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Quantile dependence and asymmetric connectedness between global financial market stress and REIT returns: Evidence from the COVID-19 pandemic

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ABSTRACT

Using daily data for the financial stress index of the US and real estate investment trusts (REITs) returns from February 2, 2020, to January 20, 2022, we investigate the frequency-dependent and asymmetric connectedness between global financial market stress and REIT returns for the top 12 REIT regimes in America, Europe, and Asia. We use a novel asymmetric, noise-reducing-domain EEMD-based quantile connectedness and quantile-on-quantile regression technique and the quantile vector autoregression (QVAR) connectedness approach. The findings divulge that at the upper quantile financial market stress is a major risk transmitter, transmitting risk towards Germany, France, Netherlands, New Zealand, the UK, and Canada. The findings of the study explicate the pivotal role of the financial soundness on the housing market, which is one of the main drivers of the economy. Investors and market participants should observe the conditional state of market dynamics and its associated policies for risk management and diversification strategies in real estate investment.

1. Introduction

It is documented that real estate investments are characterized by moderate profits, high liquidity, and low risk (Bossman, Umar, Agyei, & Owusu Junior, 2022; Lesame, Bouri, Gabauer, & Gupta, 2021). Many investors and portfolio managers see real estate investment trusts (REITs) as important diversification instruments in multi asset portfolios (Rehman, Shahzad, Ahmad, & Vo, 2022; Simon & Ng, 2009). REIT investors have a diverse portfolio of underlying real estate, thus reducing the risk of property investment (Lesame et al., 2021; Rehman et al., 2022). The growth and popularity of REITs as an investment vehicle bolsters the real estate market and contribute to its development (Lesame et al., 2021). Data available on nominal housing prices from EUROSTAT-European Statistics (2020) for the third quarter of 2019 show an increase of 4.1% compared to the third quarter of 2018 in the Euro area. With a remarkable annual growth rate of 4.47% share of global stock market capitalisation in the third quarter of 2019 (Ryu, Jang, Kim, & Ahn, 2021), the earnings growth of real estate investments responded to the shocking news of COVID-19. The COVID-19 pandemic has created momentous uncertainty in the financial and economic downturn, including contagion risk (Shehzad, Xiaoxing, Bilgili, & Koçak, 2021); thus, plummeting housing prices in both the short- and mid-runs (Del Giudice, De Paola, & Del Giudice, 2020).

As a consequence of the systemic risk occasioned by COVID-19 and its impact on REITs, there has been a growing consensus among

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REIT investors that the main investment paradigm of global REITs evolves amid the COVID-19 pandemic (Akinsomi, 2021). Many questions have emerged about the impact of the COVID-19 pandemic on REITs, as relevant information on COVID-19 was largely reflected in determining the current price of financial assets (Asafo-Adjei, Bossman, et al., 2022). This led to growing empirical studies on the relationship between COVID-19 and REITs (see Akinsomi, 2021; Bonato, Çepni, Gupta, & Pierdzioch, 2021; Bossman, Umar, & Teplova, 2022; Chong & Phillips, 2022; Del Giudice et al., 2020; Milcheva, 2022; Nanda, Xu, & Zhang, 2021). However, the baseline version of these studies did not consider two key aspects that led to the following questions. Is there an extreme dependence between financial market stress and REITs? Does financial instability matter to REITs? To enrich the evidence produced by the existing literature on the nexus between financial stress and REITs, we explore these questions by examining the asymmetric connectedness between financial market stress (FMS) and REITs in an extreme market state.

Theoretically, the study is driven by the concept of market integration, which concerns the degree of interconnectedness between countries and the global financial market (Bossman, 2021), which has been particularly noticeable during financial imbalance (Zaremba, Umar, & Mikutowski, 2019). The extreme risks associated with the financial market during COVID-19 are catastrophic for international investors (Armah, Bossman, & Amewu, 2023). Investments in the housing market are exposed to large idiosyncratic risks during systemic risk (Bossman, Umar, & Teplova, 2022). Due to the prevalent nature of this shock, various policies were employed (such as strict public health regulations, social distance, and other regulations) were employed that contributed to the synchronisation of economic activity and thus exacerbated market stress (Didier, Huneeus, Larrain, & Schmukler, 2021). The advent of black swans has devastating impacts on financial markets (see, Taleb, 2007). As the COVID-19 pandemic has been tagged a black swan (Bossman, Adam, et al., 2022; Yarovaya et al., 2022; Yousaf et al., 2022), it is imperative to understand the connectedness of FMS on REIT returns in an extreme tail distribution and to use the insights to project any economic impact in the short and long term.

Financial market stress is characterized by the inherent instability of the economic system due to shocks or disruptions in business operations (Hakkio & Keeton, 2009). Measuring uncertainty using the stress index during health systemic risk is becoming increasingly important (see X. Li, Liang, & Ma, 2023; Long & Morgan, 2023; Kumar & Gupta, 2022), as it quantifies disruption in financial market and helps monitor the financial condition (Altınkeski, Cevik, Dibooglu, & Kutan, 2022). The FSI indicator aggregates several macroeconomic components such as credit, equity valuation, funding, safe assets, and volatility (Monin, 2017), which are extremely imperative in determining the sources of vulnerability in the financial system. These indicators provide information about financial market conditions based on independent indicators that represent important market characteristics (Armah et al., 2023). For instance, in times of stress, credit lines can expand when the risk of default increases or when the functioning of the credit market is disrupted (Monin, 2017). Monin (2017) posits that for equity valuation, the value of shares can decline if investors are less likely to maintain risky assets and, finally, as stress increases, investors' behaviour led to higher volatility. During market stress the funding market may freeze if participants are aware of a higher risk of counterparty credit or liquidity which will enable investors to migrate from risky assets to a safe asset. As argued by Hakkio and Keeton (2009), when financial market is stressful, real economic activities slow down and financial assets prices wane significantly during the depressed state of the markets. Despite the relevance of these indicators and the severe impact on the housing market (Sum, 2014), the effect of FMS on REITs in the era of pandemic has not yet been documented.

Although recent researchers have analysed the effect of pandemic on REITS (see Akinsomi, 2021; Bonato et al., 2021; Bossman, Umar, & Teplova, 2022; Chong & Phillips, 2022; Del Giudice et al., 2020; Milcheva, 2022; Nanda et al., 2021), the review of the extant literature highlights the absence of studies focused on the effect of FMS on REIT. As stated previously, the growing relevance of FMS of asset prices (see (Armah, Amewu, & Bossman, 2022, 2023; Sheng, Kim, Gupta, & Ji, 2023) raises the need of empirically evaluating the effect of FSM on REITS during the pandemic era. Given that the literature has demonstrated strong predictive power of COVID-19 cases on REIT returns within the upper and lower quantile (Bossman, Umar, & Teplova, 2022), this study aims to analyse the extreme spillover between FSM and REIT returns using the QVAR approach which is more suitable for accessing the degree of connectedness spillover associated with large positive and negative shock during the distress period than the conditional mean (Bouri, Saeed, Vo, & Roubaud, 2021; Umar & Bossman, 2023). This will provide global investors and market regulators with an in-depth view of market conditions during systemic risk. The extreme quantile-based approach employed in this study enables us to access the behaviour of the tail distribution associated with bearish and bullish market condition. Abdullah, Adeabah, Joel, Abakah, and Lee (2023) posit that the study of financial market integration is important for international investors and market regulators as it can provide an insight for portfolio diversification across different classes of assets and markets. In doing so, we gauge REIT market diversification potential in a network which provides crucial information about a shock from market i is due to market j in an extreme market condition.

Third, we contribute to the hypothesis of ineffective market theory by using EEMD as a noise reduction technique in relation to REITs and market stress. We employed the kurtosis and energy entropy framework of Faysal, Ngui, and Lim (2021) in selecting sensitive IMFs for analysis. This technique caters to noisy observations and maintains the sensitive IMFs only for our analysis. Employing the noise-assisted decomposition method in reconstructing IMFs makes the uniqueness of our study in the decomposition of financial time series, which has been ignored in the existing literature (Bossman & Agyei, 2022; Owusu Junior, Adam, & Tweneboah, 2020; K. Ijasan, Owusuj Junior, Tweneboah, Oyedokum, & Adam, 2021; Bossman, 2021). Finally, we employ a novel nonlinear quantile-on-quantile regression analysis to address the effect of the shock of FMS at different quantiles on REIT returns of another quantile to reveal the quantile dependence between REIT and FMS, which will serve as a guide for market participants and policy makers whose decisions are limited by market conditions. This will aid in an in-depth assessment of the market state and effective policy decisions for investors and market regulators.

We show that financial market stress at the upper quantile is a significant risk transmitter, transmitting innovations to various REIT markets such as Germany, France, the Netherlands, New Zealand, the UK, and Canada. We render insightful conclusions to explain how important financial stability is to the housing market, one of the major economic drivers.

