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Traditional assets, digital assets and renewable energy: Investigating connectedness during COVID-19 and the Russia-Ukraine war

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ABSTRACT

This paper analyses the connectedness among traditional assets, digital assets and renewable energy for extending the data from December 31, 2019 to January 2, 2023. For an empirical analysis, time varying parameter (TVP-VAR) is employed. We find that Chainlink (DeFi) is the highest receiver, while bitcoin is the highest transmitter of shocks to the network. Additionally, we also find that Non-Fungible Tokens (NFT) acts as the most suitable asset to be included in portfolio since it is least connected with rest of the examined assets classes. Results are important for investors and portfolio managers.

1. Introduction and background

Risk measurement, portfolio management, and the development of efficient hedging strategies all necessitate an in-depth familiarity with the risk spillovers and interconnectedness among various asset classes (Mirza et al., 2020). Accordingly, there have been many recent studies on dynamic linkages amongst various asset classes to determine diversification opportunities. Specifically, while the cryptocurrency market has at times trended this market has been fraught with high volatility and unexpected upswings and downswings (Taleb, 2021; Cornelius, 2021; Nadini et al., 2021; Wang et al., 2021).

New opportunities to participate in rapidly expanding asset classes backed by technology have emerged alongside cryptocurrencies in the form of various types of investable crypto assets. Non-Fungible Tokens (NFTs) and Decentralised Finance (DeFi) are two such

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Table 1
Constituent markets.

Asset	Index
Equity	MSCI All Country Index (MSCI ACWI)
Bonds	Bloomberg Barclays Global Aggregate Total Return Index
Clean energy (Renewable energy)	S&P Global Clean Energy
Non-renewable energy	WTI crude oil
NFT	Total average daily transaction price
Chainlink, Maker & Basic Attention Token	Decentralised Finance
Cryptocurrency	Bitcoin

asset classes that have recently received attention. DeFi assets are traded peer-to-peer on blockchain technology without a central authority (Yousaf et al., 2022; Gubareva et al., 2022; Chen and Bellavitis, 2020; Zetzsche et al., 2020). Non-fungible tokens (NFTs) use blockchain technology to record and transmit ownership of unique items or material, such as artwork, music, films, or collectibles, on a blockchain network (Umar et al., 2022a). NFTs' key attribute, non-fungibility, distinguishes them from cryptocurrencies, which are identical and interchangeable (Wilson et al., 2022; Dowling 2022a; Xia et al., 2022; Corbet et al., 2023).

Recent research on volatility contagion between NFT and other asset classes includes Aharon and Demir (2022), Yousaf and Yarovaya (2022), and Umar et al. (2022a, 2022b). Aharon and Demir (2022) observe an increase in the interconnectedness of financial asset returns during COVID-19, concluding that NFTs are largely immune to disruptions from conventional asset classes. Yousaf and Yarovaya (2022) employ a TVP-VAR approach to examine volatility spillovers, finding that, although there were strong return and risk spillovers during the peak COVID-19 period., linkages between digital and traditional assets were weak. The authors find that DeFi and NFT have their risks decoupled from other assets. Umar et al. (2022a) identify short-term co-movement between NFT and other asset classes, with NFT exhibiting a risk absorbing attribute during COVID-19. Umar et al. (2023), and Ko and Lee (2023), find that NFTs were good investments and hedges in all market conditions, including during the peak COVID-19 period. Ko et al. (2022) find that NFTs differ from traditional assets, providing portfolio diversification.

However, few studies explore the return-risk dynamic of NFT with other assets. Exceptions include Alam et al. (2023) (REITs), Liu (2023) (carbon market), and Bejaoui et al. (2023) (changing linkages between NFT and conventional assets for BRICS and Gulf economies). In this paper, we examine the connectedness amongst digital assets (NFT and DeFi), traditional assets (equity, bonds, and crude oil) and the new asset class of clean energy. We investigate linkages among these assets during a period that includes heightened volatility caused by health crisis, geopolitical unrest, and asset price bubbles. Employing time varying parameter (TVP-VAR), we find that Chainlink (DeFi) is the highest receiver while bitcoin is the highest transmitter of shocks to our network. Additionally, NFT is the least connected with other examined assets.

