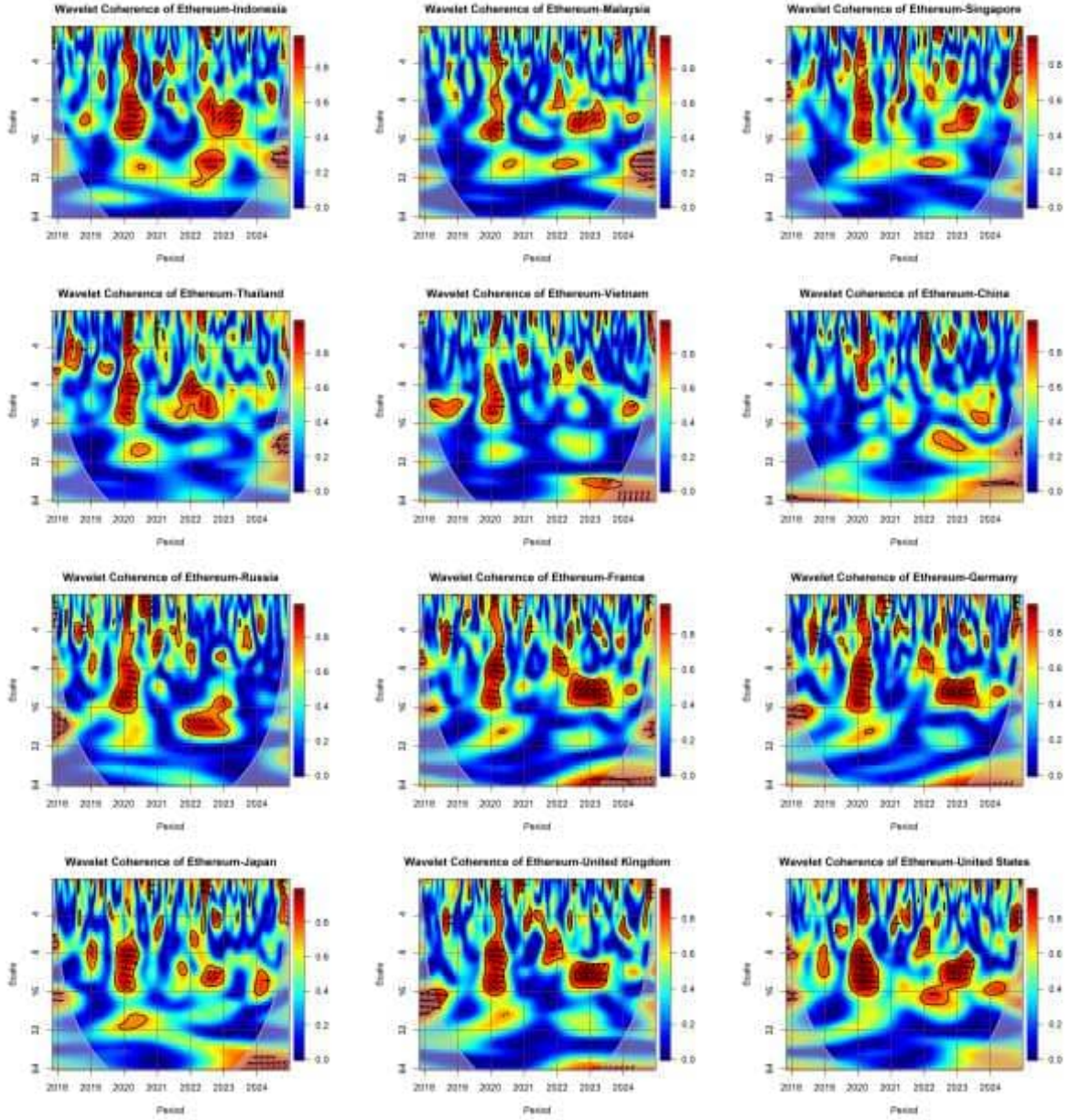
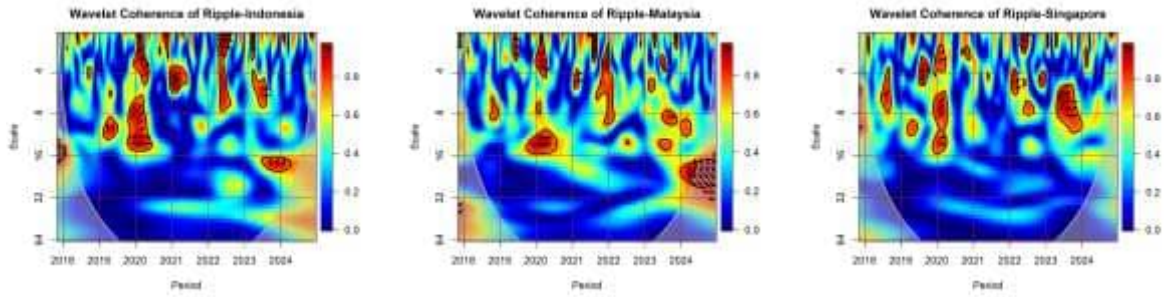


