

TIME-FREQUENCY AND QUANTILE ANALYSIS OF UNCERTAINTY INDICATORS' EFFECTS ON THE US REIT MARKET: EVIDENCE FROM WAVELET-BASED APPROACHES

Hongjun ZENG^{1#}, Huifang LIU², Han YAN³, Shenglin MA^{4*}

¹ Department of Financial Planning and Tax, School of Accounting, Information Systems and Supply Chain, RMIT University, Melbourne, Australia

² School of Economics and Management, Shandong Youth University of Political Science, Jinan, China

³ School of Business, Nankai University, Tianjin, China

⁴ School of Economics and Management, North University of China, Taiyuan, China

Article History:

- received 22 February 2025
- accepted 13 October 2025

Abstract. This paper employed wavelet coherence analysis, wavelet quantile correlation and wavelet local multiple correlation to systematically investigate the influence of multiple types uncertainty indicators on the US REITs market. The findings revealed significant time-frequency characteristics and quantile dependencies between different types of uncertainty indicators and the REITs market: geopolitical risk exhibited a safe-haven function at medium-high quantiles in high-frequency bands; market volatility showed a significant negative correlation with REITs across all quantiles in the lowest frequency band; economic policy uncertainty was positively correlated with REITs at medium-high quantiles in medium-frequency bands; financial stress was negatively correlated with REITs at most quantiles in medium-frequency bands; and commodity market uncertainty demonstrated a pronounced frequency-quantile dependency. The multivariate WLMC analysis reveals that uncertainty indicators exhibit frequency-dependent dominance patterns, with FSI dominating long-term impacts, VIX and FSI alternating in medium-term frequencies. Particularly during the COVID-19 crisis, the associations between these uncertainty indicators and the REITs market were generally enhanced and exhibited persistence in the medium-to-long-term frequency domain. The findings of this study not only enriched the theoretical understanding of the relationship between REITs markets and macroeconomic uncertainty but also provided important empirical evidence for investors' risk management and policymakers' market regulation.

Keywords: REITs market, uncertainty indicators, wavelet coherence analysis, wavelet quantile analysis.

* Corresponding author. E-mail: shenglinma5364@yeah.net

The first author's current institution is the Department of Finance, College of Finance, Nanjing Agricultural University, 210095 Nanjing, China

1. Introduction

The rapid development of global financial markets and the increasing uncertainty have significantly heightened investors' demand for investment instruments with stable cash flows and diversification advantages (Shang et al., 2024; Ma et al., 2025). Real Estate Investment Trusts (REITs), as a unique investment vehicle, provide investors with a channel to obtain real estate returns while maintaining high liquidity through the securitisation of real property (Baum, 2021; Ying et al., 2025). Since the US Congress passed REITs-related legislation in 1960, REITs have evolved into a global investment product. As of 2023, the total market value of global REITs exceeded US\$2 trillion, with the US REITs market, the largest and most mature globally, accounting for nearly 60% of the market share. The performance of the US REITs market not only profoundly influences global investors' asset allocation decisions but

is also regarded as an important indicator of the overall health of the real estate market. Specifically, REITs, subject to unique regulatory requirements such as distributing at least 90% of taxable income to shareholders, exhibit investment characteristics such as high dividend yields and relatively stable cash flows. Consequently, REITs have assumed an increasingly important role in the investment portfolios of both institutional and individual investors.

In recent years, the global economy has faced unprecedented multiple types uncertainties. Since 2018, the escalation of the US-China trade conflict has significantly increased global economic policy uncertainty (Ma & Appolloni, 2025; Zhang et al., 2019). The outbreak of COVID-19 in 2020 triggered a global public health crisis and caused severe financial market volatility (Zeng et al., 2025b). The Russia-Ukraine conflict in 2022 further exacerbated geopolitical risks and drove substantial fluctuations in global energy and commodity prices (Zeng et al., 2024).

Meanwhile, the monetary policies of major global economies have experienced a significant shift from extreme easing to rapid tightening, particularly the Federal Reserve's aggressive interest rate hike cycle initiated in 2022, which has introduced substantial uncertainty into financial markets. These macroeconomic uncertainties influence financial market volatility through various channels. Existing research indicates that economic policy uncertainty has a significant impact on asset prices and investor behaviour, potentially leading to increased risk premia, delayed investment decisions, and reduced market liquidity (Jackson & Orr, 2019; Ke et al., 2025). However, such research has predominantly focused on the stock market, with relatively limited attention paid to the REITs market. Given REITs' dual nature—exhibiting characteristics of both equities and real estate—different types of uncertainty may affect the REITs market through more complex mechanisms. On one hand, as publicly traded securities, REITs are influenced by market sentiment and macroeconomic factors similar to common stocks. On the other hand, their underlying real estate assets mean that REITs' performance is also closely related to real estate market fundamentals and long-term economic trends. This dual nature underscores the theoretical and practical significance of investigating the impact of uncertainty on the REITs market.

In the past decade, significant advancements have been made in the measurement of uncertainty. In addition to traditional market volatility indicators, researchers have developed a variety of specialised uncertainty indicators that capture the diverse uncertainties faced by economic and financial markets from different perspectives. These indicators provide rich data support for studies on the impact of uncertainty. The multiple types nature of market uncertainty makes it particularly important to comprehensively assess its impact on the REITs market. For example, the VIX index, known as the "fear index," not only reflects the expected volatility of the stock market but is also widely used as a barometer of overall market sentiment (Lu & Zeng, 2023; Zeng et al., 2025a). The OVX and GVZ indices, representing the volatility of the energy and gold markets respectively, are potentially related to the real estate industry (Shahid et al., 2023; Wu et al., 2025). Fluctuations in energy prices affect real estate operating costs, while gold, as a safe-haven asset, may reflect investors' allocation demands for physical assets through its volatility. The Financial Stress Index (FSI), which integrates multiple types financial market indicators, provides a comprehensive measure of systemic risk and helps to understand how financial stress is transmitted to the REITs market (Armah et al., 2022). The Economic Policy Uncertainty (EPU) and Geopolitical Risk (GPR) indices characterise macroeconomic uncertainty from policy and international relations perspectives, respectively. These factors may influence REITs performance through channels such as investor expectations and financing costs (Bossman et al., 2023). In the current context of multiple types challenges facing the global economy, understanding how different types of

uncertainty collectively impact the REITs market is of significant guiding importance for investors' risk management and asset allocation decisions.

Traditional studies have primarily employed linear models to analyse the relationship between uncertainty and asset returns, such as Vector Autoregression (VAR) and Generalised Autoregressive Conditional Heteroskedasticity (GARCH) models. However, these methods have several limitations. First, they struggle to capture dynamic associations across different time scales (Ben Amor et al., 2025). Second, they typically assume linear relationships between variables, neglecting the non-linear characteristics prevalent in financial markets (Rubio et al., 2023). Third, they are unable to effectively characterise tail correlations under extreme market conditions (Yang et al., 2025). In contrast, the wavelet coherence estimation employed in this work offers significant advantages. This method allows for the simultaneous analysis of correlations between variables in both the time and frequency domains, revealing association characteristics across different investment horizons (Basdekis et al., 2022; Ahmed, 2022). Additionally, wavelet quantile correlation analysis can characterise non-linear dependencies under different market conditions, particularly the correlation structure under extreme market conditions, providing a new perspective for understanding the transmission structures of uncertainty (Patel et al., 2023). Furthermore, the Wavelet Local Multiple Correlation (WLMC) methodology extends beyond traditional wavelet coherence by enabling multivariate analysis within a unified framework. This approach addresses a critical limitation of bivariate analyses where observed relationships may conflate direct effects with indirect spillovers mediated through correlated uncertainty measures (Polanco-Martínez et al., 2020). WLMC simultaneously incorporates multiple variables to isolate each indicator's net contribution whilst accounting for interdependencies, thereby providing more accurate identification of transmission mechanisms. Additionally, the dominant variable identification capability within WLMC reveals which uncertainty source exerts the strongest influence at each time-frequency location, offering crucial insights for dynamic risk management that cannot be obtained through sequential bivariate comparisons (Zeng et al., 2024).

This study makes the following contributions to the existing literature. First, it is the first to systematically examine the comprehensive impact of multiple types uncertainty indicators, including the VIX, on the US REITs market, revealing potential synergistic effects between different types of uncertainty. Second, through wavelet coherence analysis, this study identifies dynamic associations between uncertainty and REITs returns across different time scales, which is of significant practical importance for investors with varying investment horizons. Third, using wavelet quantile correlation analysis, this study explores the transmission effects of uncertainty under extreme market conditions, offering important insights for risk management and market regulation. By employing multivariate WLMC analysis to simultaneously control for multiple

uncertainty sources, this study isolates each indicator's independent contribution to REITs market dynamics across different time-frequency domains. These findings not only enrich the theoretical understanding of the relationship between REITs markets and macroeconomic uncertainty but also provide important empirical evidence for investors to formulate investment strategies and for policymakers to conduct market regulation.

