IJEEP

INTERNATIONAL JOURNAL OF ENERGY ECONOMICS AND POLICY

EJ EconJournals ISSN: 2146-4553

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2025, 15(1), 281-291.

EconJournals

The Dynamic Volatility Nexus of Blue-Green Economy, Cryptocurrency and Gold Indices during Uncertain Times

Sahar Loukil[1], Noshaba Zul iqar[2], Dimıtrios Papadas[3]*, Bikramaditya Ghosh[4]

[1]University of Sfax, Tunisia, [2]GIK Institute of Engineering Sciences and Technology, Pakistan, [3]Harper Adams University, United Kingdom, [4]Symbiosis International University, India. *Email: dpaparas@harper-adams.ac.uk

Received: 15 August 2024 **Accepted:** 06 November 2024 **DOI:** https://doi.org/10.32479/ijeep.17332

ABSTRACT

Climate change impact on the Blue-Green economy has been of great concern. Further cryptocurrency mining is impacting the economy in an adverse fashion. Moreover, impact of gold mining, extraction on Blue-Green economy and even relationship with cryptocurrency is another interesting facet. Therefore, we delved into the interconnectedness among five indices, two of which focus on the green economy (ICLN-iShares and CNRG-SandP), whereas three are on the blue economy (BJLE- BNP Paribas ESG Blue Economy ETF and PIO-Invesco Global Water ETF) and OCEN (IQ Clean Oceans ETF) alongside the traditional assets Bitcoin and gold indices. We considered between October 26, 2021, to January 5, 2024 for the study. This study highlighted some cardinal findings. First, BJLE can be used as a hedge against OCEN and PIO (all are in Blue economy). Second, excessive water usage in Bitcoin mining is detrimental to Blue-Green economy. Third, positive policy shock force spillover effect to cool down. Fourth, spillover typically increases as both economic uncertainty (US Banks collapse in 2023) and geopolitical risk (Russia-Ukraine conflict) increase. Fifth, there has been an increased responsiveness of these markets to immediate events (near-term bias). Therefore, this study would assist the policymakers and investors, especially in the Blue-Green domain.

Keywords: Blue-Green Economy, Cryptocurrency, Gold Indices
JEL Classifications: Q01, Q56, G15, C32

1. INTRODUCTION

Billions of people rely on the oceans for their livelihoods and for the sake of life itself. The significance of marine life is underscored by Sustainable Development Goal 14, which addresses life below the waterline. Coastal, marine, and associated industries are projected to be worth between USD 3 trillion and USD 5 trillion on the market, or close to 5% of the world's gross domestic product (Gunter, 2010). In some East Asian countries, the ocean economy accounts for 15–20% of GDP (Dharmapuri and Tiwari, 2022). The health of marine ecosystems (blue economy) is closely linked to terrestrial ecosystems and overall environmental health (green economy). Activities such as sustainable fishing practices, coastal zone management, and marine conservation contribute to maintaining the balance of ecosystems, which in turn supports biodiversity and ecosystem services critical for human well-being. Integrated approaches to coastal zone management, which consider both terrestrial and marine environments, are essential for promoting sustainable development and resilience to climate change. This involves coordinating land use planning, marine spatial planning, and ecosystem-based management to balance competing interests. Stakeholders can benefit from increased production, improved operational efficiency, and attractive returns through better management of blue economy assets. However, due to abuse and poor management, this valuable resource has had irreversible detrimental consequences on the ecosystem, particularly marine life, as well as the way of life for many coastal communities.

On the other hand, a green economy policy aims to combine economic growth with nature conservation. Projects pertaining to energy efficiency, renewable energy, sustainable agriculture, and green buildings can fall under this category. Sustainable loans can hasten the shift to a more sustainable economy by granting access to capital. Companies may be encouraged to adopt more environmentally friendly practices by means of sustainable loans. Lastly, sustainable loans can assist banks in showcasing their dedication to social responsibility and sustainability (Shan et al., 2023). It is not predicted returns that have driven the outperformance of green assets in recent years, but astoundingly large rises in environmental concerns (Pástor et al., 2021).

In 2022, global energy investment is expected to rise by almost 8% to USD 2.4 trillion, mostly in the clean-energy sector, according to a new estimate from the International Energy Agency. Due to environmental concerns and the necessity to abide by the 2015 Paris Climate Agreement, countries all over the world have been shifting to renewable energy sources, which has resulted in a notable boom in the adoption of renewable energy technologies (IEA, 2021).

Due to the concepts and terminology being similar, several international organisations, like the United Nations Environment Programme (UNEP), further identify the blue economy as being a part of the green economy or green growth (Smith-Godfrey, 2016). Thus, by incorporating both green-blue indicators, index frameworks can be strengthened to become comprehensive tools for tracking the advancement of sustainable issues in both terrestrial and aquatic ecosystems(CANARI, 2019). In particular, small island states and other developing countries where there is a high potential for the blue economy to create green economic opportunities because of their geographic proximity and historical reliance on marine resources should benefit from a synergy between green and blue indicators with the Green Growth Index (Patil et al., 2016). While most island nations find the combined green growth index to be very effective, it is yet unknown whether this combination model—which takes an inclusive approach—would be more successful in larger nations.

Usually, green bonds fund the green projects (blue being one part of green, gets its share too), further, a state-dependent connection between green bonds and uncertainty (VIX/OVX) has been proven. (Tsagkanos et al., 2022) explore the VaR (value at risk) based copulas to illustrate the asymmetric risk spillover between green bonds and commodities by considering the asymmetric tail distribution. The relationship between green bonds and uncertainty (VIX/OVX) changes over time, becoming more connected during times of high uncertainty, as the COVID-19 pandemic (Pham and Phuc, 2021). Therefore, to hedge such a situation we would require gold acting as an universal hedge (Chi-Wei et al., 2022). Most importantly, Gold is the most effective hedges especially in hedging volatility of financial sector or any project funding (Kang et al., 2023). Therefore, Gold becomes an integral part to hedge a Blue-Green project.

While Bitcoin and the blue-green economy may appear disparate at first glance, there are overlapping areas where they intersect, particularly in discussions surrounding energy consumption, technological innovation, and socioeconomic impacts. As the conversation around sustainability evolves, there may be opportunities to explore how blockchain technology and cryptocurrencies can contribute to the goals of the blue-green economy while addressing environmental concerns associated with Bitcoin. The adoption of Bitcoin and cryptocurrencies can have social and economic implications that intersect with the objectives of the blue-green economy. For example, in regions with limited access to traditional banking services or unstable fiat currencies, Bitcoin can provide financial inclusion and opportunities for economic empowerment. One of the main criticisms of Bitcoin is its significant energy consumption, primarily due to the process of mining, where powerful computers solve complex mathematical problems to validate transactions on the blockchain (Vries, 2020). The energy-intensive nature of Bitcoin (BTC hereafter) mining has raised concerns about its environmental impact, particularly in terms of carbon emissions (Stoll et al., 2019) and water footprints (Vries, 2024). In contrast, the blue-green economy emphasizes the transition to renewable energy sources and energy efficiency. Some argue that the energy consumption associated with Bitcoin mining runs counter to the goals of sustainability promoted by the blue-green economy (Vries, 2024).