Figure A6. Wavelet Coherence Heatmap of Ethereum-Stock Pairs (Weekly Data).

Note: The vertical axis of scale 1 to 64 here refers to weeks, Indonesia-JKSE, Malaysia-KLCI, Singapore-STI, Thailand-SETI, Vietnam-VN, China-SSEC, Russia-IMOEX, France-FCHI, Germany-GDAXI, Japan-N225, United Kingdom-FTSE & United States-SPX. Periods of COVID-19:1 January 2020 until 31 December 2021, Periods of Russia-Ukraine War: 24 January 2022 until 31 December 2022.

Figure A7 illustrates the wavelet coherence heatmap of Ripple-Stock Pairs based on weekly data.



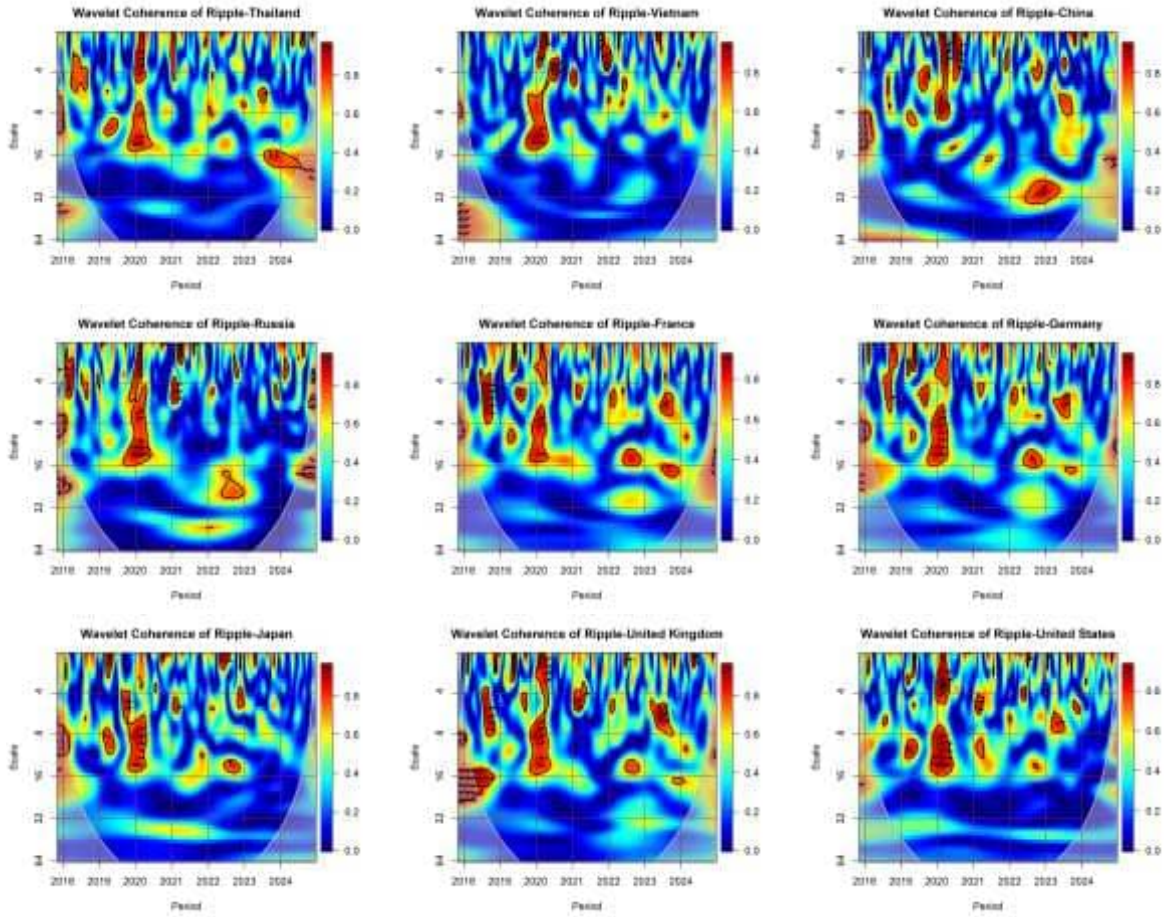
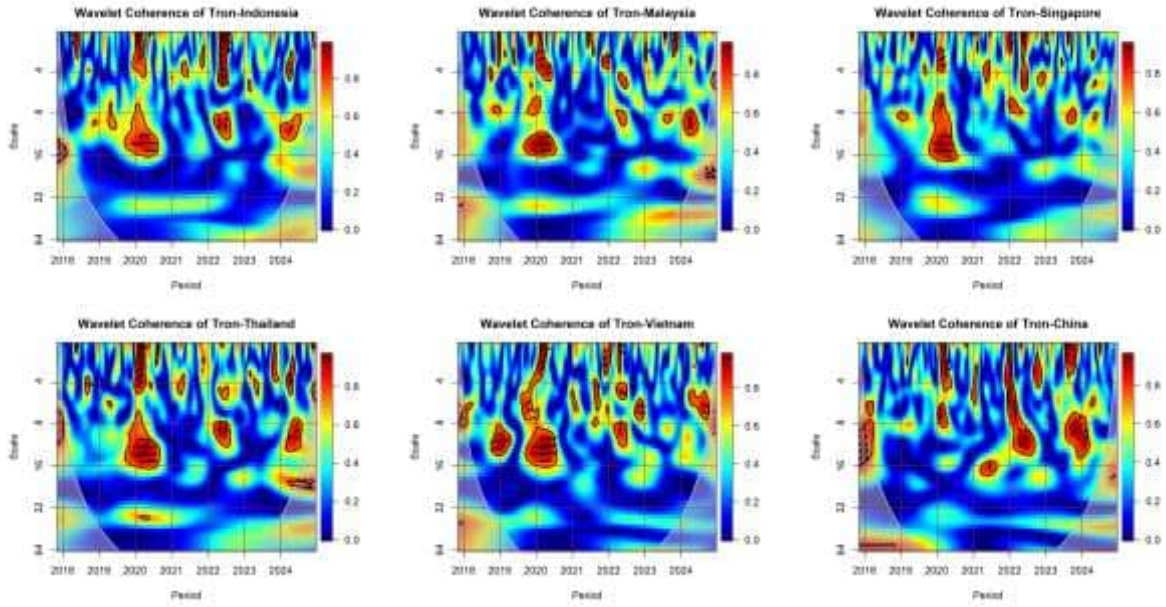


Figure A7. Wavelet Coherence Heatmap of Ripple-Stock Pairs (Weekly Data).

Note: The vertical axis of scale 1 to 64 here refers to weeks, Indonesia-JKSE, Malaysia-KLCI, Singapore-STI, Thailand-SETI, Vietnam-VN, China-SSEC, Russia-IMOEX, France-FCHI, Germany-GDAXI, Japan-N225, United Kingdom-FTSE & United States-SPX. Periods of COVID-19:1 January 2020 until 31 December 2021, Periods of Russia-Ukraine War: 24 January 2022 until 31 December 2022.

