J. Int. Financ. Markets Inst. Money 82 (2023) 101694

Contents lists available at ScienceDirect

Journal of International Financial Markets, Institutions & Money

journal homepage: www.elsevier.com/locate/intfin

The connectedness between meme tokens, meme stocks, and other asset classes: Evidence from a quantile connectedness approach

Imran Yousaf [a], Linh Pham [b,c], John W. Goodell [d,*]

[a] College of Business and Public Management, Wenzhou-Kean University, Wenzhou, China
[b] University of Central Oklahoma, USA
[c] Lake Forest College, USA
[d] University of Akron, USA

ARTICLE INFO

Keywords:
Meme stocks
Meme tokens
Extreme connectedness
Portfolio management
Diversification

ABSTRACT

The recent influence of the meme stock and meme token phenomena have raised new challenges for investors and policymakers. We examine the quantile connectedness between meme stocks, meme tokens, and traditional financial assets such as stock, gold, oil, U.S. dollars, and U.S. Treasuries. We find that meme stocks and meme tokens exhibit a time-varying connectedness with traditional financial assets that varies across quantiles. We observe the highest connectedness between meme stocks, meme tokens, and traditional financial assets at the extreme upper and lower quantiles. This highlights the importance of tail connectedness analysis. At the upper extreme quantiles, meme stocks and meme tokens are the drivers of shock transmissions, suggesting that price bubbles or market short squeezes in these meme assets can be contagious to other markets. At lower extreme quantiles, meme stocks and meme tokens are the shock receivers, while gold and Treasury bonds are shock transmitters. This is consistent with investors fleeing to quality under extreme negative market conditions. Our findings provide useful information to regulators, retail investors, and institutional investors regarding portfolio risk management and financial market stability in the extreme and normal market conditions.

1. Introduction

A meme stock is a share of a company that quickly jumps in price and becomes overvalued relative to its fundamentals because of increasing attention among the online community and social media platforms. The meme stock and meme token phenomenon have recently received considerable media attention. These are stocks or cryptocurrencies that become popular among retail investors because of endorsements by online social media. As a result, their values quickly surge above fundamentals. Since retail investors can be active on multiple platforms at the same time, investor activities on one platform easily spill over to other platforms. This implies that social media signals on a particular investment can have far-reaching consequences that spill over to the entire financial market. Considering this, we examine the asymmetric interconnectedness across meme tokens, meme stocks, and other asset classes.

The meme stock phenomenon started with GameStop, whose prices surged from $5 in July 2020 to an intraday maximum of $483 in January 2021, because of a market short squeeze triggered by the *r/wallstreetbets* forum's members on the online social platform

* Corresponding author.
E-mail addresses: imranyousaf.fin@gmail.com, iyousaf@wku.edu.cn (I. Yousaf), linhngocmy.pham@gmail.com (L. Pham), johngoo@uakron.edu (J.W. Goodell).

https://doi.org/10.1016/j.intfin.2022.101694
Received 16 September 2022; Accepted 17 November 2022
Available online 24 November 2022

Reddit. Since then, investors have taken interest in other meme stocks such as AMC Entertainment Holdings (AMC), a movie theater chain with declining profits during the COVID-19 pandemic, and Blackberry Limited (BB), an outdated smartphone maker.

On the other hand, a meme coin is a cryptocurrency that is associated with an internet joke or pop culture reference. The first meme cryptocurrency, Dogecoin, was created in December 2013. This coin pairs the Shiba Inu dog Kabusu with colorful fonts and childlike languages. As of June 2022, the two largest meme coins in terms of market capitalization are Dogecoin and Shiba Inu. As many meme coins' popularity is driven by pop culture, they are highly volatile, and can experience extreme price movements over a short period of time. For example, on January 29, 2021, Dogecoin prices increased by 370 %, after users of the Reddit forums r/CryptoCurrency and r/SatoshiStreetBets attempted to increase Dogecoin prices to make it the next Bitcoin. Between January and May 2021, Dogecoin's price increased by more than 12,000 % and reached a market capitalization of more than $90 billion, which is partly fueled by Elon Musk and other celebrities' endorsement. Since then, Dogecoin's prices have plummeted by more than 7 times, and its market capitalization as of June 2022 is around $11 billion.[1] Similarly, Shiba Inu gained more than 5,130,000 % between its debut in August 2020 and October 2021, which is followed by a consistent decline in prices between October 2021 and May 2022.

The above examples illustrate the increasing importance of online social media in spreading attention across retail investors, whose cumulative actions can cause disruptions to the larger financial markets. For example, the GameStop short squeeze of January 2021 caused hedge funds to lose billions of dollars, with estimated losses on short positions in U.S. firms totaling $70 billion (Sujata, 2021). The effects of fire sales and herd behaviors on financial markets have been documented in the literature (for example, Scharfstein and Stein, 1990; Coval and Stafford, 2007; Chiang and Zheng, 2010; Jotikasthira, Lundblad and Ramadorai, 2012; Yousaf, Ali, and Shah (2018); Braouezec and Wagalath, 2019; Barbon, Di Maggio, Franzoni and Landier, 2019; Chernenko and Sunderam, 2020). However, a characteristic of recent events is the counter-hegemonic efforts of small individual investors on social media platforms (Chohan, 2021). As social media continue to be integrated into human lives, similar events can occur more frequently in the future. Therefore, understanding the interactions of meme assets with conventional assets across normal and extreme market movements can have important implications for regulators and investors.

Modern portfolio theory (MPT) suggests that understanding the spillovers across financial markets offers useful information for effective risk mitigation and diversification strategies (Markowitz, 1952).[2] Moreover, it is well understood in the literature that financial market spillovers are asymmetric, where good and bad news travel at different speeds (Longin and Solnik, 2001; Mensi, Yousaf, Vo, and Kang, 2022; Ang and Chen, 2002). Motivated by these theoretical foundations, we examine the quantile connectedness between meme tokens, meme stocks, and other asset classes (oil, gold, stocks, Bitcoin, fiat currencies, and bonds). We collect the daily data of two meme stocks (Gamestop-GME, AMC Entertainment Holdings (AMC), two meme tokens/cryptocurrencies (Dogecoin-DOGE, Shiba Inu-SHIB), crude oil (WTI), gold, stock (S&P 500), Bitcoin-BTC, currency (US dollar index), and bonds (S&P US treasury bond current 10-year index) markets from 03 August 2020 to 25 April 2022. This period covers the meme stock short squeeze, the cryptocurrency bubble in 2021, and the start of the Russia-Ukraine war.[3]

We use the quantile-connectedness technique of Ando et al. (2022) to analyze the spillovers among meme and conventional assets at median quantile (Q = 0.50), extreme lower quantile (Q = 0.05), and extreme upper quantile (Q = 0.95). Further, for robustness purposes, we also estimate asset connectedness using the mean-based approach of Diebold and Yilmaz (2012).[4] Results show that meme assets are the drivers of shock transmissions during the period from August 2020 to April 2022, particularly at the upper extreme quantile. This indicates that shocks in the meme assets in extreme upward market movements, for example, a price bubble or a short squeeze, can spill over to other assets. On the other hand, at the extreme lower quantiles, gold and U.S. Treasuries are the main shock transmitters, with meme assets shock receivers. This reflects investors' tendency to fly to quality under bearish market conditions. Our time-varying connectedness analysis shows that the spillovers between meme and conventional assets are time-varying and tend to intensify under greater uncertainty, for example, during short squeeze periods or during the Russia-Ukraine war.

The paper contributes to the literature in several ways. First, this is the first study that explores the spillovers between meme stocks, meme cryptocurrencies, and other asset classes. Previous studies on meme assets have focused primarily on meme stocks, with little empirical investigation of the behavior of meme cryptocurrencies. Among the literature, d'Addona and Khanom (2022) investigate the tail risks of meme stocks using semiparametric conditional variance. Anand and Pathak (2022) study the role of Reddit on GameStop prices, while Lyócsa, Baumöhl and Výrost (2022) study the role of Reddit activity and consequent price movements of meme stocks. Long, Lucey and Yarovaya (2021) and Umar, Gubareva, Yousaf and Ali (2022) analyze the relationship between social media sentiment and GameStock stock prices. Umar, Yousaf, and Zaremba (2021) look at the connectedness between the stocks of heavily shorted companies during the short squeeze event of GameStop. Hasso, Müller, Pelster and Warkulat (2022) study the profiles of traders who participated in the GameStop short squeeze. They find that early investors had a history of speculative behaviors, and that the profiles of investors change throughout the frenzy period. With respect to performance, male investors perform poorly, while those who opened their accounts during the frenzy on average realized gains. Klein (2022) studies the side effects of the GameStock short squeeze on financial literacy. Costola, Iacopini and Santagiustina (2021) investigate the dynamics of price, trading volume, and social media activity of meme stocks. They identify a meme stock "momentum," which has separate characteristics compared to other stocks with high volumes of activity on social media. This mementum also has positive effects on meme stock returns. With respect to the

[1] https://coinmarketcap.com/ (accessed on June 1, 2022).

