International Journal of Contemporary Business and Economics 2025, Vol. 03 (01) 19-33 ©TARC-2023. ISSN-Print: 3005-5350, ISSN-Online: 3005-5369

The Connectedness of NFTs with Green Bonds during Turbulent Times

Rija Anwar [1] * I Syed Ali Raza [2] I

[1*] Department of Business Administration, IQRA University Karachi, Pakistan
rija.49604@iqra.edu.pk
rijaanwar29@gmail.com

[2] Department of Business Administration,
IQRA University
Karachi-75300, Pakistan
dr.aliraza@iqra.edu.pk
syed_aliraza@hotmail.com

Article History

Received: 20-04-2025
Accepted: 22-05-2025
Online: 26-06-2025

ABSTRACT:

The swift development of technology is reforming the global landscape, including the financial markets. The rise of digital assets, for instance, Non-Fungible Tokens (NFTs), has changed investor behavior, however, it has also raised concerns about their environmental effect. Environmentally sentient firms have begun issuing green bonds to finance climate-positive projects. Concurrently, major catastrophic incidents, i.e., the Bitcoin-BTC price crash-2018, the COVID-19 epidemic, the enormous decrease in demand for oil-2020, and the Russia-Ukraine conflict, have triggered substantial market volatility, additional changes in investor sentiment, and market dynamics. This study aims to inspect the connectedness of NFTs with green bonds during the aforementioned catastrophic events. The quantile connectedness with the extreme tail of distribution approach (Ando et al., 2022) is employed, spanning the time frame of 5-March-2018 to 22-May-2024. As per static quantile connectedness, the connectedness level is low in normal market states and high in extreme market states, which is corroborated by the market integration theory. Contrarily, dynamic quantile connectedness estimations specify that all NFTs and green bond switch their function from net transmitter to net receiver of spillovers and vice versa during catastrophic events. Additionally, this study is advantageous for investors, portfolio managers, and policymakers by providing them with valuable insight and practical implications.

Keywords: Theta, Digi-Byte, Green Bonds, Quantile Connectedness, Catastrophic Events.

How to cite this paper: Anwar, R., and Raza, S., A. (2025) The Connectedness of NFTs with Green Bonds during Turbulent Times. *International Journal of Contemporary Business and Economics*, 3(01), 19-33.

INTRODUCTION

Technological innovation is constantly developing the financial system (Low et al., 2021). It changes the investor appetite, and the advent of a new asset category (Glas, 2022). In the current period, one of the supreme innovations in the financial markets has been the upsurge of digital assets, particularly Non-Fungible Tokens (NFTs). NFTs are developed based on blockchain technology, and they permit the possession and trading of distinctive digital assets, including art, composition, cybernetic real estate, and even tweets (Ozdemir, 2023; Mehr & Shahim, 2023; Raman & Raj, 2021). These novel innovations have disturbed the conventional market by proposing new conducts for entities to generate, own, and trade in the digital system (Vinoth & Srivastava, 2024; Kräussl, & Tugnetti, 2024). However, their speculative nature makes them vulnerable to high-pitched price instabilities, and they are repeatedly perceived as risky and volatile investments (Upadhyay & Upadhyay, 2025). This volatility has been intensified by the occurrence of speculative bubbles, where the value of particular NFTs has risen sharply, relying upon hype relative to intrinsic value. This speculative attribute makes NFTs generally vulnerable in market catastrophic periods, as observed throughout the COVID-19 epidemic, when several markets exhibit extreme downturn. The rapid escalation and fall in the value of NFTs throughout such catastrophes may cause significant instability for investors. Simultaneously, these assets may exhibit incomparable chances for diversification (Ko et al., 2022; Aharon & Demir, 2022), particularly for investors with good risk appetite.

Among the numerous NFT collections, THETA and DigiByte (DGB) demonstrate high market capitalization. The market capitalization of DGB is substantially lower than THETA. The market capitalization of DGB is currently about $205.34 million[1], whereas, market capitalization of THETA is significantly higher, with the value of $702.67 million[2]. However, both innovative digital assets indicate technological innovation; they also encounter criticisms and challenges, specifically about their ecological influence. Al-shater et al. (2024) stated in their study that environmental influences are a challenge for NFTs.

The environmental impacts of NFTs derive from the energy-exhaustive nature of blockchain networks, particularly those NFTs that depend upon proof-of-work (PoW) consensus mechanisms (Truby et al., 2022). These apprehensions have been augmented by the swift development of digital assets and their allied carbon footprint. As individuals are involved in reducing carbon footprints and taking quick measures to address climate change, there is a mounting demand for more sustainable financial measures that can contribute to reducing environmental harm. One of the effective measures is the green bond. Green bonds are debt securities. It is issued by companies or governments to invest in ecologically sustainable projects, for instance, a renewable energy project (Li et al., 2023). They offer investors the opportunity to play a role in environmental health while attaining a financial yield. The upsurge of green bonds signifies a shift to sustainable finance, where the financial segment aligns with the worldwide aims of mitigating greenhouse gas production and addressing global warming. Kung et al. (2021) and Arshad et al. (2024) emphasized in their study that Green bonds can bring a sustainable environment in emerging countries by mitigating CO_2 emissions.

However, as green bonds are extensively observed as a feasible option for sustainable

---

[1] https://www.coinbase.com/price/digibyte
[2] https://www.coinbase.com/explore

investing, their connectedness with evolving digital assets such as NFTs is unexplored. Moreover, there are conflicting attributes of these asset categories, such as digital assets are highly volatile (Kayani et al., 2024; Loukil et al., 2025) and have ecological concerns (Abakah et al., 2023); oppositely, green bonds have steady returns and an emphasis on sustainability (Han & Li, 2022). There is a need to examine connectedness between the THETA, DGB, and green bonds during normal states of the market vs. severe market conditions, i.e., bear and bull markets. Financial crisis, health crisis, and geopolitical occasions comprising Bitcoin (BTC) price crash-2018, COVID epidemic-2019, massive decline in demand of oil-2020 and the current Russia-Ukraine conflict have instigated enormous disturbances in the global economy, causing fluctuation in market prices (Habib & Kayani, 2024) and altering investor behavior (Chowdhury & Humaira, 2024). In this state, the magnitude of the connectedness between NFTs and green bonds could render valuable insights for portfolio divergence and risk management.