We offer analysis of the interconnectedness of assets over a time frame selected to cover the full impact of disruptive events such as the Russia-Ukraine war (e.g., Boubaker et al., 2022), the extreme volatility of oil prices (e.g., Corbet et al., 2020), three waves of COVID-19 (Boubaker et al., 2023), the turbulence of cryptocurrency (e.g., Khalfaoui et al., 2023), and high inflation (e.g., Sakurai and Kurosaki, 2023). Careful consideration is given to selecting a time frame that facilitates analyzing volatility spillover during extreme times, when the connectedness of assets might be altered, with consequential effects on portfolio rebalancing and diversification.

Additionally, we incorporate clean energy, a rapidly developing alternative asset class. We compare this new asset class to the non-renewable energy market. Researchers, policymakers, and investors alike have been discussing the advent of clean energy as a possible asset for mitigating climate change and diversifying portfolios (Su et al., 2020; Saeed et al., 2020; Aktar et al., 2021). Against the backdrop of the ever-changing financial markets, it is informative to determine how NFT interacts with clean energy. An important takeaway from the research is the promising prospect of NFT and DeFi as new asset classes for investment. The recent failures at Silicon Valley Bank, Signature Bank, and Credit Suisse have eroded investor confidence in large, centralised financial institutions and contributed to widespread market instability (Yadav et al., 2023a). In these uncertain times, DeFi stands out as an asset class of new possibilities (Corbet et al., 2023; Corbet et al., 2022). However, the benefits of DeFi's reduced information asymmetry, improved transparency, and cost efficiency are yet to be fully confirmed (Grassi et al., 2022).

Regarding the rest of this paper, Section two describes the data and methodology. Section 3 reports and discusses empirical results. Section 4 provides conclusions and policy implications.

2. Data and methodology

We include daily data of select financial assets, equity, debt, clean energy, oil and cryptocurrency. Descriptive statistics are presented in Table 1. Following the methodology of Bouri et al., (2021); Aharon & Demir (2022) and Umar et al. (2022a), we use NFT daily price data rather than monthly or weekly data to develop insights. The time span of our study ranges from December 31, 2019 to January 2, 2023. The data of all major classes, except DeFi and NFT, are sourced from *Bloomberg*. The price data for DeFi was extracted from *investing.com*, while *nonfungible.com* was used for NFT secondary market trade values. The proxies of DeFi are Chainlink, Maker and Basic Attention Token.

For empirical estimation, the time varying parameter (TVP-VAR) model of Antonakakis et al., (2020) is employed to examine the dynamic connectedness among various asset classes. This approach is an extension of Diebold and Yilmaz (2009, 2012, 2014). Diebold and Yilmaz (2009, 2012, 2014) developed a rolling-window vector autoregressive approach to determine the connectedness or linkage measure from the variance decomposition results.

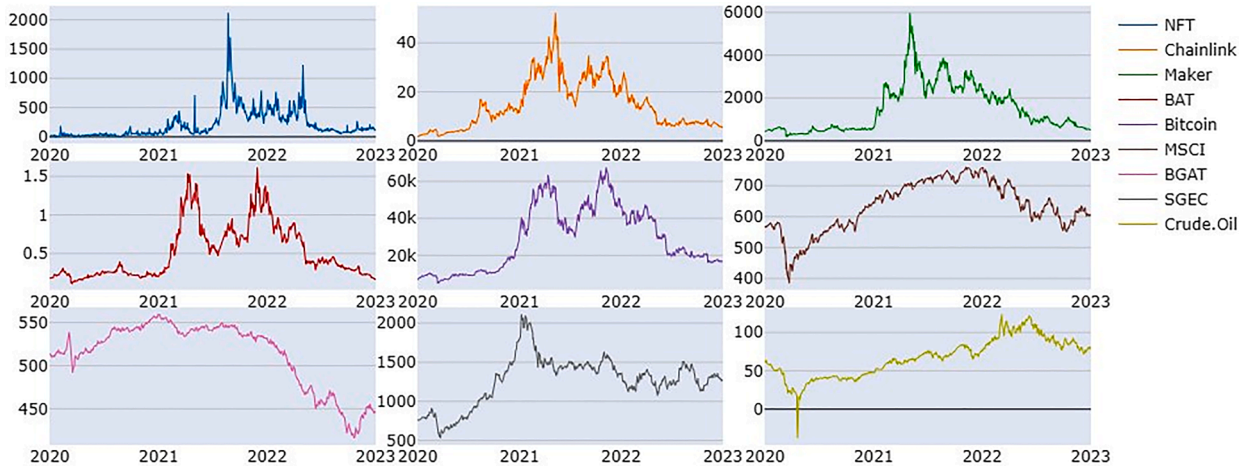

Fig. 1. Raw series.