[2] Building on this theoretical foundation, previous research has empirically documented financial market spillovers and their implications for portfolio diversification, for example, Naeem et al (2022a, b, c), Anwer et al (2022), Yousaf et al. (2022), Karim et al (2022).

[3] The cryptocurrency bubble of 2021 has been identified in previous research, for example, Yousaf and Yarovaya (2022).

[4] Diebold and Yilmaz (2012) is denoted 'DY2012' in later parts of the paper.

relationship between meme stocks and cryptocurrencies, Aloosh, Ouzan, and Shahzad (2022) study the relationship between meme stocks and major cryptocurrencies such as Bitcoin and Ethereum. They find evidence of co-explosivity among meme stocks, Bitcoin and Ethereum. These studies provide important insights into the role of social media and investor attention on meme stock movements, however, the spillover effects from meme assets to the general financial markets around the recent short squeeze have not been explored.

Further, this study explores the asymmetric effects of the spillovers between meme assets and other assets by quantifying the spillovers across different quantiles. The asymmetry in financial market spillovers has been widely documented in the literature. For example, Chen and Ghysels (2011), Bekaert, Engstrom, and Ermolov (2015), Patton and Sheppard (2015), and Palandri (2015) argue that good and bad news have different impacts, and thus, it is important to distinguish between positive and negative shocks in investment strategies. Saeed, Bouri, and Alsulami (2021) study the asymmetric spillovers between green and conventional assets. Naeem, Qureshi, Rehman, and Balli (2022) study the asymmetric spillovers among cryptocurrencies during the COVID-19 pandemic. Anwer, Khan, Naeem and Tiwari (2022) study the systemic risk between energy and non-energy commodity markets during the COVID-19 pandemic. Building on this literature, our paper provides empirical evidence on the asymmetric spillovers between meme assets and conventional assets. Our results show stronger spillovers between meme assets and other markets during extreme upward market movements, compared to normal or extreme downward market conditions.

The paper proceeds as follows. Section 2 presents the methodology. Section 3 describes the data and preliminary analyses. Section 4 discusses the empirical results, and Section 5 concludes.

2. Methodology

To investigate the quantile connectedness between the meme tokens/cryptocurrencies, meme stocks, and other asset classes, we use the quantile-connectedness technique of Ando et al. (2022). In order to compute matrices of the quantile spillover, we use the infinite order-based vector moving average specifications of QVAR(τ,p), with τ being the quantile, and p the autoregressive order, are defined as:

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

where y_t is an $n \times 1$ endogenous variable vector, $\mu(\tau)$ is an $n \times 1$ vector of intercepts at quantile τ, $\Phi_j(\tau).j = 1,\cdots,p$, is an $n \times n$ matrix of lag coefficients at quantile τ, $u_t(\tau)$ is an $n \times 1$ vector of error terms at quantile τ, and $\Omega_i(\tau)$ represents an $n \times n$ matrix of moving average lag coefficients at quantile τ. We follow Koop et al. (1996) and Pesaran and Shin (1998) for the generalized forecast error variance decomposition (GFEVD) with forecast horizon of 'H', which is defined as follows:

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

In Equation (2), e_i denotes a zero vector with the unity on i th position. In de-composition matrix, the normalization of elements is given as:

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

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

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

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

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

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

$TO_{j,t}$ indicates the effect of variable j on variable i, $FROM_{j,t}$ represents the impact of i on j. $NET_{j,t}$ shows the disparity between TO and FROM, the negative (positive) value refers to the net recipient (transmitter) of spillover. TSI_t represents average level of total spillover/connectedness."

3. Data

This study uses daily data of two meme stocks (Gamestop-GME, AMC Entertainment Holdings (AMC), two meme tokens/

cryptocurrencies (Dogecoin-DOGE, Shiba Inu-SHIB), crude oil (WTI), gold, stock (S&P 500), Bitcoin-BTC, currency (US dollar index), and bonds (S&P U.S. Treasury bond current 10-year index) markets from 03 August 2020 to 25 April 2022. We select the meme tokens whose data are available for at least two years.[5] The data for meme tokens and Bitcoin are obtained from Coinmarketcap.com, while the data for other variables are collected from Bloomberg and S&P Global. The sampling period covers the most recent cryptocurrency bubble in 2021, the short squeeze on meme stocks in 2021, and the Ukraine-Russia war in 2022. We log-difference the variables for our empirical analysis.

Table 1 presents the summary statistics of the asset returns. All returns have positive mean returns except for gold and US Treasury. Overall, the standard deviations of the meme assets are higher than those of the conventional assets. SHIB has the highest standard deviation (2.88), followed by DOGE (0.20). All meme assets are highly positively skewed, which reflects their price surges during short squeezing periods. The Jarque-Bera test statistics indicate that the series are not normally distributed, while the ADF test statistics indicate that they are stationary.

Table 2 presents the unconditional correlations across the asset returns. The largest positive correlation is 0.628 (GME v. AMC), while the largest negative correlation is −0.393 (USD v. gold). DOGE is negatively correlated with all other meme assets, WTI, and USD, and is positively correlated with gold, stock, Bitcoin, and U.S. Treasury returns. SHIB is negatively correlated with GameStop and Bitcoin but positively correlated with all other assets. GameStop is positively correlated with AMC, Bitcoin, and stock and negatively correlated with other assets. Finally, AMC stock is positively correlated with WTI and USD and negatively correlated with stock, gold, Bitcoin and U.S. Treasury. These results indicate the varying relationships between meme assets and the conventional markets.

Fig. 1 plots the daily closing prices of the markets while Fig. 2 plots their returns. Both DOGE and SHIB experience an increase in prices in the second quarter of 2021, and again in the fourth quarter. This corresponds to the timeline of the cryptocurrency market bubble in 2021 (Flitter, 2022). GameStop prices were low in 2020, before increasing to an all-time high in January 2021, because of a crowdsourced market short squeeze on Reddit. GameStop shares became more volatile during this period following this short squeeze. Similarly, AMC share prices were consistently below $20 before surging to $60 in June 2021, followed by a decline in share prices afterward. Oil, stock, and USD prices all experience an increase until the first quarter of 2022, while the US Treasuries experienced a declining trend. The increase in stock and USD prices during this period reflects market reactions to the potential recovery from the pandemic in 2021, while the increase in oil prices reflects the excess oil demand during this period. Note that both stock and oil prices are highly volatile at the beginning of 2022, because of the Russia-Ukraine war.

Finally, gold prices displayed a declining trend from the beginning of the sampling period until April 2021, and during the third and fourth quarters of 2021. Gold prices increase in the second quarter of 2021 and during the first quarter of 2022, before declining again at the beginning of the second quarter in 2022. These fluctuations in gold prices reflect multiple events that occur during this period, which include uncertainty about economic recovery, uncertainty about government monetary policy, and the risks associated with the Russia-Ukraine war.

4. Empirical results

4.1. Static quantile spillovers

Table 3 presents the static return spillovers among the assets at the mean (Panel A) and median (Panel B). The total spillover index is 73.45 % at the mean and 80.53 % at the median. This suggests a high degree of connectedness among the assets during our sampling period. To determine the contribution of each variable to the system, we look at the 'TO' connectedness, which captures the total amount of shock transmission from each variable listed on the top row to all other variables. Results show that the meme assets contribute the largest shocks to the system (84.56 %, 78.21 %, 82.72 %, and 94.22 % for DOGE, SHIB, GameStop, and AMC respectively). This suggests that events in the meme asset markets such as a short squeeze or a price bubble can spill over to the overall financial markets. Our results add to the empirical evidence of spillovers between meme assets and other financial markets. For example, Aloosh, Ouzan and Shahzad (2022) document the co-explosivity behavior between meme stocks, Bitcoin and Ethereum. Li (2022) explores the spillover between Bitcoin and meme stocks. By exploring the behavior of meme cryptocurrencies and their relationship with meme stocks and conventional financial markets, our paper highlights the relevance of social trading in driving the movements in both stock and cryptocurrency markets.

Next, we analyze the spillovers that each variable receives from all other variables in the system, as summarized in the FROM connectedness column of Table 3. We find that the conventional assets receive more shock from the system than the meme assets, which suggests that meme assets are the drivers of shock transmission during our sampling period (August 2020–April 2022). This suggests the significant influence of social trading on financial markets (Li, 2022). However, we note that the FROM and TO connectedness in Table 3 are all above 70 %, which suggests a high degree of overall spillovers among the variables. To identify the net transmitters and receivers of shocks, we estimate the NET spillovers, which are the differences between the TO and FROM connectedness for each asset.