2. LITERATURE REVIEW

No study till date has captured the nexus between Blue-Green-Volatility/Uncertainty nexus along with traditional assets Bitcoin and gold indices. Till date there are many studies conducted on green indices/bonds in connection with stock indices (Chatziantoniou et al., 2022; Pham and Nguyen, 2021; Tsagkanos et al., 2022), however Crypto currencies are better suited owing to their emission patterns over stocks. For example, BTC owing to its mining method Proof of Work (PoW) produces extraordinary carbon footprint (Ghosh and Bouri, 2022) unlike Ethereum which shifted from PoW to PoS (Proof of Stake) in September 2022. In an annualised account BTC is responsible for 77.42 Mt CO_2, 138.81 TWh electricity, 2188 GL of fresh water, 28.68 kt of electronic waste[1] as on February 2024. Existing studies are indicating that the rate of Bitcoin adoption could create electricity consumption responsible for a hike in global temperature above 2°C in a few decades (Asumadu et al., 2023). Bitcoin's water consumption (although it does not require freshwater) went from 591 GL in 2020 to 2237 GL in 2023, which is nearly 279% more (Vries, 2024). Bitcoin requires the water mostly for cooling systems and air humidification process.

The future of global ocean economy appears to be gradually advancing towards "blue economy" comprising of three distinctive features; socially equitable, environmentally sustainable and economically viable ocean industries around the world (Cisneros-Montemayor et al., 2021). The concept of the blue economy originated in 1992 during the Earth Summit in Rio. (Smith-Godfrey 2016) attempts to allow for the simplest definition of the blue economy which can be easily applied, managed, measured and easy to remember as well. The most recent context about blue economy is provided by (Graziano et al., 2022) referring to the management of ocean resources for increasing economic growth, employment, improved

1. https://digiconomist.net/bitcoin-energy-consumption

livelihoods, and maintaining the health of marine ecosystem with sustainable practices. Multiple economic sectors of blue economy like fisheries and aquaculture, shipping and transportation, coastal tourism, renewable energy, biotechnology, marine mining, and marine conservation have the potential to contribute to sustainable economic development with reduced environmental impacts (Patil et al., 2016; Choudhary et al., 2021, Wang et al., 2023; Mselmi and Mahmoud, 2024).

(Lee et al., 2020) conducted a literature survey from 1998 to 2018 related to blue economies and find that blue economy is highly associated with United Nations Sustainable Development Goals. The results further highlight the direct or indirect role of stakeholders in contribution towards SDGs. Another study by Bari, (2017) aims at discussing different ways to exploit those benefits as well as identifying challenges with a way out. The authors stressed upon the need of social awareness about this social and economic issue.

Bitcoin, being a volatile asset in financial markets and breakthrough financial technology, limiting its worldwide adoption due to environmental-related issues (Sarkodie et al., 2023). The technical and infrastructural composition of Bitcoin mining through a proof-of-work (PoW) consensus leading to massive carbon emissions due to staggering amount of energy consumption, is rarely discussed in the literature (Digiconomist, 2022). Most of the academic literature primarily give less priority to Bitcoin's water footprints.

(Siddik et al., 2023) provide a comparative assessment of Bitcoin's financial transactions to conventional transaction system. Despite representing less than 0.5% of global cashless financial transactions, cryptocurrencies' electricity use of 236 $\times 10^6$ megawatt hours (MWh) in 2021 surpassed that of the conventional transaction system. Water footprints are reported to be more than double of conventional currencies with an annual water consumption of 3670×10^6 cubic meters (m^3). Crypto mining activities are also estimated to be utilized almost 139×10^6 tonnes carbon dioxide equivalent (CO_2-eq) of global greenhouse gas emissions. Another study by Pagone and Salonitis (2023) aim at comparing the environmental impact of Bitcoin and fiat currencies (i.e. coins, banknotes, credit and debit card networks). Findings from the study reveals that Bitcoin has a carbon footprint almost 4 to 5 times greater than the sum of all forms of traditional currency together in one year.

According to Vries (2024), Bitcoin water footprints has significantly increased to 166% in 2021 as compared to 2020. Bitcoin's annual water footprint may equal 2,237 GL as of 2023. Another high-profile water security case is reported in 2021, where Bitcoin mining and power-generation company (Greenidge Generation) gained attention for discharging large volumes of hot water into New York's Seneca Lake and violating the environmental regulations and Clean Water Act.

As the phenomenon of blue-green economy is gaining attraction, the green opportunities to finance the blue economies with sustainable practices are also gaining popularity in recent years. Blue economy projects are typically financed through traditional means of public and development finance. Moreover, the percentage of funds flowing into the blue economy projects is estimated to be much lesser than the required targets (Tirumala and Tiwari 2022). Financial intermediaries play a crucial role for advancing circular and blue economies by providing strong financial support to sustainable development ventures. (Shan et al., 2023) attempt to investigate the impact of lending to blue and sustainable firms for blue projects as well as to check the impacts of digital practices to evaluate the performance of banking sector. The findings show a positive connection between blue lending and banking sector, sustainable credit and digitalization practices for seven member states of the European Union over 11 years.

Tirumala and Tiwari (2022) assess existing investment initiatives in blue economies and their adequacy. They find blue bonds to be relatively small as a funding source and argue for additional financing instruments and a shift in stakeholder participation to boost growth and innovation. The study proposes a low-cost fund from diverse investors for public sector-promoted impact projects, to be used for individual blue economy projects via market-based instruments. Volatility, uncertainty, lack of reliable market information, price fluctuations, and demand and supply challenges make it difficult for firms to identify investment funding and assess market risks. Regulatory and policy barriers also significantly limit sustainable growth and innovation in blue economy firms (Zhu et al., 2023).

Pástor et al. (2021) provide equilibrium perspective in sustainable investing. Sustainable investing prioritizes not only financial objectives but considers environmental, social, and governance criteria too. Assets managed with sustainability perspective have grown dramatically to tens of trillions of dollars and seem poised to grow further in near future. Therefore, sustainable investment approaches result in positive social and economic impact by making firms greener. Thereby, shifting real investments towards greener firms for greener projects (Tirumala and Tiwari, 2022).

To define the role of gold in Blue-Green Volatility nexus is equally important as to discuss the environment specific factors (carbon footprints and water footprints) of Bitcoin. Therefore, Blue-Green-Volatility nexus can't be discussed without Bitcoin and gold as gold is a proven hedge in times of economic and political disarray (Chi-Wei et al., 2022). Therefore, it would be interesting to note the role of Gold in this nexus. Hence, we propose a model which not only considers blue economy as a separate entity (from Green) but also, adding one more dimension of uncertainty/volatility (in the form of bitcoin and gold). We can extend the study by Pham and Phuc, 2021 and identify whether similar relations exsist between Blue and uncertainty/volatility or not. In fact, gold mining can have significant environmental impacts, including habitat destruction, water pollution, and carbon emissions. Embracing sustainable mining practices, such as reducing water usage, minimizing waste, and restoring mined areas, aligns with the principles of the blue-green economy by mitigating environmental harm and promoting responsible resource extraction. Moreover, gold is used in various green technologies, such as solar panels, catalytic converters, and electronic components for energy-efficient devices. As the blue-green economy encourages the adoption of clean technologies to reduce environmental footprint, the demand for gold in these applications may indirectly support sustainability goals. By promoting transparent and responsible supply chain management practices, the blue-green economy can help minimize the negative social and environmental impacts of gold extraction and trade. Fundamentally gold may not be inherently linked to the blue-green economy yet, embracing responsible mining practices, promoting green technology applications, and ensuring ethical supply chains are all important aspects of integrating gold into a broader framework of environmental and economic sustainability. As far as the relationship between Bitcoin and Gold is concerned, we found that it was proved that Bitcoin is extremely volatile, however, it enjoys a relatively weaker correlation with gold (Ozturk, 2020). Research finds that this relationship is especially stronger during stressed periods (Bhuiyan et al., 2023). Furthermore, it is interesting to note that gold keeps the uncertainty-hedging aura in times of economic and political disarray (Su et al., 2022). Therefore, the present study attempts to provide interesting insights related to Blue-Green Volatility nexus in association with Bitcoin and gold indices.

