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# CRYPTO-CONTAGION: A QUANTILE-BASED ANALYSIS BETWEEN GREEN–NON-GREEN EMERGING CRYPTOCURRENCIES AND ENERGY MARKETS

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**Abstract**

*Financial contagion, risk transmission, and interconnectedness have come into focus due to the rapid growth of cryptocurrency markets and their increased connection to global energy markets. Given the existence of crypto contagion effects among the emerging cryptocurrencies, this study employs a quantile-based analytical framework to examine the contagion impact of Green and Non-Green emerging cryptocurrencies on energy markets. The study attempts to analysed the degree of connectedness and spillover effects under different market conditions as well as the resilience of Green cryptocurrencies against energy market shocks, in comparison with Non-Green cryptocurrencies. Daily data is used from 2018 to 2025 for various selected Green cryptocurrencies (Cardano, Stellar), Non-Green cryptocurrencies (Bitcoin, Monero), and variables of the major energy markets (WTI crude oil, Brent crude oil, Natural Gas). The study uses the Quantile Vector Autoregression (QVAR) model and quantile connectedness framework to account for the asymmetric nature of the market and tail-risk phenomena. The results highlight the strong interdependence among cryptocurrencies and energy markets, particularly under extreme market conditions. The results suggest that the Non-Green cryptocurrencies have relatively higher linkages with the energy markets as they rely on energy intensive mechanisms, while the Green cryptocurrencies have comparatively different spillover effects. In addition, the study finds that connectivity is non-linear and not necessarily symmetrical, with risk flow building up on both the down and up sides of the market. The results provide meaningful insights to investors, portfolio managers, financial planners, policymakers, and regulators for understanding systemic risk, optimizing their diversification strategies, and ensuring financial and environmental sustainability.*

**Keywords:** Crypto-Contagion, Green Cryptocurrencies, Non-Green Cryptocurrencies, Energy Markets, Quantile Vector Autoregression (QVAR), Connectedness, Spillover Effects, Financial Contagion, Sustainable Finance.

## 1. Introduction

The global cryptocurrency ecosystem has undergone a profound structural metamorphosis in recent years, driven by mounting regulatory pressures and the urgent paradigm shift toward sustainable finance. This evolution has catalyzed a distinct bifurcation within the digital asset landscape between "green" cryptocurrencies, utilizing energy-efficient consensus mechanisms such as Proof-of-Stake (PoS) or Delegated Proof-of-Stake (DPoS) and "non-green" cryptocurrencies, which remain reliant on energy-intensive Proof-of-Work (PoW) mining. Cryptocurrencies have grown so fast that they've really changed how capital flows around the globe, initiating novel avenues for investment, facilitating digital transactions, and enabling financial management outside of conventional banking institutions (Gherghina et. at., 2026). The inception of it all was Bitcoin, designed to serve as a novel form of digital currency. Currently, it has evolved into an expansive, interconnected financial ecosystem teeming with myriad digital currencies, the underlying technology known as blockchain, decentralized applications, and various digital assets (Mensi, Belghouthi, Al-Kharusi, & Kang, 2025).

The contagion and volatility spillovers between cryptocurrency markets and energy sectors represent a complex, state-dependent phenomenon. Zhang et al. (2025), demonstrates that the energy elasticity of emerging non-green tokens remains highly sensitive to fossil fuel price shocks and grid constraint anomalies, whereas emerging green tokens exhibit a growing, albeit volatile, correlation with renewable energy certificate markets and carbon pricing mechanisms. Furthermore, Mensi et al. (2025) highlights that volatility spillovers between energy commodities and digital assets are profoundly asymmetric, intensifying significantly during periods of macroeconomic stress and energy supply shocks. However, the existing literature predominantly relies on mean-variance frameworks, which assume symmetric relationships and obscure the tail-risk dynamics inherent in these markets. Naeem et al. (2024) examine the dynamic connectedness and return spillovers between ESG equities and green cryptocurrencies to assess their co-movement across varying market regimes. The study reveals a strong positive association during normal conditions, while highlighting the potential of green cryptocurrencies to serve as effective portfolio diversifiers alongside ESG stocks during periods of financial stress.

Over the past few years, a lot of people have started paying serious attention to cryptocurrencies from big investment firms and government officials to academics. This is because they can offer big profits, but are also a bit of a gamble, and they're becoming more and more connected to regular stock and commodity markets. However, it's not all good news. Even with all that financial potential, cryptocurrencies also bring up some big worries. Things like how much their value jumps around, the risk they could cause bigger problems in the financial system, whether they're good for the environment, and how easily issues in one part of the market could spread to others. (Zhifang , Qian , & Miftah, 2025). Energy crises and crypto-market crashes do not transmit risk uniformly; rather, contagion is often concentrated in the tails of the distribution. As argued by Alqahtani and Hammoudeh (2026) capturing the state-dependent contagion between the green transition and digital asset markets necessitates advanced quantile-based methodologies. Quantile connectedness frameworks allow researchers to map how shock transmission between energy markets and cryptocurrencies varies across different market conditions

A significant issue within bitcoin markets is their close connections to energy markets. Cryptocurrency mining operations, particularly those associated with Proof-of-Work (PoW) frameworks like Bitcoin, utilize substantial quantities of electricity and energy derived from fossil fuels. This has heightened the dependence of bitcoin markets on energy costs, electricity use, and ecological regulations. Energy markets experience fluctuations due to geopolitical conflicts, inflationary pressures, transitions to renewable energy, and supply chain interruptions, while cryptocurrency markets are similarly vulnerable to financial contagion and interrelated market dynamics. Recent studies indicate that disturbances in energy markets might propagate volatility to bitcoin prices, particularly during periods of significant market strain (Yan et. at, 2026).