The study's results reveal that the relationships between uncertainty indicators and the REIT market exhibit significant time-frequency characteristics, quantile dependencies, and dynamic evolution. First, Geopolitical Risk (GPR) demonstrated a safe-haven function at medium-high quantiles in high-frequency bands, particularly in the short-to-medium-term frequency domains during 2015–2016 and 2020–2021. Second, market volatility (VIX) showed a significant negative correlation across all quantiles in the lowest frequency band, with this negative impact intensifying in the medium-to-long-term frequency domain during the COVID-19 period (2020–2022). Moreover, volatility changes preceded REIT market adjustments. Third, Economic Policy Uncertainty (EPU) exhibited a positive correlation at medium-high quantiles in medium-frequency bands, with this influence persisting in the long-term frequency domain after 2020 and policy changes leading market reactions. Fourth, Financial Stress (FSI) showed a negative correlation at most quantiles in medium-frequency bands and maintained a stable strong correlation with REITs in the medium-to-long-term frequency domain (64–256 days) after COVID-19. Fifth, the impact of commodity market uncertainty (OVX and GVZ) demonstrated pronounced frequency-quantile dependency, with this relationship significantly strengthening during the pandemic period, particularly in the medium-to-long-term frequency. Overall, the associations between all uncertainty indicators and REITs were generally enhanced after COVID-19, indicating that uncertainty factors had a more noticeable and persistent influence on the REIT index during the crisis.

The following sections include the literature review, methodology and data, interpretation of empirical analysis results, and conclusions.

2. Literature review

Real Estate Investment Trusts (REITs), as a unique asset class, hold significant importance in global financial markets, particularly in the United States, where their market maturity and liquidity make them an essential tool for portfolio diversification (Zeng, 2026). However, the performance of REITs is driven not only by the fundamentals of the real estate market but also by macroeconomic conditions and financial market volatility. In recent years, economic and financial uncertainty has become a focal point of research due to its increasingly evident impact on asset prices, investor behaviour, and market dynamics. This review synthesises relevant literature into two main streams: the interactive ef-

fects of REITs with other financial markets, and the specific impacts of economic and financial uncertainty indices on financial markets, particularly REITs. While a growing body of literature has begun to explore this nexus, such as the work by Charif et al. (2022) which investigated the impact of EPU on US REIT ETFs using a quantile framework, our study contributes by providing a more comprehensive and nuanced analysis. This paper distinguishes itself from previous research, including Charif et al. (2022), primarily by simultaneously examining a broader spectrum of uncertainty indicators—encompassing not only economic policy but also financial market and geopolitical risks. Furthermore, our research utilises a more encompassing US REIT index rather than focusing solely on ETFs. This multifaceted approach allows us to systematically dissect and compare the heterogeneous impacts of different uncertainty sources on the broader REIT market, thereby offering a more granular understanding of the risk landscape.

2.1. The interactive effects of REITs with other financial markets

As a hybrid asset class, the relationship between REITs and other financial markets has been a key area of research. Existing literature indicates that REIT returns are correlated with stock market performance. For example, Laopodis (2009) analysed US market data and found a positive correlation between REIT and stock market returns, especially during economic expansions. REITs were found to act as a hedge against stock market volatility, although their effectiveness varied across different economic cycles. Similarly, Liu et al. (2012) employed a DCC-GARCH model to examine the time-varying correlations between REIT markets in the US, Australia, Hong Kong, Japan, and Singapore. They found that these correlations were significantly influenced by factors such as inflation rates, global stock market uncertainty, US default risk premiums, and trading volumes, with currency conversion having minimal impact on the dynamics.

The impact of REITs on real estate market liquidity has also garnered attention. Morri and Parri (2017) discovered that asset tangibility was positively correlated with crises, while operating risk was negatively correlated with growth opportunities. Financial economic crises (FEC) intensified these effects, with the trade-off theory (TOT) dominating the explanation of financing decisions. DiBartolomeo et al. (2021) found that equity REITs, due to their high cash dividend requirements, exhibited negative sensitivity to market liquidity shocks. Compared to non-REIT real estate firms, REIT prices rose relatively during liquidity declines, a characteristic independent of property type and more pronounced among small REITs with high dividend frequencies. This suggests that REITs' mandatory dividend requirements reduced investors' liquidity risk. Downs and Zhu (2022) analysed REIT samples and found that holding more cash and having higher property market liquidity both enhanced REIT stock liquidity, particularly in environments with low growth opportunities.

2.2. The impact of uncertainty indices on financial markets

The impact of uncertainty indices (such as economic policy uncertainty and financial uncertainty) on financial markets has been a hot topic in recent years, especially their potential influence on REIT indices. Existing literature shows that uncertainty indicators significantly affect REIT returns, volatility, and investor sentiment. For instance, Alcock and Steiner (2018) found that small REITs with low systemic risk, low short-term momentum, low turnover, and high growth opportunities exhibited strong long-term momentum. Leverage was identified as the primary driver of asymmetric risk, significantly influencing REIT returns, particularly during crises. Cepni et al. (2021) applied a proxy SVAR framework to research the influence of uncertainty shocks on REIT from 1972 to 2015. They found that the negative effects of uncertainty shocks were more pronounced in the post-global financial crisis (GFC) period, surpassing the impact of news shocks, and that pre-GFC effects were overestimated, contrary to intuition. Similarly, Wang et al. (2023) combined oil price uncertainty indicators (oil RV and implied volatility, i.e., oil VIX) to predict the realised variance (RV) of REITs in ten major markets and regions. The results showed significant improvements in predictive performance, both statistically and economically.

Building on Harper et al. (2025), who demonstrate that market sentiment influences investor uncertainty through implied volatility dynamics, understanding these uncertainty-return relationships provides practical investment implications. Demiralay and Kilincarslan (2024) employed a nonlinear Markov method to research the influence of uncertainty indicators on US REIT returns, finding that the effects varied by institution and industry. In bear markets, office and hotel REITs were most sensitive, while residential and healthcare REITs exhibited different responses, revealing asymmetric nonlinear relationships.

Investor sentiment is also significantly affected in uncertain environments. Huerta et al. (2016) found that institutional investor sentiment had a more pronounced asymmetric impact on REIT returns and volatility than individual investors. Institutional bearish expectations had a more significant negative impact on returns and volatility, reflecting systematic risk from noise trading and loss-aversion tendencies. Letdin et al. (2022) emphasised that over half of the cross-sectional variation in REIT net asset value premiums could be explained by firm characteristics. Sentiment-driven components were negatively correlated with future returns, while characteristic-driven components showed a weak positive correlation. A long-short strategy based on sentiment-driven premiums yielded 9% annually, highlighting the key role of investor sentiment in REIT pricing. Chiang and Tsai (2023) used a threshold error correction model to examine the asymmetric adjustment behaviour and causal relationships between REIT and stock prices under different regimes defined by investor sentiment indicators (such as VIX, VXO, put-call ratios, and Google search indices). They found that the REIT market

adjusted more efficiently than the stock market, especially during periods of strong sentiment, and that bidirectional causal relationships existed in most cases.

These findings suggest that systematic tracking of uncertainty indices can enable investors to better anticipate REIT market movements and adjust portfolio allocations accordingly, potentially reducing personal uncertainty in investment decisions as highlighted by Harper et al. (2025). Despite the insights provided by the above studies, several controversies remain in the literature regarding the relationship between REITs and uncertainty indicators. Additionally, there is ongoing debate about the selection of uncertainty indicators and their impact mechanisms on REITs. For example, different types of uncertainty (economic, financial, political) may have varying effects on REITs, but consensus has yet to be reached in the existing literature. This study further explores the asymmetric impact of different uncertainty indicators on the US REIT index to fill the research gap.

3. Methodology and data

3.1. Wavelet coherence

In a framework encompassing both temporal and frequency dimensions, the correlation and temporal precedence relationship between REIT and uncertainty indices were examined through the application of wavelet coherence estimation, as per the methodology outlined by Torrence and Compo (1998).

