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The relationship between trading volume, volatility and returns of Non-Fungible Tokens: evidence from a quantile approach

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ABSTRACT

This is the first study to examine the quantile connectedness for returns-volume and volatility-volume pairs for the three non-fungible tokens (THETA, Tezos, and Enjin Coin) using the quantile VAR approach. The results report the highest connectedness of volume with returns and volatility in the extreme upper quantile compared to other quantiles, implying the asymmetric connectedness. The spillover effect is observed from volume to returns and volatilities in extreme upper and lower market conditions, whereas opposite direction of spillovers is evident for the selected non-fungible tokens at median quantile. Our findings are useful for investors in predicting the returns and risk of NFTs using trading volume in the extreme market conditions.

C12, C22, G14, G15

1. Introduction

How can a piece of digital art be worth several millions of dollars? It has become possible since the introduction of so-called Non-Fungible tokens (NFTs). NFTs are unique digital tokens representing the ownership of certain unique digital objects, e.g., artworks, images, videos or similar. The astonishing popularity of conventional cryptocurrencies, such as Bitcoin and Ethereum, has attracted the attention of investors to new and non-interchangeable type of digital assets. While a wide variety of digital assets have been introduced in the last decade, disrupting global financial markets in terms of payments, investments and financial services (E.g., Böhme et al., 2015; Cong et al., 2021; Ante et al., 2021), NFTs are the most recent innovation and relatively under-researched investment instrument to date (e.g., Dowling, 2021a; Kireyev and Evans, 2021; Yousaf and Yarovaya, 2022; Baals et al., 2022).

The prices and trading volume of NFTs have dramatically increased in the last three years, i.e., the total trading volume of THETA was $3.31 billion in first semi-annual of 2018 and it increased to $74.12 billion in first semi-annual of 2021. Moreover, the price of THETA was increased from $0.18 on 17 January 2018 to $6.48 on 20 November 2021. There is a variation in price and volume growth over time as well in the THETA. These prices and volume hikes were also observed in other NFTs blockchains (i.e., XTZ and ENJ) but with higher volatility as well (Wilson et al., 2021). Specifically, Ante (2021) reports that the trading volume of NFTs increase 23 folds from 2018 to 2021. These unprecedented hikes of prices, volume, and their associated volatility motivate us to examine the linkages among them. A very important research question is that whether volume affect the returns and volatility or vice versa? These directions of relationships are important in understanding the information arrival process, price spikes, and crashes (Marsh and Wagner, 2004).

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The background literature includes Dowling (2021a) who assessed the pricing efficiency of one virtual world based NFT, namely Decentraland. In his further work, Dowling (2021b) examines the volatility spillover between cryptocurrencies and NFTs reporting diversification potential of new digital assets. Ante (2021) also explores the connectedness of NFT wallets with traditional cryptocurrencies Bitcoin and Ethereum reporting the investment opportunities of NFTs. Yousaf and Yarovaya (2021), Karim et al. (2021), Aharon and Demir (2021), and Umar et al. (2022) investigate the connectedness between NFT and other assets classes like gold, oil, Bitcoin, fiat currency, bonds, and stocks, concluding that NFTs are decoupled from other asset classes. Ko et al., (2022) report that the performance of traditional portfolios (i.e., stock, oil, bond, and currency) improves after adding NFTs in it. Maouchi et al. (2021) identify the large but less frequent bubbles in NFT and Defi assets compare to traditional cryptocurrencies. Wang et al., (2022) provide the evidence of speculative bubbles in NFTs and Defi assets, but bubbles magnitude is higher in NFTs compared to Defi. Nadini et al., (2021) forecast the sales of NFTs using the using the machine learning algorithm. While previous studies focused on the return/volatility spillovers between NFTs and other assets classes, bubbles in NFTs, and forecasting the NFTs, no emphasis to date has been placed on return-volume and volatility-volume nexus of NFTs. Therefore, this is the first study which sheds the light on the relationships between trading volumes, returns and volatility for NFTs, contributing to the large body of literature examining the role of trading volumes in cryptocurrencies (e.g., Bouraoui, 2020, Zhang and Li, 2020; Khuntia and Pattanayak, 2020; Yarovaya and Zięba, 2021).