Figure A8 illustrates the wavelet coherence heatmap of Tron-Stock Pairs based on weekly data.



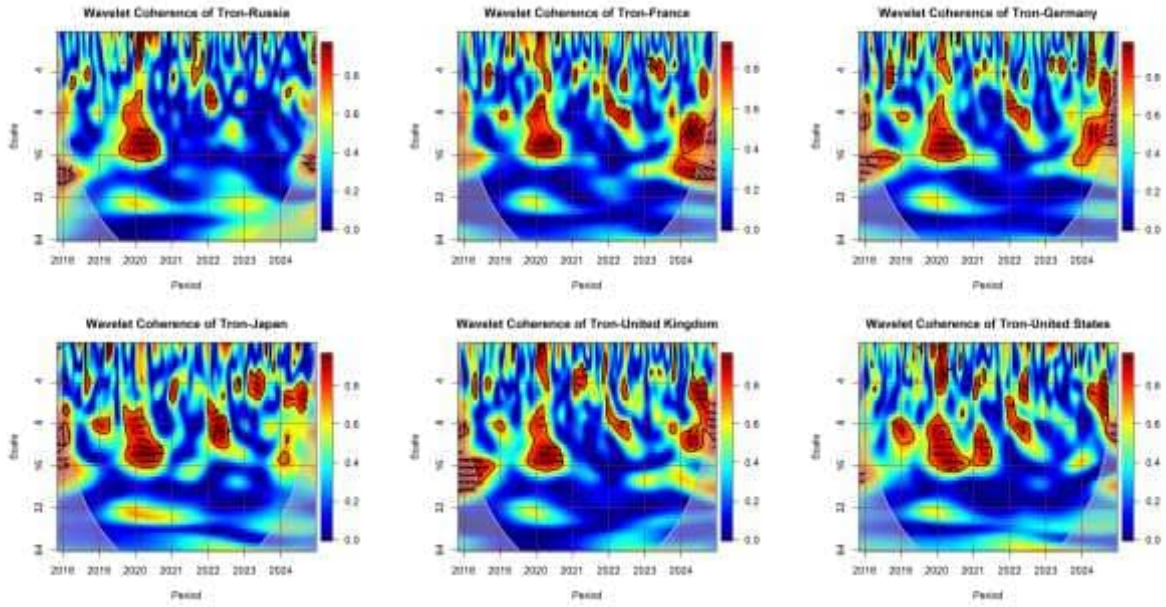
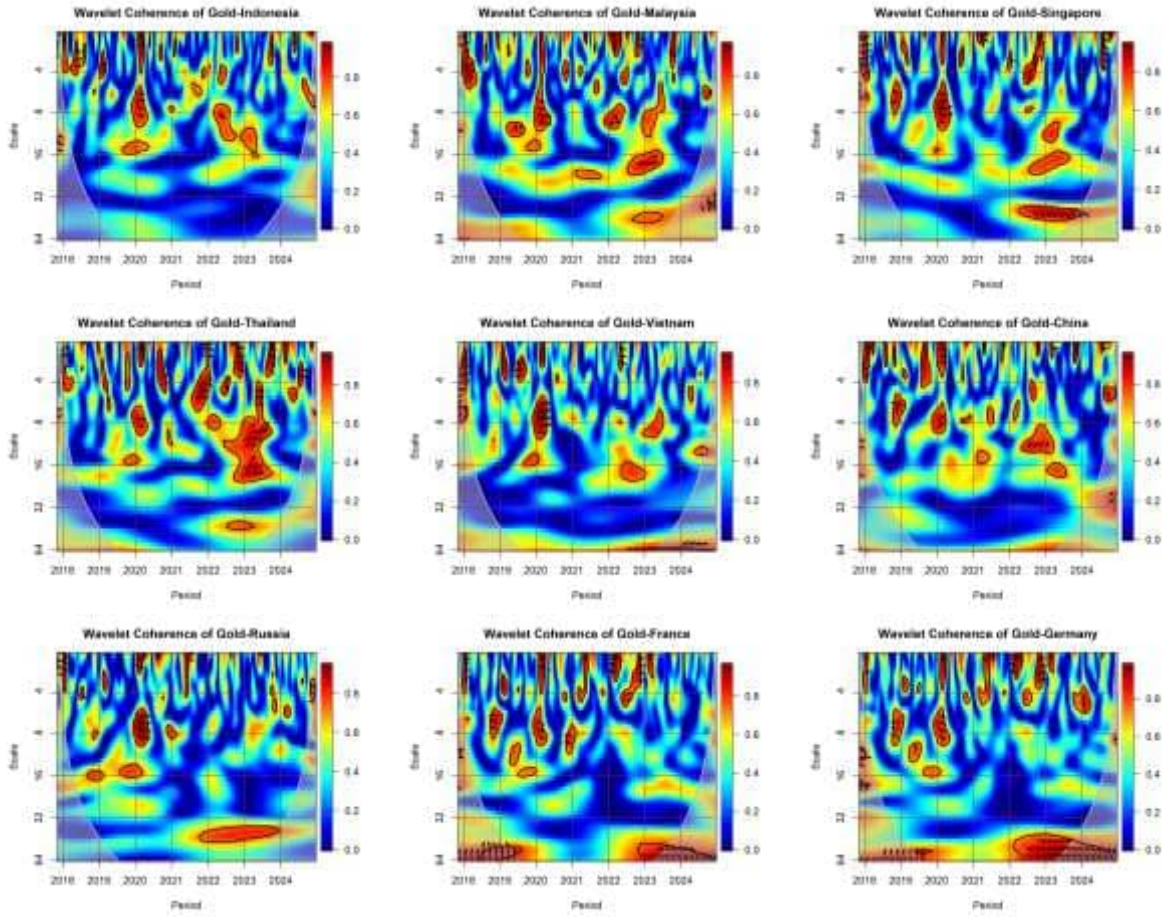