There are several studies conducted to explore emerging digital assets, i.e., NFTs. For instance; Yousaf and Yarovaya (2022), Xia et al. (2022), Umar et al. (2022a), Umar et al. (2022b), Karim et al. (2022), Wang (2022), and Aharon and Demir (2022) examined the inter-connectedness of NFTs with financial assets using different econometric approaches. The aforementioned studies indicate the significant connectedness of NFTs with financial assets. However, there is a lacuna in the current literature regarding the connectedness of NFTS with the green bond during times of financial chaos. The current research fills this lacuna by investigating the connectedness of NFTs, including THETA and DGB, and green bonds in both normal and severe market settings.

The findings are exhibited in two folds, i.e., static quantile connectedness and dynamic quantile connectedness. The static quantile connectedness displays weak connectedness of THETA and DGB with green bond in a normal market situation (q=0.5). However, throughout extreme market conditions, for instance, bearish and bullish circumstances, the connectedness level increases. Conversely, dynamic quantile connectedness discloses that the role of spillovers' transmitter or receiver changes over time. Some stances represent Theta, DGB, and GBI perform the role of spillover transmitter, while some stances show their role as spillover receiver. By examining the connectedness of THETA and DGB with green bonds, this research renders valuable insights into the capability of NFTs and green bonds to assist as risk diversifiers in investors' portfolios, mostly during periods of market chaos. Additionally, the outcomes shed light on the safe-haven attribute of these assets, providing benefits to both institutional and individual investors. Policymakers may also benefit from this research by understanding the interconnectedness of THETA and DGB with green bonds, assisting them to craft more effective policies for regulating developing markets and nurturing sustainable finance.

LITERATURE REVIEW

According to Wang (2022), NFTs are the most recognized digital asset in 2022, which fanatics the researchers to examine distinct extents of NFTs. Some research has shown the connectedness degree between emerging NFTs and conventional financial markets. For instance, Xia et al. (2022) inspect the NFTs' connectedness with traditional asset classes consisting of company stock, bonds, oil, USD, Gold, commodity, and cryptocurrencies. Using the Q-Joint spillover model, it was unraveled that inter-asset spillovers of yield and volatility are higher in the period of perilous market conditions relative to normal market states. In addition, NFTs are evident as a varied asset class in perilous market circumstances. Kong and Lin (2021) delved into the embryonic NFT collection and exposed that NFTs receive optimum yields in contrast to classical financial assets. Further, it was inferred that NFT rates surge when the call for alternative investment is extremely amplified and strives for a return at a slight rate of interest. Moreover, Umar et al. (2022b) employed the wavelet coherence method to examine pairwise time-frequency inter-connection of NFTs with other vigorous asset classes. It was disclosed that the interconnectedness between NFTs and vigorous asset classes is raised for a 2-week-plus investment timeframe and minimal for below 2 weeks-investment timeframes.

Another stream of research on NFT connectedness employs TVP-VAR to study NFT connectedness with financial markets. Wang (2022) constructed the NFT attention index to inspect the NFT attention index volatility spillover interconnectedness with financial markets via well-known framework of TVP VAR. It was unveiled that conventional asset groups, for example, equities, bonds, commodities, foreign exchange, gold, and cryptocurrencies, control the NFTs. Similarly, Yousaf and Yarovaya (2022) applied TVP-VAR to assess the return and volatility transference of NFTs and Defi to traditional and other types of tokenized assets, comprising S&P 500, Oil, Gold, and BTC. Outcomes demonstrated dismal performance and constant volatility spillovers among under-investigated variables, signifying that innovative digital asset categories are disconnected from classical classes of assets. In addition, the inter-association of dynamic yield and volatility upsurges at an early period of COVID-19 and the cryptocurrency bubble in 2021. Aharon and Demir (2022) also applied TVP-VAR method to research spillover among NFTs and classic asset groups during the COVID-19 phase and established that the magnitude of connectedness among returns of financial assets augmented in the COVID-19 epidemic phase.

Ben-Mabrouk et al. (2024) examined dynamic spillover and hedging effectiveness among distinct sectors of NFTs via TVP-VAR model. Findings display weak dynamic return spillovers between the considered NFT sectors. Lastly, Urom et al. (2024) inspected return and volatility connection of NFTs with unconventional financial assets, using QVar. Outcomes show return and volatility connectedness changes along market conditions. Additionally, the connectedness level is high during severe events

After reviewing the sound literature of NFTs, it has been found that most research scholars have concentrated on exploring the connectedness or linkages of NFTs with other categories of classic and digital assets. However, the literature did not explore the connectedness between NFTs and green bonds during extreme events by using a distinctive research methodology i.e., Quantile Connectedness with extreme Tail of Distribution Method. Thus, connectedness between NFTs and green bonds from a quantile perspective has been examined and fills the lacuna in the present literature that would offer valuable perception to investors, investment advisors, and policymakers.

METHODOLOGY

Variables Exhibition and Statistical Description:

THETA and DGB are two distinct kinds of NFTs that are used in this study. These NFTs are selected due to market size and availability of the data (Karim et al., 2022; Yousaf & Yarovaya, 2022). Green bonds are the representative of green assets in this study. It is measured through S&P Green Bond Index (GBI). Daily data of NFTs is gathered from the source coinmarketcap.com, and the day-to-day data of GBI is garnered from https://www.spglobal.com/en. Moreover, the study's timeframe, ranging from 5-March-2018 to 22-May-2024, since it includes vital disastrous incidents, for instance, the BTC Price Crash-2018, COVID-19, the severe diminishing in demand of oil-2020, and the Russia-Ukraine Conflict.

Table 1: Variables' Depiction

Variables	Variables' Depiction	Category of Asset	Data Collection Source
THETA	Theta- NFT	Digital Asset	https://coinmarketcap.com/currencies/theta-network/historical-data/
DGB	DigiByte-NFT	Digital Asset	https://coinmarketcap.com/currencies/digibyte/historical-data/
GBI	S&P Green Bond Index	Green Asset	https://www.spglobal.com/spdji/en/indices/sustainability/sp-green-bond-index/#overview

Table 2 presents descriptive statistical representation of under-examined variables' return series and elucidates that the mean value of THETA, DGB and GBI return series are near to zero which concludes that both unique assets categories did not obtain any substantial return throughout the phase of extreme incidents comprising BTC Price Crash-2018, COVID-19, large decline in Oil demand-2020, and current Russia-Ukraine conflict. Furthermore, outcomes of variance exhibited that THETA, DGB, and GBI returns are gathered close to mean values of return that reflect minimal variance in the return series of THETA, DGB, and GBI.