There are growing concerns about the amount of energy consumed by some cryptocurrencies and their impact on the environment (Kazouz & Yousfi, 2026). This concern is driving the rise of ‘Green cryptocurrencies’. These digital currencies are designed to have a lower environmental footprint by using more energy-efficient modes of operation, such as something called Proof-of-Stake (PoS). However, many conventional cryptocurrencies, known as 'Non-Green', still rely on energy-intensive mechanisms for their functioning (Gherghina et. at., 2026). That distinction is becoming critical because environmental sustainability is a big deal for investors and policymakers when it comes to making financial decisions. Green cryptocurrencies are often seen as eco-friendly alternatives to the older ones, but there isn't a lot of real-world data yet to show if they are the effects of the energy market (Jiang et. at., 2025). The theory that support the relationship is financial contagion theory explicates the manner in which shocks in one market can be transferred to another market and most particularly in this case, during the periods of financial distress. An increase in energy prices raises the cost of mining that may reduce profitability and affect the cryptocurrency prices (Katsiampa;2017). The second is the portfolio rebalancing channel, according to which the investors will be able to reallocate their assets in response to changes in risk, which will, in turn, cause changes in both energy and cryptocurrency markets (Youseaf and Yarovaya, 2022).

However, despite extensive study, there remain significant enquiries that this study has yet to resolve. Bitcoin or a select few prominent cryptocurrencies, although there has been insufficient attention given to the emerging 'Green' and 'Non-Green' alternatives (Mejri, Jare, Khan, & Leccadito, 2025). Numerous studies employ models that solely examine averages, so failing to adequately illustrate the uneven dissemination of issues during periods of significant market distress. Furthermore, few studies systematically analyses these emerging Green and Non-Green cryptocurrencies utilizing a uniform methodology that assesses risk distribution across various market conditions, rather than only the average. Finally, other types of models such as VAR-GARCH specifications could be estimated to shed more light on both mean and volatility spillovers. So the main objective of this study is to examine crypto-contagion between Green and non-Green emerging cryptocurrencies and energy markets using quantile-based analysis. This study thoroughly investigates how emerging 'green' and 'non-green' cryptocurrencies affect the energy sector. The unique methodology of this study explores multiple market tiers. This study is interested in how these worries spread during different market conditions. Quantile Vector Autoregression and a quantile connectivity framework are used in this paper to contribute to bitcoin finance, sustainable finance, and energy economics.

## 2. Literature Review

Recent studies show that cryptocurrency markets are becoming increasingly connected with energy markets, sustainable finance assets, and green investment instruments. This connection is important because cryptocurrencies differ in their energy use. Non-green cryptocurrencies (e.g. Bitcoin and other Proof-of-Work assets) are more energy intensive. Green cryptocurrencies are meant to cut down on energy consumption through more efficient mechanisms such as Proof-of-Stake (Alarmaren et. at, 2026). As such, the relationship between energy markets and cryptocurrencies is no longer limited to price movements, but also involves sustainability, energy dependence and contagion risk. Gong and Wang (2025). Jiang, Jia, and Han (2025) examined quantile return and volatility spillovers among energy, electricity, and cryptocurrency markets. Their findings show that the connection between these markets becomes stronger during extreme market conditions, which supports the use of quantile-based methods in crypto-contagion studies. This is highly relevant to the present study because it shows that normal market analysis may not fully capture the risk transmission between energy and cryptocurrency markets during bearish or bullish periods.

Similarly, Mejri (2025) examined the spillover dynamics between green and non-green cryptocurrencies considering the role of geopolitical risk. The study found that green and non-green cryptocurrencies do not behave similarly in periods of crisis. This provides an argument against cryptocurrencies being classified as a single asset class. Rather, they should be classified by their characteristics of use of energy and the environment. Yan, Cheung, and Yuan (2026) analyzed the impact of green and non-green cryptocurrency markets on traditional and clean energy markets using a TVP-VAR connectedness approach. Their findings show that connectedness between cryptocurrency and energy markets changes over time and becomes stronger during extreme events. Kazouz (2026) found that non-green cryptocurrencies have stronger links with energy markets, while green cryptocurrencies are more exposed to extreme-event probability. The study is relevant to the current work because it compares green and non-green cryptocurrencies in the context of energy markets. Corbet et al. (2026) explains that emerging green and non-green cryptos present unique, under-researched contagion channels. These emerging assets often suffer from lower liquidity and higher idiosyncratic risk, potentially acting as distinct amplifiers or shock absorbers when energy markets experience severe volatility.

Mensi et al. (2025) looked at tail-risk contagion and connectedness between clean cryptocurrencies, green assets and commodity markets. Their findings suggest that green cryptocurrencies may have greater tail risks during periods of market disruption, while assets such as green bonds, ESG indices and gold show more

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resilience. The study also reported that market interconnectedness becomes stronger during extreme market conditions, especially in bullish phases. This supports the need for a quantile-based approach because contagion is not constant across market states. Ustaoglu (2026) investigated ESG ETFs, clean cryptocurrencies, and renewable energy tokens. The study found that interconnectedness among these assets increases during crisis periods and becomes stronger during negative market conditions. This is important for the present study because it confirms that green financial assets and clean cryptocurrencies are connected, but their role changes during stress periods. Therefore, investors cannot automatically assume that green cryptocurrencies are always safer during crises.