The rest of the paper is organised as follows. Section 2 presents a review of related empirical works. The methodological steps are outlined in Section 3. In Section 4, we present data and summary statistics. Section 5 presents the empirical findings alongside policy implications, and Section 6 concludes the study.

2. Empirical review

In this section, we review the main relevant literature of the subject matter, and hence we group the literature into two branches. First, we present a review of the literature on COVID-19 and market stress, and then we present a review of the effect of the COVID-19 pandemic on REIT returns.

2.1. COVID-19 crisis and financial market stress

Recent studies have focused on the emerging market by analysing the impact of COVID-19 on the financial market from the perspective of financial stress (See Yao, Li, Shang, Le, & Li, 2023; X. Li et al., 2023; Armah et al., 2023; Armah & Amewu, 2022; Long & Morgan, 2023; Ito, 2020; Kumar & Gupta, 2022). For example, X. Li et al. (2023) use the dynamic connectedness framework of Antonakakis, Chatziantoniou, and Gabauer (2020) to explore financial stress spillover in nine Asian countries, particularly during major economic, political, and public health emergencies in COVID-19. The authors found a significant increase in the intensity of financial stress spread over nine Asian countries during COVID-19. The authors further asserted that in the first three months following the COVID-19 outbreak there were significant changes month-over-month in the financial market stress. Singapore and Japan are the main net transmitters and receivers of financial stress shocks during all incidents examined, respectively. During the COVID-19 period, China was the first country to detect and contain COVID-19 but transmitted the highest number of net financial stress shocks in March 2020. In the work of Yao et al. (2023), the authors find that the stress of a country's financial system is positively correlated with the severity of the COVID-19 pandemic country experience. Long and Morgan (2023) constructed a daily financial stress index for 15 countries from 1 April 2019 to 30 September 2021 in some advanced emerging economies during the COVID-19 pandemic. The authors document that each component of financial stress responds to the announcement of financial policies differently, and the announcement of financial policies affects financial stress on the day policy was announced. Ito (2020) posits that stress in the financial system was not connected to five countries in the eurozone countries (Germany, France, Italy, Portugal, and Spain) before COVID-19. Credit default swap premiums were paid independently, not incorporating sovereign risk as a whole. However, during COVID-19, stress was connected in five countries. The financial market was cautious about the growth in the budget deficit caused by the large-scale expenditure of the COVID-19 crisis, fearing that it could increase the risk of the financial system of the Eurozone as a whole. It is important to state that the financial system is very dynamic and reacts differently to economic and financial shocks over different investment horizons (Ferrer, Jammazi, Bolós, & Benítez, 2018). The financial system might depict less responsiveness to financial assets when the prevailing stress are low (Das, Dutta, Jana, & Ghosh, 2022). Similarly, when the stress is high, it becomes more sensitive to financial asset volatility (Das et al., 2022). As the literature on market stress continued to grow during the pandemic period, little is known about the impact of REITs, which has received a lot of attention in recent times.

2.2. COVID-19 and REITs

REITs have been at the forefront of research interests during the epoch of financial collapse in recent decades. During the past two decades, real estate markets have grown at an average annual rate of 13%, sparking investor interest as the preferred choice for investment due to their relatively low transaction cost, ease of conversion, and smaller investable units (Hoesli & Oikarinen, 2012; Ryu et al., 2021). According to the National Real Estate Investment Trust Association (NAREIT), all types of REITS collectively own more than $3 trillion in gross real estate assets in the US, with stock exchange-listed REITs holding $2 trillion US dollars in assets, and a market capitalisation of over $1 trillion in equity. The success of attracting such large-scale investment capital primarily reflects the fact that REITs are available to all investors regardless of the size of their portfolio (Bonato et al., 2021). The rapid and sustainable growth of the real estate sector raises the question whether real estate prices can quickly adapt to new information and the possibilities of arbitrage (Ryu et al., 2021). As a result, the efficiency and dynamic interrelationship of the real estate market during the pandemic period attracted the attention of both academics and practitioners to investigate the effect of COVID-19 on REIT returns (see Cai & Xu, 2022; D'Lima, Lopez, & Pradhan, 2022; Chong & Phillips, 2022; Nanda et al., 2021; Bonato et al., 2021; Ryu et al., 2021; K. Ijasan et al., 2021Y. Zhang & Hansz, 2022; Kola Ijasan, Tweneboah, Omane-Adjepong, & Owusu Junior, 2019; Milcheva, 2022; Akinsomi, 2021) These authors reported that REIT returns are sensitive to the risk factors of COVID-19 and that there was considerable heterogeneity in real estate investments in the regions studied. Grybauskas, Pilinkienė, and Stundžienė (2021) reported earlier research results, indicating that the decline in prices was not as severe as initially expected, but that the real estate business was somewhat resistant to pandemic. Cai and Xu (2022) asserted that REIT returns are determined by macro/asset price variables and structural changes during boom and bust cycles, not only by shocks from the COVID-19 pandemic. Balemi et al. (2021) also point out that market prices are significantly affected by the larger macroeconomic conditions, which are temporary and geographically constrained, therefore, isolate the effect of COVID-19 on market prices does not provide a holistic picture of the nexus during the pandemic period. Financial markets mirror REIT returns (Cai & Xu, 2022), hence it is important to understand the tail distribution between market stress and REIT returns in an extreme market state, which will provide an invaluable insight for risk management. Financial stress is typically associated with increased indecision and unexpectedness in the fundamental values of financial assets and the behaviour of investors in financial markets (Ferrer et al., 2018). Davig and Hakkio (2010) posit that an increase in financial stress will render investors more risk-averse, which will discourage investment in financial assets, thereby leading to the reduction in asset prices. As noted by

Manamperi (2015) and (Illing & Liu, 2006), the exogenic shock of financial stress can cause changes to the financial markets, and these shocks are likely to result in stress when financial conditions are frail. Financial stress is well documented as the leading indicator of economic activity and has a negative impact on the real economy through several channels (Adam, Benecká, & Matějů, 2018; Cevik, Dibooglu, & Kenc, 2016; Ishrakieh, Dagher, & El Hariri, 2020; Liang, Hong, Huynh, & Ma, 2023; Mazol, 2019; Semmler & Chen, 2014).

However, with the advent of systemic risk occasioned by COVID-19, which excerbate market stress (Yao et al., 2023; X. Li et al., 2023; Kumar & Gupta, 2022) it, it is becoming increasingly important to understand how market stress may aggravate the different response of financial systems which may have adverse effect on economic activities (Balcilar, Elsayed, & Hammoudeh, 2023). To understand the connection under extreme market conditions during the pandemic period between global financial market stress and REITs, we note that the strand of literature documented on REITs primarily focusses on the impact of COVID-19 on REIT returns. This highlights the gaps by unveiling the direction of the spillover between global financial market stress and REITs in the top 12 advanced economies during the COVID-19 outbreak and to measure their contribution to the connectedness system.

3. Methodology

We initially decomposed the series using the EEMD to extract intrinsic mode functions (IMFs), and the output generated from the EEMD is used as the input data for quantile VAR(QVAR) and quantile-on-quantile regression. For the original signal $x(t)$ the EEMD algorithm follows the following steps (Wu & Huang, 2009):

First, add white noise to the original series with a mean of 0 and a standard deviation of 1 to obtain a set of ensembles.

$$x_i(t) = x(t) + y_i(t) \tag{1}$$

Where $y_i(t)$ is the white noise of the signal of the same length as (t) $i = 1, 2, ..N$, where N is the number of ensembles.

Second, we decompose the ensemble using EMD to obtain the IMFs.

$$x_i(t) = \sum_{j=1}^{n} b_{ij}(t) + r_i(t) \tag{2}$$

Where $j = 1, 2, \ldots n$. n is the number of IMF and $b_{ij}(t)$ is the IMF and $r_i(t)$ represent the residue of the *ith* trail

Finally, determine the ensemble means of the consequent IMFs as follows;

$$b_j(t) = \frac{1}{m} \sum_{i=1}^{m} b_{ij}(t) \tag{3}$$

After performing an EEMD on the signal, we obtain a series of IMFs. The decomposition algorithms generate several IMFs. However, Faysal et al. (2021) asserted that not all IMFs are of the same physical importance and that higher-order IMFs contain the most information on the signal (Rostami, Chen, & Tse, 2017). Therefore, it is important to identify which IMFs work further for our analysis. Among other methods proposed in the selection of sensitive IMFs (see (He, Li, & Kong, 2012; Yan & Gao, 2008; & Zuo, 2009),we employ the kurtosis and energy entropy technique of Faysal et al. (2021) in the selection of sensitive models for our analysis. This technique of reconstruction of IMFs considers both time domain and time-frequency analysis when selecting IMFs (Faysal et al., 2021), which was overlooked in the existing literature.