Our research based on the literature assessing return-volume relationships between digital assets. Balcilar et al. (2017) explore the effect of volume on returns and volatility in Bitcoin market using the causality in quantiles approach and find that the volume influences the returns between 0.25 and 0.75 quantiles. Further, this study concludes that the trading volume does not affect the volatility of Bitcoin in all quantiles. Fousekis and Tzaferi (2021) examine the positive and negative spillover between volume and returns of four traditional cryptocurrencies (i.e., Bitcoin, Ethereum, XRP, Litecoin) in shorter and longer horizons using the frequency connectedness approach of Baruník and Křehlík (2018). They report the bi-directional causal relationships between volume and returns. In long run, spillovers are found to be stronger from returns to volume compared to the spillovers from volume to returns. Moreover, positive spillover is stronger than the negative spillovers between volume and returns. Borri and Shakhnov (2020) provide the evidence of simultaneous increase in volume and prices of Bitcoin in exchange for the various exchanges. Using copula-quantile causality approach, Bouri et al. (2019) estimate the impact of volume on returns and volatility of seven traditional cryptocurrencies and find that trading volume influences the extreme positive and negative returns of all cryptocurrencies, whereas volume affects the volatility of few cryptocurrencies. Using Garch-Copula based approaches, Naeem et al. (2020) examine the extreme quantile dependencies between trading volume and returns of Bitcoin, Ethereum, and Litecoin and report that tail connectedness is higher in presence of higher volumes and returns. The variation of results in above-mentioned studies over various quantiles highlights the importance of investigating the extreme tail dependence instead of average dependence. Yarovaya and Zięba (2021) analyzed return-volume relations between top 30 most tradable cryptocurrencies using high-frequency data and found that return-volume bidirectional causality is weakening with decreasing data frequencies.

While return-volume relationships has been examined in the cryptocurrency literature already, NFT blockchain are significantly different from the pioneer cryptocurrencies due to their technological characteristics and their purpose. In contrast to 'conventional', mineable cryptocurrencies, like Bitcoin, the main function of NFTs is not a money transfer, but a provision of a database system in which the participants can record and update the information on the secured ledger establishing the system trust in their communities. Katsiampa et al. (2022) discuss the differences in co-movements between three different types of digital assets, i.e. cryptocurrencies, protocols, and dApps. Using similar classification, the NFT blockchains could allocated to 'protocols' category, while NFTs tokens to applications. In comparison to the most popular NFT protocol Ethereum, the NFT blockchains analyzed in our paper claim to be much less energy consuming and more environmental friendly, hence might be more attractive for NFT communities and investors. This can result in occurrence of the different patterns in return-volume relationships in NFTs in comparison to other types of digital assets. Therefore, our study contributes to the existing literature by examining the static and dynamic relationship for the pairs of returns-volume and volatility-volume at median and extreme upper and lower quantiles for three NFT blockchains, other than Ethereum, offering a novel evidence useful for the cryptocurrency researchers, NFT communities and investors.

2. Data and Methodology

2.1. Data description

We use daily data of volume and prices of three NFTs, including THETA, Tezos (XTZ), Enjin Coin (ENJ). The sample period starts from 17 January 2018 and ends on 20 November 2021.[1] The selection of NFTs is based on the longer time-frame data and high capitalization. We collect the data of NFTs from the website of coinmarketcap.com. Returns are calculated using the formula: $R_t = \ln(P_t/P_{t-1})$, whereas P_t denotes the today's price. Following the Balcilar et al. (2017), volatility is estimated through square of returns. Due to the presence of deterministic time trends (linear and non-linear) in the volume data, we use and calculate the detrended volume following the Balcilar et al. (2017) and Bouri et al. (2019).[2] We take the natural log of the volume series and remove its trend by regressing it on a constant, (t/T) and $(t/T)^2$, where T is the total sample size.

[1] The THETA was launched on 16 January 2018, and its trading was started on 17 January 2018. Therefore, we start our sample period from 17 January 2018.

[2] Previous studies provide the evidence of deterministic time trends as well (Gallant et al., 1992; Gębka, 2012).

Table 1
Descriptive Statistics.

	Panel A. Returns			Panel B. Volatility			Panel C. Detrended Volume		
	THETA	XTZ	ENJ	THETA	XTZ	ENJ	THETA	XTZ	ENJ
Mean	0.0025	0.0001	0.0020	0.0061	0.0048	0.0065	0.0019	-0.0007	-0.0015
Maximum	0.5105	0.2599	0.7682	0.3647	0.3688	0.5902	3.6267	2.6156	4.3198
Minimum	-0.6039	-0.6073	-0.6242	0.0000	0.0000	0.0000	-2.5598	-2.3581	-3.3491
Std. Dev.	0.0782	0.0692	0.0808	0.0183	0.0148	0.0284	1.0234	0.8068	1.1267
Skewness	0.0096	-0.7895	1.2421	10.6764	14.1152	14.2829	0.1411	0.0806	0.4422
Kurtosis	9.9755	10.6369	19.8115	162.755	295.932	255.602	2.9304	3.0123	3.1378
Jarque-Bera	2842.5[a]	3552.6[a]	16870.7[a]	1517518[a]	5059249[a]	3775101[a]	4.9340[c]	1.5269	46.7923[a]
Q-stat (15)	26.109[b]	44.5240[a]	32.6270[a]	49.4540[a]	95.1100[a]	156.830[a]	8610.1[a]	10736.0[a]	9743.1[a]
ADF	-40.7434[a]	-39.4649[a]	-41.1205[a]	-33.0379[a]	-31.5221[a]	-7.3701[a]	-4.9223[a]	-5.6765[a]	-4.5152[a]
PP	-40.7805[a]	-39.4348[a]	-40.9505[a]	-34.0883[a]	-33.2966[a]	-36.9716[a]	-11.741[a]	-8.327[a]	-14.112[a]