The wavelet coherence as,

$$R_{xy}^2(a, b) = \frac{\left| S(b^{-1}W_{xy}(a, b)) \right|^2}{S(b^{-1}W_x(a, b))^2 S(b^{-1}W_y(a, b))^2}, \quad (1)$$

where $W_{xy}(a, b) = W_x(a, b)\overline{W_y(a, b)}$ is the cross wavelet transform, then S indicates the smoothing coefficient, $0 \leq R_{xy}^2(a, b) \leq 1$.

Next the phase difference of the wavelet is given by the following equation,

$$\phi_{xy} = \arctan \left(\frac{\text{Im} \left[S(b^{-1}W_{xy}(a, b)) \right]}{\text{Re} \left[S(b^{-1}W_{xy}(a, b)) \right]} \right),$$

with $\phi_{xy} \in [-\pi, \pi]$, (2)

where Im and Re point out the imaginary part and real section of the spectrum of smooth power, respectively. ϕ_{xy} can show the correlation and forward lag (causality) of two indices.

3.2. Wavelet quantile

Kumar and Padakandla (2022) combined the Quantile Correlation (QC) approach to the Wavelet QC (WQC). This new structure obeying for a more concise measure of the link between two assets, L and S . $Q_{\tau, L}$ correspond to the τ^{th}

quantile of L , and $Q_{\tau,S}(L)$ is with the τ^{th} quantile of S , suppose that L as the requirement. Next, it need to focus on that L function is independent.

Quantile covariance as,

$$q_{\text{cov}_t}(S, L) = \text{cov} \left\{ I(S - Q_{\tau,S} > 0, L) \right\} = E \left(\varphi_{\tau}(S - Q_{\tau,S})(L - E(S)) \right), \tag{3}$$

where $0 < \tau < 1$.

$$\varphi_{\tau}(w) = \tau - I(w < 0). \tag{4}$$

The QC,

$$q_{\text{cov}_t}(S, L) = \frac{q_{\text{cov}_t}(S, L)}{\sqrt{\left(\text{var}(\varphi_{\tau}(S - Q_{\tau,S})) \text{var}(L) \right)}}. \tag{5}$$

Then we need to decompose the pairs L_t and S_t at quantile j^{th} , applying specify functions to calculate the WQC for every degree j . And the calculation of WQC as:

$$WQC_{\tau}(d_j[L], d_j[S]) = \frac{q_{\text{cov}_t}(d_j[S], d_j[L])}{\sqrt{\text{var}(\varphi_{\tau}(d_j[S] - Q_{\tau,d_j[S]})) \text{var}(d_j[L])}}, \tag{6}$$

where L and S indicate the independent and dependent indices, respectively.

3.3. Wavelet local multiple correlation

The work adopted the Wavelet Local Multiple Correlation (WLMC) method developed by Polanco-Martínez et al. (2020) as the primary robust test for main empirical examination. This innovative methodology was applied to multidimensional temporal sequence datasets, which were denoted as X , set as the periods $t = 1, \dots, T$. And details that for any $(x_i \in X)$, a strategy involving the weighted sum of squared discrepancies can be engaged through localized regression at a determined point ($s \in [1, \dots, T]$).

$$S_w = \sum_t \theta(t-s) \left[f_w(R_{-i,t}) - x_{it} \right]^2, \tag{7}$$

$f_s(X_i)$ demonstrates a local function pertaining to s and $\theta(x)$ with $\{x_t\}$, representing a predetermined moving weighted average function that is reliant on the horizon between X_t and X_s . The corresponding local determination parameters, which vary over time:

$$R_r^2 = 1 - \frac{R_w SS_s}{T_w SS_s}, s = 1 \dots T, \tag{8}$$

$T_w SS_s$ show the aggregate of squares weighted for totality, while $R_w SS_s$ correspond to the sum of squares weighted for residuals.

For scale j , designate $W_{jt} = (w_{1jt}, \dots, w_{njt})$ as the wavelet components obtained using the maximal overlap discrete wavelet transform on every indicator $x_i \in X$, denoted by $i = 1, \dots, n$. Within each wavelet scale j , it is possible to estimate the WLMC coefficient $\varphi_{X,S}(\lambda_j)$ as the highest

regression parameter determination for the linear combination of indicators $w_{ij}, i = 1, \dots, n$, achieving the peak of parameter determination.

$$\hat{\varphi}X_r(\lambda_j) = \sqrt{R_{js}^2}, j = 1, \dots, js = 1, \dots, T. \tag{9}$$

Next, the correlation squared between the fitted values and the multiple local regression values of q_i using other system elements, is mirrored by the \hat{Z}_i coefficients. Presented below is the estimator for WLMC.

$$\hat{\varphi}X_s(\lambda_j) = \text{corr} \left(\vartheta((t-r)^{1/2} W_{ij}, \sqrt{Z_r^2}, \vartheta(t-s) \right)^{1/2} W_{ij}, s = 1, \dots, T, \tag{10}$$

where w_{ij} is set in a manner that enhances the determination of coefficients through local regression involving the $\{w_{kj}, k \neq i\}$ predictors; w_{ij} also serves to depict the resultant vector of estimates.

3.4. Data description

The sample period for this study is from 1 August 2011 to 30 August 2024. The start date was specifically chosen to follow the immediate aftermath of the 2008 Global Financial Crisis (GFC), an event triggered by the U.S. subprime mortgage crisis. We exclude the GFC period because this crisis originated within the real estate and credit markets, causing a fundamental structural shock to the very foundation of REITs. The extreme and systemic volatility during this time was unique, and its inclusion could disproportionately influence our econometric estimates, potentially masking the more conventional relationships between the uncertainty indices and REIT returns that this study aims to investigate. By beginning our analysis in 2011, we focus on the post-crisis era, which allows for a more stable and generalizable examination of the market dynamics. This selected timeframe is also advantageous as it encompasses several subsequent major global events, including the US-China trade conflict, the COVID-19 pandemic, and the Russia-Ukraine conflict, providing a rich setting for our analysis.

All data series were collected at a daily frequency. Given that the various markets operate on different trading schedules and holidays, we synchronised the dataset by retaining only the dates for which all series had observations; dates with any missing values were removed. This procedure ensures a perfectly aligned timeline across all variables. REITs return data were sourced from the CRSP/Ziman Real Estate Database. The Financial Stress Index (FSI), market volatility index (VIX), and Economic Policy Uncertainty (EPU) index data were obtained from the Federal Reserve Bank of St. Louis (FRED). The Geopolitical Risk (GPR) index was obtained from the publicly available data provided by Caldara and Iacoviello (2022) at <https://www.matteoiacoviello.com/gpr.htm>. The energy market volatility index (OVX) and the gold market volatility index (GVZ) were sourced from the Datastream database. The selection of these data sources was predicated on their continuity, reliability, and authoritativeness, thereby ensuring

the robustness and credibility of our findings. It is worth noting that all uncertainty indices employed in our study are grounded in the US market and US economic context, ensuring consistency and comparability among the indices while avoiding potential biases and noise that could arise from cross-country data integration.

4. Empirical analysis

Table 1 provides the results of descriptive statistics. In terms of mean values, most indicators exhibited positive values, with EPU and GPR recording the highest means at 116.804 and 111.779, respectively. This suggests that these two indices were generally at high levels throughout the sample period. FSI was the only indicator with a negative mean (-0.708), while the mean of REIT returns was close to zero (0.018), indicating relatively balanced fluctuations for these two indicators over the sample period.

Regarding volatility, variance data revealed that EPU experienced the most significant fluctuations, with a variance of 7556.109. GPR was the second most volatile, with a variance of 2531.12. In contrast, FSI had the smallest variance (0.735), indicating relative stability. These differences in volatility reflect varying sensitivities of the indicators to market shocks.

Skewness data showed that all indicators except REIT returns exhibited positive skewness, with OVX recording the highest skewness at 5.187. This suggests that the distributions of these indicators were right-skewed, with a higher probability of extreme positive values. The negative skewness of REIT returns (-1.331) indicated a left-skewed distribution, with a greater likelihood of extreme negative values.

In terms of kurtosis, all indicators had values higher than 3 (the kurtosis of a normal distribution), indicating a "leptokurtic" distribution with fatter tails. OVX and REIT returns had the highest kurtosis values at 47.739 and 23.564, respectively, suggesting a higher propensity for extreme values.

The results of Jarque-Bera test indicated that all indicators rejected the null hypothesis of normal distribution at the 1% significance level. The Elliot-Rothenberg-Stock test confirmed that all series were stationary, providing a reliable basis for subsequent statistical analyses.