Following Faysal et al. (2021), the original signal can be reconstructed as follows:

$$K_j^n = \frac{\sum\left\{\left[x_j^n(t) - x_j^{-n}(t)\right]^4\right\}}{\sigma^4_{x_i^n(t)}} \tag{4}$$

Next, we calculate the energy entropy of the IMFs by computing *the* $i - th$ IMF energy.

$$E_i = \sum_{i=1}^{k} |b_{ij}|^2 \tag{5}$$

where k is the length of an IMF. We computed the total energy of k to obtain IMFs.

$$E_i = \sum_{i=1}^{k} E_i \tag{6}$$

Next, we calculate the total energy entropy of the IMFs.

$$H_{en} = \sum_{i=1}^{k} p_i \log(p_i) \tag{7}$$

Where H_{en} is the energy -entropy calculated from the original signal and $p_i = E_i/E$ is the ratio of the energy of the *ith* IMF relative to the whole energy entropy. The most sensitive IMF is obtained by multiplying the kurtosis and the energy entropy value.

3.1. Quantile-on- quantile regression (QQR)

To estimate the effect of the shocks of FMS on REITs at different quantiles we used the QQR framework developed by Sim and Zhou (2015) to provide a more complete picture of the dependency between FMS and REITs during COVID-19. This is implemented by selecting the number of quantiles of FMS (indexed by θ) and estimating the effect that θ quantiles of market stress might have on the τ quantile of REIT returns. To do this, we constructed a model linking the quantile of the FMS indices with the quantile of the REITs returns, so that the relationship between FMS and REIT returns could vary from one point of view, depending on the distribution of each.

$$rr_t = \beta^{\theta}(fms_t) + \varepsilon_t^{\theta} \tag{8}$$

Where rr_t is the REITs for each REIT regime at time t, fms is the FMS index, $\beta^{\theta}(\bullet)$ is an unknown parameter which represent the relationship between REIT and FMS, θ is the quantile distribution of FMS and ε_t^{θ} is the quantile error term. To examine the relationship between τ- REIT returns and the θ-quantile of FMS, donated by rr^{τ}, we linearize equation (8) by taking a first Taylor expansion of β^{θ} around rr^{τ}, given that $\beta^{\theta}(\bullet)$ is unknown which leads to

$$\beta^{\theta}(rr_t) \approx \beta^{\theta}(rr^{\tau}) + \beta^{\theta'}(rr^{\tau})(rr_t - rr^{\tau}) \tag{9}$$

Where β^{θ} explain the partial derivative $\beta^{\theta}(rr_t)$ that explains the marginal impact. One stimulating feature in equation (9) is that the parameters $\beta^{\theta}(rr^{\tau})$ and $\beta^{\theta'}(rr^{\tau})$ are double indexed in θ and τ. The rr^{τ}, the τ- quantile of REIT, is a function of τ alone. Since $\beta^{\theta}(rr^{\tau})$ and $\beta^{\theta'}(rr)^{\tau}$ are the functions of θ and rr^{τ} and since rr^{τ} is the function of τ. This suggest that $\beta^{\theta}(rr^{\tau})$ and $\beta^{\theta'}(rr^{\tau})$ are both function of θ and τ. From this standpoint, we can rewrite equation (9) as follows:

$$\beta^{\theta}(rr_t) \approx \beta^{\theta}(\theta, \tau) + \beta_0(\theta, \tau)(rr_t - rr^{\tau}) \tag{10}$$

By substituting equation (8) into equation (10) we obtain the following:

$$rr_t = \underbrace{\beta_0(\theta, \tau) + \beta_1(\theta, \tau)(rr_t - rr^{\tau}) + \varepsilon_t^{\theta}}_{*} \tag{11}$$

Where (*) is the conditional quantile of θth of FMS. However, unlike standard conditional quantile functions, this expression represents the relationship between the quantile of REIT returns and the quantile of FMS given that indexed in β_0 and β_1 are double indexed in θ and τ. In this respect, (*) captures the general structure of dependency between REITs and the FMS by relying on their respective distributions. Finally, we replace rr_t and rr^{τ} by $\widehat{rr_t}$ and $\widehat{rr^{\tau}}$ as follows:

$$\min_{b_0 b_1} \sum_{t=1}^{n} \rho\theta[fms_t - b_1(\widehat{rr_t} - rr^{\tau})] K\left(\frac{F_n(\widehat{rr}) - \tau}{h}\right) \tag{12}$$

Where $\varphi\theta$ is the quantile loss represented as $\varphi\theta = \mu(\theta - 1(<0))$, i is the function. Since we are interested in, the effect exerted by the τ -quantile of REIT returns, we employ a gaussian kernel $K(\bullet)$ whereas h represents bandwidth. The purpose of the kernel function is to weight the observation of rr^{τ} whiles the bandwidth method provides accurate information about the target point and determines the size and simplicity of the estimated result. These weights are negatively related to the distribution of the function $\widehat{rr_t}$. Thus, the distribution is explained as follows:

$$F_n(\widehat{rr}) = \frac{1}{n} \sum_{k=1}^{n} I(\widehat{rr_k} < \widehat{rr_t}) \tag{13}$$

We follow Sim and Zhou (2015) in selecting the bandwidth to avoid bias in our results, especially when the bandwidth is larger and higher variance when the bandwidth is smaller. We chose a plug-in bandwidth of $h = 0.05$ to 0.95 for empirical QQR analysis.

3.2. Quantile connectedness approach

To get the pictorial view of overall quantile connectedness to determine the spillover effect between REITs and FMS at the various quantiles (τ) we employ QVAR approach. Following (Ando, Greenwood-Nimmo, & Shin, 2022; Chatziantoniou, Gabauer, & Stenfors, 2021), we defined k-dimensional $q-$ order QVAR model as follows;

$$x_t = \mu_t(\tau) + \varphi_1(\tau)x_{t-1} + \varphi_2(\tau)x_{t-2} + \ldots \varphi_q(\tau)x_{t-q} + \mu_t(\tau) \tag{14}$$

Where x_t and $x_{t-1,}$ $i = 1,..\ q$ are $KX1$ dimensional endogenous variables vectors, τ is between (0,1) and signifies the quantile of interest, q represent the lag length of the QVAR $\mu(\tau)$ is an KX1 dimensional conditional mean vector, $\varphi_i(\tau)$ is KXK dimensional error variance-covariance matrix, $\sum(\tau)$. To transform QVAR (q) to its quantile moving average representation,the study uses the Word's theorem as follows:

$$x_t = \mu_t(\tau) + \sum_{i=1}^{q} \varphi_i + (\tau)x_{t-i} + \mu_t(\tau)x_{t-i} + \ldots\mu_t(\tau) + \sum_{i=0}^{\infty} \Psi_i + (\tau)\mu_{t-i} \tag{15}$$

The generalized forecast error variance decomposition (GFEVD) with a forecast horizon H is defined as follows (Pesaran & Shin, 1998):

$$\Omega_{ij}^{g}(H) = \frac{\sum(\tau)_{ij}^{-1} \sum_{h=0}^{H-1} \left(e_i^{'}\varnothing_h(\tau)\sum(\tau)e_j\right)^2}{\sum_{h=0}^{H-1} \left(e_i^{'}\varnothing_h(\tau)\sum(\tau)^{'}e_j\right)^2} \tag{16}$$

Where e_i depicts a zero vector with a unity at the ith position. The normalization in decomposition matrix is presented as follows:

$$\Omega_{ij}^{g}(H) = \frac{\Omega_{ij}^{g}(H)}{\sum_{j=1}^{k=1} \Omega_{ij}^{g}(H)} \text{ where } \sum_{i=1}^{k} \Omega_{ij}^{g} = 1 \text{ and } \sum_{i,j=1}^{k} \Omega_{ij}^{g}(H) = 1 \tag{17}$$

In the spirit of Diebold and Yilmaz (2012) the connectedness can estimated using GFEVD method as follows:

$$TCI(\tau) = \frac{\left(\sum_{i=1}^{k} \sum_{j=1, i \neq j-}^{k} \varnothing_{i,j}^{-g}(\tau)\right)}{\sum_{i=1}^{k} \sum_{j=1,}^{k} \varnothing_{ij}^{-g}(\tau)} X100 \tag{18}$$

At the quantile τ, the TCI from variable i to all other variables j given as "TO"

$$CI_{i \to j(\tau)} \frac{\sum_{i=1}^{N} \sum_{j=1, i \neq j}^{N} \varnothing_{j,i}^{-g}(\tau)}{\sum_{i=1}^{N} \sum_{j=1,}^{N} \varnothing_{ji}^{-g}(\tau)} X100 \tag{19}$$

At the quantile τ, the TCI from all others variables j to variable I is given as "FROM"

$$CI_{i \leftarrow j(\tau)} \frac{\sum_{i=1}^{N} \sum_{j=1, i \neq j}^{N} \varnothing_{i,j}^{-g}(\tau)}{\sum_{i=1}^{N} \sum_{j=1,}^{N} \varnothing_{ij}^{-g}(\tau)} X100 \tag{20}$$

The net in general is given as follows:

$$NCI(\tau) = CI_{i \to j(\tau)} - CI_{i \leftarrow j(\tau)} \tag{21}$$

Table 1
Summary statistics of REITs and financial market stress indexes.