Notes: "XTZ-Tezos, ENJ-Enjin Coin, Q stat-Ljung Box Q statistics, ADF-Augmented Dickey–Fuller test, PP-Phillips Perron test. [a,b,c] denote the 1%, 5%, and 10% level of significance". The Augmented Dicky Fuller test and Phillip-Perron test results are significant, indicating the stationarity of all series of returns, volatility, and detrended volume.

Table 1 presents the descriptive statistics of returns, volatility, volume, and detrended volume of NFTs, while Fig. 1 illustrates the time-varying prices, returns, volatility, and detrended volatility.

2.2. Methodology

The existence of return-volume and volatility-volume connectedness provides insightful information about market efficiency (Fama, 1970), i.e. if the spillover effect is observed from the volume to returns and volatility then the NFTs' returns and volatility can be forecasted using trading volumes data which contradict the proposition of efficient market hypothesis. The anti-efficiency market hypothesis results also imply that investors can get abnormal returns by adding volume as predictor of returns in their technical analysis of NFTs. Furthermore, the sequential information arrival hypothesis (SIAH) claims that the arrival of new information affects the trading volume and then trading volume influences the volatility (Copeland, 1976). SIAH proposes the positive impact of volume on volatility of market. Hence, to add to the empirical evidence of these seminar hypotheses, we formulate the following two research hypotheses.

H1: *NFTs trading volumes are connected to NFTs returns and volatilities in extreme market conditions.*

H2: *The volume-return and volume-volatility connectedness is asymmetric and time-varying.*

To investigate the quantile connectedness for the pairs of returns-volume and volatility-volume of the NFTs, we use quantile connectedness approach proposed by Ando et al. (2022) and Bouri et al. (2021). In order to compute metrices of the quantile spillover, the infinite order-based vector moving average specifications of QVAR are defined as:

$$y_t = \mu(\tau) + \sum\nolimits_j^p \Phi_j(\tau) y_{t-j} + u_t(\tau) = \mu(\tau) + \sum\nolimits_{i=0}^{\infty} \Omega_i(\tau) u_{t-i} \tag{1}$$

Following Pesaran and Shin (1998) and Koop et al. (1996), the "generalized forecast error variance decomposition (GFEVD)" with forecast horizon of H is defined as follows:

$$\Theta_{ij}^g(H) = \frac{\sum(\tau)_{jj}^{-1} \sum_{h=0}^{H-1} \sum \left(e_i' \Omega_h(\tau) \sum(\tau) e_j\right)^2}{\sum_{h=0}^{H-1} \left(e_i' \Omega_h(\tau) \sum(\tau) \Omega_h(\tau)' e_i\right)} \tag{2}$$

where e_i denotes a zero vector with the unity on ith position. In the de-composition matrix, the normalization of elements is given as:

$$\widetilde{\Theta}_{ij}^g(H) = \frac{\Theta_{ij}^g(H)}{\sum_{j=1}^k \Theta_{ij}^g(H)}, \text{with} \sum\nolimits_{j=1}^k \widetilde{\Theta}_{ij}^g .1 \text{ and} \sum\nolimits_{i,j=1}^k \widetilde{\Theta}_{ij}^g(H) = 1 \tag{3}$$

The GFEVD based spillover measures are defined below following the Diebold and Yilmaz (2012) approach:

$$TO_{j,t} = \sum\nolimits_{i=1,\ i \neq j}^k \widetilde{\Theta}_{ij,t}^g(H), \tag{4}$$