Kazouz (2026) studied asymmetric risk transmission between energy-efficient and energy-intensive cryptocurrencies using a quantile-on-quantile VAR framework. The study used daily data from September 2021 to July 2025 and found that cryptocurrency markets become almost fully interconnected during financial stress periods. This finding strongly supports the present study's focus on crypto-contagion because it shows that extreme conditions increase the risk of contagion between different cryptocurrency categories. Alamaren et al. (2026) explored the connectedness among Bitcoin, green bonds, renewable energy, and gold using a quantile connectedness approach. Their findings showed that the roles of these assets as risk transmitters or receivers change under different market conditions. This supports the idea that market connectedness is dynamic and cannot be understood properly by using only traditional linear models. Their study also highlights the importance of including renewable energy and green finance assets when studying cryptocurrency contagion. Gök (2025) examined spillovers between cryptocurrency, DeFi, carbon, and energy markets. The study found that clean energy markets are more strongly interconnected with cryptocurrency and DeFi markets than dirty energy and carbon markets. This finding is important for the present study because it shows that the crypto-energy relationship is expanding beyond traditional fossil energy markets and now includes clean energy and carbon-related financial markets. Kaur (2025) investigates the volatility spillover dynamics between green finance instruments, renewable energy markets, and the cryptocurrency sector to map their interconnected risk transmission. The study reveals significant cross-market contagion, highlighting the critical need for integrated risk management strategies for investors navigating the intersection of sustainable and digital asset transitions.

The first and most direct channel is the energy-use channel. Mining non-green cryptocurrencies takes up a lot of electricity. So as energy prices rise, mining becomes costly. This can affect the profitability of miners and can put pressure on the prices of cryptocurrencies and investor sentiment. The second channel is the investor sentiment channel. Investors tend to be more cautious in energy markets during crises, whether it is oil price shocks, electricity shortages or geopolitical conflicts. During such periods, investors may reduce their exposure to risky assets, including emerging cryptocurrencies. This can increase contagion between energy markets and cryptocurrency markets. Jiang et al. (2025) found that connectedness among energy, electricity, and cryptocurrency markets becomes stronger at extreme quantiles, showing that market stress increases the relationship between these markets. The third channel is the sustainability channel. Green cryptocurrencies are linked to ESG and clean finance concepts, and clean energy markets are also part of the green finance ecosystem. This means that changes in clean energy markets may influence the perception of green cryptocurrencies. Alamaren et al. (2026) studied Bitcoin, green bonds, renewable energy, and gold using a quantile connectedness approach and found that the role of these assets as transmitters changes across market conditions. The fourth channel is the tail-risk channel. Contagion is usually stronger during extreme market conditions, such as market crashes, energy crises, or speculative booms. Mean-based models may show weak relationships during normal periods, but quantile-based models can reveal stronger relationships in lower and upper quantiles. Mensi et al. (2025) found that market interconnectedness becomes stronger during extreme conditions, especially in bullish phases. This supports your use of quantile-based analysis because your study wants to examine crypto-contagion under bearish, normal, and bullish conditions. Duan et al. (2023) investigate how economic policy uncertainty (EPU) differentially drives the return and volatility connectedness between clean (green) and dirty (non-green) cryptocurrencies and traditional financial assets.

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Overall, the recent literature suggests that the relationship between cryptocurrencies and energy markets is dynamic, asymmetric and highly sensitive. The studies suggest that green and non-green cryptocurrencies should be analyzed separately, as they could be differently exposed to energy market shocks. The literature also highlights that quantile-based models are more suitable for analyzing crypto-contagion because they capture risk transmission during bearish, normal, and bullish market conditions. Therefore, the present study contributes to the literature by focusing specifically on crypto-contagion between Green–Non-Green emerging cryptocurrencies and energy markets using a quantile-based framework.

## 3. Methodology

The study adopts a quantitative study methodology because the study focuses on measuring and analyzing the statistical relationships between energy market and cryptocurrency volatility. Quantitative study is considered appropriate for financial studies as it allows to examine market behavior using numerical data, statistical testing, and econometric modeling techniques. Since cryptocurrency and energy markets are highly volatile, nonlinear behavior, and time-varying interactions, the use of quantitative methods enables a more reliable and provide measurable evidence regarding risk transmission and market connectedness. An explanatory study design has been selected because the study aims to explain the causal relationship between energy market and green and non-green emerging cryptocurrencies. Furthermore, the study follows a time-series and comparative study framework. Time-series analysis is appropriate because the data consist of daily observations collected over a specific period, allowing the study to capture dynamic market relationships over time. The comparative aspect of the study emerges from the distinction between green and non-green emerging cryptocurrencies, enabling the study to examine whether environmentally sustainable cryptocurrencies respond differently to energy market shocks compared to energy-intensive cryptocurrencies. Gallersdörfer et al. (2020) reveals that these alternative cryptocurrencies collectively represent a substantial and often overlooked energy footprint, emphasizing the need for comprehensive environmental policies that address the entire Proof-of-Work ecosystem rather than just Bitcoin.

The study population includes all types of cryptocurrencies and energy markets thus this study narrows down to emerging cryptocurrencies because of low level of volatility, liquidity, or sensitivity to external shocks as compared to established cryptocurrencies such as Bitcoin and Ethereum. The size of the sample of this study is distributed between green and non-green. The selected Green cryptocurrencies include Cardona, and Stellar while the non-green cryptocurrencies selected for the study include Bitcoin (BTC), and Monera. Moreover, the study covers such important energy variables as crude oil (WTI/Brent), natural gas, and indices of renewable energy. This mix will make sure that the sample represents a holistic picture of the crypto-energy nexus.

The study uses daily time-series data covering the period from 2018 to 2025. This time horizon is selected because it includes several major global events such as the COVID-19 pandemic, geopolitical tensions, energy crises, and the transition toward renewable energy, all of which significantly affected both cryptocurrency and energy markets. The data on cryptocurrencies are gathered on the sites like Coin Market Cap, Binance, and Yahoo Finance, coin gecko that provide detailed information about the cryptocurrency prices, market capitalization, and trading volumes. The sources of the energy market information include the U.S. Energy Information Administration (EIA), the Bloomberg and the World Bank, which provide the reliable data on the oil prices, natural gas, electricity, and renewable energy indices.