Figure 1 presents the time-series trends of the variables from 2011 to 2024. Overall, all indicators exhibited

significant peaks in volatility at the beginning of 2020, likely attributable to the global outbreak of COVID-19. Specifically, the REIT index generally displayed relatively stable fluctuations but experienced severe volatility in 2020. The FSI maintained a low level overall, except for its peak in 2020. The VIX demonstrated typical characteristics of a "fear index," with sharp increases during periods of market stress. The GPR showed frequent fluctuations, with a notable increase in 2022, possibly related to heightened global geopolitical tensions. The EPU exhibited increased volatility in recent years, with a new peak in early 2024. The OVX also experienced severe volatility in 2020, reflecting significant uncertainty in the energy market at that time. The GVZ displayed relatively mild fluctuations but still indicated increased demand for safe-haven assets during crises. These changes collectively reflected the various significant events and risk shocks experienced by global financial markets over the past decade.

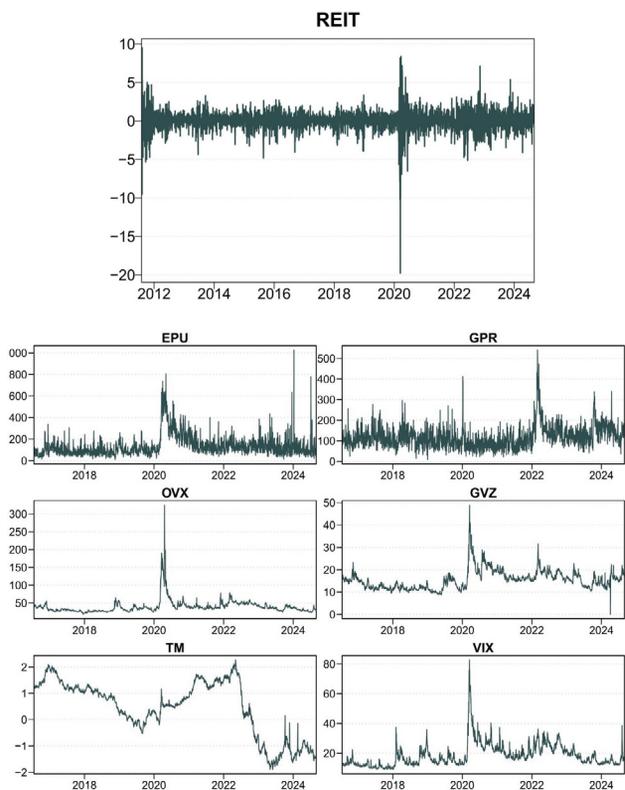


Figure 1. The trends of the variables

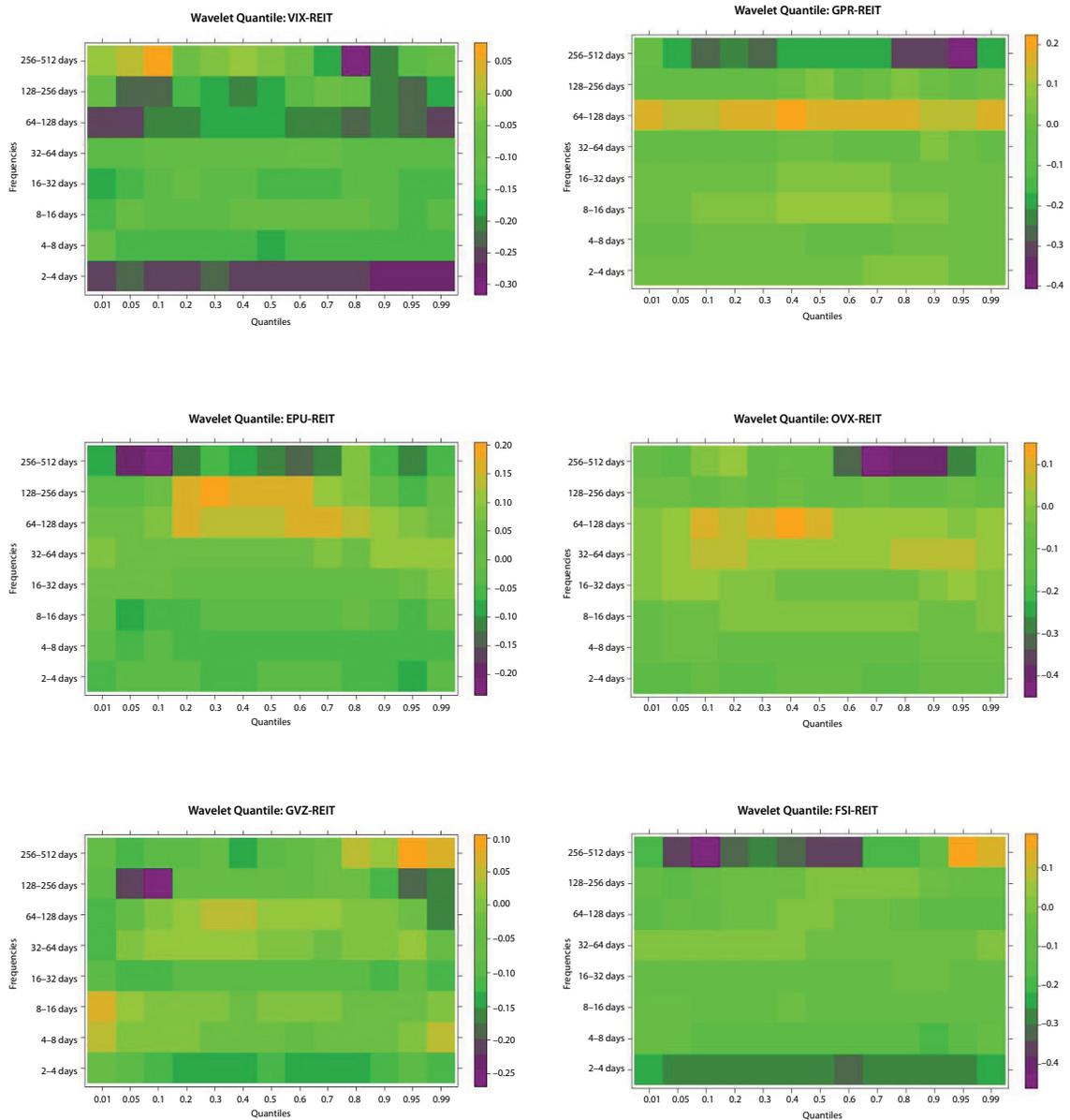
Table 1. Descriptive statistics

| | REIT | FSI | VIX | GPR | EPU | OVX | GVZ |
|----------|--------------|-------------|--------------|--------------|--------------|---------------|-------------|
| Mean | 0.018 | -0.708 | 18.073 | 111.779 | 116.804 | 37.352 | 16.882 |
| Variance | 1.712 | 0.735 | 51.61 | 2531.129 | 7556.108 | 327.628 | 23.125 |
| Skewness | -1.331 | 1.86 | 2.484 | 2.048 | 2.808 | 5.187 | 1.365 |
| Kurtosis | 23.564 | 6.116 | 11.228 | 9.2 | 12.506 | 47.739 | 3.571 |
| JB | 76785.322*** | 6998.468*** | 20584.839*** | 13846.972*** | 25662.523*** | 325872.582*** | 2757.880*** |
| ERS | -3.935*** | -2.690*** | -4.407*** | -9.953*** | -2.495** | -5.509*** | -4.473*** |

Notes: The ERS test is a unit root test, while the JB test is a normality test. The notation *** indicates significance at the 1% level.

Table 2. BDS test

| Variable | Optimal_dimension | Optimal_Eps | Statistic | P_value | Nonlinearity |
|----------|-------------------|-------------------|------------------|---------|--------------|
| REIT | 8 | 0.654266267213022 | 45.0081495889036 | 0.001 | Yes |
| FSI | 8 | 0.428537251734582 | 16161.4677354396 | 0.001 | Yes |
| VIX | 8 | 3.59201525718744 | 2813.22788904187 | 0.001 | Yes |
| GPR | 8 | 25.1551612186772 | 75.421389198429 | 0.001 | Yes |
| EPU | 8 | 43.4629386445454 | 150.837051063336 | 0.001 | Yes |
| OVX | 8 | 9.05024486184329 | 3237.89802070906 | 0.001 | Yes |
| GVZ | 8 | 2.4044470957836 | 16965.0064727401 | 0.001 | Yes |



Notes: This figure depicted the associative intensity amongst various uncertainty indices and the REIT benchmark throughout diverse temporal frameworks (portrayed on the vertical dimension, spanning from 2–4 day periods to 256–512 day intervals) and quantile thresholds (represented along the horizontal dimension, extending from 0.01 through 0.99). The chromatic spectrum transitioned from deep purple (denoting feeble association) towards intense orange (signifying robust association), demonstrating the fluctuation in the magnitude of relationship betwixt the pair.