The NET spillover measures are positive for the meme stocks and cryptocurrencies, while they are negative for other assets. Thus, meme stocks and meme cryptocurrencies are the drivers of shock transmissions during this period. Altogether, these results imply a high degree of integration across meme and conventional assets. As meme assets are the drivers of shock transmissions, disruptions in

[5] After the selection of two highly capitalized meme coin, we use similar number of top two highly capitalized meme stocks.

Table 1
Summary statistics.

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	ADF
DOGE	0.01922	−0.00075	3.55547	−0.39111	0.20683	12.21430	200.7415	719534.5***	−19.3159***
SHIB	0.21084	0.00000	58.52381	−0.64533	2.88554	19.19709	385.7583	2682102.0***	−20.4296***
GME	0.01595	−0.00071	1.34836	−0.60000	0.13901	3.97303	35.4029	20174.7***	−10.3847***
AMC	0.01203	−0.00690	3.01210	−0.56633	0.17793	11.47976	189.3824	639188.1***	−13.3659***
WTI	0.00237	0.00284	0.08561	−0.11995	0.02529	−0.48402	5.6662	145.8235***	−20.2378***
GOLD	−0.00005	0.00074	0.02590	−0.05656	0.00973	−0.95900	6.8186	330.9696***	−20.1566***
STOCK	0.00066	0.00117	0.02570	−0.03529	0.00995	−0.42779	3.6921	21.9499***	−21.0087***
BTC	0.00394	0.00344	0.21110	−0.13766	0.04469	0.17028	4.6981	54.3646***	−20.8016***
USD_INDEX	0.00020	0.00000	0.01365	−0.01100	0.00351	0.16964	3.2846	13.5546*	−20.7332***
US_TREASURY	−0.00040	−0.00042	0.01408	−0.01643	0.00431	−0.15420	4.1415	25.3403***	−22.0194***

DOGE is Dogecoin, SHIB is Shiba Inu, GME is Gamestop, AMC is AMC Entertainment Holdings, WTI is West Texas Intermediate, Stock is S&P 500, BTC is Bitcoin, US Treasury is S&P U.S. Treasury bond current 10-year index. Std. Dev. is Standard deviation. ***, **,* indicate the 1, 5, and 10% level of significance.

Table 2
Correlations between meme tokens, meme stocks, and other asset classes.

	DOGE	SHIB	GME	AMC	WTI	GOLD	STOCK	BTC	USD_INDEX	US_TREASURY
DOGE	1.000									
SHIB	−0.069	1.000								
GME	−0.096	−0.123	1.000							
AMC	−0.117	0.007	0.628	1.000						
WTI	−0.015	0.047	−0.004	0.008	1.000					
GOLD	0.044	0.030	−0.011	−0.056	0.146	1.000				
STOCK	0.091	0.069	0.015	−0.013	0.143	0.061	1.000			
BTC	0.325	−0.035	0.045	−0.046	0.012	0.037	0.298	1.000		
USD_INDEX	−0.087	0.052	−0.016	0.045	−0.085	−0.393	−0.287	−0.155	1.000	
US_TREASURY	0.003	0.017	−0.019	−0.005	−0.085	0.268	−0.101	−0.026	−0.019	1.000

DOGE is Dogecoin, SHIB is Shiba Inu, GME is Gamestop, AMC is AMC Entertainment Holdings, WTI is West Texas Intermediate, Stock is S&P 500, BTC is Bitcoin, US Treasury is S&P U.S. Treasury bond current 10-year index.

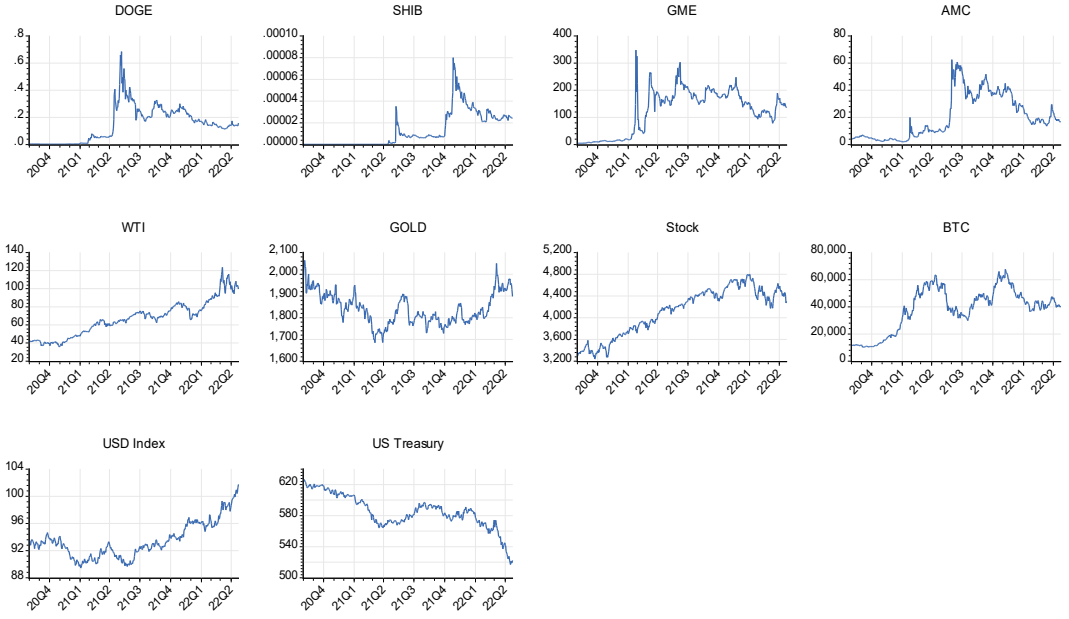


Fig. 1. Prices of meme tokens, meme stocks, and other asset classes.

these markets could be contagious to the general financial markets. As the movements of meme assets are largely driven by investor attention and sentiment, particularly through online social media platforms, our results provide indirect empirical evidence for the influence of investor sentiment and social media on the interconnectedness and stability of the financial market. Previous research has found a magnifying impact of social media during periods of price explosivity, for example, a price bubble or short squeeze (Campbell, Turner, and Walker, 2012; Steiger and Pelster, 2020). In addition, by incorporating meme assets into a network model of stocks and cryptocurrencies, our results add to the empirical evidence of the weakening roles of cryptocurrencies as safe havens and hedges against stock markets (Klein, Thu and Walther, 2018; Wang, Zhang, Li and Shen, 2019).

Panels A and B of Fig. 4 plot the network of spillovers among the assets. We find that the magnitude of the pairwise connectedness among the assets is different under the mean connectedness and median connectedness models. This is expected because of the high skewness of the meme stocks and meme cryptocurrencies (Table 1). Therefore, the mean connectedness network may be driven by extreme values, which distinguishes it from the median connectedness network. Fig. 4 shows that at the median quantile, WTI, gold, stock, USD, and U.S. Treasuries are the main receivers of shocks, as most of the arrows are directed toward these assets. In contrast, meme assets are the main transmitters of these shocks. Moreover, Bitcoin (BTC) receives shocks mainly from AMC, SHIB, and stock. Altogether, these results imply that conventional market investors should consider the risks that originate from meme assets. Our results are consistent with Aloosh, Ouzan and Shahzad (2022), who show that meme stocks and cryptocurrencies exhibit co-explosive behaviors. Our analysis differs from Aloosh, Ouzan and Shahzad (2022) in allowing for the potential spillover effects from meme tokens to other financial markets.

Fig. 4 shows that Bitcoin is the least connected to other assets, thereby implying the potential hedging benefits of Bitcoin for other assets at the median quantile (normal market conditions). Previous studies assess the hedging and safe-haven properties of Bitcoin and show that Bitcoin can be a hedge or safe-haven asset under certain conditions (Selmi, Mensi, Hammoudeh, and Bouoiyour, 2018;