Quantile regression and QVAR models are used as the core analysis, which enables the study to analyze relationships in different market conditions. Specifically, the techniques are employed to pick up asymmetric effects and tail-risk dynamics. As an example, the change in the energy market may have a greater influence on cryptocurrency during extreme market periods than during normal periods.The initial step is to calculate the daily returns of all the selected cryptocurrencies and energy market variables. The return will be calculated as:

$$R_t = \ln \frac{P_t}{P_{t-1}} \times 100$$

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Where $R_t$ represents the daily returns, $P_t$ represent current daily price and $P_{t-1}$ represent previous daily price.

The main econometric model in this study is Quantile Vector Autoregression Model (QVAR). The traditional VAR model examines the average relationship among variables, but it does not fully capture relationships during extreme market conditions. Since the present study focuses on crypto-contagion across bearish, normal, and bullish states, so the QVAR model is more suitable. Jiang, Jia, and Han (2025) used the QVAR model to examine energy, electricity, and cryptocurrency markets and found that connectedness among these markets becomes stronger in extreme low and high quantiles. Their study supports the use of QVAR for analyzing crypto-energy market relationships.

The general QVAR model can be written as:

$$Q_{Yt}(\tau|F_{t-1}) = \mathrm{c}(\tau) + \sum_{i-1}^{p} Ai(\tau)Y_{t-i} + \varepsilon t\ (\tau)$$

where $Q_{Yt}(\tau|F_{t-1})$ is the conditional quantile of the dependent variable at quantile τ, $Y_t$ is a vector of cryptocurrency and energy market returns, c(τ) is the quantile-specific intercept, Ai is the coefficient matrix of lag i, p is the lag length and εt(τ) is the error term. The quantile level can be lower quantiles like 0.05 or 0.10, median quantile 0.50 and upper quantiles like 0.90 or 0.95. Lower quantiles indicate bearish market conditions, median quantile indicates normal market conditions and upper quantiles indicate bullish market conditions.

To measure crypto-contagion and connectedness, the study will use the quantile connectedness framework based on forecast error variance decomposition. This method helps identify how much of the forecast error variance of one market is explained by shocks from another market. In simple words, it shows whether a market is a transmitter or receiver of shocks. Mensi et al. (2025) used a quantile connectedness framework to examine tail-risk contagion between clean cryptocurrencies, green assets, and commodity markets. Their findings showed that interconnectedness becomes stronger during extreme market conditions, which supports the current study's quantile-based contagion approach.

## 4. Empirical Results

The empirical results of the study are presented and discussed in this chapter. The chapter first presents descriptive statistics and correlation analysis, to give a first insight into the behavior, distributional characteristics, and interrelationships of the variables selected. The analysis covers green and non-green cryptocurrencies such as Bitcoin, Monero, Cardano and Stellar, among the major energy market variables are known as the prices of both the West Texas Intermediate (WTI) crude oil and the Brent crude oil, as well as Natural Gas. The data is collected every day from 2018 to 2025. The main empirical analysis is then performed using the Quantile Vector Autoregression (QVAR) connectedness framework, to examine the contagion effects between the selected markets under various market conditions. The results are reported using several indicators of connectedness – directional spillovers (TO and FROM connectedness) and Net Spillover measures – all of which indicate the overall system-wide interconnectedness and the relative contribution of each indicator as a transmitter or receiver of shocks.

The table 4.1 shows the descriptive statistics for the daily returns of Bitcoin, Brent Oil, Cardano, Monero, NAGS, Stellar and WTI Oil. Descriptive statistics are used to gain insights on the nature of the data, including average returns, risk, distribution shape, and normality.

The mean is the average of the daily returns for each asset. Bitcoin's mean return is positive at 0.000629, which suggests that there is a small average increase in Bitcoin's value during the sample period. WTI Oil also has a positive mean return (0.000195), whereas the other four assets, namely Brent Oil, Cardano, Stellar, and NAGS, have slightly negative average returns. Standard deviation is a measure of risk or volatility. Higher values indicate greater fluctuations in returns. NAGS has the largest standard deviation (0.131597), and is the riskiest asset in the sample. The standard deviation for Brent Oil is the smallest (0.030710), indicating relatively less volatility. Bitcoin, Cardano, Monero, Stellar and WTI have moderate risk levels. The results reveal that the return distribution of all assets is non-normal with high volatility and extreme price

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movements. The stock NAGS seems to be the most volatile and risky asset, and the stock of Brent Oil seems to be relatively less volatile. This indicates that there is substantial skewness and very high kurtosis which means that there is a substantial tail risk for investors opting for these assets.

**Table 4.1**

*Descriptive Statistics*

| | R_Bitcoins | R_Brent | R_Cardano | R_Monero | R_NAGS | R_Steller | R_WTI |
|---|---|---|---|---|---|---|---|
| Mean | 0.000629 | -0.000218 | -0.000259 | 7.12E-05 | -0.003584 | -0.000641 | 0.000195 |
| Median | 0.000567 | 0.000245 | -0.000252 | 0.002303 | 0.000000 | -0.000711 | 0.000523 |
| Maximum | 0.176026 | 0.693147 | 0.547726 | 0.317772 | 3.258331 | 0.464850 | 1.380000 |
| Minimum | -0.433714 | -0.643699 | -0.524402 | -0.511995 | -3.963027 | -0.439361 | -1.406152 |
| Std. Dev. | 0.034166 | 0.030710 | 0.053591 | 0.047050 | 0.131597 | 0.051386 | 0.046300 |
| Skewness | -0.863485 | 0.445534 | 0.207807 | -1.336835 | -9.051029 | 0.543545 | 0.388103 |

Source: "Developed from authors' own source"

The correlation matrix in Table 4.2 provides information regarding the linear association between the selected cryptocurrencies and energy market variables. The results indicate that there are positive relationships and the greater ones are found between cryptocurrency variables. Bitcoin is highly positively correlated with Cardano (0.712) and Stellar (0.650), which means that these cryptocurrencies are largely moving in the same direction in response to market conditions. Likewise, the peak correlation coefficient in the correlation matrix comes from Cardano and Stellar (0.753) implying that these two green crypto assets have a very strong co-movement. These results suggest a high level of integration in cryptocurrency markets because of the common investor sentiment, as well as the common speculative trading and market-wide information, which leads to the synchronization of prices.