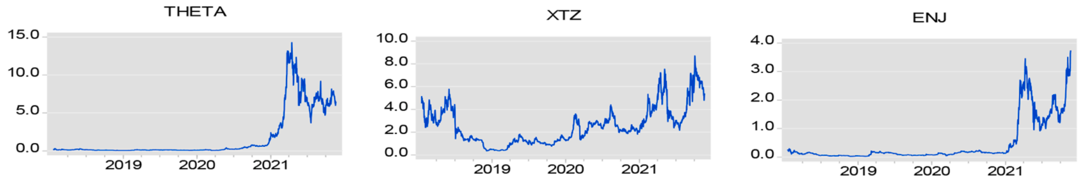
$$FROM_{j,t} = \sum\nolimits_{i=1,\ i \neq j}^k \widetilde{\Theta}_{ji,t}^g(H), \tag{5}$$

$$NET_{j,t} = TO_{j,t} - FROM_{j,t}, \tag{6}$$

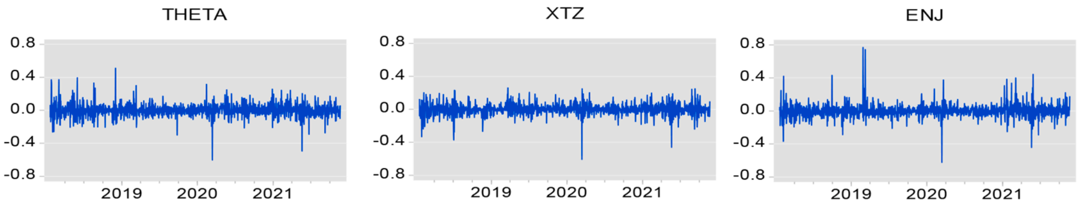
$$TCI_t = \frac{\sum_{i,j=1,\ i \neq j}^k \widetilde{\Theta}_{ij}^g(H)}{k-1}, \tag{7}$$

$TO_{j,t}$ indicates the effect of variable j on variable i, whereas $FROM_{j,t}$ represents the impact of i on j. $NET_{j,t}$ shows the disparity

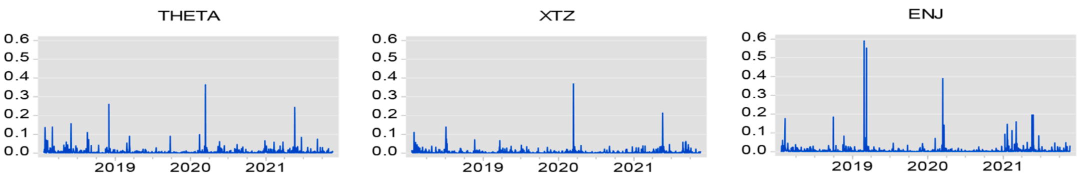
Panel A. Prices



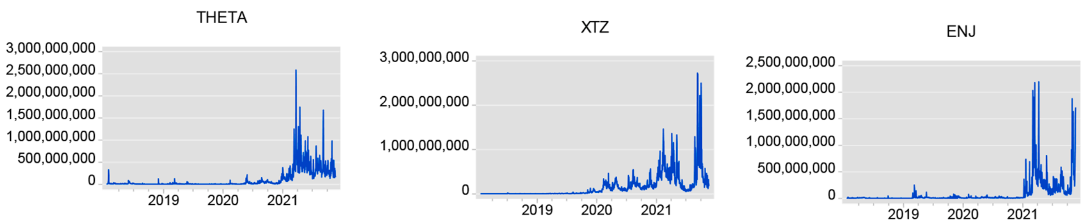
Panel B. Returns



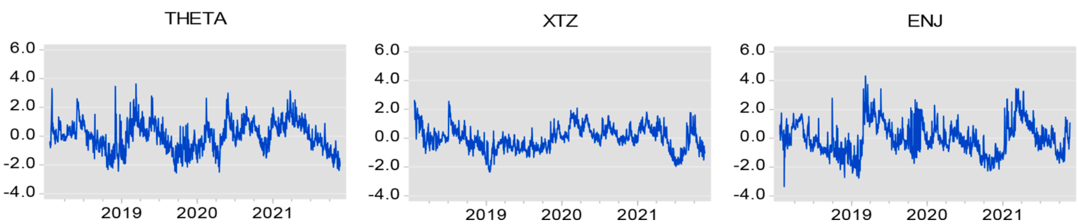
Panel c. Volatility



Panel D. Volume



Panel E. Volume (De-trended)



(caption on next page)

Fig. 1. Prices, returns, volatility, volume, and De-trended Volume.

Table 2
Static quantile-based spillovers between return and volume.