Figure 2. The wavelet quantile relationships between GPR and REITs

Table 2 presents the results of the BDS test for all seven variables. The test revealed that all variables exhibited significant non-linear characteristics at the optimal embedding dimension of 8, with p -values of zero, well below the significance level of 0.05. The values of the BDS statistics were quite large, ranging from a minimum of 45.01 to a maximum of 16,965.01, which further reinforced the robustness of rejecting the null hypothesis. Notably, the BDS statistics for FSI, VIX, OVX, and GVZ were particularly high, suggesting that these variables may have stronger non-linear dependencies. These findings indicated that none of the variables were independently and identically distributed (IID), and their time-series behaviour likely contained complex non-linear dynamic features. This has important implications for the choice of modelling and forecasting methods for these variables, suggesting that models capable of capturing non-linear characteristics should be employed.

Figure 2 presents the wavelet quantile relationships between GPR and REITs. At higher frequencies (64–128 days), geopolitical risk exhibited a significant positive correlation with REITs at medium-to-high quantiles. This suggests that in the short term, increases in geopolitical risk led investors to allocate more funds to the REIT market, likely because REITs were perceived as relatively safe haven assets. However, at lower frequencies (128–256 days) and lower quantiles, a negative correlation was observed, indicating that long-term geopolitical risk could erode investor confidence in the REIT market.

The relationship between OVX and REITs revealed that at higher frequencies (32–64 days), the oil volatility index was generally negatively correlated with REITs across all quantiles. This implies that short-term increases in oil price volatility had a negative impact on the REIT market, possibly due to heightened uncertainty in operating costs. At lower frequencies (128–256 days), this negative correlation weakened, suggesting that the REIT market could better absorb and adapt to the effects of oil price volatility over the long term.

The analysis of VIX and REITs showed a significant negative correlation across all quantiles at the lowest frequencies (2–4 days). This reflects the immediate impact of market panic on REITs. Interestingly, at higher frequencies (256–512 days) and higher quantiles, this negative correlation diminished, indicating that the REIT market had some capacity to withstand volatility over the long term.

The relationship between EPU and REITs revealed a positive correlation at medium frequencies (64–128 days) and medium-to-high quantiles. This suggests that during periods of increased policy uncertainty, investors favoured REITs due to their stable cash flows. However, at lower frequencies (128–256 days), this positive correlation weakened, indicating that the long-term impact of policy uncertainty was gradually absorbed by the market.

The analysis of FSI and REITs indicated a negative correlation at most quantiles at medium frequencies (32–64 days), reflecting the short-term negative impact of financial market stress on REIT performance. At higher fre-

quencies (16–32 days) and higher quantiles, this negative correlation was weaker, suggesting that the REIT market exhibited some resilience under extreme conditions.

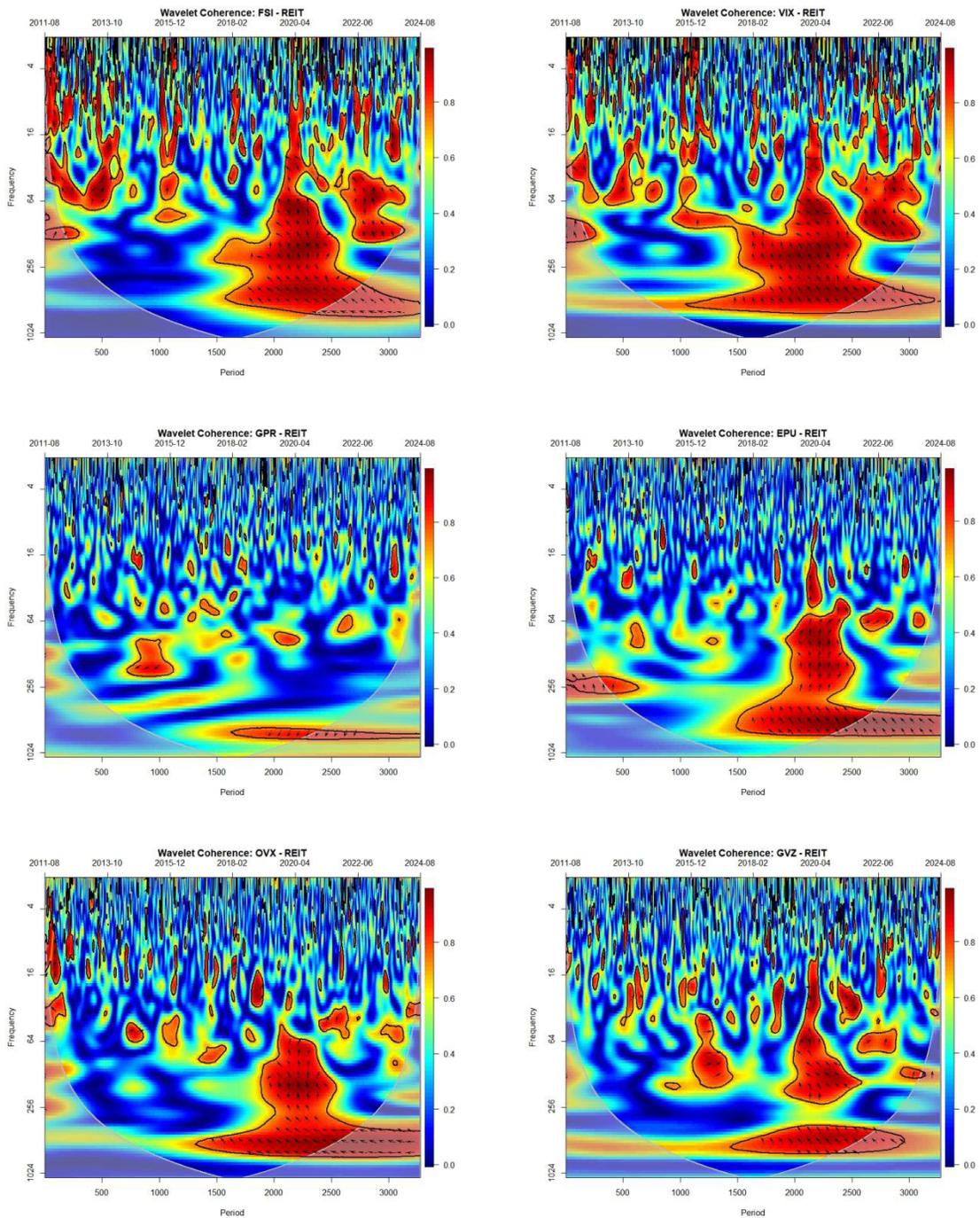
The relationship between GVZ and REITs showed a positive correlation across all quantiles at lower frequencies (8–16 days). This suggests that when safe-haven sentiment increased, leading to higher gold market volatility, the REIT market also experienced positive effects, indicating that REITs may have some safe-haven characteristics. However, at higher frequencies (64–128 days), this positive correlation weakened, suggesting that the safe-haven effect was primarily evident in the short term.

Overall, this study used wavelet quantile analysis to examine the relationships between various uncertainty indicators and the US REIT market, revealing several important findings. First, different types of uncertainty had distinct time-frequency and quantile-dependent effects on the REIT market. In the short term, VIX and FSI generally had negative impacts on REITs, reflecting the immediate transmission of market panic. Second, GPR and EPU exhibited positive correlations with REITs in the medium-to-long term, suggesting that REITs may serve as partial safe-haven assets during periods of high uncertainty. Additionally, the impact of commodity market uncertainty, such as OVX and GVZ, varied across time scales and market conditions. This dynamic relationship provides important insights for risk management. These findings not only deepen our understanding of how the REIT market responds to various uncertainties but also offer empirical evidence for investors' asset allocation decisions in different market environments.

Based on Figure 3, the wavelet coherence relationships between various economic and financial uncertainty indices and the US REIT index are explained. For the relationship between the GPR and REITs, intermittent coherence was observed in the short- and medium-term frequency bands (4–64 days), particularly during the periods of 2015–2016 and 2020–2021. The enhanced coherence during these periods may be associated with significant geopolitical events, such as trade disputes and the COVID-19 pandemic. In the long-term frequency band (64–256 days), stronger coherence emerged after 2022, with arrows indicating the right and downwards, denoting that geopolitical risk led the movement of the REIT market.