3. RESEARCH METHODOLOGY

3.1. Data

The analysis delves into the interconnectedness and spillover relationships among five indices, two of which focus on the green economy—ICLN (iShares Global Clean Energy ETF) and CNRG (SPDR SandP Kensho Clean Power ETF)—and three on the blue economy—BJLE (BNP Paribas Easy ECPI Global ESG Blue Economy UCITS ETF), PIO (Invesco Global Water ETF) and OCEN (IQ Clean Oceans ETF)—alongside the traditional assets Bitcoin and gold indices. The green economy indices concentrate on clean energy innovation and sustainability, encompassing renewable energy production, energy efficiency, and clean power technologies. Conversely, the blue economy indices emphasize the sustainable use and conservation of ocean resources, including ocean clean-up efforts, waste management, and water treatment solutions. The dataset spans from October 26, 2021, to January 5, 2024, capturing significant market events and fluctuations during this period. Returns for the respective indices are calculated using the formula Rt = ln (Pt/Pt-1), where Pt represents the price for the current day. This analysis provides insights into the dynamics of environmentally conscious investment vehicles, both within the green and blue economy sectors, and their integration with traditional assets amidst changing market conditions.

3.2. Methodology

To explore the quantile spillover dynamics across different financial markets, we employ a quantile and frequency connectedness framework. This approach allows us to analyze the transmission mechanisms through both quantiles (q) and frequencies (ω). The quantile connectedness methodology, as established by Ando et al. (2022), Bouri et al. (2021), and Chatziantoniou et al. (2021), provides the foundation for our analysis.

$$Y_t = \mu_t^q + \Phi_1^q Y_{t-1} + \Phi_2^q Y_{t-2} + \ldots \Phi_p^q Y_{t-p} + \varepsilon_t^q$$

In this equation, Y_t and Y_{t-1} are vectors of endogenous variables, with q representing a quantile in the range [0, 1], and p being the lag length. The μ_t^q is the conditional mean vector, Φ_p^q is a matrix of QVAR coefficients, and ε_t^q is an error term with a corresponding covariance matrix.

To move forward, Equation (1) is transformed into the QVMA(∞) form, leveraging Wold's theorem:

$$Y_t = \mu^q + \sum_{j=1}^{p} \Phi_j^q Y_{t-j} + \varepsilon_t^q = \mu^q + \sum_{i=1}^{\infty} \Omega_j^q \varepsilon_{t-j}$$

The next step is to calculate the Generalized Forecast Error Variance Decomposition (GFEVD) with a forecast horizon H. The decomposition explains how much of the forecast error variance of series iii is due to shocks in series j:

$$\Phi_{ij}^H = \frac{\sum_{h=0}^{H-1} \left(\Omega_h^q \Sigma_q\right)_{ij}^2}{\sum_{h=0}^{H-1} \left(\Omega_h^q \Sigma_q \Omega_h^{q'}\right)_{ii}}$$

Since the rows of Φ_{ij}^H do not sum to one, normalization is required:

$$\Phi_{ij}^H = \frac{\Phi_{ij}^H}{\sum_{k=1}^{N} \Phi_{ij}^H}$$

This normalized form allows us to compute key measures of connectedness. Net Pairwise Directional Connectedness (NPDC) is calculated as:

$$NPDC_{ij}^H = \Phi_{ij}^H - \Phi_{ji}^H$$

When $NPDC_{ij}^H > 0$, series j has a greater influence on series i, and vice versa if $NPDC_{ij}^H < 0$.

The Total Directional Connectedness "To others" (TO) and "From others" (FROM) are then derived:

$$TO_i^H = \sum_{i \neq j} \Phi_{ji}^H$$

$$FROM_i^H = \sum_{i \neq j} \Phi_{ji}^H$$

The Net Total Directional Connectedness (NET) represents the difference between TO and FROM:

$$NET_i^H = TO_i^H - FROM_i^H$$

A positive NET_i^H means that series i is a net transmitter of shocks, while a negative value indicates it is a net receiver.

Finally, the Total Connectedness Index (TCI) is computed to assess overall system interconnectedness:

$$TCI^H = \frac{1}{N}\sum_{i=1}^{N} TO_i^H = \frac{1}{N}\sum_{i=1}^{N} FROM_i^H$$

For the frequency-domain analysis, we use Stiassny's spectral decomposition method to examine the frequency response function:

$$\left(\Omega e^{-i\omega}\right) = \sum_{h=0}^{\infty} e^{-i\omega h}\Omega_h$$

The spectral density is calculated through a Fourier transformation of the QVMA(∞) form. The frequency-domain GFEVD, normalized in a similar fashion to the time-domain GFEVD, is represented as:

$$\Phi_{ij}(\omega) = \frac{\sum_{h=0}^{\infty}\left(\Omega_h^q \Sigma_q\right)_{ij}^2 e^{-i\omega h}}{\sum_{h=0}^{\infty}\left(\Omega_h^q \Sigma_q \Omega_h^{q'}\right)_{ii} e^{-i\omega h}}$$

By aggregating over specific frequency bands, we obtain frequency-based connectedness measures. In our analysis, two frequency bands are considered: d1= (π/5, π) for short-term (1 to 5 days) and d2= (0, π/5) for long-term dynamics (6 days and beyond).

These frequency-based measures are analogous to the time-domain measures and provide a comprehensive view of spillover effects in both the short and long terms.

4. INTERPRETATION OF RESULTS

4.1. Descriptive Statistics

Table 1 presents the descriptive statistics for the daily return series. All the returns exhibit stationarity at the 1% significance level, as indicated by the ERS unit root test. The skewness statistics reveal valuable insights. Bitcoin and BJLE exhibit negative skewness, suggesting that their return distributions are skewed to the left, indicating potential downside risks with more extreme negative returns. Conversely, OCEN, PIO, CNRG, and ICLN display positive skewness, indicating distributions skewed to the right, implying potential upside opportunities with more extreme positive returns. These skewness values provide essential information for investors to understand the asymmetry and potential risks and opportunities associated with investing in each asset. The excess kurtosis statistics provide insights into the distributional characteristics of the returns for each variable. BJLE exhibits a platykurtic distribution with a value of 0.807, indicating fewer extreme values compared to a normal distribution. Conversely, OCEN, PIO, and ICLN demonstrate leptokurtic distributions with values of 1.471, 1.072, and 1.363 respectively, suggesting a higher likelihood of extreme returns. CNRG displays a platykurtic distribution with a value of 0.537, indicating fewer outliers. Bitcoin, however, stands out with a highly leptokurtic distribution, indicated by a value of 9.377, signifying a significantly higher likelihood of extreme returns, reflecting its volatile nature. These statistics aid investors in assessing the potential risks and opportunities associated with each asset. The analysis is in line with the Jarque-Bera test, confirming the non-normality of the returns. Moreover, Q(20) and $Q^2(20)$ values indicate autocorrelation in the percentage changes of the variables and their squared returns. Furthermore, based on Kendall's coefficients, the analysis reveals significant dependencies among various assets. The highest dependence is observed between CNRG and ICLN.

4.2. Total Dynamic Connectedness

The interconnectedness indices within the cryptocurrency market showcase notable variability, illustrating the diverse influence dynamics among various digital assets. The average total connectedness index stands at 69.05%, indicating the extent of interrelation and transmission of shocks within the market. Notably, OCEN and ICLN, acted as significant transmitters. In contrast, BJLE, Bitcoin, and Gold are identified as net receivers, suggesting their tendency to absorb shocks or external influences. On the other hand, OCEN, PIO, CNRG, and ICLN are recognized as net transmitters, indicating their propensity to propagate shocks or influences across the market.