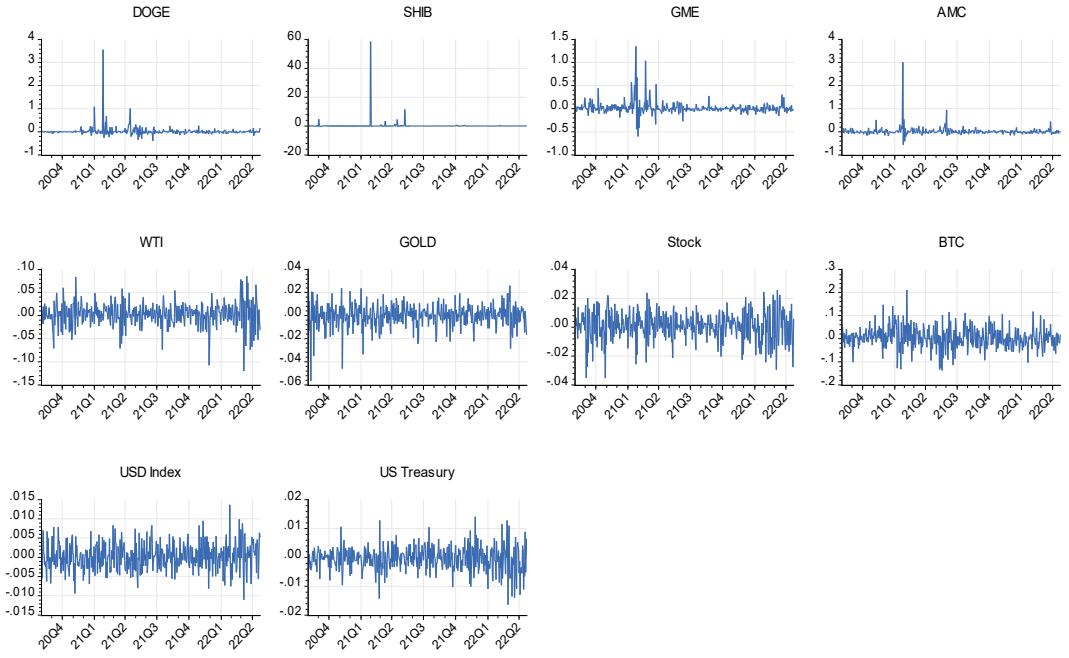


Fig. 2. Returns of meme tokens, meme stocks, and other asset classes.

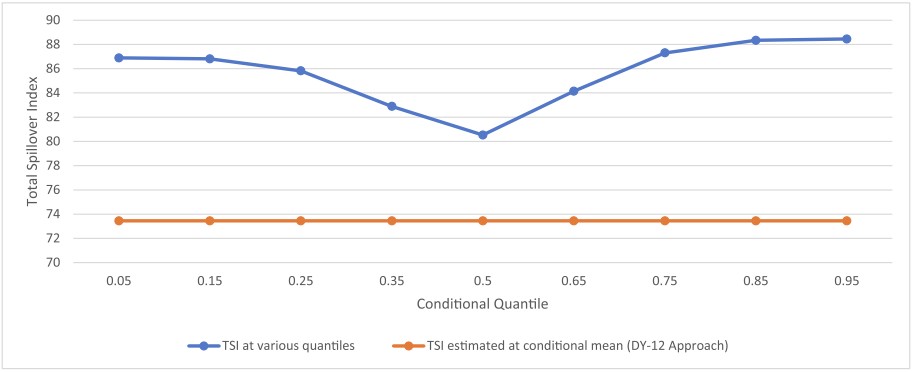


Fig. 3. Variations in total spillover index (TSI) over various quantiles.

Shahzad, Bouri, Roubaud, Kristoufek, and Lucey, 2019; Bouri, Shahzad, Roubaud, Kristoufek, and Lucey, 2020). With respect to the connectedness among the meme stocks and cryptocurrencies, AMC is the largest net transmitter of shocks and is highly connected to SHIB and DOGE returns. GME is a net shock transmitter to SHIB while it is a net shock receiver from DOGE. SHIB is a net shock receiver from AMC while it is a net shock transmitter to all other assets. Finally, DOGE returns are mainly influenced by the returns of AMC and SHIB.

Table 4 presents the static return spillovers at the extreme lower quantile (Panel A) and extreme upper quantile (Panel B). The total spillover index is 86.89 % at the lower quantile and 88.45 % at the upper quantile, indicating an increase in connectedness among the assets under extreme market movements. This is illustrated in Fig. 3, which shows a higher total spillover index at the left and right quantiles than at the median quantile. At the extreme lower quantile, gold and USD are the highest contributors of spillovers to the system, with a TO connectedness of 103.64 % and 109.17 % respectively. This is consistent with investors' tendency to flight to quality and liquidity under extreme market conditions. On the other hand, all variables receive similar amounts of spillovers from the system, as the FROM connectedness ranges between 84.22 % and 89.07 % for all assets.

Our results also show that SHIB, GME, and AMC are the largest net receivers of shocks, while gold and USD are the largest net transmitters of shocks at the extreme lower quantiles. This can be explained by flights to quality and flights to liquidity, where investors allocate funds from risky assets to safer assets under bearish market conditions (Baur and Lucey, 2010; Baur and McDermott, 2010; Cho, Choi, Kim & Kim, 2016). At the extreme upper quantile, results show that USD and gold are the largest contributors of shocks to the system (102.99 and 97.99 % respectively). Our results also indicate a larger contribution of the meme assets to the system

Table 3
Static returns spillovers at mean and median.

Panel A. Spillover at mean-based approach of Diebold and Yilmaz (2012)

	DOGE	SHIB	GME	AMC	WTI	Gold	Stock	BTC	USD	US.Treasury	FROM
DOGE	25.30	10.54	8.77	8.53	6.82	6.63	6.49	12.79	6.71	7.41	74.7
SHIB	11.11	27.11	8.31	7.82	6.41	7.49	7.66	9.52	6.68	7.90	72.89
GME	6.64	6.25	28.98	13.49	9.01	7.59	7.36	7.18	6.15	7.36	71.02
AMC	7.17	6.71	15.74	25.56	10.1	7.72	6.65	7.19	5.80	7.37	74.44
WTI	8.09	7.76	9.33	8.42	27.48	8.03	8.46	6.52	8.27	7.65	72.52
GOLD	7.89	6.67	6.93	7.60	7.42	27.78	8.00	6.85	10.75	10.11	72.22
Stock	7.44	7.60	8.29	7.66	8.42	8.07	26.39	7.35	9.78	9.00	73.61
BTC	14.3	9.80	7.09	7.57	6.78	6.54	7.59	25.64	7.34	7.35	74.36
USD.Index	7.56	7.56	7.72	7.54	8.22	10.77	9.98	7.03	24.63	8.99	75.37
US.Treasury	8.70	8.56	7.34	7.41	7.64	8.89	9.48	7.68	7.71	26.59	73.41
TO others	78.88	71.45	79.51	76.04	70.84	71.71	71.67	72.11	69.19	73.13	734.53
Inc. own	104.19	98.56	108.49	101.6	98.32	99.49	98.05	97.75	93.82	99.72	TSI
NET	4.19	−1.44	8.49	1.60	−1.68	−0.51	−1.95	−2.25	−6.18	−0.28	73.45

Panel B. Spillover at median quantile (Q = 0.50)

	DOGE	SHIB	GME	AMC	WTI	Gold	Stock	BTC	USD	US.Treasury	FROM
DOGE	18.94	9.83	8.39	12.57	7.81	8.06	7.78	10.5	8.05	8.06	81.06
SHIB	9.44	26.57	8.34	13.05	6.62	7.32	7.26	8.09	6.45	6.85	73.43
GME	8.76	7.56	21.4	11.94	8.87	8.48	8.18	8.53	7.94	8.33	78.6
AMC	8.32	7.81	11.29	22.96	9.41	8.44	8.09	7.67	7.64	8.35	77.04
WTI	9.87	8.74	9.54	9.13	17.48	8.99	9.41	9.26	8.62	8.97	82.52
GOLD	9.1	8.13	9.12	9.63	8.55	18.24	9.03	8.86	9.32	10.03	81.76
Stock	9.33	8.59	9.13	9.77	8.99	9.44	17.83	8.95	8.95	9.03	82.17
BTC	10.72	9.63	8.52	9.3	8.38	8.57	9.32	17.75	9.02	8.78	82.25
USD.Index	9.29	8.8	8.9	9.42	8.86	9.84	9.66	9.12	16.15	9.96	83.85
US.Treasury	9.7	9.12	9.49	9.41	8.52	9.38	9.93	8.94	8.16	17.35	82.65
TO others	84.56	78.21	82.72	94.22	76.02	78.5	78.67	79.92	74.14	78.36	805.31
Inc. own	103.5	104.78	104.12	117.18	93.5	96.74	96.5	97.68	90.29	95.71	TSI
NET	3.5	4.78	4.12	17.18	−6.5	−3.26	−3.5	−2.32	−9.71	−4.29	80.53

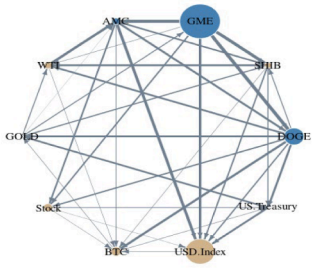
DOGE is Dogecoin, SHIB is Shiba Inu, GME is Gamestop, AMC is AMC Entertainment Holdings, WTI is West Texas Intermediate, Stock is S&P 500, BTC is Bitcoin, US Treasury is S&P U.S. Treasury bond current 10-year index.

at the upper quantile compared to the lower quantile. For example, AMC contributes 90.83 % of shocks to the system at the upper quantile, but only 76.79 % at the lower quantile. Like our results at the lower quantiles, we find that all variables receive similar amounts of shock from the system, where the FROM connectedness ranges between 86.22 % and 89.85 %. Gold and USD are still the largest net transmitter of shocks at the extreme upper quantile. Note, all meme assets, except for SHIB, become net shock transmitters at the upper quantiles. This indicates increasing contagion from the meme assets to other markets under extreme upward market movements such as a price bubble or a short squeeze (Li, 2022). A higher connectedness among markets at extreme quantiles is consistent with previous research, which documents an increase in financial contagion under extreme market conditions (Pham, Karim, Naeem and Long, 2022; Naeem, Pham, Senthilkumar and Karim, 2022; Farid, Naeem, Paltrinieri, and Nepal, 2022).