The positive correlations that Monero exhibits are relatively weaker with other cryptocurrencies. It has a positive correlation with Bitcoin (0.148), Cardano (0.148), and Stellar (0.136), which are relatively weak. This indicates to some extent that Monero moves differently from the other currencies chosen, and it might offer limited diversification in a cryptocurrency portfolio.

Overall, the relationship between cryptocurrencies and energy market variables is weak. Bitcoin is almost perfectly uncorrelated with Brent crude oil (-0.024) and only slightly positively correlated with WTI crude oil (0.013). Likewise, Cardano, Monero and Stellar show close to zero correlation with both Brent and WTI crude oil. These weak relationships suggest that the returns of cryptocurrencies are not significantly associated with the returns on the oil market within the sample period. Additionally, Natural Gas also shows minimal correlation with all cryptocurrencies. Bitcoin's correlation with Natural Gas is -0.006, and the correlation between Cardano (0.012), Monero (0.002), and Stellar (0.030), and Natural Gas is very weak positive. This indicates that cryptocurrency returns are not directly affected by the short-term movements of natural gas prices in regular times.

Energy variables exhibit a moderate positive correlation between Brent crude oil and WTI crude oil (0.249), which is reasonable given that both are a good reflection of the global oil market and are affected by similar economic and geopolitical factors. In summary, the results of the correlation analysis reveal that the cryptocurrency markets are highly interconnected while the linear relationships between cryptocurrency and energy markets are relatively weak. These results argue for the application of more sophisticated econometric approaches like Quantile Vector Autoregression (QVAR) model, which can capture dynamic and nonlinear contagion effects which are not captured by simple correlation analysis

**Table 4.2**

*Correlation Analysis*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **1. R_Bitcoins** | 1 | | | | | | |
| **2. R_Brent** | -0.024160<br>0.1923 | 1 | | | | | |
| **3. R_Cardano** | 0.712092*** | -0.009741 | 1 | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0.0000 | 0.5991 | | | | | |
| **4. R_Monero** | 0.147679*** | -0.024306 | 0.147897*** | 1 | | | |
| | 0.0000 | 0.1896 | 0.0000 | | | | |
| **5. R_NAGS** | -0.005598 | 0.035105** | 0.012212 | 0.001858 | 1 | | |
| | 0.7626 | 0.0581 | 0.5099 | 0.9201 | | | |
| **6. R_Stellar** | 0.650151*** | 0.002942 | 0.752979*** | 0.136061*** | 0.030303* | 1 | |
| | 0.0000 | 0.8739 | 0.0000 | 0.0000 | 0.1020 | | |
| **7. R_WTI** | 0.012554 | 0.249245*** | 0.001971 | 0.005911 | 0.039268** | 0.011775 | 1 |
| | 0.4981 | 0.0000 | 0.9153 | 0.7498 | 0.0340 | 0.5252 | |

Source: “Developed from authors' own source”

Figure 4.1 shows the Net Total Directional Connectedness analysis is a measure of the disequilibrium in the flow of the variable under bull market conditions (95% quantile). If the values of NET are positive, the asset adds more volatility to the system than it absorbs; if they are negative, the asset absorbs more volatility. From the results, it can be seen that Monero (XMR) is the number one net transmitter of shocks as it has a NET value of 9.12. This indicates that, in the bull run, the volatility of financial assets is influenced mainly by Monero. Bitcoin also has a positive NET value of 1.73, meaning that it is a moderate transmitter of spillovers. Also, green crypto has NET positive values, albeit small, for Cardano and Stellar – green crypto is helping to facilitate the shock transmission during market booms. Overall, the study shows that the cryptocurrency markets are the main drivers of the markets' connectedness during bull market years, especially for non-green cryptocurrencies such as bitcoin and Monero.