Table 2: Descriptive statistics of return series

	THETA	DGB	GBI
Mean	0.002	-0.001	0.000
Variance	0.006***	0.005***	0.000***
Skewness	-0.187***	0.049	-0.072
Ex.Kurtosis	7.086***	5.691***	4.760***
JB	3403.221***	2189.302***	1532.381***
ERS	-7.700***	-4.634***	-10.341***
Q.20.	29.671***	25.171***	65.082***
Q2.20.	65.020***	89.917***	428.586***

Source: Authors' own creation

The values of Skewness and Kurtosis demonstrated in Table 2 illustrate that all return series of the considered THETA, DGB, and GBI are non-normally distributed because all values diverge from 0. It corroborates with the Jarque and Bera (1980) normality examination.

This normality test concludes that the return series of all considered variables are significantly non-normally distributed

Table 3 reveals bivariate unconditional correlations between THETA, DGB, and GBI. Outcomes validate that all considered NFTs possess a slight +ve correlation with GBI. These findings support the divergence and hedging ability of the aforementioned emerging NFTs when added to a portfolio. Alam et al. (2023) also found a weak correlation between digital assets class and other assets and illustrated the possible benefits of digital financial assets in portfolio divergence and hedging opportunities.

Figure 1 demonstrates a price evolution of Theta, DGB, and GBI, which reveals that the price of all THETA and DGB escalated from the year 2021 and touched its highest price level at the end of 2021. Subsequently, the prices of NFTs decrease from their highest price level and then exhibit fluctuation with a small magnitude for the rest of the covered period. In addition, the prices of GBI inclined from the beginning of 2020 and reached a peak somewhere in the middle of 2021. Then the prices drop and fluctuate for the rest of the period. The fluctuation in all NFTs and green bonds prices corroborates with Naeem et al. (2023), who stated that prices of assets continuously fluctuate during periods of crisis.

Table 3: Unconditional Correlation

	THETA	DGB	GBI
THETA	1.000***	0.438***	0.063***
DGB	0.438***	1.000***	0.045***
GBI	0.063***	0.045***	1.000***

Note: JB= Jarque Berra test, * represents level of significance at 1 percent

Source: Authors' own creation

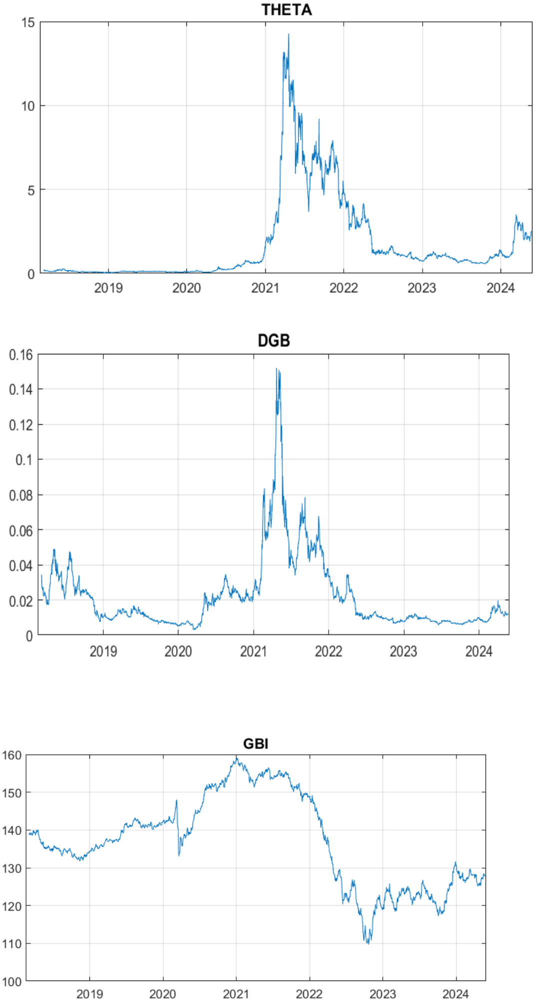


Figure 1: Time series exhibition

Source: Authors' own creation

Figure 2 reflects the temporal variation of the return series and shows greater volatility during considered time frame. BTC Price Crash-2018, COVID-19, the large decline in demand of oil-2020, and the current Russia and Ukraine conflict are leading variability of THETA, DGB, and GBI.

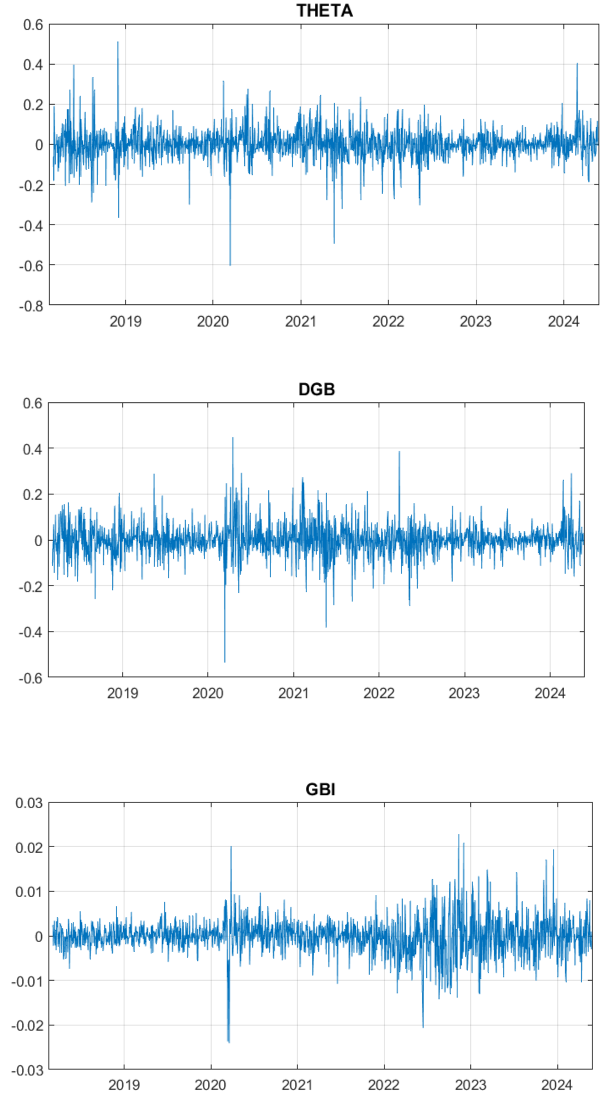


Figure 2: Return series plot

Source: Authors' own creation

Research Methodology:

In this study, we have applied N-variable vector autoregression (VAR) to assess directional spillovers of THETA, and DGB with GBI. In accordance with Koenker and Bassett (1978), the zn reliance over yn in every quantile (δ ∈ (0,1)) of a probability distribution is evaluated. The equation 1 creates quantile deviation employing the VAR method of the nth structure.

zn=c (δ) + $\sum_{\delta=1}^{p}$ β_i (δ) zn - δ + et (δ), n=1,.........., N (1)

In equation 1, zn is employed for the vector of elucidated variable, c (δ) specifies vector of intercept, and et (δ) signifies quantile (δ) residual. β_i (δ) designates lagged coefficients at quantiles (δ), through d=1,..........,m, which can be validated through examining that residuals assure a curb of population quantile, Q δ (et(δ)|zn-1, ..., zn-m) = 0. The δth denotes the quantile of retort z that is displayed as below:

Q δ (et(δ)| zn-m) = c (δ) + $\sum_{i=1}^{m} B\hat{}_i$ (δ) zn-δ (2)

The projected framework of Cecchetti and Li (2008) is employed in the above equation to achieve a quantile regression perceptive.

Measure of Connectedness at Each Quantile

This method measures several estimates of network spillover at all quantiles δ through QVar variant, developed by Ando et al. (2022). This mean-based measure was initially developed by Diebold and Yilmaz (2012). Thus, equation 1 can be revised as a vector moving average in replacement of an infinite order:

zn=μ (δ) + $\sum_{q=0}^{\infty} A_q$ (δ) en-q (δ), n=1,........,N (3)

with,

μ(δ)=(Lt-$\beta_1(\delta) - \cdots - \beta_m(\delta)$)-1 c (δ), Aq (δ)

$$\begin{cases} 0, q < 0 \\ L_t, s = 0 \\ \beta_1(\delta)A_{q-1}(\delta) + \cdots + \beta_g(\delta)A_{q-m}(\delta), q > 0. \end{cases}$$

In equation 3 above, zn designates the collective residuals et at each quantile (δ). Current research used techniques by Koop et al. (1996) and Pesaran and Shin (1998) in consideration of Cholesky-factor ordering issue. Consequently, the estimation is consistent with a variable arrangement. As well, each variable's spillover is varied, because of a cumulative of contributions and variance of estimated error is different from 1. Hence, for an assessment prospect F, a quantified equation signifies a computation of generalized forecast error variance decomposition (GFEVD) of the understudied variable attributable to shocks of several variables:

$$\phi_{dk}^{h}\text{ (F)} = \frac{\alpha_{dk}^{-1}\sum_{f=0}^{F-1}(e_d' A_f \sum ek)^2}{\sum_{f=0}^{F-1}(e_d' A'_f \sum ed)} \qquad (4)$$

In equation 4, ϕ_{dk}^{h} (F) represents kth variable to anticipated error variance of variable d at horizon F. whereas, Σ, α_{dk} exemplifies a variance matrix-vector of errors which designates the kth transverse constituent of Σ matrix, and vector has value of 1 for dth constituent and 0 in other esteem is quantified through ed. Equation 5 displays variance decomposition matrix for each admission

$$\tilde{\phi}_{dk}^{h}\text{ (F)} = \frac{\phi_{dk}^{h}\text{ (F)}}{\sum_{k=1}^{T}\phi_{dk}^{h}\text{ (F)}} \qquad (5)$$

The number of calculations of connectedness at δth conditional quantile was achieved by Diebold and Yilmaz (2012) approach. Then, GFEVD is applied for this determination. Henceforth, net connectedness index (NCI) at quantile δ is recorded as:

$$\text{NCI } (\delta) = \frac{\sum_{d=1}^{T}\sum_{k=1, i\neq k}^{T} \alpha_{dk}^{F}(\delta)}{\sum_{d=1}^{T}\sum_{k=1}^{T} \alpha_{dk}^{F}(\delta)} \text{ X } 100 \qquad (6)$$

Therefore, directional connectedness (DC) to index d from all other indexes at quantile δ exhibits as follows:

$$\text{Cd} \leftarrow (\delta) = \frac{\sum_{k=1, i\neq k}^{T} f(\delta)}{\sum_{k=1}^{T} \alpha_{ik}^{f}(\delta)} \text{ X } 100 \qquad (7)$$

Likewise, DC from index i to all other indexes at quantile δ designates as:

$$\text{Cd} \rightarrow (\delta) = \frac{\sum_{k=1, i\neq k}^{T} \alpha_{ik}^{f}(\delta)}{\sum_{k=1}^{T} \alpha_{ik}^{f}(\delta)} \text{ X } 100 \qquad (8)$$

In view of equation 8, net volatility spillover connectedness (NVC) is itemized as:

NVC (δ) = Cd → (δ) - Cd ← (δ) (9)

Last of all, pairwise connectedness (PC) at quantile δ is specified as:

PC (δ)= $\alpha_{kd}^{f}(\delta) - \alpha_{dk}^{f}(\delta)$ (10)

We applied rolling window method to evaluate time variations as assessed by Diebold and Yılmaz (2014). Additionally, a VAR lag order=1 is working to calculate connectedness, and a 10-step forward estimate EVD depends on the Akaike Information Criterion – AIC.

OUTCOMES AND DISCUSSION

Static Quantile Connectedness:

Table 4 demonstrates empirical results of the static QVAR approach at normal, bearish, and bullish market circumstances. Table 4 Panel A presents the QVAR connectedness between THETA, DGB, and GBI under normal market conditions. At normal condition of the market (q=0.5), the connectedness value is 31.15 TCI. However, at severe bearish market states (q=0.05) and severe bullish market states (q=0.95), connectedness measures are sturdier, such as TCI=72.74 and 73.95 at quantile 0.05 and 0.95, respectively. This reflects the greater influence of drastic events on the measures of connectedness. Connectedness between THETA, DGB, and GBI is sturdier during the stress period than the normal market state. Similarly, Figure 3 illustrates the high connectedness magnitude at severe lower and upper quantiles. In contrast, the TCI at the median quantile is low. In other words, in case of a large shock, the TCI significantly surges at extreme lower and upper quantiles, signifying that the strength of return connectedness surges with shock (Bouri et al., 2021). These harmonies with prior research on contagion display a spillover of drastic events (Londono, 2019). Consistent with Abdullah et al. (2022) and Chowdhury et al. (2022), the existence of high degree connectedness is owing to the COVID-19 adverse shock on financial markets, triggering market disorganizations, asymmetric data, and differences in investors' appetite. Moreover, Adekoya et al. (2022) and Yousaf et al. (2023) stated that most variations in TCI across bull and bear markets are fairly symmetric, indicating that connectedness is high at both market conditions.