Country	Mean	Variance	Skewness	Ex. Kurtosis	JB	ERS	Q (10)	Q2 (10)
Australia	0.00	0.00	−2.18 [a]	17.17 [a]	6724.93 [a]	−7.87 [a]	17.05 [a]	510.98 [a]
Canada	0.00	0.00	−2.8 [a]	29.13 [a]	18855.37 [a]	−6.40 [a]	31.91 [a]	279.59 [a]
China	0.00	0.00	0.52 [a]	4.14 [a]	391.13 [a]	−0.79	4.02	8.00
France	0.00	0.00	−0.04	14.53 [a]	4524.09 [a]	−8.43 [a]	30.08 [a]	144.81[a]
Germany	0.00	0.00	−0.97 [a]	9.84 [a]	2153.40 [a]	−7.53 [a]	20.93 [a]	442.38 [a]
Hong. Kong	0.00	0.00	−0.09	2.93 [a]	184.72 [a]	−9.56 [a]	4.48	123.62 [a]
Japan	0.00	0.00	−0.43 [a]	17.29 [a]	6418.63 [a]	−7.54 [a]	50.73 [a]	360.46 [a]
The Netherlands	0.00	0.00	0.05	8.22 [a]	1447.89 [a]	−9.16 [a]	18.21 [a]	105.06 [a]
New Zealand	0.00	0.00	−3.86 [a]	50.41 [a]	55688.62 [a]	−9.11 [a]	38.01 [a]	89.37 [a]
Singapore	0.00	0.00	−0.89 [a]	13.56 [a]	4006.95 [a]	−4.26 [a]	31.63 [a]	531.40 [a]
UK	0.00	0.00	−0.56 [a]	7.04 [a]	1087.60 [a]	−9.60 [a]	18.99 [a]	204.96 [a]
US	0.00	0.00	3.51 [a]	15.64 [a]	6296.19 [a]	−1.90 [c]	1952.04 [a]	1452.67 [a]
USFSI	−0.96	−0.20	0.69 [a]	14.37 [a]	4464.88 [a]	−9.77 [a]	27.57 [a]	2.18

Notes a, b, and c denote significance at 1%,5%, and 10% significance level, respectively; Kurtosis test; Anscombe and Glynn (1983) JB; Jarque and Bera (1980) normality test; ERS; (Elliott, Rothenberg, and Stock (1996), Unit root test; $Q(20)$ and $Q^2(20)$ (Fisher & Gallagher, 2012). USFSI donates the financial market stress of USA.

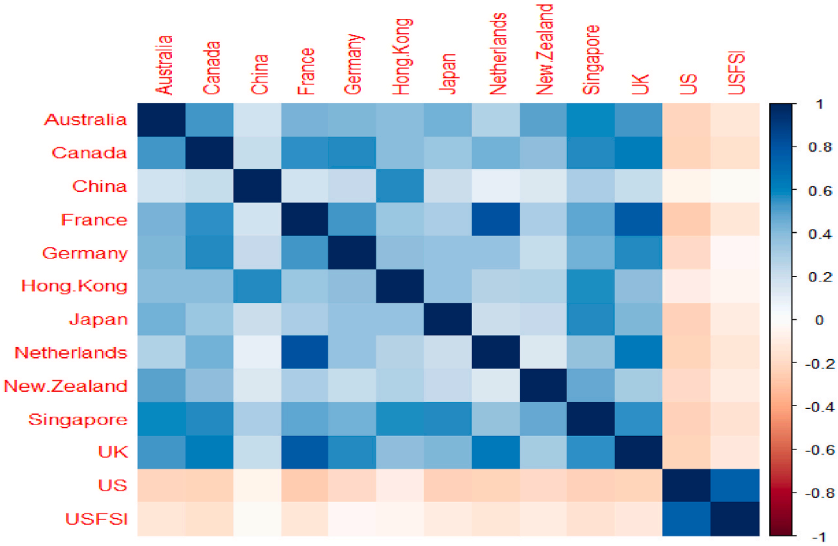

Fig. 1. Heatmap of pairwise correlation between FMS and top 12 REIT regimes across America, Europe, and Asia. In this figure, the darker (lighter) the colour, the stronger (weaker) correlation. (for the interpretation of the colour in this figure legend, the reader is referred to the Web version of this article. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

4. Data and summary statistics

4.1. Data

The data considered in this study are the daily data of the US Financial Stress Index (UFSI) from the Office of Financial Research (OFR), We use OFR FSI because, unlike other FSI's where the arrows of time and all time -series are reestimated each time. This implies that the value on each given day depends only on the information available on that day and, once estimated, its value does not change (Monin, 2017). The index presents the stress contribution of one region, namely the US. This is because the financial market condition in the US reflects a significant degree of the overall condition of the global financial market (Chen, Hamori, & Kinkyo, 2014). FSI is a monitoring tool that helps predict decreases in the economic activity market (Monin, 2017). Owing to the argument asserted by Niu, Ma, and Zhang (2022), we believe that FSI offers a deeper understanding of investor expectation changes and captures the dynamics of capital markets. Data for REIT returns of 12 top developed countries (USA, UK, Singapore, New Zealand, China, Japan, the Netherlands, Germany, France Canada, Hong Kong, and Australia) were obtained from data streams. The sample period covers from 02 February 2020 to 20 January 2022, covering different six waves of COVID-19 pandemic (Jareño, Escribano, & Umar, 2023). The daily REIT returns were transformed taking the logarithmic difference between consecutive prices given by $R_t = [In(p_t) - In(p_{t-1})] * 100$ Where R_t is return at the time *t*, p_t and p_{t-1} are respectively current price/index and one-period lagged/index.

4.2. Descriptive statistics

Table 1 shows the summary statistics of the transform series of financial market stress and REIT returns. We found that all series are significantly skewed except for France, Hong Kong, and the Netherlands. While all series except China, the Netherlands, US, and USFSI indices are left skewed. In addition, except for Hong Kong, all series are leptokurtic distributions, which means that the distribution has a fatter tail. This supports the argument asserted by Jarque and Bera (1980) that normality tests all returns are significantly non-normally distributed. Fig. 1 illustrates the unconditional correlation matrix between FMS and the top 12 REIT regimes in the US, Europe, and Asian markets. From the heatmap, we observe that FMS are negatively correlated with REITs except for US, whereas all REIT regimes are positively correlated to each other except for US.

5. Empirical results

5.1. Analysis of QQR for market stress and REITs

Before we examine the quantile connectedness between FMS and REITs returns, we first look at the shock of FMS at different quantiles on REITs returns of another quantile to reveal the quantile dependence between the nexus. To achieve this, we used QQR in three dimensions, as shown in Fig. 2. It is carried out by selecting several quantiles of market stress indexed by θ and the impact on τ-quantile on the REIT returns. The effect of market stress is captured by the slope coefficients $\beta_1(\theta, \tau)$. In Fig. 2 plots the estimates of $\beta_1(\theta, \tau)$ in z-axis against the quantiles of FMS (θ) in the x-axis and quantile of REIT returns (τ) in the *y-axis*. Following the extant literature (Bossman, 2021; b, c; Bossman, 2021; Gubareva et al., 2023; Umar et al., 2022; 2023) approach, we define a quantile range