**Figure 4.1**

*Net Total Directional Connectedness*

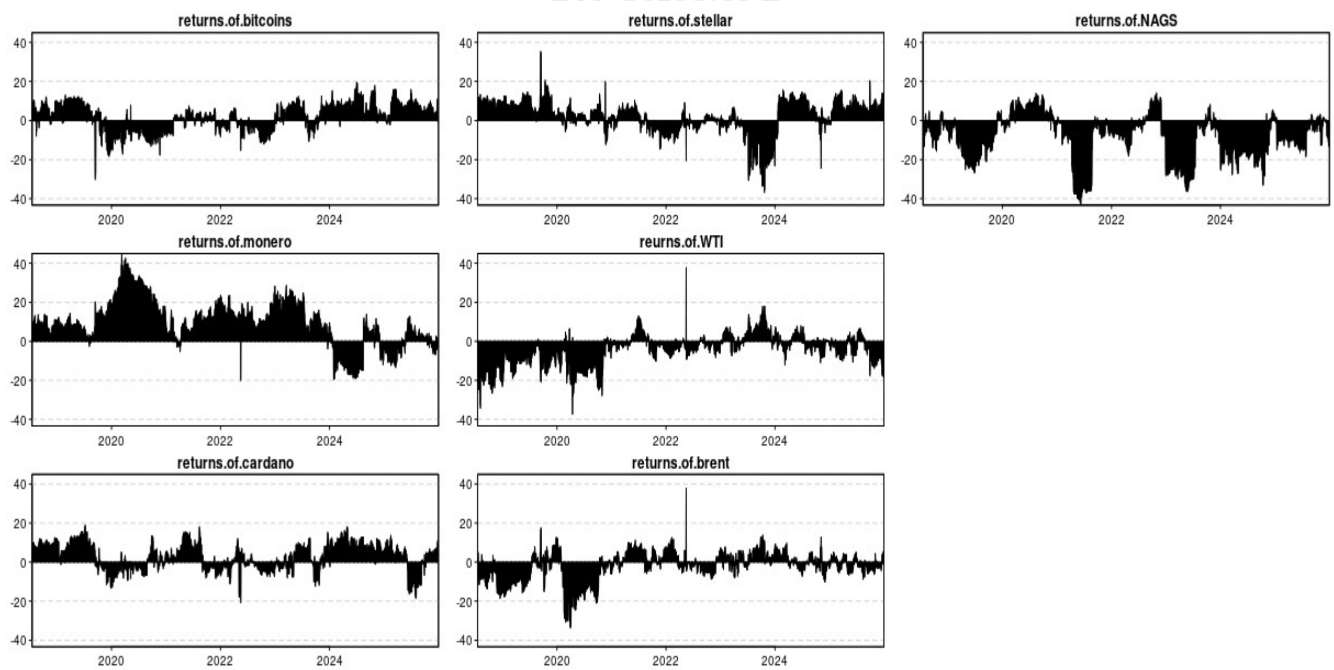


Figure 4.2 measure of the bi-directional spillover relation among individual asset pairs in a bull market regime is called Net Pairwise Directional Connectedness analysis. Positive numbers mean that the first asset of the pair is the stronger shock transmitter, negative numbers mean that the second asset is the stronger shock transmitter. The study could be used to better comprehend the direct spread of contagion in the days of heightened investor optimism in cryptocurrencies to the energy sector (Ando et al., 2022; Le, 2023).

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The Bitcoin–Monero relationship is extremely characterized by spillover transmission, as both assets have a significant effect on each other in bull markets. However, when it comes to the shock transmission, Monero seems to be more dominant, strengthening its central role in the cryptocurrency system. The pair-wise correlation between Bitcoin and other green cryptocurrencies like Cardano and Stellar are still relatively low but significant. The similar trend during bull runs indicates that green cryptocurrencies are tightly in sync with the overall cryptocurrency market. The spillover effects from cryptocurrencies to energy markets are not as strong as the spillover effects from cryptocurrencies to cryptocurrencies. Overall, the pairwise analysis doesn't contradict the previous results: the spread of contagion is the highest among the non-green cryptocurrencies and other crypto assets, as well as within the digital asset markets.

**Figure 4.2**

*Net Pairwise Directional Connectedness*

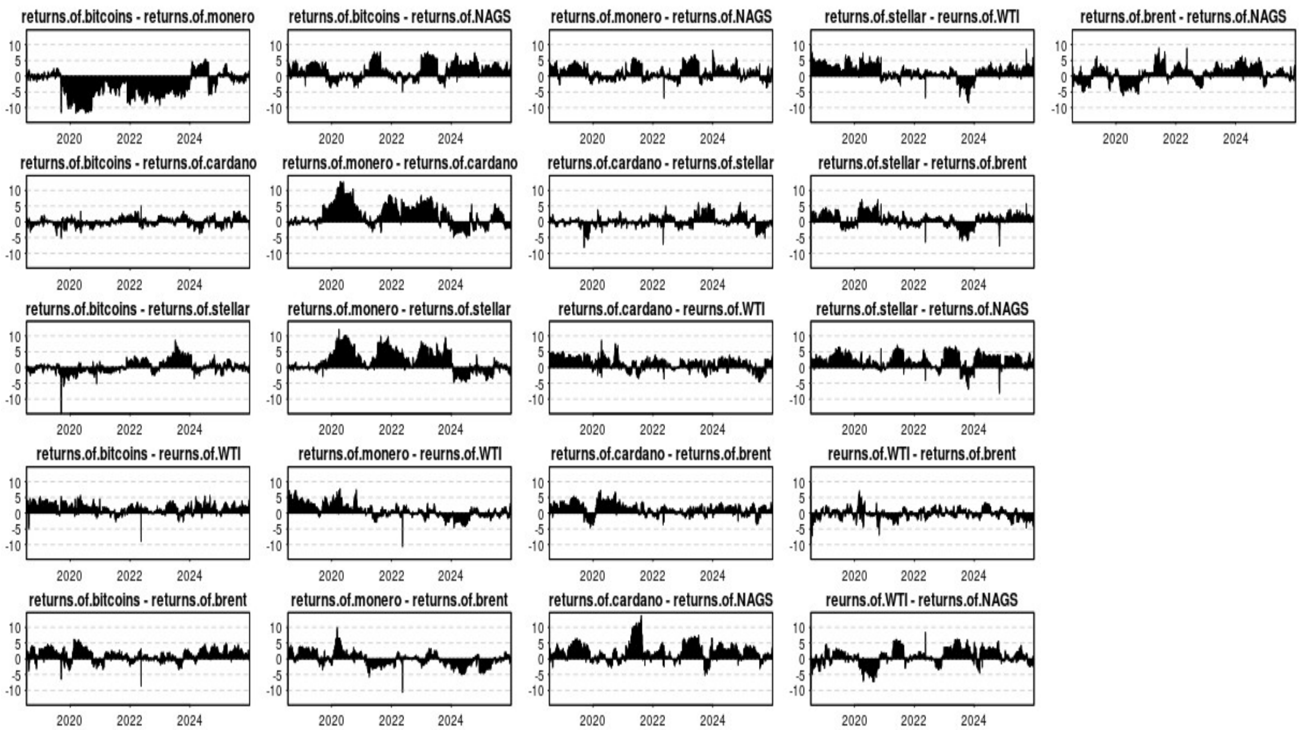


Figure 4.3 explains the dynamic pairwise connectedness analysis looks at the temporal changes in the relationships between asset pairs when the market is positive. This system reflects the varying levels of contagion which have occurred between cryptocurrencies and energy markets when investors are in a speculative mood and strongly optimistic mood. Cryptocurrencies and energy markets' relationships are still relatively low but not negligible. The temporary interconnectedness seems to be caused by volatilities in the energy market and by international economic uncertainties. This implies that energy costs have an indirect effect on cryptocurrencies, via investor sentiment or financial market conditions. Another key discovery is that when the bulls are very bullish, so too is the connectedness. The surge in speculation and optimism helps to reinforce digital asset market movements and volatility spillovers. These results coincide with the results of the study and indicate that financial contagion is not only a phenomenon during crisis periods, but also during market booms. Overall, the results indicate that the markets of cryptocurrencies are still well connected in bull markets, and that they have more contagion within the market than the markets of energy.