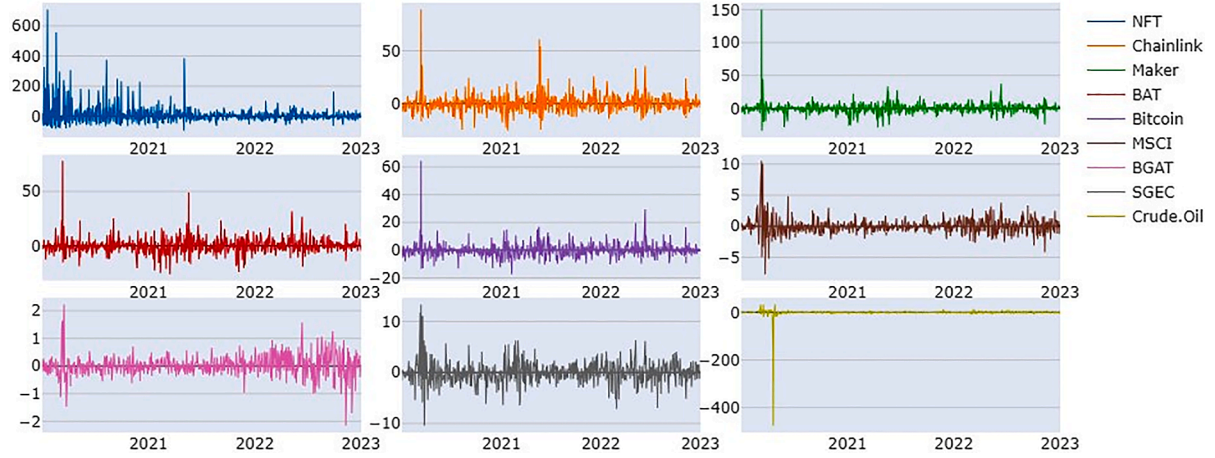

Fig. 2. Returns.

The TVP-VAR(p) model is presented as:

$$Y_t = \beta_t Z_{t-1} + \varepsilon_t, \varepsilon_t|\Omega_{t-1} \sim N(0, \Sigma_t), \tag{1}$$

$$\beta_t = \beta_t + \vartheta_t \vartheta_t|\Omega_{t-1} \sim N(0, R_t) \tag{2}$$

Eq. (1) is derived from Wold representation theorem and can be converted into a moving average equation as presented in Eq. (3):

$$Y_t = \sum_{j=0}^{\infty} \Theta_{jt} \varepsilon_{t-j}, \tag{3}$$

Wherein, Θ_{jt} denotes a N *X* N dimensional matrix. Time -varying parameters and Diebold and Yilmaz variance-covariance matrices of the TVP-VAR model are employed to obtain the dynamic connectedness between the selected variables. The rudiments of the dynamic H-step generalized variance decomposition matrix $D_t^{gH} = [d_{ij,t}^{gH}]$ can be represented as:

$$d_{ij,t}^{gH} = \frac{\sigma_{jj,t}^{-1} \sum_{h=0}^{H-1} \left(e_i' \Theta_{h,t} \Sigma_t e_j\right)^2}{\sum_{h=0}^{H-1} \left(e_i' \Theta_{h,t} \Sigma_t \Theta_{h,t}' e_j\right)}, \tag{4}$$

Wherein, $\sigma_{jj,t}^{-1}$ is denoting the j^{th} diagonal element of Σ_t. $\tilde{d}_{ij,t}^{gH} = \frac{d_{ij,t}^{gH}}{\sum_{j=1}^{N} d_{ij,t}^{gH}}$ as normalised. Further, the net pairwise directional connectedness is defined as: $NPDC_{ij}^{gH} = (\tilde{d}_{ji,t}^{gH} - \tilde{d}_{ij,t}^{gH})$ X 100. If the value of this expression is more than zero, then variable 'i' controls variable 'j' and vice-versa.