The FSI exhibited a more pronounced pattern of coherence with REITs. Strong coherence was maintained throughout the sample period, particularly in the medium- to long-term frequency band (64–256 days). Notably, after the outbreak of COVID-19 in 2020, the coherence in the long-term frequency band significantly intensified, with the expansion of red areas and arrows indicating that changes in financial stress preceded movements in the REIT market. This reflects the substantial impact of financial market stress on REITs.

The coherence map between the VIX Volatility Index and REITs showed large red areas in the medium- to long-term frequency band during the COVID-19 period (2020–2022), with arrows pointing to the right and downwards. This indicates that increases in market volatility led



Notes: The figure presented wavelet coherence outcomes amongst diverse uncertainty indices and the REIT index. The horizontal dimension depicted the temporal domain (encompassing the complete sampling interval), whilst the vertical dimension illustrated the frequency domain (spanning from 4 through 256 day periods). Co-movement magnitude was denoted by chromatic variations positioned on the diagram's right portion; intensified hues (with crimson representing maximum intensity) indicated more robust absolute associations, whereas subdued tones (with azure representing minimum intensity) suggested diminished associations. The saturation of intense colouration or existence of minute crimson patches demonstrated enhanced consistency amongst the indicators. Directional markers were employed to portray phase connections between indicator pairs, with zero phase differential implying simultaneous movement at a specified scale. During synchronised (or opposing) alignment scenarios, markers directed rightward (or leftward). Markers oriented towards the upper right or lower left suggested the initial indicator preceded (or the subsequent indicator delayed), whilst markers directed towards the lower right or upper left revealed the subsequent indicator preceded (or the initial indicator delayed). These findings within this analysis demonstrated grey interrupted lines, signifying that association between regions achieved statistical significance at the 5% threshold.

Figure 3. The wavelet coherence relationships between various economic and financial uncertainty

the adjustment of the REIT market. This pattern suggests that heightened market volatility had a significant negative impact on the REIT market during the crisis. A similar pattern was observed in the relationship between the GVZ and REITs, although the strength of coherence was relatively weaker.

The coherence map between the US EPU Index and REITs revealed significant red areas in the long-term frequency band after 2020. This suggests that increases in domestic policy uncertainty in the US had a persistent impact on the REIT market. The direction of the arrows indicates that changes in policy uncertainty often preceded movements in the REIT market. This relationship was particularly evident during the COVID-19 period, likely reflecting the market's sensitivity to US fiscal and monetary policy responses. Similarly, the relationship between the OVX and REITs also showed enhanced coherence during the pandemic period, especially in the medium- to long-term frequency band.

Overall, the relationships between these uncertainty indices and the REIT market generally intensified after the outbreak of COVID-19, particularly in the medium- to long-term frequency bands. This indicates that during the crisis, various sources of market uncertainty had a more pronounced and persistent influence on the REIT market. Financial stress, market volatility indices, and US economic policy uncertainty all exhibited significant impacts on the REIT market, especially over longer time scales. These findings are of significant importance for understanding how uncertainty factors are transmitted to the real estate financial market.

We further conduct robustness tests based on the quantile regression results presented in Table 3. This research reveals the heterogeneous impact mechanisms of different uncertainty indices on the REIT index under varying market conditions, providing crucial robustness verification for our primary empirical findings.

The quantile regression results in Table 3 are highly consistent with the core findings of the wavelet quantile analysis (Figure 2), particularly in revealing the conditional

Table 3. Quantile regression results of uncertainty indices on US REIT returns

| Index | Q05 | Q25 | Q50 | Q75 | Q95 |
|-------|---------|---------|---------|---------|--------|
| FSI | -0.5527 | -0.1706 | -0.0167 | -0.0131 | 0.105 |
| VIX | -0.6949 | -0.257 | -0.0652 | 0.0201 | 0.1808 |
| GPR | 0.1852 | -0.0198 | -0.0951 | -0.0027 | 0.008 |
| EPU | -0.4026 | -0.138 | -0.0807 | 0.0486 | 0.09 |
| OVX | -0.4819 | -0.1638 | -0.0262 | 0.026 | 0.1197 |
| GVZ | -0.4851 | -0.1164 | -0.0742 | -0.011 | 0.1473 |

Notes: This table presents the quantile regression coefficients of various uncertainty indices on US REIT returns across different quantiles (Q05, Q25, Q50, Q75, Q95). The coefficients indicate the marginal effects of a one-unit increase in each uncertainty index on REIT returns at the corresponding quantiles. Positive coefficients suggest that increases in uncertainty lead to higher REIT returns, while negative coefficients indicate adverse effects. The quantile regression methodology allows for examining the heterogeneous effects of uncertainty across different market conditions, with Q05 representing extremely bearish market conditions and Q95 representing extremely bullish market conditions. Standard errors are robust to heteroscedasticity and autocorrelation.

dependence of uncertainty indices' effects on REIT markets. Specifically, the FSI demonstrates significant quantile-dependent characteristics, with the most severe negative impact occurring under extremely low quantiles (Q05), where the coefficient reaches -0.5527 . As quantiles increase, the negative effects gradually diminish, approaching zero at the median (Q50) with a coefficient of -0.0167 , whilst transitioning to positive influence at high quantiles (Q95) with a coefficient of 0.105 . This transition mechanism perfectly aligns with the findings in Figure 2, where FSI exhibits negative correlation with REITs at medium frequencies and weakening negative correlation at high quantiles. It also resonates with the evidence presented in Figure 3, which shows persistent strong coherence between FSI and REITs in medium- to long-term frequency bands.

The VIX presents even more extreme quantile effects, with the negative impact coefficient reaching -0.6949 at the lowest quantile (Q05), reflecting the significant amplification effect of market panic sentiment on distressed REIT markets. However, it turns positive at the Q75 quantile (0.0201) and reaches 0.1808 at the highest quantile (Q95). This perfectly corroborates the findings in Figure 2, where VIX shows significant negative correlation with REITs at the lowest frequencies and weakening negative correlation under long-term high quantile conditions. It also mutually supports the evidence shown in Figure 3, which demonstrates VIX's strong coherence in medium- to long-term frequency bands during the COVID-19 period.

Furthermore, we observe that GPR's impact pattern is relatively complex but highly consistent with previous wavelet analysis results. At the lowest quantile (Q05), it exhibits positive influence (0.1852), which may reflect investors' hedging behaviour during extremely pessimistic periods. However, it transitions to negative influence in the medium quantile range (Q25 to Q50), with the lowest point occurring at the median (-0.0951), whilst under high quantile conditions, the impact tends towards neutrality or slight positivity. We can argue that this nonlinear pattern completely conforms to the findings in Figure 2, where GPR shows positive correlation with REITs at high frequencies and medium-high quantiles, but negative correlation at low frequencies and low quantiles. This is also consistent with the time-varying characteristics shown in Figure 3, which displays GPR's intermittent coherence during 2015–2016 and 2020–2021, as well as strong coherence in long-term frequency bands after 2022.

Additionally, EPU's quantile effect pattern resembles that of FSI and VIX but with relatively moderate impact magnitude. Under low quantile conditions (Q05), the negative impact reaches -0.4026 , turning positive at the Q75 quantile (0.0486), and further strengthening to 0.09 at the highest quantile (Q95). Interestingly, this corroborates the findings in Figure 2, where EPU shows positive correlation with REITs at medium frequencies and medium-high quantiles, as well as the evidence in Figure 3, which demonstrates EPU's significantly enhanced coherence in long-term frequency bands after 2020.

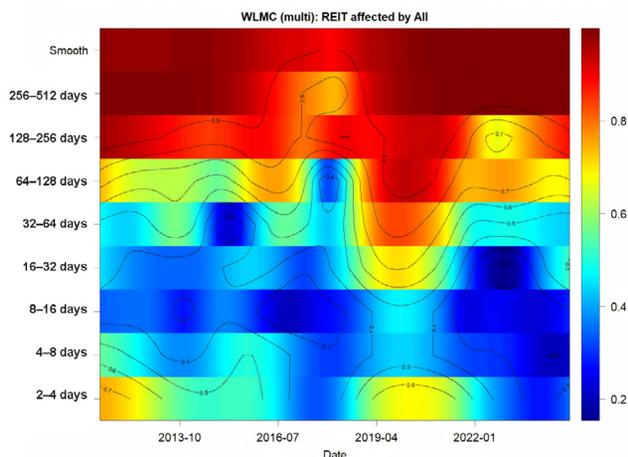
Finally, both OVX and GVZ exhibit similar quantile-dependent patterns, with GVZ displaying a more extreme pattern. GVZ shows negative influence of -0.4851 at low quantiles (Q05) and positive influence of 0.1473 at high quantiles (Q95), representing one of the highest positive coefficients among all indices. We can argue that these findings are consistent with the results in Figure 2, where OVX shows negative correlation with REITs at high frequencies and GVZ shows positive correlation at low frequencies. They also align with the evidence shown in Figure 3, which demonstrates enhanced coherence of these commodity market uncertainty indices during the COVID-19 period.