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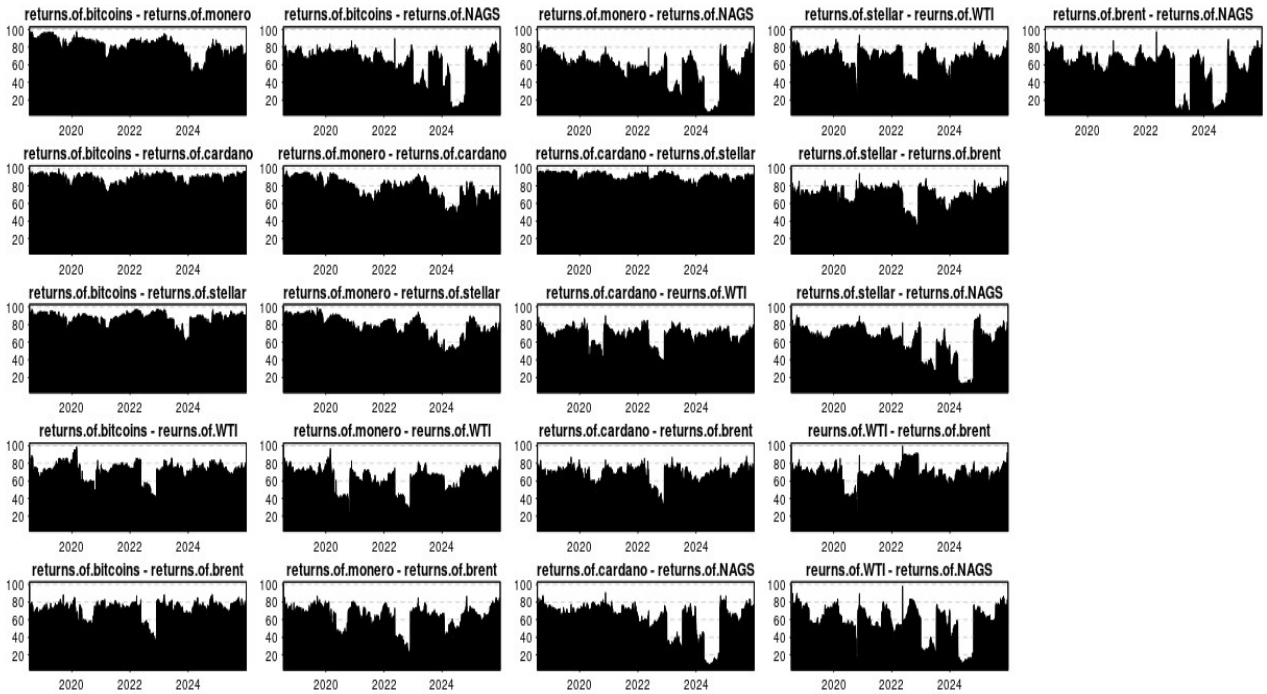
**Figure 4.3**
*Dynamic Pairwise Connectedness*




Diebold and Yilmaz (2012) introduce a novel framework using forecast error variance decomposition from vector autoregressions to measure directional volatility spillovers across multiple financial markets. This approach uniquely distinguishes between volatility transmitted "to" and "from" specific assets, enabling researchers to precisely identify the net transmitters and receivers of financial shocks. The Average Dynamic Connectedness in Table 4.3 identify the spillover connections among cryptocurrencies and energy markets during bull market conditions. The table displays the directional spillovers, own variance shares, net connectedness and the Total Connectedness Index (TCI). The diagonal elements are the proportional 'variance contributions' of the shocks of each asset to the volatility of the asset. 26.38% of Monero's future volatility is explained by Monero, 19.28% by Bitcoin. The OWNs tend to be smaller when the markets are bullish, as the cryptocurrencies are highly inter-connected at this time. The off-diagonal elements show spillover transmission between variables (Cifuentes, Alofaysan, & Doğan; 2026)

The results in table 4.3 explains that the cryptocurrencies Bitcoin, Cardano, and Monero have significant spillovers to each other, hence high levels of contagion between cryptocurrencies. The results indicate that there are strong spillover effects between other cryptocurrencies and Bitcoin, which translates to strong contagion effect between cryptocurrencies. Also, the green cryptocurrencies are highly correlated with non-green digital currencies.

As seen on the FROM column in table 4.3, Bitcoin gets 80.72% of its volatility from external markets, as do Cardano and Stellar with about 79% each. The high values suggest high market dependence when the market is bullish. The “TO” row reveals that Monero transmits the highest level of spillovers with a value of 82.74%, followed closely by Bitcoin and Cardano. The Total Connectedness Index (TCI) is at 75.75% and the corrected TCI is at 88.37%. These are extremely high values and imply very high levels of market interconnections in bullish periods.

The findings demonstrate that cryptocurrencies continue to be key drivers of spillover transmission during market booms while energy markets are relatively less powerful drivers of systemic risk.