Figure A8. Wavelet coherence heatmap of Tron-Stock Pairs (Weekly Data).

Note: The vertical axis of scale 1 to 64 here refers to weeks, Indonesia-JKSE, Malaysia-KLCI, Singapore-STI, Thailand-SETI, Vietnam-VN, China-SSEC, Russia-IMOEX, France-FCHI, Germany-GDAXI, Japan-N225, United Kingdom-FTSE & United States-SPX. Periods of COVID-19:1 January 2020 until 31 December 2021, Periods of Russia-Ukraine War: 24 January 2022 until 31 December 2022.

Figure A9 illustrates the wavelet coherence heatmap of Gold-Stock Pairs based on weekly data.



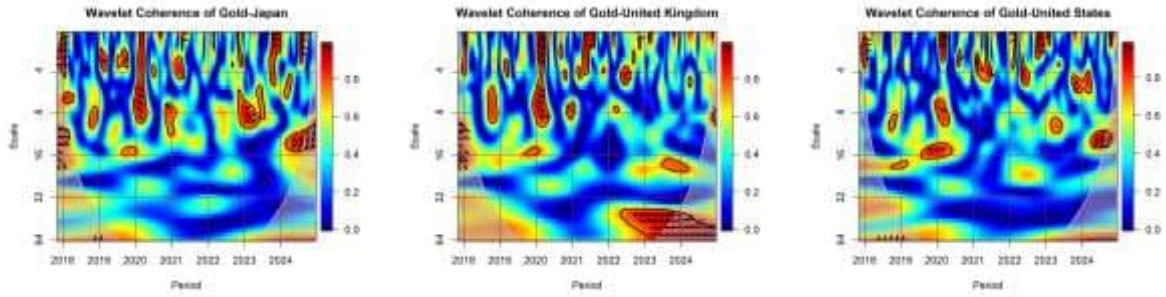


Figure A9. Wavelet Coherence Heatmap of Gold-Stock Pairs (Weekly Data).