Through network plots (Figure 1), we explored the pairwise connectedness within the cryptocurrency market, assessing the strength of connections between various digital assets. Our analysis revealed significant connections, highlighting OCEN's substantial ties with Gold, BJLE, and Bitcoin, suggesting potential impactful relationships between these assets. Additionally, we observed a notable connection between PIO and BJLE, indicating significant interrelation between them. Conversely, the least important pairwise connection was found between PIO and OCEN, suggesting a comparatively weaker relationship. These findings underscore the importance of connectivity analysis in

Table 1. Descriptive statistics

Statistic	BJLE	OCEN	PIO	CNRG	ICLN	Bitcoin	Gold
Mean	0.0000503	−0.0002888	−0.0001642	−0.0007932	−0.0008753	−0.0006452	0.0002243
Variance	0.0095444	0.0133759	0.0126705	0.0216109	0.0193319	0.036514	0.0088322
Skewness	−0.123	0.316***	0.157	0.366***	0.524***	−0.876***	0.150
Kurtosis	0.807***	1.471***	1.072***	0.537**	1.363***	9.377***	1.063***
JB	16.257***	58.532***	28.499***	18.799***	67.476***	2077.699***	27.865***
ERS	−7.086***	−6.111***	−9.734***	−7.960***	−9.792***	−9.395***	−3.913***
Q (20)	11.870	10.421	10.031	9.018	17.048*	2.509	17.474**
Q2 (20)	37.301***	37.081***	41.181***	12.084	28.890***	4.454	20.173**

Figure 1: Net-Pairwise directional connectedness

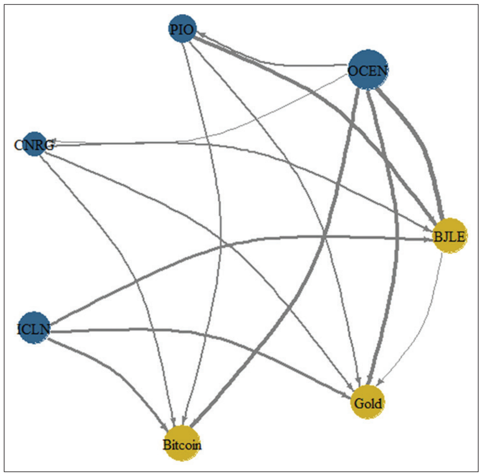
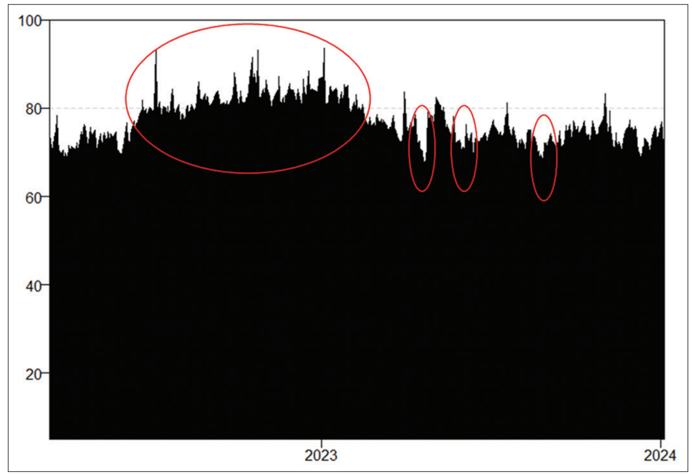


Figure 2: Total dynamic connectedness



comprehending the green, blue, cryptocurrency market markets and gold dynamics and informing investment decisions and risk management strategies. Representing Blue, BJLE can be used as a hedge against OCEN and PIO as despite being in the similar category they're either receiver or emitter of shocks (refer Table 2). Therefore, investors interested in Blue economy can diversify their wealth across these three ETFs.

Notes: Blue (yellow) nodes represent net transmitter (net recipient) of shocks. Vertices are weighted by averaged net pairwise directional connectedness measures. The size of nodes represents weighted average net total directional connectedness. The network plot results are based on a TVP-VAR model with lag length of order one (BIC) and a 10-step-ahead generalized forecast error variance decomposition.

In Figure 2, we delve into the evolution of the Total Connectedness Index (TCI) over the sample period, aiming to gain deeper insights into the studied market's risk dynamics. Throughout the sample period, our analysis uncovers noteworthy patterns in connectedness. Notably, there is a significant period of heightened connectivity, spanning nearly the entirety of the second half of 2022 and into 2023. During this time, the TCI consistently maintains elevated levels, surpassing the average, signaling a period of intensified interrelationships among the asset's indices.

As we scrutinize the graph further, it becomes evident that there are notable fluctuations downwards in connectedness (TCI) during specific periods of 2023. Particularly around March, May, and August, 2023 the TCI experiences a gradual decline, dipping below the average level. Typically, TCI dips on positive policy shocks. First, March 2023 witnessed the agreement about biological diversity of areas beyond national jurisdiction (BBNJ)[2] and the EU Net Zero Industry Act in March 2023[3]. Second, May, 2023 witnessed the call for 'Blue Deal' by the 3rd UN Trade Forum in order to protect Oceans[4]. Third, August, 2023 Future of Jobs Report from WEF stated a staggering growth for Green-Jobs[5].

However, it's essential to note that despite these fluctuations, the overall connectedness strengthens notably in the third quarter of 2023, exceeding the average threshold. The major reason came from excessive rise on Bitcoin mining. This is coupled with water usage problem as water is required for cooling bitcoin mining datacenters[6]. These dynamics underscore the significant influence of Green, Blue, and crypto-risks on network interconnectedness. They highlight the intricate relationship between market fluctuations and the overall connectedness of the ecosystem.

4.3. Total and Net Connectedness using Quantile Frequency

In order to have a better understanding of market dynamics, we provide the total (Figure 4) and net directional connectedness (Figures 5-11) of indices in time-quantile space. Precisely, the heatmap depicted in Figure 4 was generated using a 100-day rolling window and a 10-day ahead forecast based on the QVAR (1) model. The timeline is shown by the x-axis, and the quantiles, which range from 0.05 to 0.95 and are iterated at 1% intervals, are represented by the y-axis. Warmer segments show higher levels of connectedness, whereas lighter regions present lower levels. Dynamic shocks emanating from both significantly positive (above the 75% quantile) and negatively shifted assets (below the 25% quantile) demonstrate robust interconnections across the whole sample period. It is also important to highlight that this dynamic connectedness shows symmetrical pattern. Additionally, the fluctuations in the 50% quantile, which represents the network's average Total Connectedness Index (TCI), show a cyclical pattern. Spillovers were particularly intensified during the second half of 2022 until the beginning of 2023, coinciding with destabilizing events such as the war between Russia and Ukraine and the SVB collapse. In this context, policy announcements and price fluctuations, likely spurred interest in sustainable investments

2. https://kpmg.com/xx/en/home/insights/2023/05/the-blue-economy.html
3. https://www.lseg.com/content/dam/ftse-russell/en_us/documents/research/investing-in-the-green-economy-2023.pdf
4. https://news.un.org/en/story/2023/05/1136422
5. https://www.weforum.org/agenda/2023/08/inflation-reduction-act-one-year-green-jobs/
6. https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/bitcoin-mining-energy-use-doubled-in-2023-as-crypto-prices-rose-79854382