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**Table 4.3: Average dynamic connectedness**

| | BTC | XMR | ADA | XLM | WTI | Brent | NAGS | FROM |
|---|---|---|---|---|---|---|---|---|
| Returns of bitcoins | 19.28 | 16.90 | 15.70 | 15.00 | 11.54 | 11.81 | 9.76 | 80.72 |
| Returns of Monero.(xmr) | 13.89 | 26.38 | 13.42 | 13.45 | 11.27 | 11.97 | 9.62 | 73.62 |
| Returns of Cardano.(ada) | 15.73 | 15.65 | 20.37 | 16.58 | 10.99 | 11.18 | 9.50 | 79.63 |
| Returns of stellar.(xlm) | 15.20 | 15.58 | 16.74 | 20.25 | 10.89 | 11.83 | 9.52 | 79.75 |
| Returns of WTI | 13.05 | 11.99 | 12.24 | 12.40 | 26.02 | 13.74 | 10.56 | 73.98 |
| Returns of Brent | 12.95 | 11.86 | 12.47 | 12.61 | 13.45 | 25.97 | 10.68 | 74.03 |
| Returns of NAGS | 11.63 | 10.77 | 11.77 | 11.73 | 11.22 | 11.38 | 31.51 | 68.49 |
| TO | 82.45 | 82.74 | 82.35 | 81.77 | 69.36 | 71.91 | 59.65 | 530.22 |
| Inc.Own | 101.73 | 109.12 | 102.72 | 102.02 | 95.37 | 97.89 | 91.15 | 184.96 |
| NET | 1.73 | 9.12 | 2.72 | 2.02 | -4.63 | -2.11 | -8.85 | 88.37 |
| NPT | 5.00 | 5.00 | 4.00 | 3.00 | 1.00 | 3.00 | 0.00 | 75.75 |

**Note:** BTC stands for Bitcoin, XMR stands for Monero, ADA stands for Cardano, and XLM stands for Stellar Lumens. In the energy and commodity markets, WTI stands for West Texas Intermediate, Brent refers to Brent Crude Oil (Brent Blend), and NAGS stands for Natural Gas.

## 5. Conclusion

The study explored contagion relationship between the non-Green–Green emerging cryptocurrencies and the energy markets on the basis of quantile analysis. The main goal of the study was to explore the possibility of different transmission rates of energy market shocks to Green and Non-Green cryptocurrencies in bearish, normal, and bullish market conditions. Data of the selected cryptocurrencies (Bitcoin (BTC), Monero (XMR), Cardano (ADA), and Stellar (XLM) and major energy market variables (WTI crude oil, Brent crude oil, and Natural Gas) were used for this study. Dynamic and asymmetric spillover relationships at different quantiles were identified with the Quantile Vector Autoregression (QVAR) model and the quantile connectedness framework. The empirical results indicated that the crypto and energy markets are very interdependent and that such interdependence varies considerably when markets are in different states. The descriptive statistics indicated that all the variables exhibited high volatility, non-normality, fat tails and volatility clustering, further confirming the speculation and volatility of both cryptocurrencies and energy markets. These results would serve as justification of the adoption of quantile-based econometric methods rather than the traditional linear models based on the mean since extreme market behaviour could not be explained properly with the linear models.

The hypothesis also shows that contagion is stronger under extreme market conditions. During the financial crisis, the market interconnection grows due to financial crisis events and uncertainty related to geopolitics, inflation and energy- related shocks. The non-green cryptocurrencies like Bitcoin and Monero were shown to be more sensitive to changes in energy markets due to the fact that they rely on energy-consuming mining systems. The results corroborate the first hypothesis that there is significant crypto-contagion in bearish market conditions. The level of dependency of cryptocurrencies and energy markets was high overall, although not significant, during normal market conditions.

Overall, the study concludes that the energy-to-cryptocurrency transmission of volatility and financial shocks is of crucial importance, as energy markets play a key role in the transmission process. Green and non-green cryptocurrencies have an important difference as they react differently to the instability of energy markets. Green coins are not as energy consuming as the mining of traditional cryptocurrencies, but when times are uncertain, there are contagion effects**.** Cryptocurrencies are therefore not only just an asset in the financial markets, but have also become part of the energy markets, sustainable financial systems and the world economy as a whole.

This study contributes to theoretical literature by expanding the use of the Financial Contagion Theory and Quantile Regression Theory to the analysis of the interconnectedness of the cryptocurrency and energy markets. The overall results lend support to the notion that financial contagion is not only taking place within the traditional financial markets, but also from digital assets markets to energy markets, especially during the

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extreme markets. Furthermore, the study enriches the literature on sustainable finance by highlighting the differences between Green and Non-Green cryptocurrencies in terms of their exposure to energy market volatility.

This study provides some practical implications for investors, portfolio managers, policymakers, regulators and financial institutions. The results can help portfolio managers create better diversification and risk management plans. Some knowledge on whether green cryptocurrencies display various contagion tendencies compared to non-green cryptocurrencies can assist investors in building a portfolio which can be more stable during market volatility. This study contributes to the understanding of the practical implications of cryptocurrencies, enabling individuals and institutions to make informed financial decisions while considering the interconnectedness of cryptocurrency markets with overall economic and energy developments. The performance of cryptocurrencies can change because of energy price fluctuations, geopolitical events, and shifts towards renewable energies. Hence, it is essential to appreciate these connections to help investors minimize losses, boost portfolio return, and manage risk more effectively and in a long-term investment perspective.

**Contribution of Authors**

All the authors participated in the ideation, development, and final approval of the manuscript, making significant contributions to the work reported.

**Conflict of Interest Statement**

The authors declare no conflict of interest.

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**Informed Consent**

Informed consent was obtained from all participants.

**Data Availability**

This study relies exclusively on publicly available secondary sources, including corporate disclosures, industry reports, and peer-reviewed literature, all of which are cited in the References section.

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