Note: The vertical axis of scale 1 to 64 here refers to weeks, Indonesia-JKSE, Malaysia-KLCI, Singapore-STI, Thailand-SETI, Vietnam-VN, China-SSEC, Russia-IMOEX, France-FCHI, Germany-GDAXI, Japan-N225, United Kingdom-FTSE & United States-SPX. Periods of COVID-19:1 January 2020 until 31 December 2021, Periods of Russia-Ukraine War: 24 January 2022 until 31 December 2022.

APPENDIX B. Wavelet Coherence Heatmap of Cryptocurrencies-Stock and Gold-Stock Pairs (Daily Data).

Table B1. Summary of important findings.

Before COVID-19	During COVID-19	During the Russia-Ukraine War	During 2023 to 2024
Long Term Hedge (> 128 days) • ADA-JKSE • ADA-SSEC • LINK-FCHI • DOGE-JKSE • DOGE-KLCI • DOGE-STI • DOGE-SETI • DOGE-SSEC • DOGE-FCHI • ETH-SETI • XRP-JKSE • XRP-KLCI • XRP-STI • XRP-SETI • XRP-SSEC • XRP-FCHI • XRP-GDAXI • XRP-N225 • XRP-FTSE • XRP-SPX • TRX-SSEC	**Long Term Weak Safe Haven (> 128 days)** • DOGE-VN • DOGE-FTSE • XRP-KLCI • XRP-VN • XRP-SSEC • XRP-FCHI • XRP-FTSE	**Long Term Strong Safe Haven (64-128 days)** • LINK-IMOEX **Long Term Strong Safe Haven (100-128 days)** • BTC-IMOEX • BCH-IMOEX • ETH-IMOEX **Long Term Strong Safe Haven (> 128 days)** • G-IMOEX **Long Term Weak Safe Haven (> 128 days)** • BTC-SETI • BTC-IMOEX • BTC-SPX • BCH-FCHI • BCH-GDAXI • ADA-STI • ADA-IMOEX • DOGE-KLCI • DOGE-VN • DOGE-SSEC • DOGE-SPX • ETH-IMOEX • XRP-SETI • TRX-STI • TRX-FCHI • TRX-GDAXI • TRX-N225 • TRX-FTSE • G-JKSE	**Long Term Hedge (> 128 days)** • BTC-STI • BTC-FTSE • BCH-JKSE • BCH-KLCI • BCH-STI • BCH-VN • BCH-IMOEX • BCH-FTSE • ADA-JKSE • ADA-KLCI • ADA-STI • ADA-IMOEX • ADA-FCHI • ADA-GDAXI • ADA-FTSE • LINK-STI • LINK-IMOEX • LINK-N225 • LINK-FTSE • LINK-SPX • DOGE-JKSE • DOGE-STI • DOGE-IMOEX • DOGE-GDAXI • DOGE-N225 • DOGE-FTSE • ETH-STI • XRP-STI • XRP-VN • XRP-GDAXI • XRP-N225 • XRP-SPX • TRX-JKSE • TRX-STI • TRX-SETI

Before COVID-19	During COVID-19	During the Russia-Ukraine War	During 2023 to 2024
		• G-VN • G-SSEC • G-SPX	• TRX-VN • TRX-FCHI • TRX-GDAXI • TRX-N225 • TRX-FTSE • TRX-SPX • G-VN • G-N225 • G-SPX

Notes: Periods of COVID-19:1 January 2020 until 31 December 2021, Periods of Russia-Ukraine War: 24 January 2022 until 31 December 2022, BTC-Bitcoin, BCH-Bitcoin Cash, ADA-Cardano, LINK-Chainlink, DOGE-Dogecoin, ETH-Ethereum, XRP-Ripple, TRX-Tron, G-gold, Indonesia-JKSE, Malaysia-KLCI, Singapore-STI, Thailand-SETI, Vietnam-VN, China-SSEC, Russia-IMOEX, France-FCHI, Germany-GDAXI, Japan-N225, United Kingdom-FTSE & United States-SPX.