Table 2: Average dynamic connectedness

	BJLE	OCEN	PIO	CNRG	ICLN	Bitcoin	Gold	FROM
BJLE	36.21	16.88	15.08	11.95	14.03	3.54	2.30	63.79
OCEN	11.78	27.84	21.10	14.92	16.04	4.72	3.60	72.16
PIO	10.80	24.11	31.29	13.19	12.73	4.40	3.49	68.71
CNRG	8.48	16.02	12.85	30.31	25.19	4.61	2.54	69.69
ICLN	9.86	16.62	11.71	24.63	29.81	4.64	2.71	70.19
Bitcoin	3.61	7.52	6.42	7.62	7.65	63.30	3.88	36.70
Gold	4.10	7.39	6.19	5.26	5.85	4.29	66.91	33.09
TO	48.63	88.55	73.36	77.57	81.50	26.20	18.53	414.33
Inc.Own	84.84	116.38	104.65	107.88	111.31	89.49	85.44	TCI=69%
NET	−15.16	16.38	4.65	7.88	11.31	−10.51	−14.56	

Figure 3: Net total directional connectedness

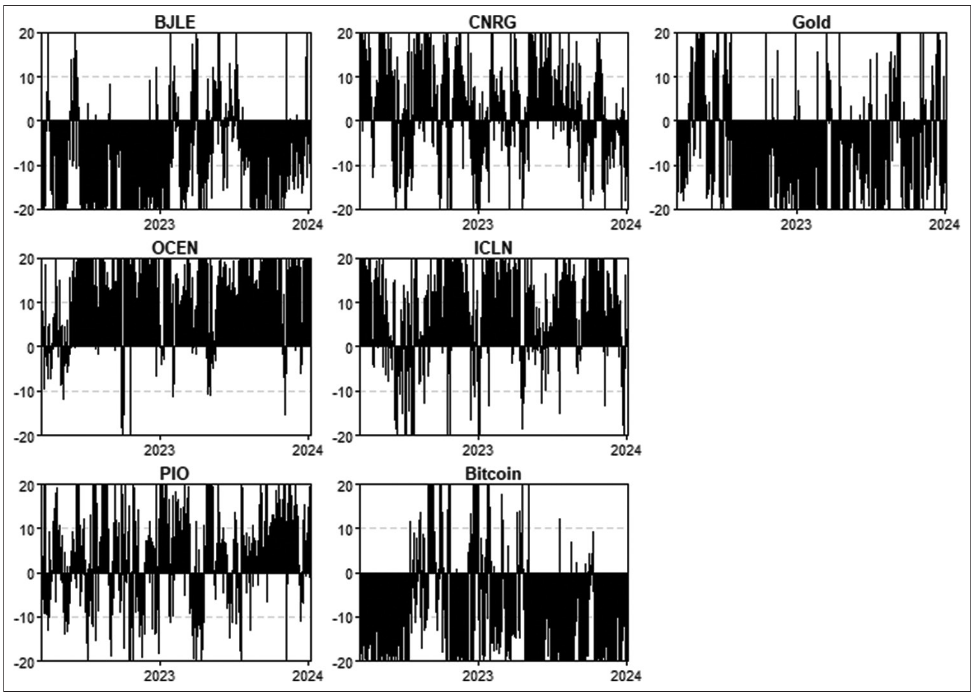


Figure 4: Quantile total connectedness

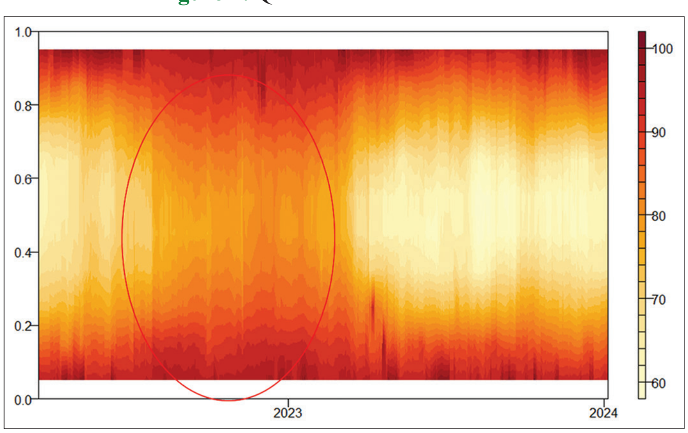
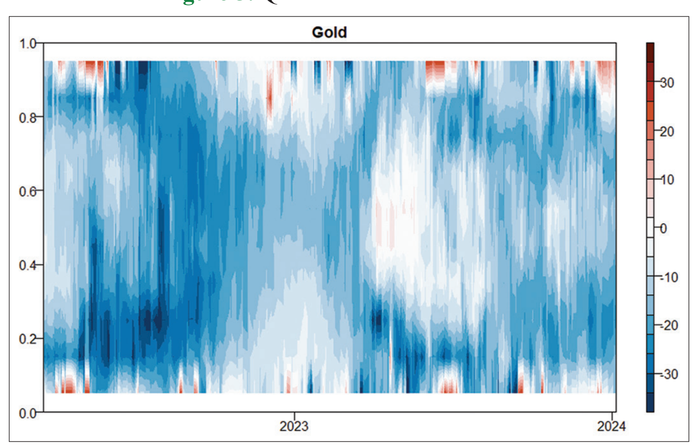


Figure 5: Quantile total connectedness



and digital assets. Heightened market volatility during this period may have driven investors to seek diversification and safety, thus increasing the attractiveness of assets like Bitcoin and gold. Additionally, the growing adoption of digital assets and environmental regulations may have further fueled connectivity between these sectors. Overall, a combination of these factors likely contributed to the observed increase in connectivity, highlighting the dynamic relationship between market dynamics and asset connectivity.

As previously mentioned, Figures 5-11 present the quantile net directional spillovers. The objective is to comprehend the ways in which investors react to diverse market conditions, whether bearish