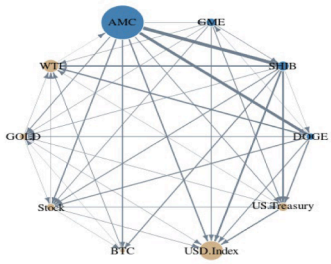
Panels C and D of Fig. 4 present a network of spillovers across the assets at the extreme quantiles. The meme assets (AMC, GME, SHIB, and DOGE) are transmitters of shocks at the lower quantile, while other assets are shock receivers. The meme assets are strongly connected to one another at the extreme lower quantiles, with AMC transmitting the largest amount of shocks to SHIB and DOGE. At the extreme upper quantile, USD, gold, DOGE, AMC, and GME are shock transmitters, while other assets are shock receivers. Moreover, the markets are more connected at the extreme upper quantiles, as indicated by thicker arrows in Fig. 4D, compared to Fig. 4A-C. Our results imply that meme assets are highly connected to conventional assets at the extreme quantiles. Moreover, this connectedness strengthens under extreme upward market movements, for example, during a market short squeeze episode.

4.2. Rolling quantile spillovers

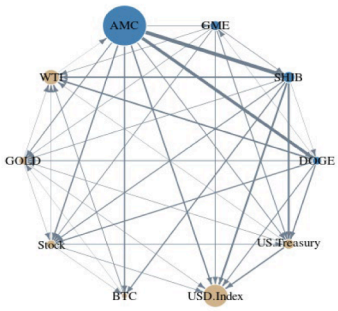
Next, we investigate time-varying spillovers among meme assets and other markets. Fig. 5 shows the time-varying total spillover indices at various quantiles. The total spillover indices are time-varying across all the quantiles. At the median quantile, the total spillover indexes range between 70 and 90 %, while they range between 80 and 95 % at the extreme quantiles. This indicates a high degree of integration across the markets, with the spillovers stronger at the extreme quantiles than at the median quantiles. Moreover, the total spillover indices increase at the beginning of 2021. This corresponds to the GameStop price surge from 17.25 USD to an intraday maximum of 483 USD in January 2021, as driven by a large crowd-sourced short squeeze on GameStop shares (Chohan, 2021). This caused disruptions to trading across financial markets, thus increasing the spillovers across meme assets and conventional assets. Fig. 6 presents relative tail spillovers, which are the differences between the total spillover index at the 95th and 5th quantiles. Throughout the sampling period, the relative tail spillover indexes are generally positive, indicating that the markets are more contagious during extreme positive movements than during extreme negative movements. This suggests short squeezes on meme assets



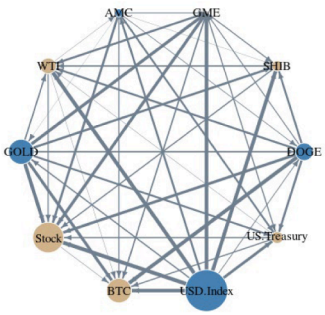
Panel A. Mean



Panel B. Median (Q=0.50)



Panel C. Extreme lower quantile (Q=0.05)



Panel D. Extreme upper quantile (Q=0.95)

Fig. 4. Net pairwise directional returns connectedness. Blue (yellow) nodes illustrate net transmitter (receiver) of shocks. Vertices are weighted by averaged net pairwise directional connectedness measures. Size of nodes represents weighted averaged net total directional connectedness. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

lead to large contagion in financial markets. Previous research has shown that interdependence and contagion among markets differs between bubbles and normal periods. For example, Gharib, Mefteh-Wali, and Jabeur (2021) find contagion effects of bubbles between gold and oil market during several crisis periods such as the oil price glut of 2014–2015 and the COVID-19 outbreak. Bazan-Palomino (2022) studies the contagion among cryptocurrencies, finding that the 2017 and 2021 cryptocurrency bubbles changed the interdependence among cryptocurrencies.

Figs. 7–8 plot the net spillovers of each asset at the mean and median. Consistent with the findings in Fig. 5, the net return spillovers vary over time in all markets. The net spillovers for the meme assets are mostly positive, which suggests that they are shock transmitters throughout the sampling period. This can be explained by the high volatility of meme assets during our sampling period. This is partly driven by increasing investor and media attention to meme assets. Note that the net spillovers for GME show an increasing trend between the first and second quarters of 2021, and spike again in the last quarter of 2021 and in the first quarter of 2022. The net spillovers for AMC increase sharply at the end of the first quarter and the beginning of the second quarter of 2021. The net spillovers for DOGE experience sharp increases at the beginnings of 2021 and 2022. The net spillovers for SHIB increase significantly during the first and third quarters of 2021. These changes match the timeline of increasing support for these assets on social media forums such as Reddit, which leads to subsequent surges in the prices of these assets. Thus, our results support the notion that investor sentiment can drive spillovers across financial markets (Da, Engelberg and Gao, 2011).

With respect to the spillovers of the conventional markets at the mean and median quantiles, the results show that the net spillovers for these markets fluctuate between positive and negative values, consistent with their changing roles as shock transmitters and receivers throughout the sampling period. We find that the net spillovers for WTI, stock, and BTC increase at the beginning of 2022, corresponding to the beginning of the Russia-Ukraine war. In contrast, gold experiences a sharp increase in net spillovers during the fourth quarter of 2021, before reverting to its mean value at the beginning of 2022. Figs. 9–10 plot the net spillovers at the lower and upper extreme quantiles. Overall, these figures show similar patterns to Figs. 7–8, suggesting the time-varying nature of the spillovers across meme assets and conventional markets. We find that the net spillovers for gold and U.S. Treasury increase at the beginning of 2022. This reflects a flight-to-quality phenomenon during this period, as the Russia-Ukraine war increased the level of uncertainty in financial markets (Khalfaoui, Gozgor, and Goodell, 2022). Note that the net spillovers in Figs. 9–10 switched between positive and negative values more frequently than in Figs. 7–8. This suggests that extreme spillovers are more unpredictable than spillovers at the median or mean.

Table 4
Static returns spillovers at lower and upper extreme quantiles.

Panel A. Spillover at extreme lower quantile (Q = 0.05)											
	DOGE	SHIB	GME	AMC	WTI	Gold	Stock	BTC	USD	US.Treasury	FROM
DOGE	12.81	7.38	7.76	9.25	10.25	12.3	9.23	9.33	12.15	9.54	87.19
SHIB	9.26	15.78	7.41	9.55	9.72	10.46	9.25	8.44	10.81	9.31	84.22
GME	9.54	6.89	10.93	8.58	10.87	12.01	9.7	8.99	12.9	9.59	89.07
AMC	9.65	6.95	9.03	13.34	10.66	11.52	9.38	8.57	11.32	9.58	86.66
WTI	10.06	7.27	8.27	8.02	12.83	11.46	10.42	9.15	12.76	9.77	87.17
GOLD	10.02	7.52	8.28	8.14	10.45	14.28	9.78	8.59	12.63	10.3	85.72
Stock	9.55	7.44	8.47	8.68	11.14	11.59	12.71	9.01	11.97	9.45	87.29
BTC	10.86	7.99	7.94	8.4	10.74	11.22	9.8	11.1	12.16	9.78	88.9
USD.Index	9.66	7.37	7.84	8.09	10.58	11.6	10.35	9.09	15.16	10.27	84.84
US.Treasury	9.74	7.36	8.27	8.07	10.86	11.49	10.52	9.04	12.45	12.19	87.81
TO others	88.32	66.17	73.27	76.79	95.26	103.64	88.45	80.22	109.17	87.58	868.87
Inc. own	101.14	81.95	84.19	90.13	108.09	117.92	101.16	91.32	124.32	99.78	TSI
NET	1.14	−18.05	−15.81	−9.87	8.09	17.92	1.16	−8.68	24.32	−0.22	86.89
Panel B. Spillover at extreme upper quantile (Q = 0.95)											
	DOGE	SHIB	GME	AMC	WTI	Gold	Stock	BTC	USD	US.Treasury	FROM
DOGE	11.35	9.01	9.68	11	9.53	11.2	8.68	9.06	11.25	9.23	88.65
SHIB	10.32	11.59	10.15	9.36	8.89	10.48	8.49	9.17	11.73	9.82	88.41
GME	10.32	9.44	11.7	10.96	8.99	11.09	8.26	8.78	11.65	8.81	88.3
AMC	10.55	9.19	10.44	12.38	9.74	10.83	8.75	8.53	10.93	8.65	87.62
WTI	10.89	9.86	10.42	9.53	10.18	10.41	8.54	9.15	11.58	9.44	89.82
GOLD	10.2	8.94	9.05	10.97	9.49	12.83	8.49	9.03	11.53	9.49	87.17
Stock	10.54	9.31	10.26	10.27	9.19	10.74	10.15	8.45	11.68	9.4	89.85
BTC	11.51	9.26	9.72	9.22	9.36	10.99	8.73	10.19	11.39	9.64	89.81
USD.Index	10.73	9.35	9.26	9.59	9.11	10.67	9.12	8.96	13.78	9.43	86.22
US.Treasury	10.67	9.88	9.56	9.91	9.21	10.78	8.56	8.86	11.26	11.31	88.69
TO others	95.72	84.25	88.54	90.83	83.5	97.19	77.62	79.98	102.99	83.93	884.55
Inc. own	107.08	95.83	100.24	103.2	93.69	110.02	87.76	90.16	116.77	95.24	TSI
NET	7.08	−4.17	0.24	3.2	−6.31	10.02	−12.24	−9.84	16.77	−4.76	88.45