In summary, the key findings from Table 3, serving as a robustness test, indicate that the quantile regression results not only systematically reveal the conditional dependent nature of multiple types uncertainty factors' impacts on REIT markets, but more importantly, provide robust statistical verification for the nonlinear dynamic characteristics discovered in previous wavelet analyses.

Figures 4 and 5 provide robust validation within a multivariate WLMC framework to overcome the limitations of bivariate analysis, where direct and indirect effects remain confounded, by simultaneously incorporating all uncertainty indicators to isolate each variable's independent contribution. The multivariate WLMC analysis in Figure 4 demonstrates that the combined effect of all uncertainty indicators generates persistently strong positive correlations (exceeding 0.8) in the long-term frequency band (above 256 days), substantially surpassing any single indicator's bivariate effect shown in Figure 3, with high-correlation regions during mid-2018 and the COVID-19 period particularly validating the enhanced effects of FSI and VIX during crisis periods; the medium-term frequency

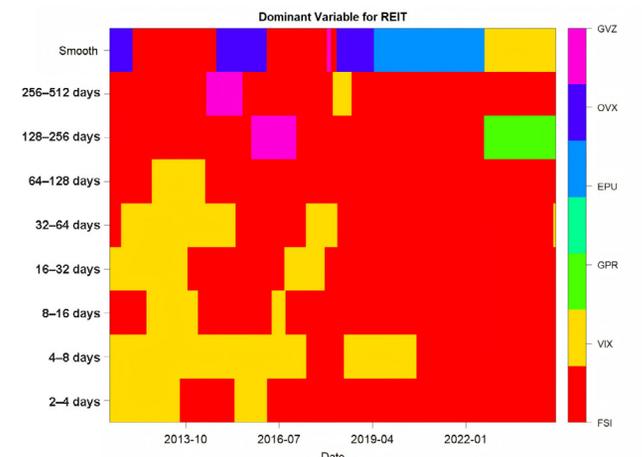
band (32–128 days) exhibits complex time-varying characteristics that both confirm the significant impacts of FSI, VIX and EPU observed in Figure 3 and reveal potential hedging effects between different indicators during 2017–2018; whilst the low correlations (0.2–0.4) in the short-term frequency band indicate that multiple uncertainties generate partial offsetting effects through their interactions in the very short term, a non-linear interaction that bivariate analysis cannot identify.

Figure 5's dominant variable analysis further advances understanding of transmission mechanisms by explicitly identifying each indicator's net contribution after controlling for other uncertainties. FSI's overwhelming dominance in the long-term frequency band explains why FSI exhibits the strongest and most persistent coherence pattern in Figure 3, with this dominance becoming more pronounced after removing confounding effects from other variables; the alternating dominance between VIX and FSI in the medium-term frequency band validates that these two indicators' significant impacts in this frequency band shown in Figure 3 indeed reflect their independent contributions rather than spurious relationships caused by correlations; whilst the complex dominant pattern switching in the short-term frequency band reveals that the intermittent coherence exhibited by various indicators in high frequencies in Figure 3 likely stems from different risk sources taking turns as drivers across different periods. This multivariate analysis not only confirms the robustness of bivariate results but more importantly, by controlling for inter-variable correlations, accurately identifies each uncertainty indicator's independent impact pathway on the REITs market, providing more precise empirical evidence for understanding complex risk transmission mechanisms.



Notes: The figure displays the wavelet local multiple correlation between REITs and all uncertainty indicators simultaneously. The vertical axis represents frequency bands ranging from high-frequency (2–4 days) to low-frequency (smooth). The horizontal axis represents the time dimension. The color scale indicates correlation strength, with warmer colors (red) representing stronger positive correlations and cooler colors (blue) representing weaker correlations. Black contour lines denote statistical significance levels.

Figure 4. WLMC of multiple uncertainty indicators on REITs



Notes: The heat map identifies which uncertainty indicator exhibits the maximum contribution to the multiple correlation with REITs at each time-frequency location. Different colors represent different dominant variables: FSI (red), VIX (yellow), GPR (green), EPU (cyan), OVX (blue), and GVZ (magenta). The vertical axis shows frequency bands and the horizontal axis represents the time dimension.

Figure 5. Dominant variable analysis in WLMC framework for REITs

5. Conclusions

This paper systematically examined the relationship between various economic and financial uncertainty indicators and the US REIT market using wavelet quantile and wavelet coherence analyses. It revealed the time-frequency characteristics, quantile dependencies, and dynamic patterns of how uncertainty factors impact the REIT market. The findings indicated that different types of uncertainty had distinct effects on REITs across various time-frequency bands and quantiles. In the short-term frequency band (2–64 days), VIX and FSI exhibited significant negative correlations with REITs, reflecting the immediate transmission of market panic and financial stress. OVX also showed a negative correlation, suggesting that oil price volatility increased the uncertainty of operating costs in the short term. In contrast, GVZ displayed a positive correlation, indicating that REITs may have short-term safe-haven characteristics. In the medium- to long-term frequency band (64–256 days and above), GPR and EPU were positively correlated with REITs, suggesting that they may serve as safe-haven assets during periods of heightened uncertainty. However, this relationship weakened at lower frequencies. The negative correlations of OVX and VIX with REITs also eased over the long term, indicating that REITs have some capacity to adapt to and withstand volatility.

Wavelet quantile analysis further uncovered the dynamic evolution of the relationship between uncertainty and the REIT market, particularly during the COVID-19 period (2020–2022). The correlations between GPR, FSI, VIX, EPU, and OVX with REITs significantly strengthened in the medium- to long-term frequency band. These uncertainty indicators also led changes in the REIT market, highlighting the deepened and persistent impact of uncertainty during crises. The influence of commodity market uncertainty (such as OVX and GVZ) on REITs varied depending on the time scale and market conditions. OVX had a pronounced negative effect in the short term, while GVZ had a positive impact. This dynamic relationship provides important insights for risk management. Our multivariate WLMC framework successfully disentangles the direct and indirect effects of uncertainty indicators, demonstrating that FSI emerges as the dominant long-term driver whilst short-term impacts reflect complex non-linear interactions that bivariate analyses cannot capture.

For investors, this study offers empirical evidence for asset allocation and risk management. In the short term, investors should monitor indicators such as VIX and FSI to adjust their positions in response to market panic and financial stress. In the medium to long term, they can leverage the safe-haven characteristics of REITs during periods of rising GPR and EPU for diversified investment. Meanwhile, they should adjust their strategies based on the dynamic impacts of OVX and GVZ to balance the risks associated with commodity price volatility. These findings help investors optimise their decision-making in different market environments, particularly in effectively hedging against uncertainty during crises.

For policymakers, the study highlights the significant impact of economic policy uncertainty and financial stress on the REIT market, particularly their persistence in the long-term frequency band. Policymakers should consider the potential impact of fiscal and monetary policies on the real estate financial market to avoid excessive uncertainty that could undermine market confidence. They can also support the safe-haven function of REITs during crises through policies that stabilise financial market stress and geopolitical risks, thereby maintaining market stability and protecting investors' interests.

Future research could further explore how the influence of different types of uncertainty on the REIT index varies across economic cycles. For example, it could examine whether the relationship between uncertainty indicators and REITs differs significantly during economic expansions and recessions. Additionally, comparative analyses of REIT markets in different countries and regions could shed light on how institutional environments, market structures, and economic contexts influence the transmission mechanisms of uncertainty.