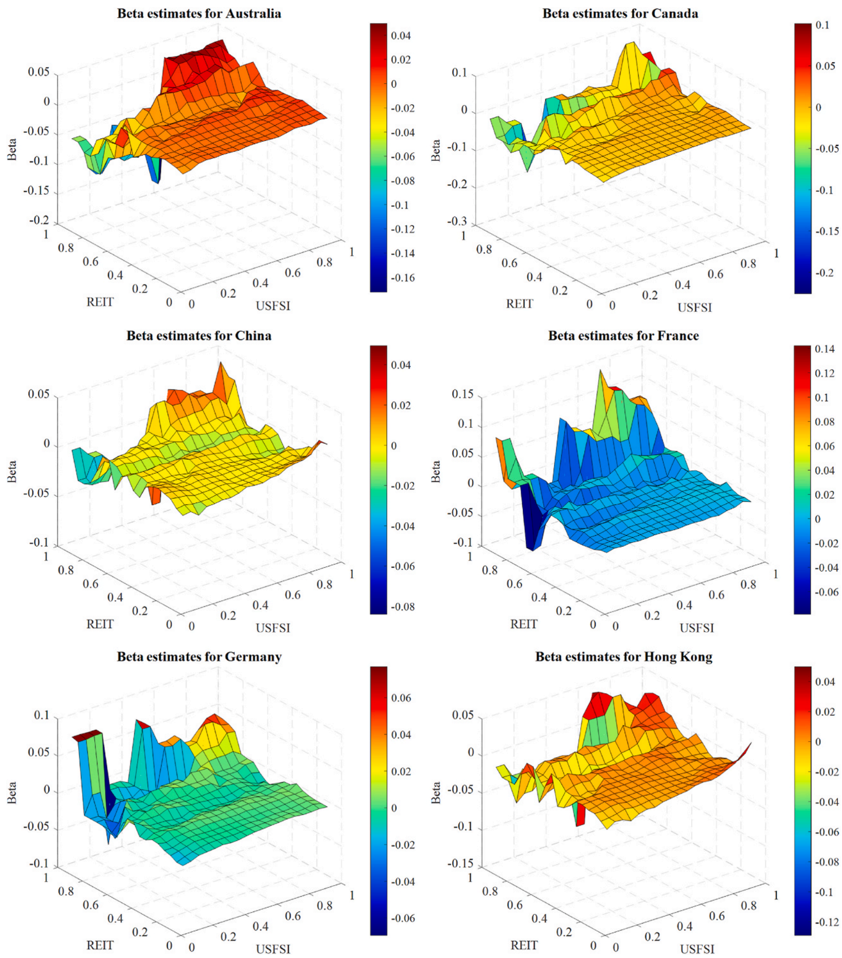

Fig. 2. Represents the 3D plots. The QQR estimates of the slope coefficient of REIT and market stress. The graph estimates of the slope coefficents $\beta_1(\theta, \tau)$ in the z-axis against the quantile financial market stress (θ) in thex axis and the quantile of REIT return (τ) in the y-axis.

of 0.05–0.35 as the bearish market state, 0.4–0.6 as the normal state, and 0.65–0.95 as the bullish market state. Fig. 2 supported numerically in Table 1 in Appendix A, shows the estimates of QQR coefficients for FMS and REITs returns. We observed that at the extreme quantile (left and right tail) FMS and REITs demonstrated a very high degree of interaction with QQR coefficients ranging from 0.65 to 1.75 at the right tail and 0.46 to 1.3 at the left tail compared to the normal market which ranges from 0.24 to 0.45. This implies that there is high interaction between FMS and REIT returns in the extreme quantiles.

In Fig. 2, we observe that the effect of market stress in Australia is negatively related to REIT within the medium and upper quantiles (0.45–0.95) and positively related to REIT within the lower quantiles (0.15–035) with a magnitude of 0.25. We also observed that in Japan, market stress negatively affects REIT return in almost the entire quantile distribution except the medium quantile (0.45–0.50) and the upper quantile (0.85). This inverse relationship between market stress and REIT at the extreme quantile is indicative of limited diversification during the health crisis. Regarding Singapore and Canada, the results are similar in all aspects to those of Japan, but with a high magnitude across the entire quantile distribution except for the lower quantile and medium (0.05 & 0.3, 0.45–0.5) and the upper quantile (0.70 &0.85). We also document that the negative impact of the lower medium quantile for Germany, the Netherlands, the UK, and France on market stress occurs within the quantile range of 0.05–0.60, and is positively related for REITS at the upper quantile. In the case of Hong Kong, New Zealand, and China, we report the positive effect of the low distribution of FMS within the quantiles of 0.05–0.450 and 0.20–0.40. Turning to the USA, we find that the effect of market stress occasioned by COVID-19 is positively related to REIT returns in the bearish and normal market states and is inversely related to the bullish market states. Overall, our results tend to suggest that there is a diversification, safe haven, and hedging prospect in the bullish market state. In general, our finding establishes a strong link between financial market stress and REIT during COVID-19, which is consistent with similar work of (Bossman, Umar, Agyei, & Owusu Junior, 2022; Bossman, Umar, & Teplova, 2022; Chong & Phillips, 2022; Tanrıvermiş, 2020). To get the overall view of the quantile connectedness between FMS and REITs across various quantiles, we employ QVAR to measure the connectedness of the system.

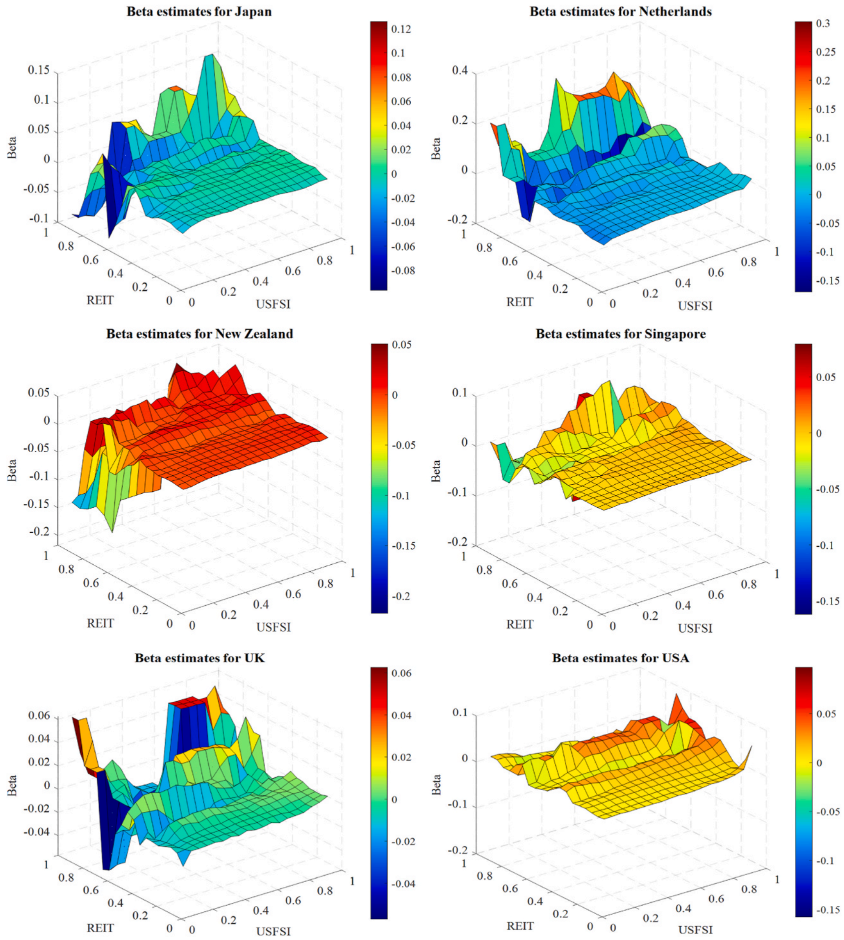

Fig. 2. (*continued*).

5.2. *Extreme spillover connectedness*

We extend our analysis by considering the spillover under extreme market conditions using the quantile connectedness approach under the extreme quantiles of the joint distribution. The return spillover of REITs and FMS indices is carried out based on a 200-day rolling window QVAR model with a lag length of 1(BIC) and a 20-step ahead forecast (Chatziantoniou et al., 2021).

Tables 2–4 in appendix A display the average results of quantile connectedness for extreme downside (left tail $\tau = 0.05$), normal ($\tau = 0.5$) and upside (right tail $= \tau = 0.95$). The two extreme quantiles ($= 0.05$ & $\tau = 0.95$) represent the bear and bull markets, whereas the middle quantiles ($\tau = 0.5$) represent the normal market (Abakah, Tiwari, Lee, & Ntow-Gyamfi, 2023). The primary diagonal elements are one's own contribution, while the off-diagonal is considered the contribution of others (labelled as TO) and the values in each column represent the quantile spillover received from other markets (labelled as FROM). The difference between TO and FROM spillover is captured by the NET in the last row. The total connectedness (TCI) is reported in the bottom right corner of the table.

From Tables 2–4, we observed that the spillover risk in the left tail (93.35%) and the right tail (96.4%) exceeds the spillover reported under normal market conditions (47.54%). This implies that there is an excess risk spillover across the quantile distribution in the same investment horizon (Bouri, Lucey, Saeed, & Vo, 2020). The variation of TCI suggests that the magnitude of risk contagion increases in extreme market states (Zhu, Li, & Huang, 2023). FMS and REITs are more connected in both the bullish and bearish market states. The connectedness between the nexus may be driven by macroeconomic fundamentals as a result of exogenous news.