	Median (0.50)	Lower Quantile (0.05)	Upper Quantile (0.95)
1. THETA			
Total spillover	14.01	38.86	40.36
To:			
Returns	14.5	38.4	40.64
Volume	13.49	39.33	40.08
Net:			
Returns	1.01	-0.93	0.55
Volume	-1.01	0.93	-0.55
2. XTZ			
Total spillover	5.82	36.42	38.27
To:			
Returns	6.70	35.72	37.97
Volume	4.95	37.12	38.58
Net:			
Returns	1.75	-1.40	-0.62
Volume	-1.75	1.40	0.62
3. ENJ			
Total spillover	14.26	37.44	40.92
To:			
Returns	14.77	37.19	40.14
Volume	13.76	37.68	41.7
Net:			
Returns	1.01	-0.50	-1.55
Volume	-1.01	0.50	1.55

Notes: ‘Total spillover’ means the total connectedness between return and volume of NFT. ‘To returns’ indicates the spillover from volume to returns, whereas ‘To Volume’ represents the spillover from return to volume. The positive ‘Net returns’ spillover shows the returns as net transmitter of spillover to volume, and vice versa. The length of rolling window is 200 days.

Table 3
Static quantile-based spillovers between volatility and volume.

	Median (0.50)	Lower Quantile (0.05)	Upper Quantile (0.95)
1. THETA			
Total spillover	13.03	18.41	33.8
To:			
Volatility	12.56	17.89	30.72
Volume	13.49	18.93	36.88
Net:			
Volatility	-0.93	-1.05	-6.16
Volume	0.93	1.05	6.16
2. XTZ			
Total spillover	12.38	20.51	41.15
To:			
Volatility	11.91	20.2	40.84
Volume	12.84	20.83	41.46
Net:			
Volatility	-0.93	-0.63	-0.62
Volume	0.93	0.63	0.62
3. ENJ			
Total spillover	12.68	17.2	30.17
To:			
Volatility	12.76	17.09	26.58
Volume	12.60	17.31	33.76
Net:			
Volatility	0.17	-0.22	-7.18
Volume	-0.17	0.22	7.18

Notes: ‘Total spillover’ means the total connectedness between volatility and volume of NFT. ‘To volatility’ indicates the spillover from volume to volatility, whereas ‘To Volume’ represents the spillover from volatility to volume. The positive ‘Net volatility’ spillover shows the volatility as net transmitter of spillover to volume, and vice versa. The length of rolling window is 200 days.