In addition, three market conditions were found that THETA is a net transferor of return spillover, and GBI is a net recipient of return spillover with different magnitudes. However, DGB performs the role of return spillover transmitter during extreme market states and return spillover receiver in normal market states. These findings support the persistent robustness of NFTs at severe tails. Karim et al. (2022) established a dynamic trait of NFTs and concluded that NFTs possess a diversification attribute.

Table 4 Panel A: Static spillover measures relied upon the quantile VAR (q = 0.5)

	THETA	DGB	GBI	FROM
THETA	74.35	23.96	1.69	25.65
DGB	25.49	71.95	2.56	28.05
GBI	4.78	3.81	91.41	8.59
TO	30.28	27.77	4.25	62.29
Inc.Own	104.63	99.72	95.65	cTCI/TCI
NET	4.63	-0.28	-4.35	31.15/20.76

Panel B: Static spillover measures relied upon the quantile VAR (q= 0.05)

	THETA	DGB	GBI	FROM
THETA	49.34	30.61	20.05	50.66
DGB	31.27	48.06	20.67	51.94
GBI	21.12	21.75	57.13	42.87
TO	52.39	52.37	40.72	145.47
Inc.Own	101.73	100.43	97.84	cTCI/TCI
NET	1.73	0.43	-2.16	72.74/48.49

Panel C: Static spillover measures relied upon the quantile VAR (q = 0.95)

	THETA	DGB	GBI	FROM
THETA	51.51	28.85	19.63	48.49
DGB	28.89	51.33	19.78	48.67
GBI	27.33	23.42	49.25	50.75
TO	56.22	52.28	39.41	147.91
Inc.Own	107.73	103.61	88.66	cTCI/TCI
NET	7.73	3.61	-11.34	73.95/49.30

Source: Authors' own creation

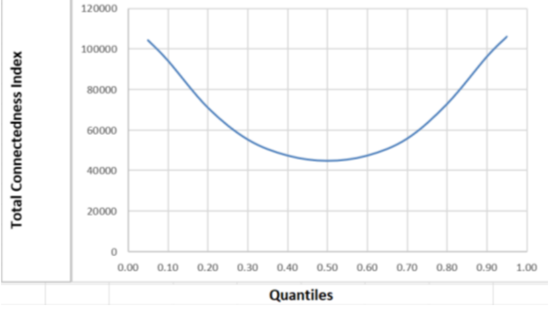


Figure 3: Total connectedness between THETA, DGB, and GBI over different quantiles

Source: Authors' own creation

Dynamic Quantile Connectedness:

Figure 4 magnifies a time-varying total connectedness between THETA, DGB, and GBI at three market conditions. In the graph, blue lines demonstrate TCI changes at median quantile (q=0.5), whereas the green and red lines epitomize the deviation of TCI at extremely upper and extremely lower quantiles, respectively. Considering Figure 4, the connectedness between THETA, DGB, and GBI varies over time at a normal market state. Least connectedness is found at the middle of 2021, and high connectedness is present at the beginning of 2023 and 2024. This is the time of the Russia-Ukraine conflict. Additionally, in severe bullish and bearish market states, connectedness is high, around 95% during extreme market events. As a result, catastrophes like the BTC Price Crash-2018, COVID-19, a large decline in demand for oil-2020, and the Russia-Ukraine Conflict instigated numerous market encounters, financial volatility, and economic suffering that caused distress faced by one asset, transmitted it to other classes of assets, establishing a negative reaction sphere. This outcome is corroborated by the market integration theory (Abakah et al., 2023; Kearney & Lucey, 2004). Moreover, Chatziantoniou et al. (2021) stated that a higher TCI value at severe quantiles indicates that connectedness is highly reliant on events. Moreover, Yousaf and Yarovaya, (2022) validated that dynamic return and volatility connectedness strengthened at commencement of coronavirus period-2019 and the cryptocurrency bubble-2021. Similarly, Umar et al. (2022b) unveil that return and volatility spillovers were high because of the pandemic, specifically, in the first three months of 2020.

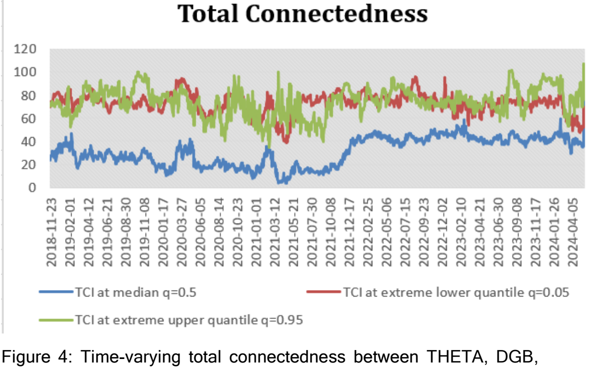


Figure 4: Time-varying total connectedness between THETA, DGB, and GBI at median, extreme upper quantile, and extreme lower quantile.

Source: Authors' own creation

Figures 5A, 5B, and 5C are the graphical representations of net spillover at three distinct market conditions. Figure 5A demonstrates net spillover at median quantile (q=0.5). In covered period, THETA, DGB, and GBI switched their function rapidly from net transmitter to net receiver and vice versa. During extreme catastrophes (see figures 5B and 5C), the upsurge of NFTs concurred with substantial changes in international markets, producing spillover effects that impacted GBI. As individuals spent more time online and searching for substitute investments during COVID-19, NFTs affected GBI and caused augmented volatility. This trend was sustained throughout the phase when the large decline in oil demand-2020 was reported, where uncertainty in energy markets drove investors to digital and sustainable investments, promoting both NFTs and green assets. Russia-Ukraine combat further escalated economic uncertainty and volatility in energy markets, strengthening the charm of green bonds and assertive investors to discover THETA and DGB. These interconnected events expose how the accumulative interest in digital financial assets during times of crisis impacted capital flows, market sentiment, and diversification strategies, eventually affecting the wider financial setting.