At the extreme quantiles (left tail and right tail) reported in Tables 2 and 4 in Appendix A, we observe that FMS contributed 58.68% and 92.29% in all REIT regimes in the system indicating a higher transmission in the network at the bearish and bullish market state. The results for extreme quantiles show that the spillover from FMS in the lower and upper quantiles exceeds the spillover reported under normal market conditions. This implies that risk transmission among REIT returns tends to be significantly affected by FMS as a result of exogenous news. Under extreme market conditions, the intensity of risk implies that if market volatility is caused by positive news, it is riskier for international investors to hold the portfolio compared to the normal and bearish market conditions. Notwithstanding the higher transmission rate of FMS in all REIT regimes, we also observed that the percentage contribution is markedly higher at the extreme quantile than they were at the normal market. In the left tail, the UK (97.94%) has the largest contributor, followed by Canada (93.47%), Germany (92.12%), France (91.24%) whereas in the right tail Hong Kong has the largest contributor (98.88%), followed by Japan (96.555), China

(91.7%) Singapore (90.87%).

To comprehend the transmission effect between FMS and REIT returns, we present the network transmission plots in Fig. 3. The results demonstrate a more comprehensive mechanism across all REIT returns over the conditional distribution. In the median quantile (panel B) FMS transmits risk only to the US, whereas in the lower quantile (panel A) FMS is a major risk receiver that receives risk from France, Canada, UK, Singapore, Japan, Germany, and Australia. Finally, the upper quantile (panel C) shows that FMS is a major risk transmitter, transmitting risk towards France, New Zealand, the Netherlands, Germany, the UK, and Canada. We observed that connectedness in the right tail dominates the left tail, so we contend that the REIT returns under this market condition carry a high significant risk for portfolio management. Therefore, investors can create portfolios using information from net-transmitting and net-receivers' for risk management and portfolio diversification. The high connectedness between FMS and REIT during the pandemic period is consistent with similar existing studies by (Armah & Amewu, 2022; Armah et al., 2022, 2023)who documented that FMS impacts real assets.

5.3. Time-varying quantile connectedness

At this point, it is important to mention that the average quantile connectedness summarises the underlying relationship within a network (Nyakurukwa & Seetharam, 2023) and obscure time specific (Ashraful, Chowdhury, Abdullah, & Masih, 2023). A dynamic connectedness is important in this regard as it will reveal a specific significant event during the pandemic period that may vary the connectedness over time.

Fig. 4a shows the dynamic connectedness in the extreme (lower and upper quantiles) and median quantiles. The results demonstrate that the TCI in the upper quantile fluctuates very high, between 92% and 100% compared to the dynamics of connectedness at the median and lower quantile. The strong evolution of connectedness at the right tail of the distribution signifies greater sensitivity between FMS and REITs.

The net directional connectedness in Fig. 4b of the individual variables demonstrates that FMS is a net transmitter at the upper quantile and a net receiver at the lower quantile. The heterogeneous appearance between FMS and REIT as the net transmitter of risk in the upper quantile and the net receiver of risk in the lower quantile suggests that both nexus receive and transmit shocks in an extreme event. Diversification is recommended during these difficult times.

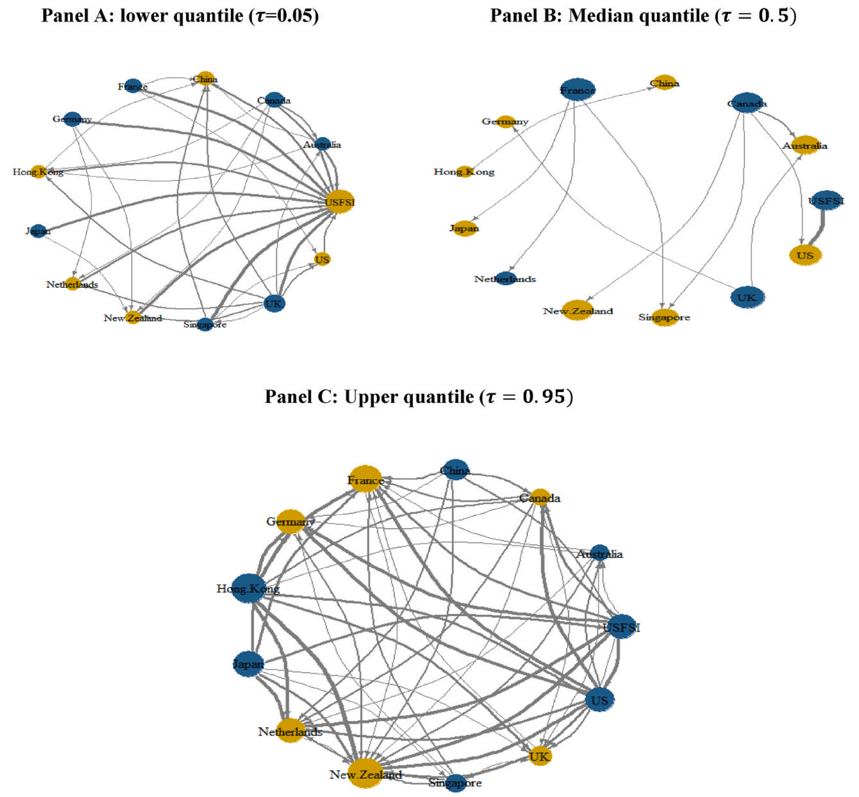

Fig. 3. Net pairwise directional connectedness network at different quantiles τ Note: The blue (yellow) nodes depict the net transmitters (recipients) of the shock, and the size of the nodes indicates the magnitude of net transmission. The direction of arrows indicates spillover between the variables which represent net contributing variables. The thickness of the arrows shows the strength of the transmitter-receiver interaction between the nodes.

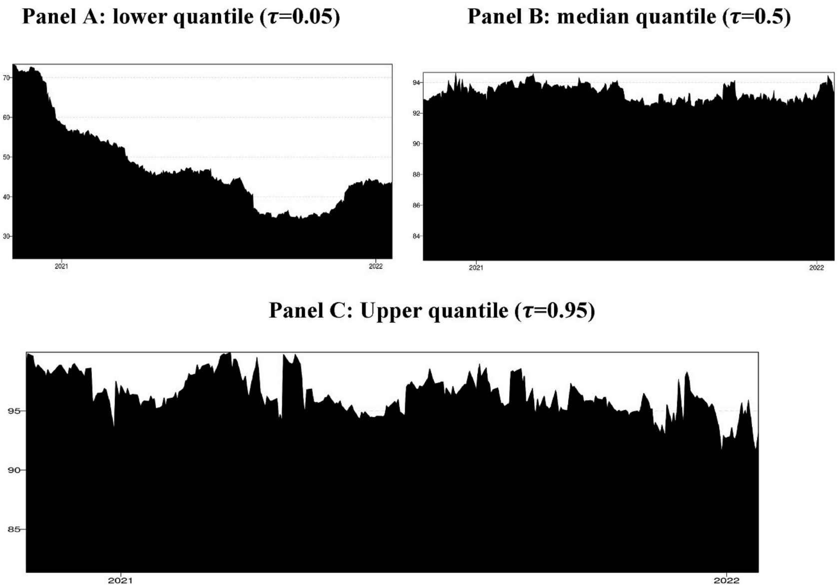

Fig. 4a. Notes: Total dynamic connectedness. The results are based on the TVP-VAR model with a lag length of 1(BIC) and 20-step forward GFEVD. The grey-shaded area represents the maximum and minimal TCI forecast variance.

5.4. Discussion and policy implications

It should be noted that the heterogeneity of international financial markets is mainly due to the reaction of investors, which exacerbates market stress (Armah et al., 2022), and the mechanism of risk transfer through diversification becomes affected (Jena, Tiwari, Hammoudeh, & Roubaud, 2019). This suggests why, in times of high risk and systemic crises, it is necessary to determine how various assets and classes react to risk pressures at different trading horizons (Asafo-Adjei, Bossman, et al., 2022). From the precept of asset pricing theory based on the expectation hypothesis, Fama (1970) states that the future price is efficient and unbiased by the predictor of expected prices. This hypothesis is practicable under different market conditions and therefore cannot be compromised in the application of this study. Our finding contributes new empirical evidence to support the importance of market conditions during the pandemic period in identifying diversification opportunities. In an extreme market downturn, survival and tracking of REIT performance are important for investors in risk management strategies. Thus, we infer that the diversification benefit of investing in REITS is germane for Germany, France, New Zealand, UK and Canada in the upper quantile. This finding confirms the results that have been reported by existing studies, mainly outlining the connectedness of market stress and REIT amplifes in the presence of global significant events such as COVID-19 (Lesame et al., 2021; Rehman et al., 2022). The findings are consistent with the existing literature that emphasises the practicability of information efficiency in the future market and under different conditions (Chong & Phillips, 2022; Hoesli & Oikarinen, 2012; Jena et al., 2019; Kumah & Odei-Mensah, 2022; Owusu Junior et al., 2020). This study also confirms Müller et al. (1993) heterogeneous market hypothesis, arguing that asset markets are linked to changes in time, especially during an economic event.