DOGE is Dogecoin, SHIB is Shiba Inu, GME is Gamestop, AMC is AMC Entertainment Holdings, WTI is West Texas Intermediate, Stock is S&P 500, BTC is Bitcoin, US Treasury is S&P U.S. Treasury bond current 10-year index.

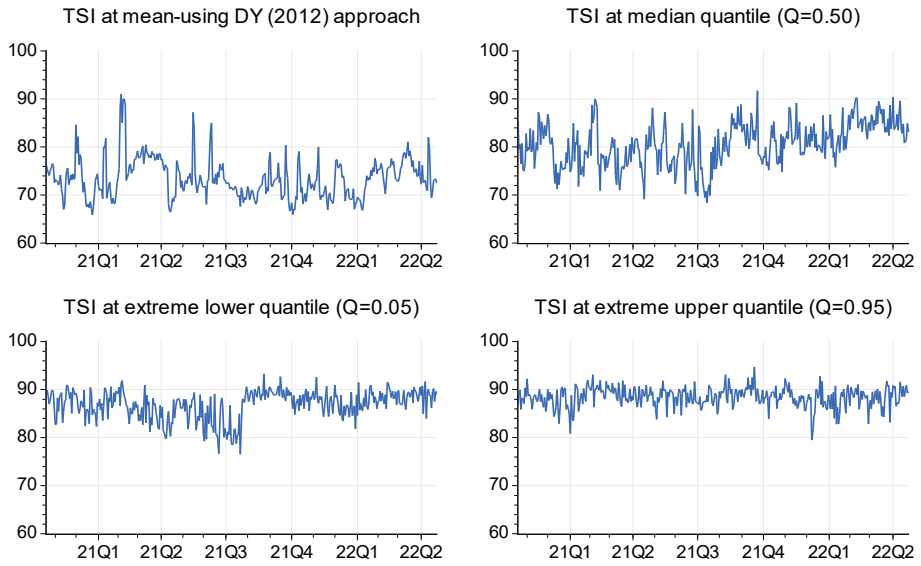


Fig. 5. Time-varying total spillover index (TSI) at mean and various quantiles.

5. Conclusions

The recent influence of the meme stock and meme token phenomena have raised new challenges for investors and policymakers. In this paper, we explore the spillover effects of meme stocks and meme tokens on traditional financial assets such as stock, gold, oil, U.S. dollars, and U.S. Treasury bonds. Our findings show that meme stocks and meme tokens exhibit a time-varying connectedness with

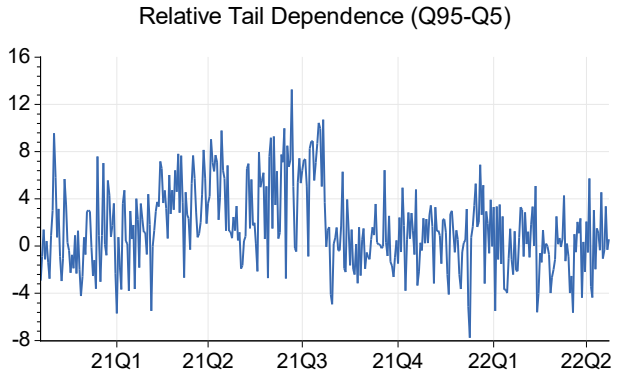


Fig. 6. Relative tail dependence ($TSI_{Q=0.95} - TSI_{Q=0.05}$).

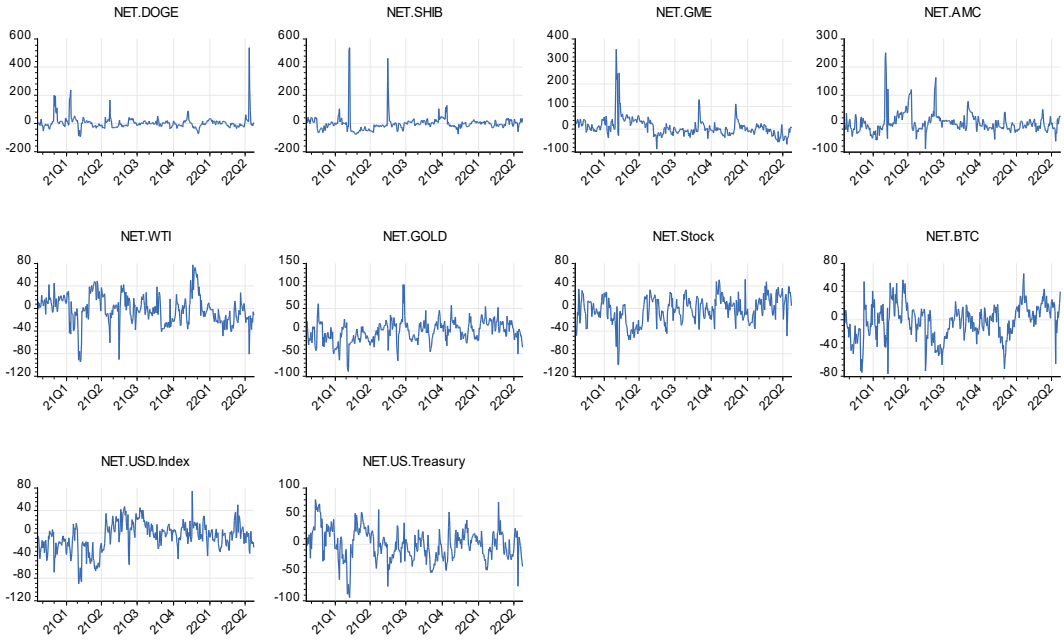


Fig. 7. Time-varying net directional spillovers at mean using Diebold and Yilmaz (2012) approach.

traditional financial assets. In addition, their relationship with other assets varies across quantiles. At the upper extreme quantiles, meme stocks and meme tokens are the drivers of shock transmissions, consistent with price bubbles or market short squeezes in these assets being contagious to other markets. This also indirectly evidences potentially destabilizing effects of investors on social media platforms. At the lower extreme quantiles, meme stocks and meme tokens are the shock receivers, while other assets such as gold and Treasury bonds are shock transmitters. This indicates investors' tendency to fly to quality under extreme negative market conditions.