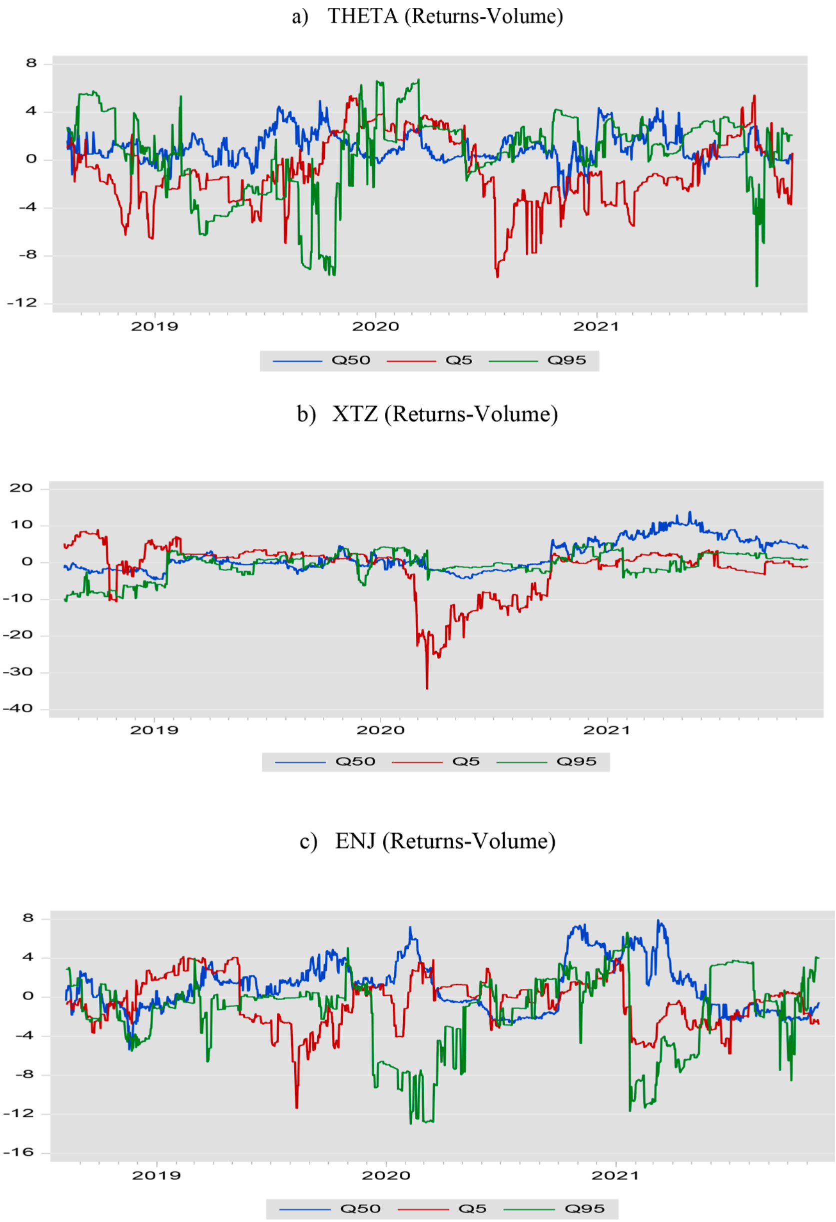


Fig. 2. Time-varying net spillovers in quantile VAR for returns-volume pairs of NFTs [The positive value indicates that returns are the net transmitter of spillover to volume whereas negative value shows that returns are net recipient of spillover from volume].

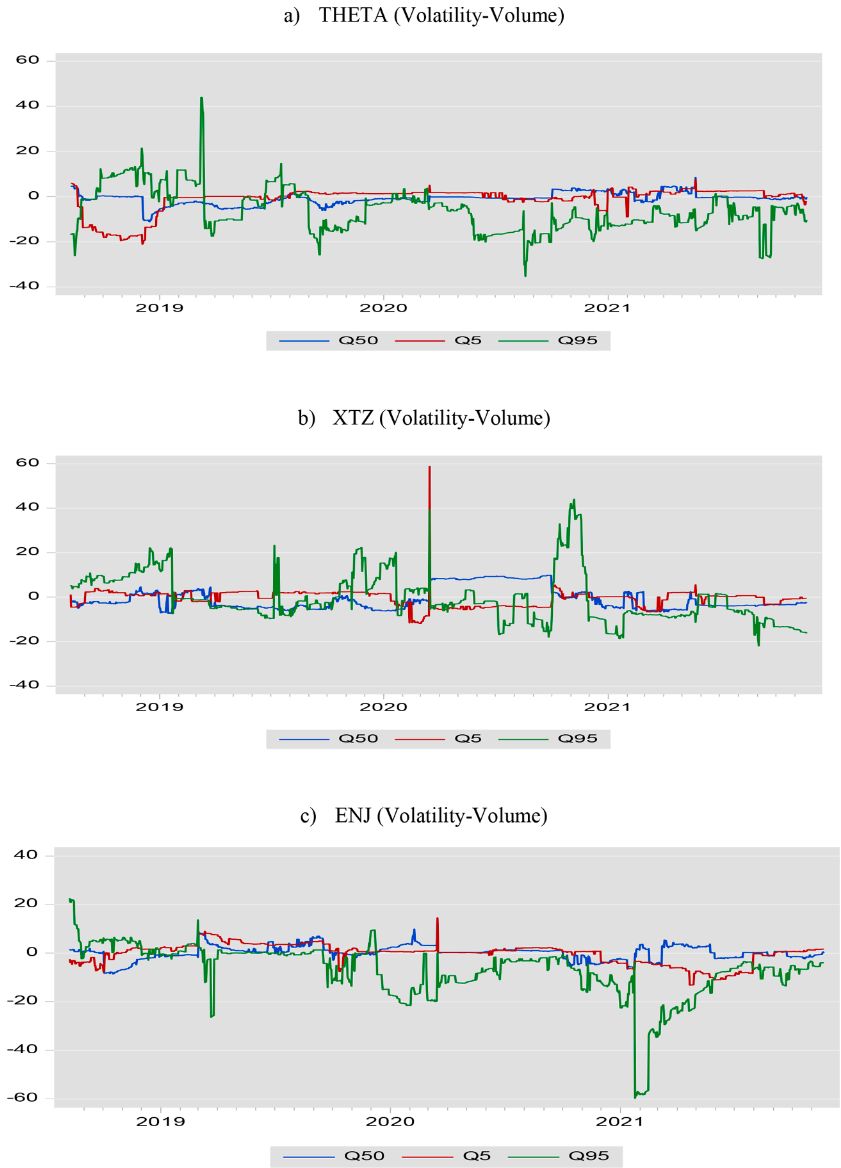


Fig. 3. Time-varying net spillovers in quantile VAR for volatility-volume pairs of NFTs [The positive value indicates that volatility is the net transmitter of spillover to volume whereas negative value shows that volatility is net recipient of spillover from volume].

between "TO" and "FROM," the negative (positive) value refers to the net recipient (transmitter) of spillover. TCI_t represents average level of total connectedness.