6. Conclusions

We investigate the quantile dependence and asymmetry connectedness between FMS and REIT for the top 12 REIT regimes in America, Europe, and Asia. Our study stretches from February 2, 2020 to January 20, 2022, a period that covers different COVID-19 waves to establish frequency-dependent asymmetric connectedness between the nexus. We employ QQR from Sim and Zhou (2015) to examine the effect of shock between REIT and FMS across market states. We found that in the bearish and bullish market states, FMS are inversely and positively related to the REIT returns and within the left and right tail. The implication to be drawn from this finding is that, in an extreme bearish and bullish market condition, the market participant should observe the conditional state of market dynamics and its associated policies for risk management and diversification strategies in real estate investment. When considering the connectedness in extreme quantiles, we found that in the median quantile ($\tau = 0.5$) FMS transmits risk only to US, whereas in the lower quantile ($\tau = 0.05$) FMS is a major risk receiver that receives risk from France, Canada, UK, Singapore, Japan, Germany, and Australia. Finally, the upper quantile ($\tau = 0.95$) shows that FMS is a major risk transmitter, which transmits risk towards France, New Zealand, the Netherlands, Germany, the UK, and Canada. The application of a time-varying analysis shows that the tail interdependence changes over time and responds to different waves in COVID-19. Overall, our result suggests a positive relationship between FMS and REITs, particularly during the extreme stress period.

Our results show the importance of modelling the interconnectedness between FMS and REIT returns at different quantiles to determine how the connectedness of FMS and REIT evolves in different markets during the health systemic crisis. For investors and portfolio managers operating in these markets, the role shifts of links and returns (positive, negative) in various quantiles during systematic risk

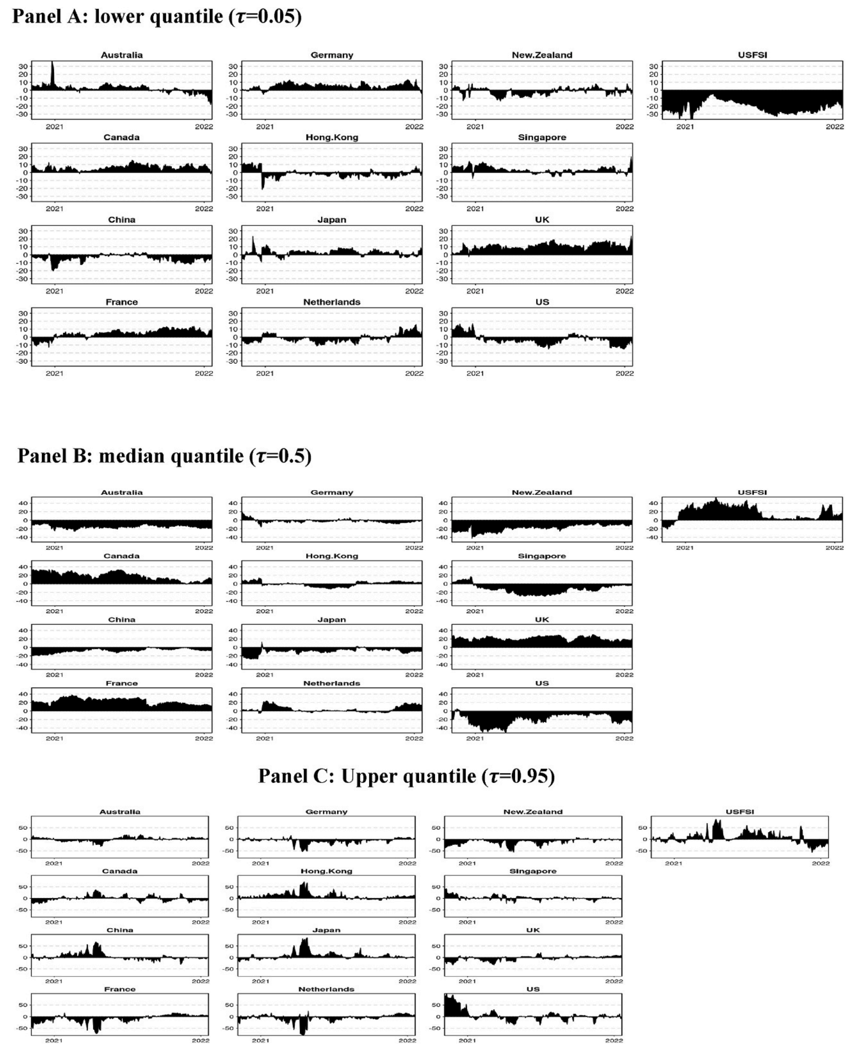

Fig. 4b. Notes:Net directional connectedness. The results are based on TVP-VAR model with a lage length of 1(BIC) and 20-step-ahead GFEVD. The grey-shaded area represents the maximum and minimal TCI forecast variance.

underscore the importance of portfolio management. The study is limited to a single FSI, that is, in the US, in the future, time frequency may be used to explore emerging market economies that are more vulnerable to shocks in real estate business during economic events.

CRediT authorship contribution statement

Mohammed Armah: Conceptualization, Methodology, Validation, Formal analysis, Data curation, Writing – original draft, Writing – review & editing. **Godfred Amewu:** Conceptualization, Validation, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declared that there are no conflicts of interest.

Data availability

Data will be made available on request.

Appendix A

Table 1
Quantile-on-Quantile estimates for REIT returns and financial market stress

τ	Australia	Canada	China	France	Germany	Hong.Kong	Japan	Netherlands	New.Zealand	Singapore	UK	US
0.05	−0.0005	−0.0022	0.0027	−0.0031	−0.0021	0.0028	−0.0032	−0.0022	−0.0001	0.0006	−0.0034	0.0083
0.10	−0.0002	−0.0020	0.0020	−0.0026	−0.0016	0.0013	−0.0027	−0.0030	0.0011	−0.0001	−0.0026	0.0047
0.15	0.0000	−0.0015	0.0011	−0.0028	−0.0010	0.0005	−0.0018	−0.0038	0.0016	−0.0012	−0.0020	0.0041
0.20	0.0000	−0.0008	0.0010	−0.0022	−0.0004	−0.0003	−0.0014	−0.0048	0.0012	−0.0014	−0.0012	0.0076
0.25	0.0001	0.0002	0.0018	0.0001	0.0014	0.0002	−0.0002	−0.0025	−0.0002	−0.0001	0.0006	0.0115
0.30	0.0002	0.0009	0.0006	0.0000	0.0030	0.0003	−0.0002	−0.0020	−0.0008	0.0011	0.0018	0.0145
0.35	0.0031	−0.0013	−0.0033	−0.0054	0.0011	−0.0020	−0.0003	−0.0090	0.0002	−0.0004	−0.0019	0.0253
0.40	0.0014	−0.0039	−0.0032	−0.0071	−0.0021	−0.0027	−0.0018	−0.0093	−0.0013	−0.0001	−0.0086	0.0241
0.45	−0.0015	−0.0022	0.0020	−0.0018	−0.0031	0.0007	0.0009	0.0009	−0.0069	0.0025	−0.0032	0.0078
0.50	−0.0017	0.0042	0.0034	0.0022	−0.0015	0.0060	0.0042	0.0055	−0.0008	0.0044	0.0079	0.0083
0.55	−0.0069	−0.0034	−0.0040	−0.0057	−0.0019	−0.0048	−0.0018	−0.0093	0.0047	−0.0051	0.0001	0.0146
0.60	−0.0068	−0.0082	−0.0098	−0.0104	−0.0027	−0.0140	−0.0177	−0.0091	0.0033	−0.0134	−0.0011	0.0214
0.65	0.0125	0.0100	−0.0043	−0.0057	−0.0009	−0.0042	−0.0137	0.0234	−0.0033	−0.0051	0.0067	0.0407
0.70	0.0067	0.0070	0.0005	−0.0039	−0.0001	0.0066	0.0095	0.0170	0.0029	0.0027	0.0019	0.0342
0.75	−0.0024	−0.0222	−0.0002	−0.0046	−0.0007	0.0026	−0.0031	−0.0708	0.0098	−0.0138	−0.0134	0.0132
0.80	−0.0195	−0.0396	0.0019	−0.0020	−0.0038	−0.0110	−0.0119	−0.0633	0.0188	−0.0049	−0.0178	−0.0081
0.85	−0.0274	−0.0212	0.0046	0.0254	0.0097	−0.0058	0.0143	0.0303	0.0034	0.0246	0.0139	−0.0098
0.90	−0.0445	−0.0145	−0.0033	0.0494	0.0399	−0.0075	−0.0117	0.1324	−0.0310	−0.0105	0.0220	−0.0415
0.95	−0.0524	−0.0895	−0.0196	0.0434	0.0238	−0.0282	−0.0129	0.1621	−0.1064	−0.0616	0.0069	−0.0674

Notes; The table shows the average conditional(QQ) relationship between financial market stress REIT return. The significance of QQR coefficients is not incorporated into non-parametric models. Therefore, the QQR results are verified by estimating QR. The estimate for entire QQR distribution for FMS and REIT return are not reported. This will be provided upon request.