Figure 6: Quantile total connectedness

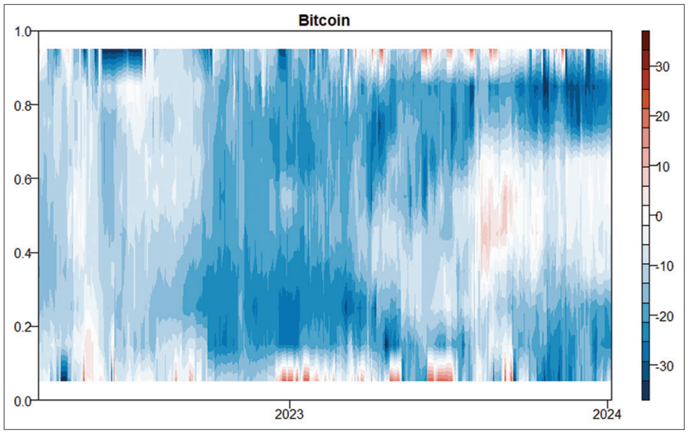


Figure 7: Quantile total connectedness

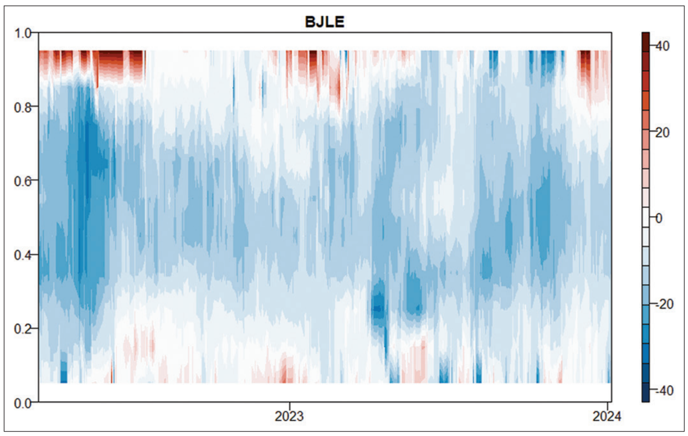


Figure 8: Quantile total connectedness

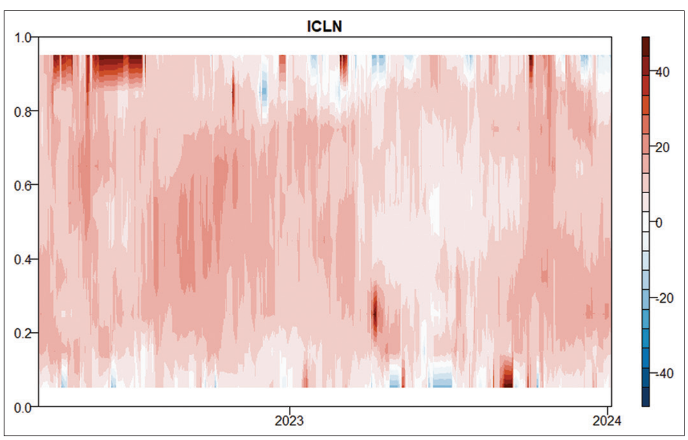


Figure 9: Quantile total connectedness

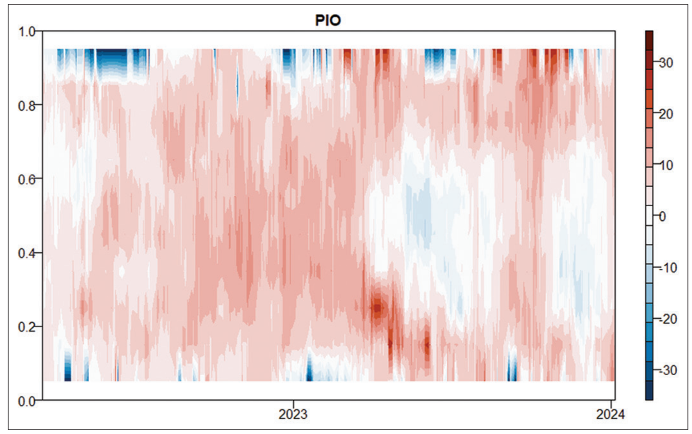


Figure 10: Quantile total connectedness

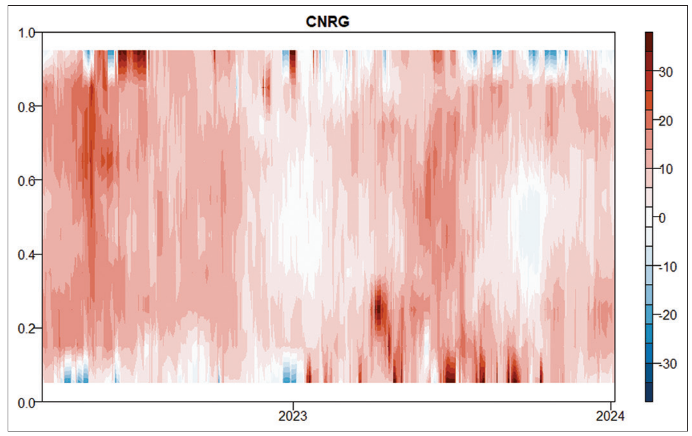
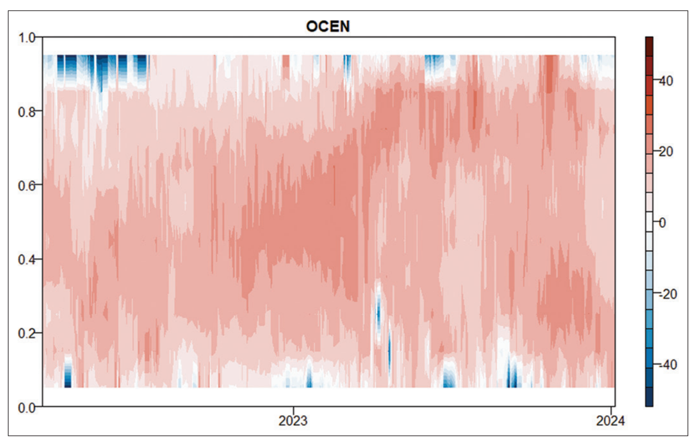


Figure 11: Quantile total connectedness



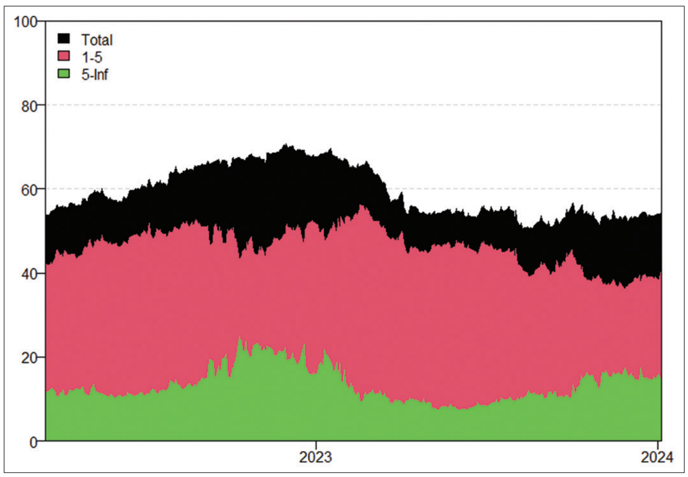
(low quantile), stable (middle quantile), or bullish (high quantile). In each heatmap diagram, warmer shades reveal a net contributing asset, while colder shades reveal a net receiving asset. Our findings show that time-varying attributes identify numerous economic events that shape dynamic spillovers at various quantiles.

Precisely, indices like OCEN, PIO, ICLN and CNRG stand out as prominent actors within the system, exhibiting a consistent net transmitter effect between the 15th and 85th quantiles throughout the entire sample period. This observation is consistent with the conclusions drawn from Figure 3, highlighting their status as the primary net transmitters within the network. Looking at the extremes of the data, both show a general trend towards being net recipients, on average. Notably, during periods of positive price changes (in the upper quantiles), a discernible shift towards cooler colors becomes apparent. On the other hand, the role of Bitcoin, Gold and BJLE in the network appears to shift between a strong and weak net receiver during the period and quantiles. Particularly, gold is a weak net receiver only during the first half of 2023 while bitcoin shift to be a weak net receiver during the second half of the same year. A remarkable behavior is the BJLE standing as a stable net receiver during almost all the sample period.

4.4. Time Frequency Connectedness Analysis

The network's overall dynamics can be fully understood by highlighting the complex interaction between short-term effects and long-term relationships, which is why this approach is essential. The results highlight the predominance of short-term frequencies, indicating that these markets react more quickly to immediate events or temporary disruptions (Figures 12-14). This rapid reactivity suggests strong short-term connections between indices. However, at certain times (such as late 2022 and in the beginning of 2023), long-term frequencies become more prevalent. This change may signal periods when longer-term events or deeper structural trends are more likely to impact market connectivity. The association of these phases with major economic upheavals or geopolitical developments can lead to long-term and sustainable links between markets.