We contribute to the literature by being the first study to explore the relationship between meme stocks, meme tokens, and traditional financial markets across quantiles. Our results of the different spillover patterns between meme assets and other markets at the lower extreme, upper extreme, and median quantiles highlight the relevance of studying the behaviors of meme assets under different market conditions. Our findings have several implications for investors and policymakers. For investors, it is important to monitor the behavior of meme assets. Although they represent a small share of the financial markets, these assets can significantly influence the interconnectedness among different sectors of the financial markets, particularly during an extreme upward market movement. Our results show that a market squeeze on meme assets can have contagious effects on conventional assets, which lowers the effectiveness of risk mitigation and portfolio management strategies. Second, user comments on social media platforms are useful in predicting asset movements. Therefore, fast access to information on these platforms can provide investors with profitable investment strategies. However, to take advantage of such opportunities, investors should be proficient in their knowledge of financial markets to distinguish between credible and non-credible information. Third, monitoring user attention and sentiment on social media platforms is important to identify future asset short squeezes. This, in turn, helps lower the contagious effects of such events on financial markets. For policymakers, regulation reforms are necessary to mitigate asset bubbles or price manipulation from online

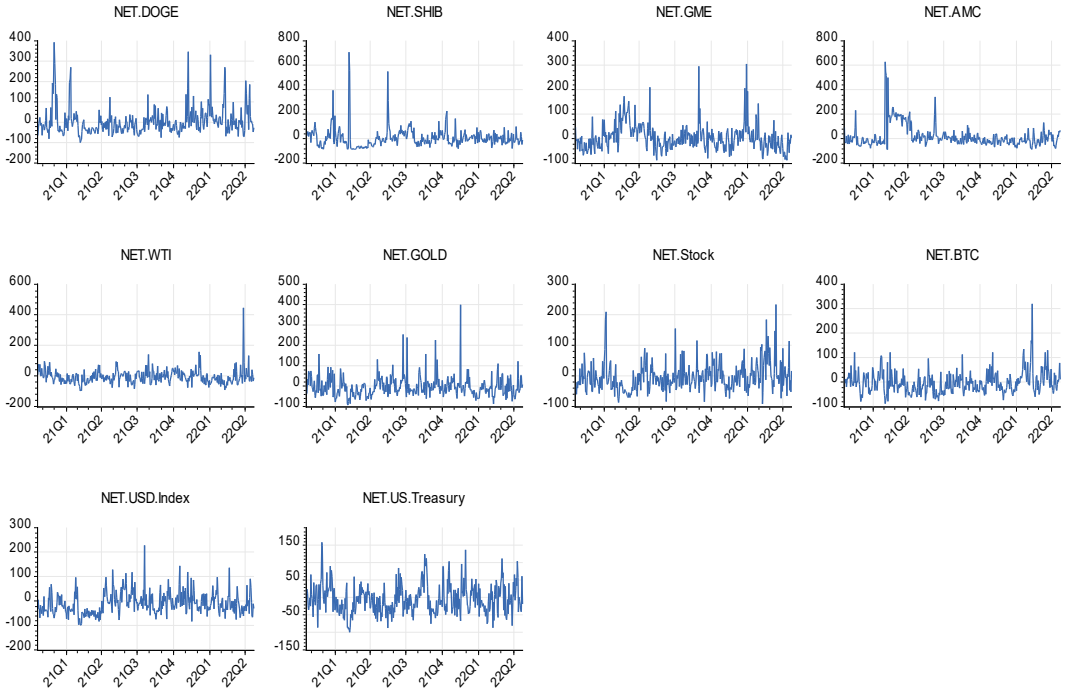


Fig. 8. Time-varying net directional spillovers at median (Q = 0.50).

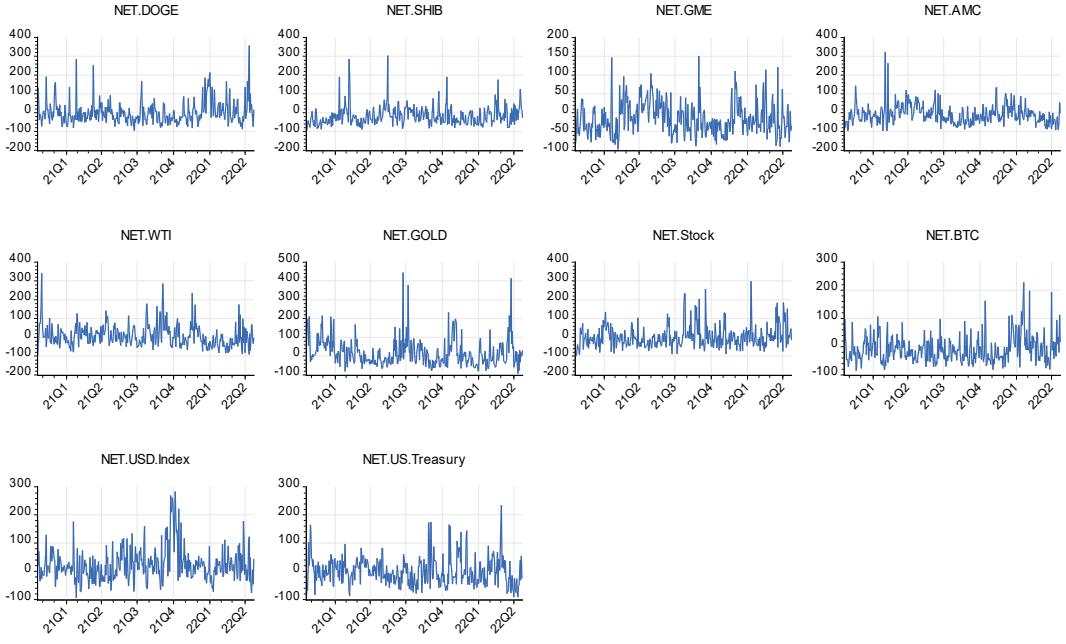


Fig. 9. Time-varying net directional spillovers at extreme lower quantile (Q = 0.05).

social media users, thereby promoting the stability of the financial systems.

Future research can extend our study by analyzing the intraday relationship between investor attention on social media and financial markets and identifying the real-time effects of investor attention on financial market contagion. Textual analysis of investor discussion on various social media channels such as Twitter, Reddit, Google can help identify the mechanism behind the influences of each platform on financial markets.

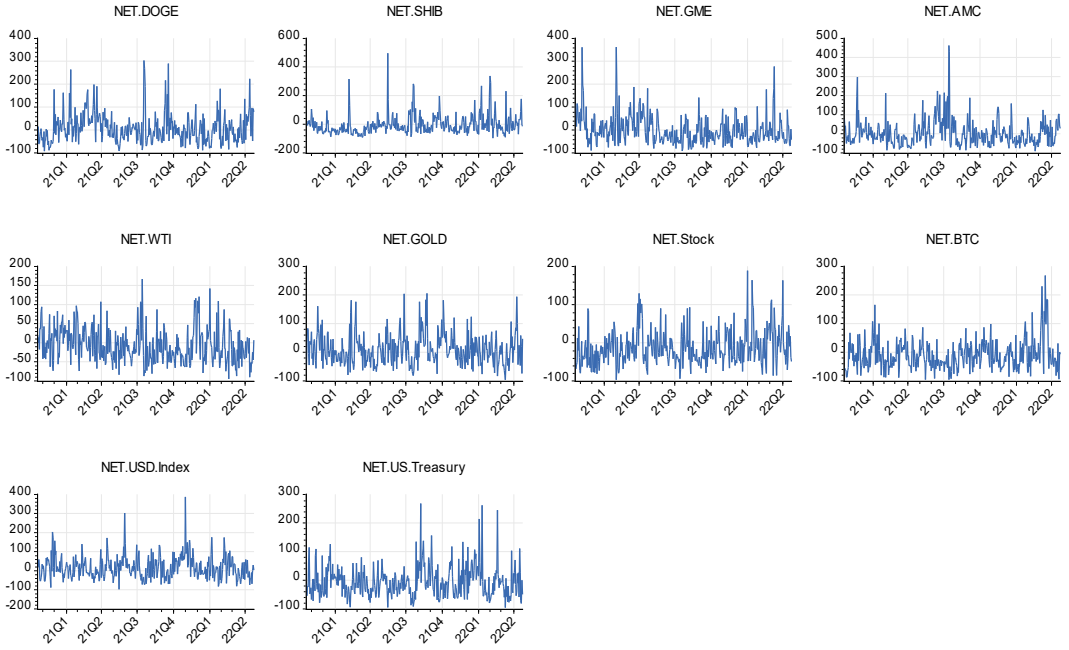


Fig. 10. Time-varying net directional spillovers at extreme upper quantile (Q = 0.95).

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.