Table 2
Average spillover connectedness at the lower quantile($\tau = 0.05$)

	USFSI	Australia	Canada	China	France	Germany	Hong.Kong	Japan	Netherland	New.Zealand	Singapore	UK	US	FROM
USFSI	19.6	6.61	6.43	6.53	6.3	6.95	6.2	6.65	6.01	7.33	6.9	6.6	7.89	80.4
Australia	4.88	12.67	8.59	6.21	7.42	8.12	6.57	8.18	6.76	7.22	7.8	8.64	6.92	87.33
Canada	4.72	7.69	12.46	6.67	7.84	8.3	7	7.66	7.4	7.06	7.61	8.57	7.02	87.54
China	4.82	6.94	7.16	14.53	6.95	7.54	10.06	7.17	6.33	6.86	7.85	7.43	6.36	85.47
France	4.23	7.26	8.21	6.11	13.12	7.5	6.41	7.04	10.15	7.13	6.95	9.98	5.92	86.88
Germany	5.2	7.65	8.18	7.03	7.55	12.99	7.49	7.34	6.73	6.83	7.33	8.33	7.35	87.01
Hong. Kong	4.59	7.31	7.62	9.22	6.78	7.83	12.8	8.06	6.59	6.91	8.26	7.69	6.33	87.2
Japan	4.61	8.35	7.75	6.88	7.02	7.69	7.61	13.2	6.97	6.72	8.19	8.05	6.96	86.8
Netherlands	4.38	6.91	8.12	5.96	10.59	7.38	6.52	7.2	13.31	6.88	7.48	9.16	6.11	86.69
New.Zealand	5.35	7.66	7.73	6.62	7.54	7.62	6.96	7.49	6.91	13.82	7.51	8.09	6.69	86.18
Singapore	4.72	7.72	7.96	6.96	7.31	7.58	7.91	8.06	7.02	7.43	12.68	8.03	6.69	87.38
UK	4.47	7.82	8.52	6.36	9.43	7.95	6.71	7.51	8.14	6.89	7.39	12.4	6.41	87.6
US	6.73	7.3	7.21	6.57	6.51	7.65	6.43	7.03	6.33	7.16	7.4	7.37	16.33	83.67
TO	58.68	89.21	93.47	81.11	91.24	92.12	85.88	89.4	85.34	84.41	90.68	97.94	80.67	1120.15
Inc.Own	78.29	101.89	105.93	95.65	104.36	105.11	98.67	102.6	98.64	98.2	103.3	110.34	97	cTCI/TC
NET	−21.71	1.89	5.93	−4.35	4.36	5.11	−1.33	2.6	−1.36	−1.7	7.3	10.34	−3	93.35/86.17

Notes: REITs and FMS indices are carried out based on a 200-day rolling window QVAR model with a lag length of 1(BIC) and a 20-step ahead forecast(Chatziantoniou et al., 2021).

Table 3
Average spillover connectedness at the lower quantile($\tau = 0.5$)

	USFSI	Australia	Canada	China	France	Germany	Hong.Kong	Japan	Netherlands	New.Zealand	Singapore	UK	US	FROM
USFSI	87.36	0.59	1.91	0.13	0.86	0.52	1.26	1.000	0.71	0.31	0.66	1.04	3.64	12.64
Australia	1.77	49.15	9.31	0.98	5.33	5.81	2.65	7.07	3.09	1.39	2.86	10.03	0.55	50.85
Canada	1.41	4	50.51	1.23	9.51	4.57	2.79	2.93	6.42	1.4	2.57	11.97	0.69	49.49
China	0.73	0.68	2.63	64.3	1.21	2.4	19.67	1.84	0.66	0.69	2.98	1.83	0.37	35.7
France	1.14	3	7.39	0.6	38.33	3.15	1.63	1.78	21.12	0.87	2.69	17.76	0.55	61.67
Germany	1.23	4.32	5.55	2.27	4.81	60.94	4.23	2.08	2.63	1.14	2.1	8.09	0.61	39.06
Hong.Kong	1.66	2.09	4.55	16	2.78	3.43	50.34	4.55	2.28	1.07	7.27	3.4	0.59	49.66
Japan	1.33	6.39	4.94	1.42	5.25	2.25	4.11	55.06	4.4	0.75	6.62	6.13	1.34	44.94
Netherlands	0.61	2.04	6.35	0.35	24.84	2.17	1.53	2.12	44.61	1.06	2.36	11.12	0.83	55.39
New.Zealand	2.41	1.86	4.61	1.17	3.43	3.52	1.37	2.04	2.86	69.82	2.32	3.7	0.89	30.18
Singapore	1.29	2.96	7.23	2.64	5.9	3.65	7.19	5.91	3.91	1.43	51.59	5.73	0.57	48.41
UK	0.83	6.17	9.58	0.94	18.43	4.84	2.38	3.36	10.28	1.16	3.02	38.4	0.61	61.61
US	15.67	1.35	3.8	0.41	2.21	0.78	0.77	1.47	1.33	0.73	0.65	1.7	69.13	30.87
TO	30.07	35.45	67.85	28.15	84.56	37.08	49.59	36.16	59.7	11.99	36.09	82.52	11.25	570.45
Inc.Own	117.44	84.6	118.36	92.44	122.89	98.01	99.93	91.22	104.31	81.82	87.68	120.92	80.38	cTCI/TCI
NET	17.44	−15.4	18.36	−7.56	22.89	−1.99	−0.07	−8.78	4.31	−18.18	−12.32	20.92	−19.62	47.54/43.88

Notes: REITs and FMS indices are carried out based on a 200-day rolling window QVAR model with a lag length of 1(BIC) and a 20-step ahead forecast(Chatziantoniou et al., 2021).

Table 4
Average spillover connectedness at the upper quantile($\tau = 0.95$)

	USFSI	Australia	Canada	China	France	Germany	Hong.Kong	Japan	Netherland	New.Zealand	Singapore	UK	US	FROM
USFSI	14.16	7.3	7.26	8.07	5.34	6.33	8.87	8.45	5.91	6.45	7.26	6.34	8.26	85.84
Australia	7.72	10.72	7.29	7.19	6.9	7.27	7.84	8.01	6.98	6.65	7.71	7.39	8.34	89.28
Canada	8.21	7.38	10.32	7.48	6.77	7.02	8.31	7.87	6.79	6.65	7.42	7.49	8.3	89.68
China	7.46	7.1	6.82	1.94	6.39	6.98	9.34	7.99	6.6	6.97	7.56	6.64	8.23	88.06
France	6.28	7.42	7.66	7.13	10.35	7.07	7.46	7.64	8.92	6.43	7.6	8.75	7.28	89.65
Germany	7.78	7.64	7.55	7.43	6.83	10.06	8.29	7.9	6.99	6.55	7.6	7.38	8.01	89.94
Hong.Kong	8.7	7.24	7.52	9.08	6.07	6.85	10.6	8.67	6.36	6.38	8.11	6.78	7.64	89.4
Japan	7.31	7.81	7.96	7.68	6.71	6.76	8.33	10.83	6.89	6.6	7.73	7.47	7.92	89.17
Netherlands	7.13	7.38	7.4	7.38	8.56	6.69	7.68	8.14	10.21	6.6	7.53	7.88	7.44	89.79
New.Zealand	7.89	7.35	7.04	7.73	6.85	7.22	7.9	7.67	7.02	10.71	7.56	6.96	8.12	89.29
Singapore	7.36	7.44	7.15	7.69	6.71	7.18	8.36	8.14	6.83	6.88	11.09	6.84	8.36	88.91
UK	6.76	7.85	8.03	6.95	8.33	7.41	7.79	7.85	7.8	6.15	7.36	10.66	7.04	89.34
US	9.69	7.54	6.99	7.96	5.89	6.72	8.72	8.23	6.35	6.64	7.45	6.37	11.44	88.56
TO	92.29	89.44	88.66	91.77	81.34	83.5	98.88	96.55	83.43	78.9	90.87	86.28	94.95	1156.9
Inc.Own	106.45	100.16	98.98	3.71	91.69	93.55	109.48	107.39	93.63	89.65	101.95	96.94	106.39	cTCI/TCI
NET	6.45	0.16	−1.02	3.71	−8.31	−6.45	9.48	7.39	−6.37	−10.35	1.95	−3.06	6.39	96.41/88.

Notes: REITs and FMS indices are carried out based on a 200-day rolling window QVAR model with a lag length of 1(BIC) and a 20-step ahead forecast(Chatziantoniou et al., 2021).

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