3. Empirical results

Our results provide three important pieces of evidence. First, according to the results from static quantile-based spillover analysis presented in Table 2, the total connectedness between return and volume is the highest in the upper quantile, whereas lowest in the median quantile for all three NFTs. These results indicate the asymmetric spillovers between return and volume, suggesting that investors should formulate different strategies during normal and extreme bullish and extreme bearish market conditions of NFTs. These findings are in line with Naeem et al. (2020) who also provide the evidence of asymmetric tail connectedness between volume and returns of fungible cryptocurrencies, like Bitcoin, Ethereum, and Litecoin. The net spillover of returns is positive at median quantile in three NFTs, showing that the direction of spillovers is from return to volume in three NFTs analyzed. However, the net spillover of returns is negative at extreme lower (upper) quantile in three NFTs (XTZ and ENJ), therefore the direction of spillover is from volume to returns in extreme upper and lower quantiles, in line with anti-efficiency market hypothesis. These results suggest that the volume has predictive power for returns only in extreme bullish and bearish market conditions, which indicates the NFT market as inefficient market. This predictive power of volume for returns in extreme market conditions is also useful to make trading decisions. Bouri et al. (2019) report the volume as predictor of positive and negative returns in leading (fungible) cryptocurrencies. Further, volume is not the predictor for returns in the extreme bullish market condition for THETA because the net spillover of returns is positive for THETA in upper quantile.

Second, the results of static quantile-based spillovers between volatility and volume presented in Table 3 show that the total connectedness index is higher in upper quantile compared to the lower and median quantiles, providing the evidence of asymmetric connectedness between volatility and volume of three NFTs. At median quantile, the net spillover of volatility is negative in THETA and XTZ but positive in ENJ, indicating that volume can be used to forecast volatility of THETA and XTZ in normal or average market conditions. Bouri et al. (2019) report that volume can forecast volatility of only few traditional fungible cryptocurrencies, and our results add to their findings providing novel evidence from non-fungible cryptocurrencies. In the upper and lower quantiles, the net spillover of volatility is negative in three NFTs therefore volatility is the net recipient of spillover from volume, implying that the information content of volume is useful in forecasting the volatility of three NFTs in extreme bearish and extreme bullish market conditions. These findings are in line with anti-efficiency market hypothesis and sequential information arrival hypothesis. We check the robustness of static results by changing the sample period[3] and empirical method[4], see Table A1, A2, and A3.

Third, we illustrate the time-varying spillover between returns and volume for three NFTs in Fig. 2, and show that returns are net transmitters to volume throughout the whole observation period in THETA and ENJ, whereas returns were net recipient (transmitters) of spillover from (to) volume before (after) third quarter of 2020 only. In extreme upper and lower quantiles, the status of returns as net recipient or net transmitter varies frequently over time, which is similar to the findings of Naeem et al. (2019) in traditional cryptocurrencies. Fig. 3 demonstrates that volatility is net recipient of spillover from volume before mid of 2020 in THETA whereas patterns of net spillovers are mixed after that time at median quantile. The status of returns as net recipient or transmitter frequently varies in XTZ and ENJ. In extreme bullish conditions, volatility is net recipients of spillover from volume over majority sample period in THETA and ENJ, whereas the patterns of extreme upper spillovers are mixed in XTZ over time. The net spillovers of returns frequently change in extreme lower quantile in three NFTs. To summarize, the frequent change in status of returns/volatility as net recipient or transmitter of spillover suggests that investors of NFTs should continuously monitor the movements of market's trading volume and prices and adjust the investment strategy over time to get higher returns.

4. Conclusion

Previous studies have only focused on the examining of the return-volume or volatility-volume nexus of fungible tokens, such as Bitcoin and other 'conventional' cryptocurrencies. Our results add to a better understanding of return-volume and volatility-volume relationships of the non-fungible tokens, i.e. THETA, Tezos, and Enjin Coin that are built on alternative blockchain to increasingly popular among NFT communities Ethereum protocol. Using Quantile VAR approach and daily data for three popular NFTs for the period from 17 January 2018 to 20 November 2021, we reveal that trading volume is strongly connected to the returns and volatilities at extreme bullish market conditions compared to the other quantiles. The results report the asymmetric connectedness of trading volume with returns and volatilities, where connectedness is also time varying. These findings are useful for cryptocurrency scholars aiming to understand the difference in return-volume and volatility-volume relationships among different types of digital assets. In terms of future research directions, we suggest comparing the return-volume and/or volatility-volume nexus for traditional cryptocurrencies, NFTs, and Defi assets simultaneously.

Author statement

Imran Yousaf: data collection; empirical analysis; performing robustness tests; writing.
Larisa Yarovaya: conceptualisation; literature review; writing and editing.

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.

Appendix

Tables A1, A2 and A3

[3] We use the sample period from 17 February 2018 and ends on 20 November 2021, and calculate the spillovers at median, extreme upper and extreme lower quantiles.