References

Aloosh, A., Ouzan, S., Shahzad, S.J.H., 2022. Bubbles across Meme Stocks and Cryptocurrencies. Financ. Res. Lett. 49, 103155.
Anand, A., Pathak, J., 2022. The role of Reddit in the GameStop short squeeze. Econ. Lett. 211, 110249.
Ando, T., Greenwood-Nimmo, M., Shin, Y., 2022. Quantile connectedness: Modeling tail behavior in the topology of financial networks. Manag. Sci. 68 (4), 2401–2431.
Ang, A., Chen, J., 2002. Asymmetric correlations of equity portfolios. J. Financ. Econ. 63 (3), 443–494.
Anwer, Z., Khan, A., Naeem, M.A., Tiwari, A.K., 2022. Modelling systemic risk of energy and non-energy commodity markets during the COVID-19 pandemic. Ann. Oper. Res. 1–35.
Barbon, A., Di Maggio, M., Franzoni, F., Landier, A., 2019. Brokers and order flow leakage: Evidence from fire sales. J. Financ. 74 (6), 2707–2749.
Baur, D.G., Lucey, B.M., 2010. Is gold a hedge or a safe haven? An analysis of stocks, bonds and gold. Financ. Rev. 45 (2), 217–229.
Baur, D.G., McDermott, T.K., 2010. Is gold a safe haven? International evidence. J. Bank. Financ. 34 (8), 1886–1898.
Bazán-Palomino, W., 2022. Interdependence, contagion and speculative bubbles in cryptocurrency markets. Financ. Res. Lett. 49, 103132.
Bouri, E., Shahzad, S.J.H., Roubaud, D., Kristoufek, L., Lucey, B., 2020. Bitcoin, gold, and commodities as safe havens for stocks: New insight through wavelet analysis. Quarterly Rev. Econ. Financ. 77, 156–164.
Braouezec, Y., Wagalath, L., 2019. Strategic fire-sales and price-mediated contagion in the banking system. Eur. J. Oper. Res. 274 (3), 1180–1197.
Campbell, G., Turner, J.D., Walker, C.B., 2012. The role of the media in a bubble. Explor. Econ. Hist. 49 (4), 461–481.
Chernenko, S., Sunderam, A., 2020. Do fire sales create externalities? J. Financ. Econ. 135 (3), 602–628.
Chiang, T.C., Zheng, D., 2010. An empirical analysis of herd behavior in global stock markets. J. Bank. Financ. 34 (8), 1911–1921.
Cho, J.W., Choi, J.H., Kim, T., Kim, W., 2016. Flight-to-quality and correlation between currency and stock returns. J. Bank. Financ. 62, 191–212.
Chohan, U.W., 2021. Counter-hegemonic finance: The GameStop short squeeze. Available at SSRN 3775127.
Costola, M., Iacopini, M., Santagiustina, C.R.M.A., 2021. On the "mementum" of meme stocks. Econ. Lett. 207, 110021.
Coval, J., Stafford, E., 2007. Asset fire sales (and purchases) in equity markets. J. Financ. Econ. 86 (2), 479–512.
Da, Z., Engelberg, J., Gao, P., 2011. In search of attention. J. Financ. 66 (5), 1461–1499.
d'Addona, S., Khanom, N., 2022. Estimating tail-risk using semiparametric conditional variance with an application to meme stocks. Int. Rev. Econ. Financ. 82, 241–260.
Diebold, F.X., Yilmaz, K., 2012. Better to give than to receive: Predictive directional measurement of volatility spillovers. Int. J. Forecast. 28 (1), 57–66.
Farid, S., Naeem, M.A., Paltrinieri, A., Nepal, R., 2022. Impact of COVID-19 on the quantile connectedness between energy, metals and agriculture commodities. Energy Econ. 109, 105962.
Flitter, E., 2022. It's hard to tell when the crypto bubble will burst, or if there is one. The N.Y. Times. Accessed June 2, 2022.
Gharib, C., Mefteh-Wali, S., Jabeur, S.B., 2021. The bubble contagion effect of COVID-19 outbreak: Evidence from crude oil and gold markets. Financ. Res. Lett. 38, 101703.
Hasso, T., Müller, D., Pelster, M., Warkulat, S., 2022. Who participated in the GameStop frenzy? Evidence from brokerage accounts. Financ. Res. Lett. 45, 102140.

Jotikasthira, C., Lundblad, C., Ramadorai, T., 2012. Asset fire sales and purchases and the international transmission of funding shocks. J. Financ. 67 (6), 2015–2050.
Karim, S., Naeem, M.A., Hu, M., Zhang, D., Taghizadeh–Hesary, F., 2022. Determining dependence, centrality, and dynamic networks between green bonds and financial markets. J. Environ. Manage. 318, 115618.
Khalfaoui, R., Gozgor, G., Goodell, J.W., 2022. Impact of Russia-Ukraine war attention on cryptocurrency: Evidence from quantile dependence analysis. Financ. Res. Lett. 103365.
Klein, T., 2022. A note on GameStop, short squeezes, and autodidactic herding: An evolution in financial literacy? Financ. Res. Lett. 46, 102229.
Klein, T., Thu, H.P., Walther, T., 2018. Bitcoin is not the New Gold–A comparison of volatility, correlation, and portfolio performance. Int. Rev. Financ. Anal. 59, 105–116.
Koop, G., Pesaran, M.H., Potter, S.M., 1996. Impulse response analysis in nonlinear multivariate models. J. Econ. 74 (1), 119–147.
Li, S., 2022. Spillovers between Bitcoin and Meme stocks. Financ. Res. Lett. 50, 103218.
Long, C., Lucey, B.M., Yarovaya, L., 2021. I Just Like the Stock“ versus” Fear and Loathing on Main Street“: The Role of Reddit Sentiment in the GameStop Short Squeeze. SSRN Electron. J. 31, 1–37.
Longin, F., Solnik, B., 2001. Extreme correlation of international equity markets. J. Financ. 56 (2), 649–676.
Lyócsa, Š., Baumöhl, E., Výrost, T., 2022. YOLO trading: Riding with the herd during the GameStop episode. Financ. Res. Lett. 46, 102359.
Markowitz, H., 1952. Portfolio selection. J. Financ. 7 (1), 77–91.
Mensi, W., Yousaf, I., Vo, X.V., Kang, S.H., 2022. Asymmetric spillover and network connectedness between gold, BRENT oil and EU subsector markets. J. Int. Finan. Markets. Inst. Money 76, 101487.
Naeem, M.A., Karim, S., Uddin, G.S., Junttila, J., 2022a. Small fish in big ponds: Connections of green finance assets to commodity and sectoral stock markets. Int. Rev. Financ. Anal. 83, 102283.
Naeem, M.A., Karim, S., Tiwari, A.K., 2022b. Risk connectedness between green and conventional assets with portfolio implications. Comput. Econ. 1–29.
Naeem, M.A., Lucey, B.M., Karim, S., Ghafoor, A., 2022c. Do financial volatilities mitigate the risk of cryptocurrency indexes? Financ. Res. Lett. 50, 103206.
Naeem, M.A., Qureshi, S., Rehman, M.U., Balli, F., 2022d. COVID-19 and cryptocurrency market: Evidence from quantile connectedness. Appl. Econ. 54 (3), 280–306.
Naeem, M.A., Pham, L., Senthilkumar, A., Karim, S., 2022e. Oil shocks and BRIC markets: Evidence from extreme quantile approach. Energy Econ. 108, 105932.
Pesaran, H.H., Shin, Y., 1998. Generalized impulse response analysis in linear multivariate models. Econ. Lett. 58 (1), 17–29.
Pham, L., Karim, S., Naeem, M.A., Long, C., 2022. A tale of two tails among carbon prices, green and non-green cryptocurrencies. Int. Rev. Financ. Anal. 82, 102139.
Saeed, T., Bouri, E., Alsulami, H., 2021. Extreme return connectedness and its determinants between clean/green and dirty energy investments. Energy Econ. 96, 105017.
Scharfstein, D.S., Stein, J.C., 1990. Herd behavior and investment. Am. Econ. Rev. 465–479.
Selmi, R., Mensi, W., Hammoudeh, S., Bouoiyour, J., 2018. Is Bitcoin a hedge, a safe haven or a diversifier for oil price movements? A comparison with gold. Energy Econ. 74, 787–801.
Shahzad, S.J.H., Bouri, E., Roubaud, D., Kristoufek, L., Lucey, B., 2019. Is Bitcoin a better safe-haven investment than gold and commodities? Int. Rev. Financ. Anal. 63, 322–330.
Steiger, S., Pelster, M., 2020. Social interactions and asset pricing bubbles. J. Econ. Behav. Organ. 179, 503–522.
Sujata, R., 2021. Losses on short positions in U.S. firms top $70 billion - Ortex data. Thomson Reuters. Retrieved From Http:// https://www.reuters.com/.
Umar, Z., Gubareva, M., Yousaf, I., Ali, S., 2021a. A tale of company fundamentals vs sentiment-driven pricing: The case of GameStop. J. Behav. Exp. Financ. 30, 100501.
Umar, Z., Yousaf, I., Zaremba, A., 2021b. Comovements between heavily shorted stocks during a market squeeze: lessons from the GameStop trading frenzy. Res. Int. Bus. Financ. 58, 101453.
Wang, P., Zhang, W., Li, X., Shen, D., 2019. Is cryptocurrency a hedge or a safe haven for international indices? A comprehensive and dynamic perspective. Financ. Res. Lett. 31, 1–18.
Yousaf, I., Ali, S., Shah, S.Z.A., 2018. Herding behavior in Ramadan and financial crises: the case of the Pakistani stock market. Financial Innovation 4 (1), 1–14.
Yousaf, I., Nekhili, R., Gubareva, M., 2022. Linkages between DeFi assets and conventional currencies: Evidence from the COVID-19 pandemic. Int. Rev. Financ. Anal. 81, 102082.
Yousaf, I., Yarovaya, L., 2022. Static and dynamic connectedness between NFTs, Defi and other assets: Portfolio implication. Glob. Financ. J. 53, 100719.