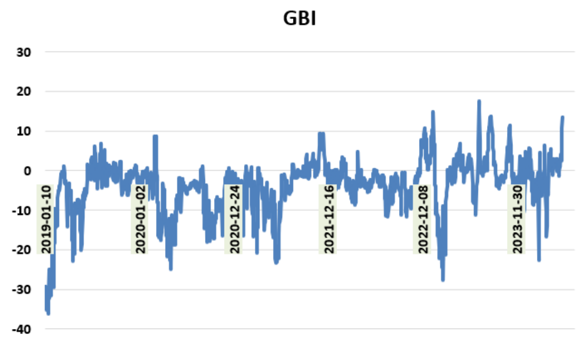


Figure 5A: Net spillovers of THETA, DGB, and GBI at median (q = 0.50).
Source: Authors' own creation

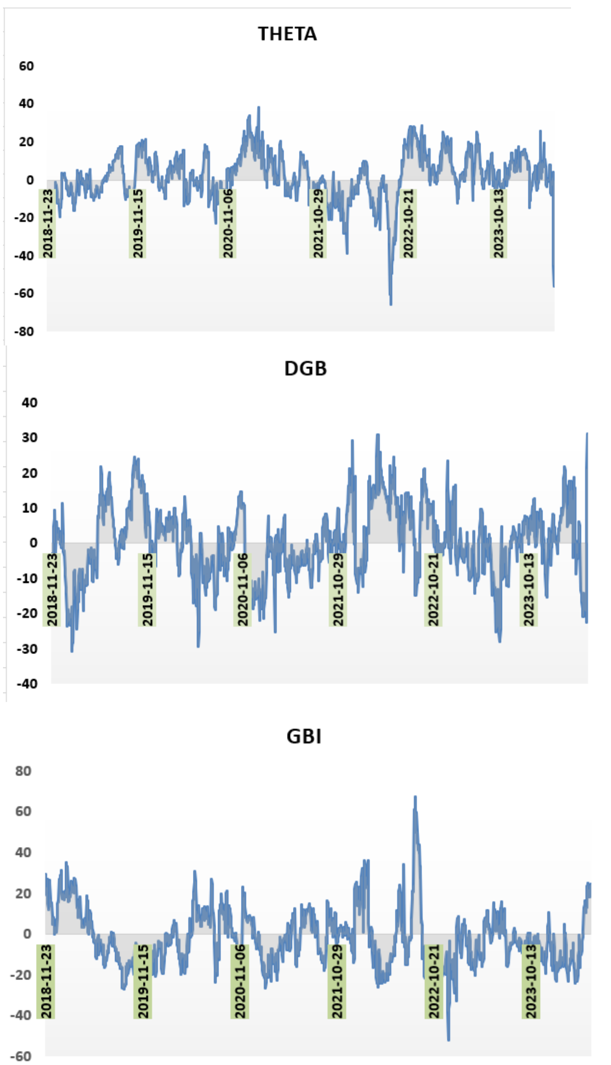
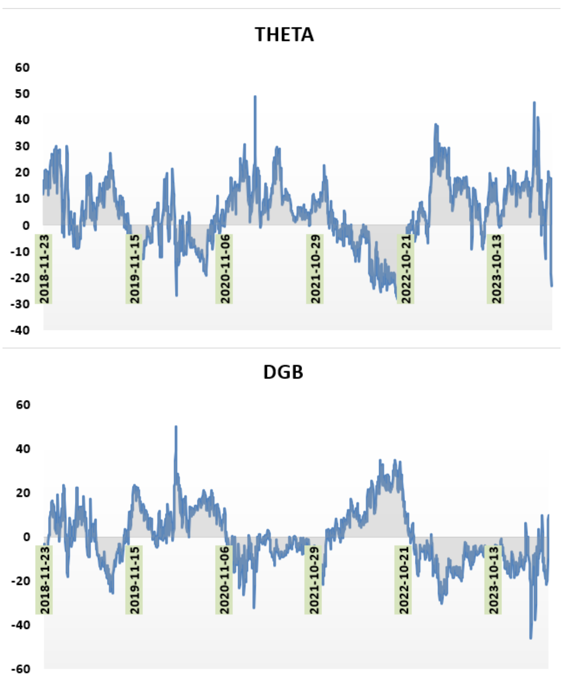


Figure 5B: Net spillovers of THETA, DGB, and GBI at extreme lower quantile (q = 0.05).
Source: Authors' own creation



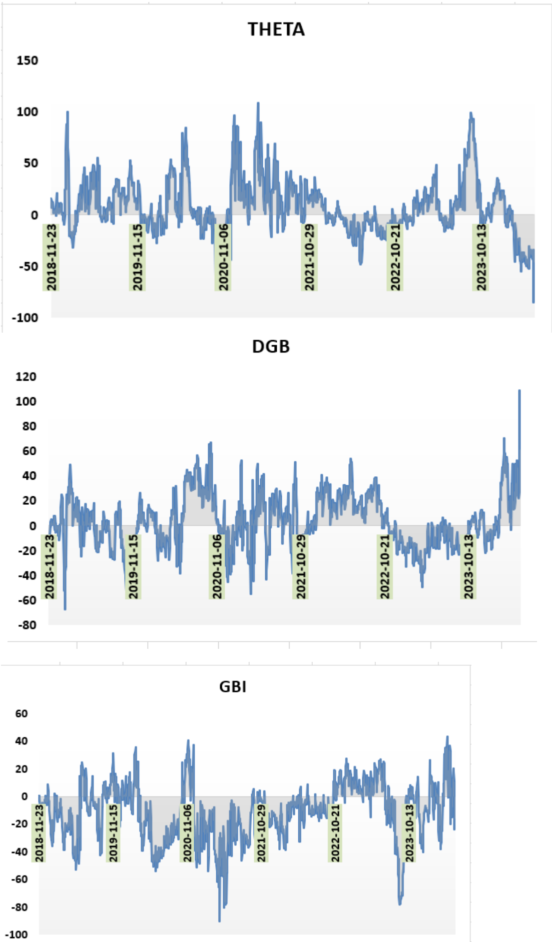
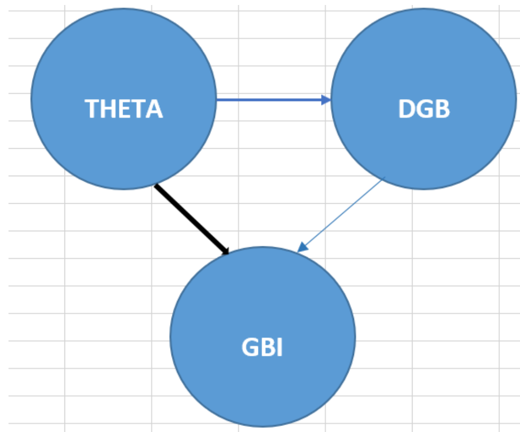