[4] We use the Diebold and Yilmaz (2012) approach to calculate the mean-based spillovers, which are only comparable to the median (Q=0.50) quantile.

Table A1
Static quantile-based spillovers between return and volume using sample period from 17 February 2018 to 20 November 2021.

	Median (0.50)	Lower Quantile (0.05)	Upper Quantile (0.95)
1. THETA			
Total spillover	13.83	38.79	40.27
To:			
Returns	14.34	38.31	40.53
Volume	13.33	39.27	40.01
Net:			
Returns	1.01	-0.96	0.52
Volume	-1.01	0.96	-0.52
2. XTZ			
Total spillover	5.88	36.35	38.39
To:			
Returns	6.78	35.59	38.15
Volume	4.98	37.11	38.63
Net:			
Returns	1.80	-1.51	-0.47
Volume	-1.80	1.51	0.47
3. ENJ			
Total spillover	14.39	37.45	41.00
To:			
Returns	14.90	37.21	40.19
Volume	13.88	37.70	41.80
Net:			
Returns	1.03	-0.49	-1.61
Volume	-1.03	0.49	1.61

Notes: 'Total spillover' means the total connectedness between return and volume of NFT. 'To returns' indicates the spillover from volume to returns, whereas 'To Volume' represents the spillover from return to volume. The positive 'Net returns' spillover shows the returns as net transmitter of spillover to volume, whereas negative 'Net returns' spillover indicate the returns as net recipient of spillover from volume. The length of rolling window is 200 days.

Table A2
Static quantile-based spillovers between volatility and volume using sample period from 17 February 2018 to 20 November 2021.

	Median (0.50)	Lower Quantile (0.05)	Upper Quantile (0.95)
1. THETA			
Total spillover	13.01	18.34	33.70
To:			
Volatility	12.52	17.80	30.68
Volume	13.51	18.88	36.71
Net:			
Volatility	-0.99	-1.09	-6.03
Volume	0.99	1.09	6.03
2. XTZ			
Total spillover	12.28	20.44	41.00
To:			
Volatility	11.83	20.15	40.64
Volume	12.73	20.73	41.36
Net:			
Volatility	-0.90	-0.58	-0.72
Volume	0.90	0.58	0.72
3. ENJ			
Total spillover	12.85	17.26	30.13
To:			
Volatility	12.93	17.18	26.37
Volume	12.77	17.33	33.90
Net:			
Volatility	0.16	-0.16	-7.53
Volume	-0.16	0.16	7.53

Notes: 'Total spillover' means the total connectedness between volatility and volume of NFT. 'To volatility' indicates the spillover from volume to volatility, whereas 'To Volume' represents the spillover from volatility to volume. The positive 'Net volatility' spillover shows the volatility as net transmitter of spillover to volume, whereas negative 'Net volatility' spillover indicate the volatility as net recipient of spillover from volume. The length of rolling window is 200 days.

Table A3
Static mean-based spillovers for the return-volume and volatility-volume using the Diebold and Yilmaz (2012) model.

	Return-volume		Volatility-volume
1. THETA		**1. THETA**	
Total spillover	14.41	**Total spillover**	12.96
To:		**To:**	
Return	15.12	Volatility	11.80
Volume	13.70	Volume	14.11
Net:		**Net:**	
Return	1.42	Volatility	-2.30
Volume	-1.42	Volume	2.30
2. XTZ		**2. XTZ**	
Total spillover	5.86	**Total spillover**	14.01
To:		**To:**	
Return	6.92	Volatility	13.87
Volume	4.81	Volume	14.14
Net:		**Net:**	
Return	2.11	Volatility	-0.26
Volume	-2.11	Volume	0.26
3. ENJ		**3. ENJ**	
Total spillover	14.72	**Total spillover**	12.06
To:		**To:**	
Return	15.63	Volatility	12.72
Volume	13.82	Volume	11.40
Net:		**Net:**	
Return	1.81	Volatility	1.31
Volume	-1.81	Volume	-1.31

Notes: 'Total spillover' indicatess the total connectedness between Return/volatility and volume of NFT. 'To returns' indicates the spillover from volume to returns, whereas 'To Volume' represents the spillover from return to volume. 'To volatility' indicates the spillover from volume to volatility, whereas 'To Volume' represents the spillover from volatility to volume. The positive 'Net returns' spillover shows the returns as net transmitter of spillover to volume, whereas negative 'Net returns' spillover indicate the returns as net recipient of spillover from volume. The positive 'Net volatility' spillover shows the volatility as net transmitter of spillover to volume, whereas negative 'Net volatility' spillover indicate the volatility as net recipient of spillover from volume. The length of rolling window is 200 days.

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