Figure 12: Total net connectedness through frequencies



In summary, the time dynamics between the Green, Blue, Bitcoin and Gold indices show that short-term interactions generally dominate long-term. These markets, as suggested by this pattern, are highly reactive to immediate changes or temporary events, resulting in significant short-term impacts. Nevertheless, there are instances when long-term interactions increase beyond their usual levels, often linked to structural changes or ongoing trends. These long-term periods of increases may reflect the influence of major economic or geopolitical changes, resulting in more lasting connections between indices.

5. DISCUSSION AND POLICY IMPLICATIONS

Investors often turn to both Bitcoin and gold as hedges against fiat currency depreciation and inflation. During times of economic uncertainty or currency devaluation, traditional investors often seek refuge in gold. Similarly, some investors view Bitcoin as a hedge against inflation and a potential alternative to fiat currencies. Both Bitcoin and gold are used in investment portfolios to diversify risk. Gold has historically had a low correlation with other asset classes such as stocks and bonds, making it a popular choice for diversification. Similarly, some investors view Bitcoin as a non-correlated asset that can provide diversification benefits in a traditional investment portfolio. Bitcoin and gold often exhibit similar market behavior, particularly during periods of economic uncertainty or financial market volatility. Both assets have experienced periods of rapid price appreciation during times of crisis or geopolitical tension, as investors seek safe-haven assets.

Figure 13: Total net connectedness through frequencies

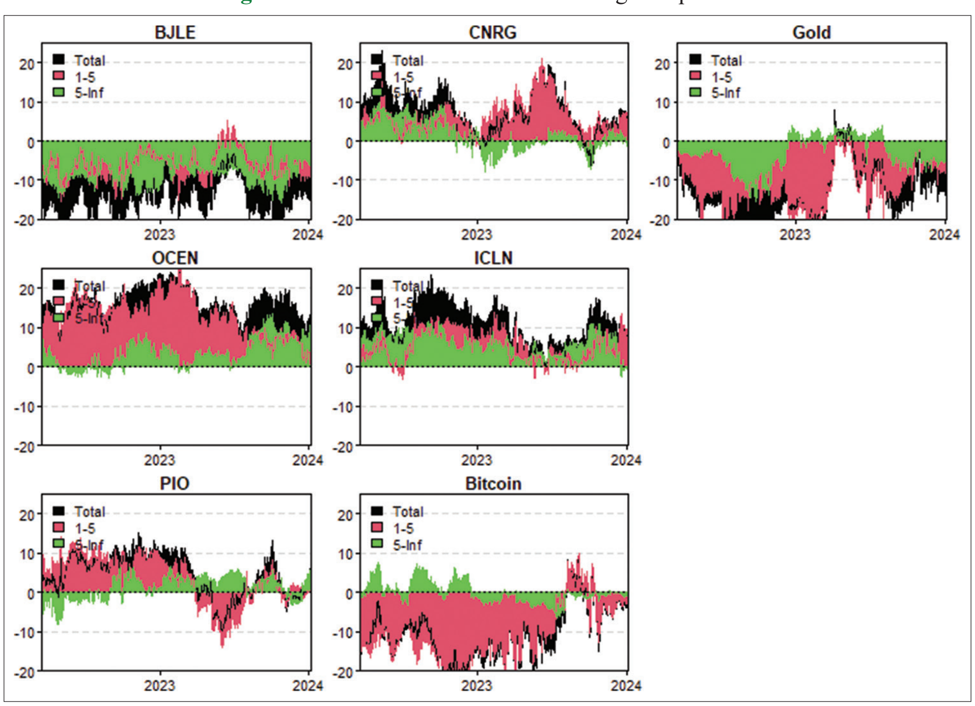
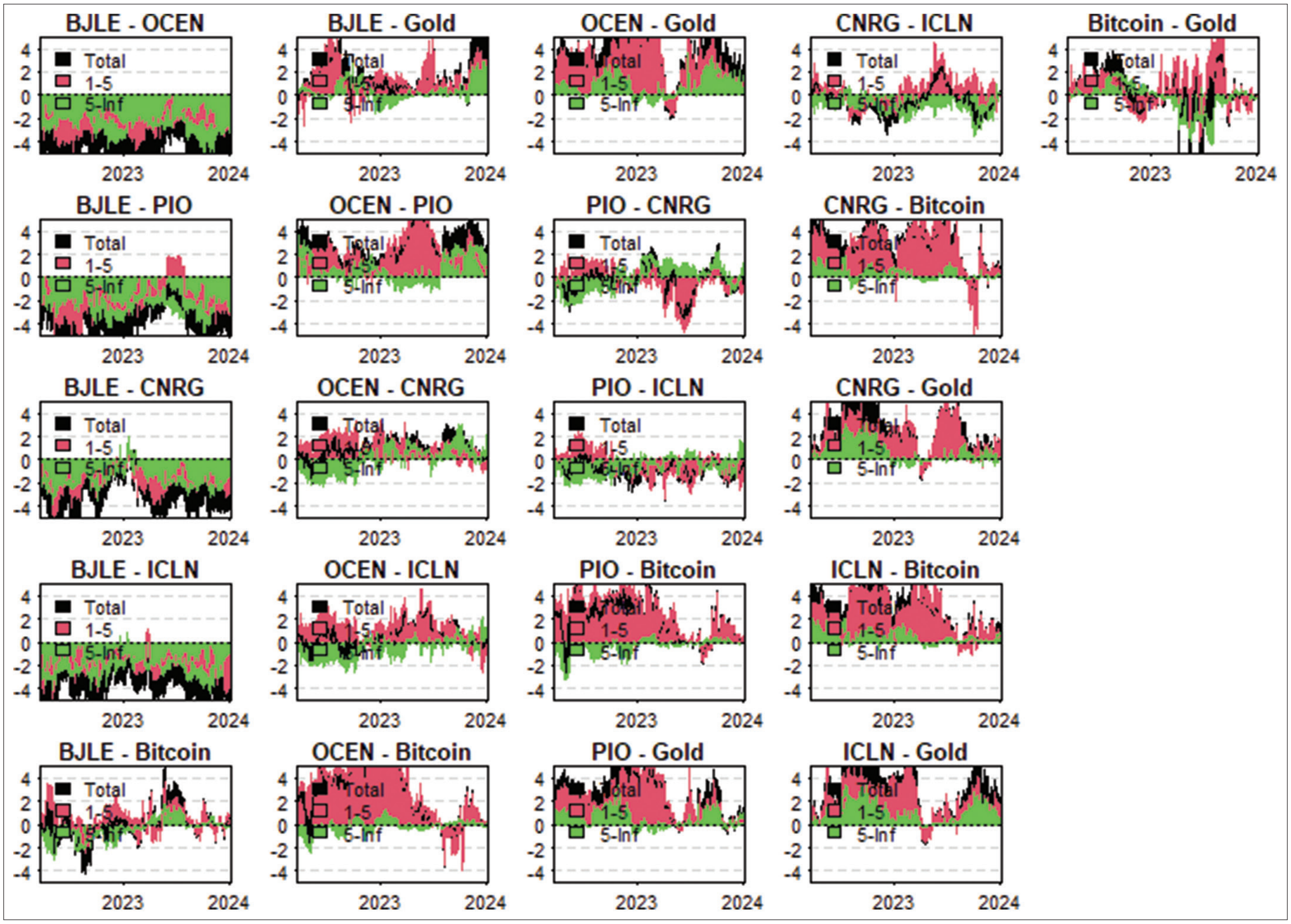


Figure 14: Pairwise net total connectedness through frequencies



Linking the blue and green economy involves recognizing the interconnectedness between sustainable practices in both environmental conservation (green economy) and ocean-related activities (blue economy). By recognizing the interdependence between the blue and green economies, policymakers, businesses, and communities can work together to promote sustainable practices that protect and conserve natural resources while supporting economic development and human well-being.