Table 2
Summary statistics.

	NFT	Chainlink	Maker	BAT	Bitcoin	MSCI	BGAT	SGEC	Crude oil
Mean	10.671	0.174	0.31	0.28	0.01	−0.001	0.02	−0.04	−0.83
Variance	3885.87	70.649	78.92	56.57	24.70	1.68	0.14	4.69	333.98
Skewness	4.41***	2.64***	6.17***	1.9***	3.28***	1.34***	0.29***	0.64***	-23.19***
Ex.Kurtosis	33.285***	22.07***	104.52***	17.54***	37.85***	13.75***	5.30***	5.26***	588.84***
JB	38,586.95***	16,760.56***	360,472.09***	10,486.12***	48,031.92***	6389.370***	926.47***	952.35***	11,353,348.05***
ERS	−7.22***	−10.12***	−11.09***	−7.66***	−11.85***	−10.75***	−9.13***	−11.64***	−12.25***
Q(10)	88.75***	31.67***	35.24***	17.06***	16.54***	57.43***	52.63***	32.34***	83.46***
Q2(10)	14.89***	41.35***	6.89	7.78	3.38	447.446***	207.23***	296.55***	7.59

Source: Authors. The table shows the descriptive statistics for the selected asset classes. The reported values are mean, variance, skewness, kurtosis and the Jarque-Bera test for normality.

Table 3
Dynamic connectedness using TVP-VAR.

	NFT	Chainlink	Maker	BAT	Bitcoin	MSCI	BGAT	SGEC	Oil	FROM
NFT	**91.22**	0.88	1.14	1.58	1.16	1.3	0.54	1.44	0.74	8.78
Chainlink	0.74	**35.81**	15.54	20.49	18.71	4.9	0.62	2.91	0.28	64.19
Maker	0.5	6.63	**49.23**	16.96	17.26	5.11	0.77	3.1	0.43	50.77
BAT	0.82	6.29	15.86	**45.65**	20.91	5.71	0.74	3.54	0.47	54.35
Bitcoin	0.58	5.7	16.1	20.54	**43.9**	6.02	1.58	5.23	0.34	56.1
MSCI	0.65	3.68	6.22	6.7	7.21	**50.32**	2.78	18	4.44	49.68
BGAT	0.4	1.07	2.14	2.2	3.24	8.58	**73.62**	6.56	2.19	26.38
SGEC	0.98	2.45	4.05	5.51	7.19	19.58	3.06	**56.11**	1.07	43.89
Oil	0.56	0.42	1.97	1.72	1.96	6.21	1.8	2.26	**83.11**	16.89
TO	5.23	27.11	63.01	75.7	77.64	57.41	11.9	43.05	9.96	
NET	−3.55	−37.07	12.25	21.35	21.54	7.74	−14.49	−0.84	−6.93	46.38

Source: Authors.

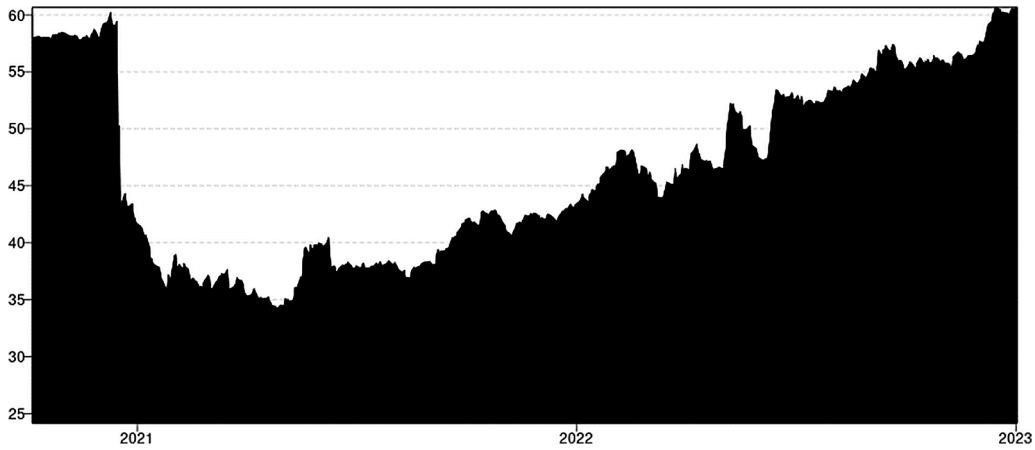

Fig. 3. Total connectedness index (TCI) during examined period.