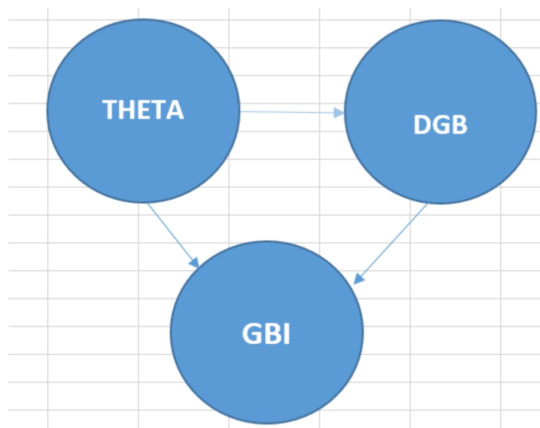
Figure 5C: Net spillovers of THETA, DGB, and GBI at extreme upper quantile (q = 0.95).

Source: Authors' own creation

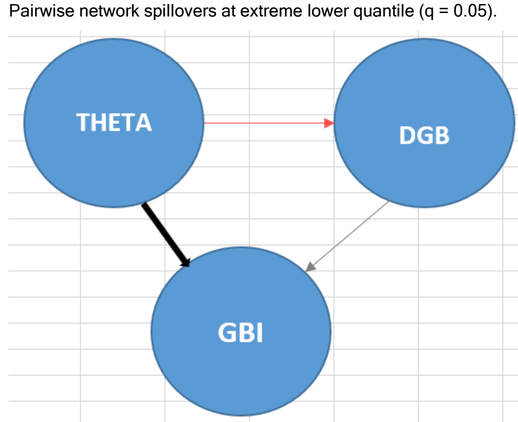
Net pairwise connectedness between THETA, DGB, and GBI at diverse quantiles is established in Figure 6. Figure 6 shows that at median quantile (q=0.5), THETA and GBI share strong connectedness, whereas DGB and GBI share moderate connectedness. Similarly, the bullish market (q=0.95) presents. However, at a bearish market state (q=0.05), THETA and DGB share moderate connectedness with GBI.



Pairwise network spillovers at median (q=0.5)



Pairwise network spillovers at extreme lower quantile (q = 0.05).



Pairwise network spillovers at extreme upper quantile (q = 0.95).

Figure 6: Net pairwise connectedness between THETA, DGB, and GBI

Source: Authors' own creation

Figure 7 displays the relative tail dependence (RTD), which refers to the propensity for adverse shocks to spread more sturdily than positive shocks, and this propensity can vary over time. Moreover, in the RTD diagram, when RTD is positive, it advocates that bad news has a greater influence compared with good news, and vice versa when RTD is negative.

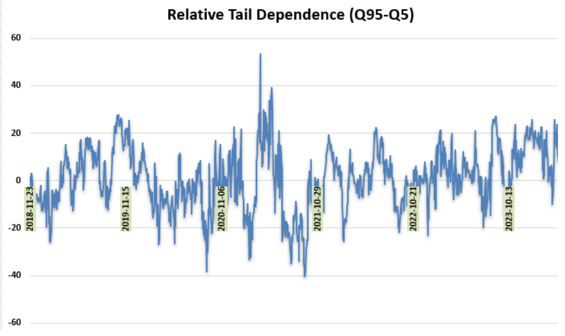


Figure 7: RTD (Q95-Q5) of THETA, DGB, and GBI

Source: Authors' own creation

CONCLUSION

In conclusion, the establishment of digital assets, for instance, NFTs, and the escalation of green bonds signify two substantial shifts in the financial networks. While NFTs provide new opportunities for investors looking for high yields in the digital economy, they come with extensive risks and ecological distress. Green bonds, conversely, provide a harmless, more sustainable investment selection, aligning financial yields with progressive environmental results. Accepting the behavior of these assets in diverse market settings is crucial for investors and policymakers equally. Current study bridges the gap in current literature by investigating the connectedness of THETA, DGB, and green bonds in both steady and volatile market conditions, contributing to an insightful grasp of how these assets connect and how they can be leveraged for risk management and sustainable investing. Firstly, the outcomes of static quantile connectedness reveal that THETA and DGB have a minimal level of connectedness with green bonds under normal market conditions. Conversely, during the period of extreme bearish and bullish market conditions, the measures of connectedness became sturdier.

Then, findings of dynamic time-varying total connectedness elucidate that TC between understudied variables changes in response to catastrophic incidents. At the median quantile, the connectedness measures are weak relative to the extreme circumstances of markets. A connectedness between NFTs and green bonds is robust at extreme bearish and bullish markets during catastrophic incidents, comprising the BTC Price Crash-2018, COVID-19, the large decline in demand of oil-2020, and the Russia-Ukraine Conflict. Next, time-varying net directional connectedness estimations specify that THETA, DGB, and green bonds switch their function from net transferor to net receiver of spillovers and vice versa during the covered timespan. These findings advocate that investors must notice spillover motions in all market states regularly and amend their investment distributions accordingly.

There are certain suggestions to investors and portfolio advisors in line with the findings of the current study. It is revealed that connectedness is high during extreme conditions of the market; therefore, investors and portfolio advisors should assess the risk associated with both NFTs and green bonds. Scenario analysis, such as stress testing and tail risk hedging, can also be performed to understand the degree of influence of market conditions over NFTs and green bonds. In addition, investors and portfolio advisors should have the latest information regarding market trends and technological innovations, so that they can make rational decisions to mitigate losses during catastrophic events.

The findings of this study recommend that policymakers should take appropriate actions and inspect systems to manage potential negative impacts as a consequence of extreme events. Otherwise, focusing only on connectedness in normal market conditions is likely to cause the formulation and implementation of unsuitable and useless policies during an extreme phase.

Moreover, policymakers should boost sustainable practices in the digital financial asset segments by executing regulations that require the mining process to use renewable energy sources.