This study highlighted some crucial findings. First, BJLE can be used as a hedge against OCEN and PIO (all are in Blue economy). Second, excessive water usage in Bitcoin mining is detrimental to Blue-Green economy. Third, positive policy shock force spillover effect to cool down. Fourth, spillover typically increases as both economic uncertainty (US Banks collapse in 2023) and geopolitical risk (Russia-Ukraine conflict) increase. Fifth, there has been an increased responsiveness of these markets to immediate events (near-term bias). Therefore, this study would assist the policymakers and investors, especially in the Blue-Green domain.

REFERENCES

Ando, T., Greenwood-Nimmo, M., Shin, Y. (2022), Quantile connectedness: Modeling tail behavior in the topology of financial networks. Management Science, 68(4), 2401-2431.

Asumadu, S., Amin, M., Yakubu, M. (2023), Assessment of Bitcoin carbon footprint. Sustainable Horizons, 7, 100060.

Bari, A. (2017), Our oceans and the blue economy: Opportunities and challenges. Procedia Engineering, 194, 5-11.

Bhuiyan, R.A., Husain, A., Zhang, C. (2023), Diversification evidence of bitcoin and gold from wavelet analysis. Financial Innovation, 9(1), 1-36.

Bouri, E., Saeed, T., Vo, X.V., Roubaud, D. (2021), Quantile connectedness in the cryptocurrency market. Journal of International Financial Markets, Institutions and Money, 71, 101302.

CANARI. (2019), Transitioning to Inclusive, Resilient and Environmentally Sustainable Economies in the Easter Caribbean. In CANARI Policy Brief (No. 25). Trinidad and Tobago: Caribbean Natural Resources Institute.

Chatziantoniou, I., Gabauer, D., Stenfors, A. (2021), Interest rate swaps and the transmission mechanism of monetary policy: A quantile connectedness approach. Economics Letters, 204, 109891.

Chatziantoniou, I., Joel, E., Abakah, A., Gabauer, D., Competence, S., Tiwari, A. (2022), Quantile Time-frequency Price Connectedness between Green Bond, Green Equity, Sustainable Investments, and Clean Energy [SSRN Papers].

Chi-Wei Su, Pang, L., Umar, M., Lobonţ, O.R., Moldovan, N.C. (2022), Does gold's hedging uncertainty aura fade away? Resources Policy, 77, 102726.

Choudhary, P., Subhash G.V., Khade, M., Savant, S., Musale, A., Krishna Kumar, G.R., Chelliah, M.S., Dasgupta, S. (2021), Empowering

blue economy: From underrated ecosystem to sustainable industry. Journal of Environmental Management, 291, 112697.
Cisneros-Montemayor, A.M., Moreno-Báez, M., Reygondeau, G., Cheung, W.W.L., Crosman, K.M., González-Espinosa, P.C., Lam, V.W.Y., Oyinlola, M.A., Singh, G.G., Swartz, W., Zheng, C.W., Ota, Y. (2021), Enabling conditions for an equitable and sustainable blue economy. Nature, 591(7850), 396-401.
Dharmapuri, R., Tiwari, P. (2022), Innovative financing mechanism for blue economy projects. Marine Policy, 139, 104194.
Digiconomist. (2022), Bitcoin Energy Consumption Index. Digiconomist. Available from: https: //digiconomist.net/bitcoin-energy-consumption
Ghosh, B., Bouri, E. (2022), Is Bitcoin's carbon footprint persistent? Multifractal evidence and policy implications. Entropy, 24(5), 647.
Graziano, M., Alexander, K.A., McGrane, S.J., Allan, G.J., Lema, E. (2022), The many sizes and characters of the blue economy. Ecological Economics, 196, 107419.
Gunter, P. (2010), Blue Economy. Colorado: Paradigm Publication.
IEA. (2021), Net Zero by 2050: A Roadmap for the Global Energy Sector. Available from: https://www.iea.org/reports/net-zero-by-2050
Kang, S.H., Hernandez, J.A., Ur Rehman, M., Shahzad, S.J.H., Yoon, S.M. (2023), Spillovers and hedging between US equity sectors and gold, oil, Islamic stocks, and implied volatilities. Resources Policy, 81, 103286.
Lee, K.H., Noh, J., Khim, J.S. (2020), The blue economy and the United Nations' sustainable development goals: Challenges and opportunities. Environment International, 137, 105528.
Mselmi, A., Mahmoud, I. (2024), Cryptocurrencies versus gold: Safe-haven competition. International Journal of Economics and Financial Issues, 14(6), 201-210.
Ozturk, S.S. (2020), Dynamic connectedness between bitcoin, gold, and crude oil volatilities and returns. Journal of Risk and Financial Management, 13(3), 1-14.
Pagone, E., Salonitis, K. (2023), Carbon footprint comparison of bitcoin and conventional currencies in a life cycle analysis perspective. Procedia CIRP, 116, 468-473.
Pástor, Ľ., Stambaugh, R.F., Taylor, L.A. (2021), Sustainable investing in equilibrium. Journal of Financial Economics, 142(2), 550-571.
Patil, P., Virdin, J., Diez, S.M., Roberts, J., Singh, A. (2016), Toward a Blue Economy: A Promise for Sustainable Growth in the Caribbean. Washington, DC: World Bank Group.
Pham, L., Nguyen, C.P. (2021), Asymmetric tail dependence between green bonds and other asset classes. Global Finance Journal, 50, 100669.
Pham, L., Phuc, C. (2021), How do stock, oil, and economic policy uncertainty influence the green bond market? Finance Research Letters, 2021, 102128.
Sarkodie, S.A., Amani, M.A., Ahmed, M.Y., Owusu, P.A. (2023), Assessment of Bitcoin carbon footprint. Sustainable Horizons, 7, 100060.
Shan, S., Mirza, N., Umar, M., Hasnaoui, A. (2023), The nexus of sustainable development, blue financing, digitalization, and financial intermediation. Technological Forecasting and Social Change, 195, 122772.
Siddik, M.A.B., Amaya, M., Marston, L.T. (2023), The water and carbon footprint of cryptocurrencies and conventional currencies. Journal of Cleaner Production, 411, 137268.
Smith-Godfrey, S. (2016), Defining the blue economy. Maritime Affairs: Journal of the National Maritime Foundation of India, 12(1), 58-64.
Stoll, C., Klaaßen, L., Gallersdörfer, U. (2019), The Carbon footprint of bitcoin. Joule, 3(7), 1647-1661.
Su, C.W., Pang, L., Umar, M., Lobonţ, O.R. (2022), Will gold always shine amid world uncertainty? Emerging Markets Finance and Trade, 58(12), 3425-3438.
Tirumala, R.D., Tiwari, P. (2022), Innovative financing mechanism for blue economy projects. Marine Policy, 139, 104194.
Tsagkanos, A., Sharma, A., Ghosh, B. (2022), Green bonds and commodities: A new asymmetric sustainable relationship. Sustainability, 14(11), 6852.
Vries, A. (2020), Bitcoin's energy consumption is underestimated: A market dynamics approach. Energy Research and Social Science, 70, 101721.
Vries, A. (2024), Bitcoin's growing water footprint. Cell Reports Sustainability, 1(1), 100004.
Wang, H., Mirza, N., Umar, M., Xie, X. (2023), Climate change and blue returns: Evidence from Niche firms in China. Finance Research Letters, 56, 104119.
Zhu, B., Liang, C., Mirza, N., Umar, M. (2023), What drives gearing in early-stage firms? Evidence from blue economy startups. Journal of Business Research, 161, 113840.