3. Empirical result

Prior to empirical estimation, graphical representations of raw series and return series are inspected, as displayed in Figs. 1 and 2 respectively. It is observed that each raw series follows a stochastic trend which is removed by converting into return series. Further, Table 2 presents the descriptive statistics for the selected assets. NFT recorded with highest average return and standard deviation compared to other asset classes (Aharon and Demir, 2022; Umar et al., 2022b). It is worth noting that the volatility of all digital assets viz., NFTs, DeFi and Bitcoin is quite high with respect to conventional assets. Additionally, it is noticed that the return for most of the series is leptokurtic, skewed and non-normal. The result of ADF and Phillip-Perron test is in the similar line since stationarity is confirmed at 1% of level of significance.

Next, we employ TVP-VAR modeling to examine the connectedness amongst considered asset classes, with results reported in Table 3. We document, on average, 46.38% of the forecast error variation in this network's connection is attributed to the shock transmission among the specified assets, with the remaining 53.62% being explained by the unique characteristics of each asset. Turning to the 'From' and 'To' connectedness, we report that Chainlink (DeFi) is highest receiver of shock (64.19%), followed by bitcoin (56.10%), while NFT is the least receiver of shock (8.78%). It infers that DeFi will be affected in either direction due to the shock (increase/decrease) in respective examined assets class. Therefore, stakeholders of the market (DeFi) must be cautious towards shock. The finding derived from our study differs from the study of Umar et al., (2022a).

In the context of transmission, bitcoin is the largest transmitter of shock (77.64%), followed by BAT (75.7%). Further, net connectedness is computed differentiating the recipient and transmission of the connectedness. We find that Maker, BAT, bitcoin and MSCI are net transmitters of shocks, while NFT, Chainlink, BGAT, SCEC and Oil are net receivers. This suggests NFT as a diversifier for other asset classes.

Towards deepening our understanding of shocks, Fig. 3 displays the connectedness over the examined period. The vertical axis displays TCI in percentage, illustrating the proportion of variance that may, on average, be attributed to the interaction between the system variables. Prior to 2021, there is a noticeable increase in connectivity due to the sudden COVID-19 pandemic breakout and its presentation of unforeseen challenges for the financial markets, economy, and healthcare sector.

Growing cross-market linkages accentuated the volatility transmission between traditional assets, energy markets, and crypto assets. The connectedness value increased gradually in 2022 and peaked in 2023. The year 2022 was a turbulent one for the financial

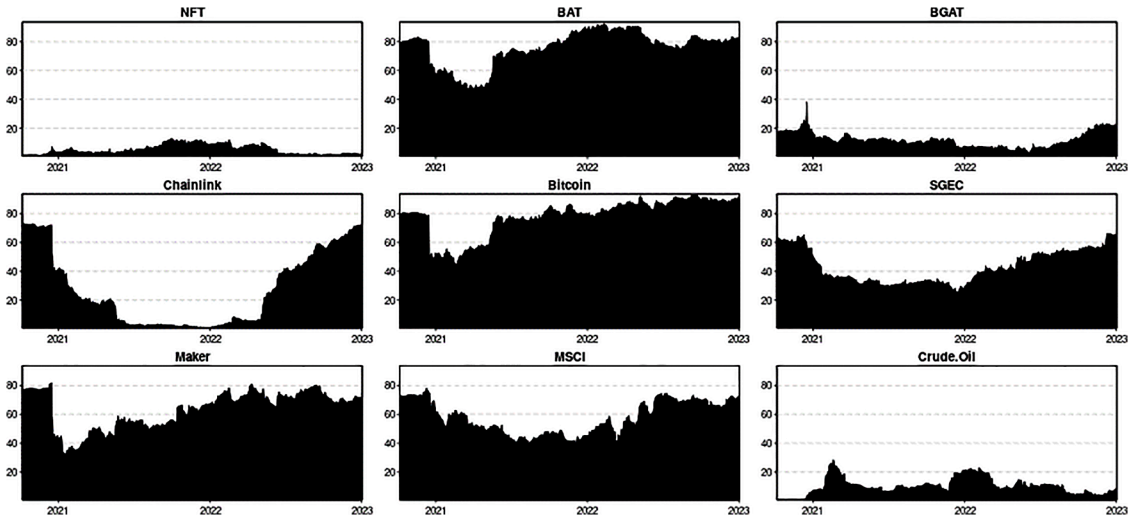

Fig. 4. Transmission of shocks to network connection.