THETA, DGB, and green bonds are the only under-investigated novel assets of this study, whereas another emerging asset category, such as Islamic Shariah-based Cryptocurrencies, was not examined. Hence, this new asset class can be investigated in future studies. It will reveal the connectedness and hedging attributes of Islamic Shariah-based Cryptocurrencies.

REFERENCES

Abakah, E. J. A., Ullah, G. W., Adekoya, O. B., Bonsu, C. O., & Abdullah, M. (2023). Blockchain market and eco-friendly financial assets: Dynamic price correlation, connectedness and spillovers with portfolio implications. *International Review of Economics & Finance*, 87, 218-243.

Abdullah, M., Wali Ullah, G. M., & Chowdhury, M. A. F. (2022). The asymmetric effect of COVID-19 government interventions on global stock markets: New evidence from QARDL and threshold regression approaches. *Investment Analysts Journal*, 51(4), 268-288.

Adekoya, O. B., Akinseye, A. B., Antonakakis, N., Chatziantoniou, I., Gabauer, D., & Oliyide, J. (2022). Crude oil and Islamic sectoral stocks: Asymmetric TVP-VAR connectedness and investment strategies. *Resources Policy*, 78, 102877.

Aharon, D. Y., & Demir, E. (2022). NFTs and asset class spillovers: Lessons from the period around the COVID-19 pandemic. *Finance Research Letters*, 47, 102515.

Alam, M., Chowdhury, M. A. F., Abdullah, M., & Masih, M. (2023). Volatility spillover and connectedness among REITs, NFTs, cryptocurrencies and other assets: Portfolio implications. *Investment Analysts Journal*, 52(2), 83-105.

Ando, T., Greenwood-Nimmo, M., & Shin, Y. (2018). Quantile Connectedness: modelling tail behaviour in the topology of financial networks. Available at SSRN 3164772.

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.

Cecchetti, S. G., & Li, L. (2008). Do capital adequacy requirements matter for monetary policy?. *Economic Inquiry*, 46(4), 643-659.

Chatziantoniou, I., Gabauer, D., & Stenfors, A. (2021). Interest rate swaps and the transmission mechanism of monetary policy: A quantile connectedness approach. Economics Letters, 204, Article 109891. https://doi.org/10.1016/j.econlet.2021.109891

Chowdhury, E. K., & Humaira, U. (2024). Transformation of investor attitude towards financial markets: A perspective on the Russia–Ukraine conflict. *International Social Science Journal*, 74(252), 561-583.

Chowdhury, M. A. F., Abdullah, M., & Masih, M. (2022). COVID-19 government interventions and cryptocurrency market: Is there any optimum portfolio diversification?. *Journal of International Financial Markets, Institutions and Money*, 81, 101691.

Diebold, F. X., & Yilmaz, K. (2012). Better to give than to receive: Predictive directional measurement of volatility spillovers. *International Journal of forecasting*, 28(1), 57-66.

Diebold, F.X. and K. Yilmaz (2014), "On the

Network Topology of Variance Decompositions: Measuring the Connectedness of Financial Firms," *Journal of Econometrics*, 182, 119- 134.

Jarque, C. M., & Bera, A. K. (1980). Efficient tests for normality, homoscedasticity and serial independence of regression residuals. *Economics letters*, 6(3), 255-259.

Karim, S., Lucey, B. M., Naeem, M. A., & Uddin, G. S. (2022). Examining the interrelatedness of NFTs, DeFi tokens and cryptocurrencies. *Finance Research Letters*, 47, 102696.

Kearney, C., & Lucey, B. M. (2004). International equity market integration: Theory, evidence and implications. *International Review of Financial Analysis*, 13(5), 571-583.

Ko, H., Son, B., Lee, Y., Jang, H., & Lee, J. (2022). The economic value of NFT: Evidence from a portfolio analysis using mean–variance framework. *Finance Research Letters*, 47, 102784.

Koenker, R., & Bassett Jr, G. (1978). Regression quantiles. Econometrica: *Journal of the Econometric Society*, 33-50.

Kong, D. R., & Lin, T. C. (2021). Alternative investments in the Fintech era: The risk and return of Non-Fungible Token (NFT). Available at SSRN 3914085.

Koop, G., Pesaran, M. H., & Potter, S. M. (1996). Impulse response analysis in nonlinear multivariate models. *Journal of econometrics*, 74(1), 119-147.

Li, G., Wu, H., Jiang, J., & Zong, Q. (2023). Digital finance and the low-carbon energy transition (LCET) from the perspective of capital-biased technical progress. *Energy Economics*, 120, 106623.

Londono, J. M. (2019). Bad bad contagion. Journal of Banking & Finance, 108, 105652.

Naeem, M. A., Karim, S., & Tiwari, A. K. (2023). Risk connectedness between green and conventional assets with portfolio implications. *Computational Economics*, 62(2), 609-637.

Pesaran, H. H., & Shin, Y. (1998). Generalized impulse response analysis in linear multivariate models. *Economics letters*, 58(1), 17-29.

Truby, J., Brown, R. D., Dahdal, A., & Ibrahim, I. (2022). Blockchain, climate damage, and death: Policy interventions to reduce the carbon emissions, mortality, and net-zero implications of non-fungible tokens and Bitcoin. *Energy Research & Social Science*, 88, 102499.*yu/

Umar, Z., Abrar, A., Zaremba, A., Teplova, T., & Vo, X. V. (2022a). The return and volatility connectedness of NFT segments and media coverage: fresh evidence based on news about the COVID-19

Umar, Z., Gubareva, M., Teplova, T., & Tran, D. K. (2022b). COVID-19 impact on NFTs and major asset classes interrelations: Insights from the wavelet coherence analysis. *Finance Research Letters*, 102725.

Wang, Y. (2022). Volatility spillovers across NFTs news attention and financial markets. *International review of financial analysis*, 83, 102313.

Xia, Y., Li, J., & Fu, Y. (2022). Are non-fungible tokens (NFTs) different asset classes? Evidence from quantile connectedness approach. *Finance Research Letters*, 49, 103156.

Yousaf, I., & Yarovaya, L. (2022). Static and dynamic connectedness between NFTs, Defi and other assets: Portfolio implication. *Global Finance Journal*, 53, 100719.

Yousaf, I., Jareño, F., & Tolentino, M. (2023). Connectedness between Defi assets and equity markets during COVID-19: A sector analysis. *Technological Forecasting and Social Change*, 187, 122