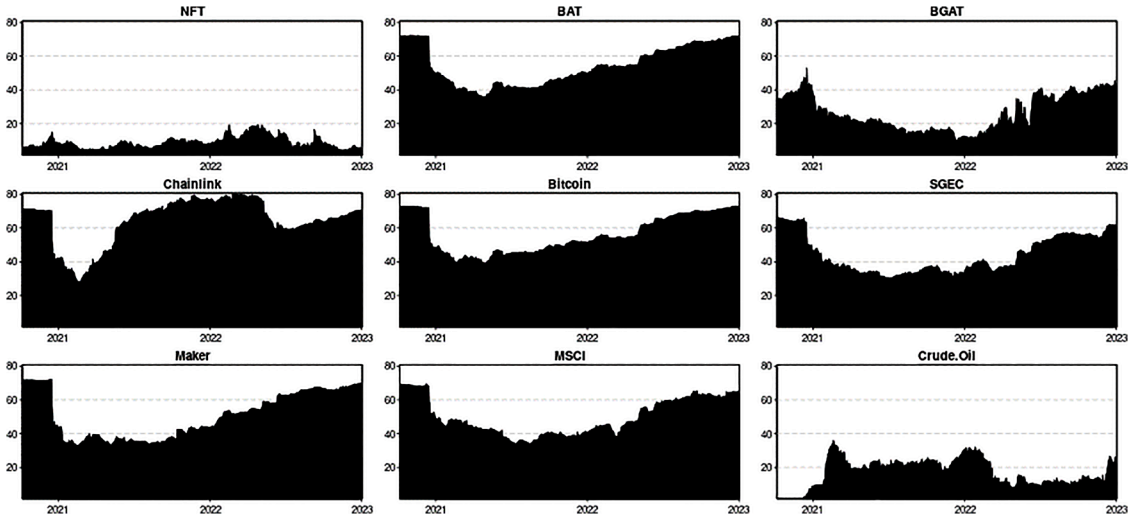

Fig. 5. Recipient of shocks from network connection.

and energy markets due to several cascading shocks, including the Russian invasion of Ukraine, the US pursuing an aggressive monetary policy position that drove up interest rates and inflation, as well as the extreme volatility in cryptocurrencies, downside risk in asset pricing, and a slowdown in China's economy (Yadav et al., 2023b; Malhotra et al., 2023).

Additionally, Figs. 4 and 5 graphically represent receiving and transmitting of shocks among select assets classes. As indicated by these figures, volatility from bitcoin, Chainlink, Maker, and BAT grew dramatically in 2022 and persisted into early 2023.

This heightened spillover can be attributed to the high volatility in the cryptomarket in 2022 brought on by the failure of FTX, one of the biggest global crypto exchanges, the crash of Terra-Luna, and tightened tax rules, which had a significant negative impact on crypto-assets. Results of volatility spillover FROM others show largely similar characteristics for crypto and DeFi assets, except for NFT and crude oil as they show decreased spillover with passage of time (Bains et al., 2022).

4. Conclusions

In the current juncture of volatile markets, specifically, the asset classes backed by technology have emerged in the form of Non-Fungible Tokens (NFTs), Decentralised Finance (DeFi) and other assets. At the same time, stakeholders of the markets are worried that how the traditional assets can relate to digital asset class. On this note, it is of utmost importance to undertake a study to analyze the dynamic linkage. This study is an attempt to unravel connectedness among traditional assets, digital assets, and renewable energy, including during COVID-19 and the Russia-Ukraine invasion. It is found that Chainlink (DeFi) and bitcoin are respectively the highest

receiver and transmitter of shock. At the same time, NFT transmits and receives the least shocks from the network, consistent with Umar et al., (2023) and Ko and Lee (2023). We highlight the diversification benefit of NFT. Scholars and practitioners interested in efficient portfolio construction will find our results very interesting. In addition, investors and portfolio managers can diversify their portfolio of examined assets class based on recipient and transmission of shock.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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