References

- Ahmed, W. M. (2022). On the higher-order moment interdependence of stock and commodity markets: A wavelet coherence analysis. *The Quarterly Review of Economics and Finance*, 83, 135–151. <https://doi.org/10.1016/j.qref.2021.12.003>
- Alcock, J., & Steiner, E. (2018). Fundamental drivers of dependence in REIT returns. *The Journal of Real Estate Finance and Economics*, 57, 4–42. <https://doi.org/10.1007/s11146-016-9562-3>
- Armah, M., Amewu, G., & Bossman, A. (2022). Time-frequency analysis of financial stress and global commodities prices: Insights from wavelet-based approaches. *Cogent Economics & Finance*, 10(1), Article 2114161. <https://doi.org/10.1080/23322039.2022.2114161>
- Basdekis, C., Christopoulos, A., Katsamposakis, I., & Nastas, V. (2022). The impact of the Ukrainian war on stock and energy markets: A wavelet coherence analysis. *Energies*, 15(21), Article 8174. <https://doi.org/10.3390/en15218174>
- Baum, A. (2021). Tokenization—The future of real estate investment. *The Journal of Portfolio Management*, 47(10), 41–61. <https://doi.org/10.3905/jpm.2021.1.260>
- Ben Amor, N., Ghorbel, A., & Bahloul, S. (2025). Frequency connectedness and portfolio implication between financial, green and commodity markets: A TVP-VAR approach. *Studies in Non-linear Dynamics & Econometrics*. <https://doi.org/10.1515/snde-2024-0083>
- Bossman, A., Gubareva, M., & Teplova, T. (2023). Economic policy uncertainty, geopolitical risk, market sentiment, and regional stocks: Asymmetric analyses of the EU sectors. *Eurasian Economic Review*, 13(3), 321–372. <https://doi.org/10.1007/s40822-023-00234-y>
- Caldara, D., & Iacoviello, M. (2022). Measuring geopolitical risk. *American Economic Review*, 112(4), 1194–1225. <https://doi.org/10.1257/aer.20191823>
- Cepni, O., Dul, W., Gupta, R., & Wohar, M. E. (2021). The dynamics of US REITs returns to uncertainty shocks: A proxy SVAR approach. *Research in International Business and Finance*, 58, Article 101433. <https://doi.org/10.1016/j.ribaf.2021.101433>

- Charif, H., Assaf, A., Demir, E., & Mokni, K. (2022). The effects of economic policy uncertainty on the US REITs ETFs: A quantile analysis. *Investment Analysts Journal*, 51(1), 67–82. <https://doi.org/10.1080/10293523.2022.2076372>
- Chiang, S. L., & Tsai, M. S. (2023). Analyses for the effects of investor sentiment on the price adjustment behaviors for stock market and REIT market. *International Review of Economics & Finance*, 86, 425–439. <https://doi.org/10.1016/j.iref.2023.03.007>
- Demiralay, S., & Kilincarslan, E. (2024). Uncertainty measures and sector-specific REITs in a regime-switching environment. *The Journal of Real Estate Finance and Economics*, 69(3), 545–584. <https://doi.org/10.1007/s11146-022-09898-w>
- DiBartolomeo, J. A., Gatchev, V. A., & Harrison, D. M. (2021). The liquidity risk of REITs. *Journal of Real Estate Research*, 43(1), 47–95. <https://doi.org/10.1080/08965803.2021.1889288>
- Downs, D. H., & Zhu, B. (2022). Property market liquidity and REIT liquidity. *Real Estate Economics*, 50(6), 1462–1491. <https://doi.org/10.1111/1540-6229.12381>
- Harper, A., Lu, Y., & Tembhurne, S. (2025). Firm policies and uncertainty about risk. *Journal of Risk and Financial Management*, 18(2), Article 96. <https://doi.org/10.3390/jrfm18020096>
- Huerta, D., Egly, P. V., & Escobari, D. (2016). The liquidity crisis, investor sentiment, and REIT returns and volatility. *Journal of Real Estate Portfolio Management*, 22(1), 47–62. <https://doi.org/10.1080/10835547.2016.12089979>
- Jackson, C., & Orr, A. (2019). Investment decision-making under economic policy uncertainty. *Journal of Property Research*, 36(2), 153–185. <https://doi.org/10.1080/09599916.2019.1590454>
- Ke, Z., Cao, Y., Chen, Z., Yin, Y., He, S., & Cheng, Y. (2025). Early warning of cryptocurrency reversal risks via multi-source data. *Finance Research Letters*, 85, Article 107890. <https://doi.org/10.1016/j.frl.2025.107890>
- Kumar, A. S., & Padakandla, S. R. (2022). Testing the safe-haven properties of gold and bitcoin in the backdrop of COVID-19: A wavelet quantile correlation approach. *Finance Research Letters*, 47, Article 102707. <https://doi.org/10.1016/j.frl.2022.102707>
- Laopodis, N. (2009). REITs, the stock market and economic activity. *Journal of Property Investment & Finance*, 27(6), 563–578. <https://doi.org/10.1108/14635780910993168>
- Letdin, M., Sirmans, S., & Sirmans, G. S. (2022). Betting against the sentiment in REIT NAV premiums. *The Journal of Real Estate Finance and Economics*, 64, 590–614. <https://doi.org/10.1007/s11146-020-09803-3>
- Liu, J., Loudon, G., & Milunovich, G. (2012). Linkages between international REITs: The role of economic factors. *Journal of Property Investment & Finance*, 30(5), 473–492. <https://doi.org/10.1108/14635781211256747>
- Lu, R., & Zeng, H. (2023). VIX and major agricultural future markets: Dynamic linkage and time-frequency relations around the COVID-19 outbreak. *Studies in Economics and Finance*, 40(2), 334–353. <https://doi.org/10.1108/SEF-02-2022-0121>
- Ma, S., & Appolloni, A. (2025). Can financial flexibility enhance corporate green innovation performance? Evidence from an ESG approach in China. *Journal of Environmental Management*, 387, Article 125869. <https://doi.org/10.1016/j.jenvman.2025.125869>
- Ma, S., Benkraiem, R., Abedin, M. Z., & Zeng, H. (2025). Climate anomalies and corporate environmental governance: Empirical evidence from ENSO events. *Finance Research Letters*, 85, Article 107970. <https://doi.org/10.1016/j.frl.2025.107970>
- Morri, G., & Parri, E. (2017). US REITs capital structure determinants and financial economic crisis effects. *Journal of Property Investment & Finance*, 35(6), 556–574. <https://doi.org/10.1108/JPIF-07-2016-0055>
- Patel, R., Goodell, J. W., & Chishti, M. Z. (2023). Assessing connectiveness of transportation cryptocurrencies and transportation stocks: Evidence from wavelet quantile correlation. *Finance Research Letters*, 58, Article 104504. <https://doi.org/10.1016/j.frl.2023.104504>
- Polanco-Martínez, J. M., Fernández-Macho, J., & Medina-Elizalde, M. (2020). Dynamic wavelet correlation analysis for multivariate climate time series. *Scientific Reports*, 10(1), Article 21277. <https://doi.org/10.1038/s41598-020-77767-8>
- Rubio, L., Palacio Pinedo, A., Mejía Castaño, A., & Ramos, F. (2023). Forecasting volatility by using wavelet transform, ARIMA and GARCH models. *Eurasian Economic Review*, 13(3), 803–830. <https://doi.org/10.1007/s40822-023-00243-x>
- Shahid, M. N., Azmi, W., Ali, M., Islam, M. U., & Rizvi, S. A. R. (2023). Uncovering risk transmission between socially responsible investments, alternative energy investments and the implied volatility of major commodities. *Energy Economics*, 120, Article 106634. <https://doi.org/10.1016/j.eneco.2023.106634>
- Shang, Y., Ma, X., Bhatia, M., Alofaysan, H., & Walsh, S. T. (2024). Unveiling the enigma: Exploring how uncertain crude oil prices shape investment expenditure and efficiency in Chinese enterprises. *Energy Economics*, 132, Article 107423. <https://doi.org/10.1016/j.eneco.2024.107423>
- Torrence, C., & Compo, G. P. (1998). A practical guide to wavelet analysis. *Bulletin of the American Meteorological Society*, 79(1), 61–78. [https://doi.org/10.1175/1520-0477\(1998\)079<0061:APTWA>2.0.CO;2](https://doi.org/10.1175/1520-0477(1998)079<0061:APTWA>2.0.CO;2)
- Wang, J., Gupta, R., Çepni, O., & Ma, F. (2023). Forecasting international REITs volatility: The role of oil-price uncertainty. *The European Journal of Finance*, 29(14), 1579–1597. <https://doi.org/10.1080/1351847X.2022.2137422>
- Wu, R., Zeng, H., Abedin, M. Z., & Ahmed, A. D. (2025). The impact of extreme climate on tourism sector international stock markets: A quantile and time-frequency perspective. *Tourism Economics*, 37(8), 1598–1628. <https://doi.org/10.1177/13548166241311633>
- Yang, Z., Zeng, H., Liu, F., & Wu, R. (2025). Assessing the complex dynamics of climate risk on tourism stock performance: Insights from European and US markets. *Global NEST Journal*, 27(4), 1–10.
- Ying, J., Lu, P., Fang, L., & He, S. (2025). How digital leadership drives ambidextrous innovation: Evidence from Chinese digital startups. *Journal of Knowledge Management*. <https://doi.org/10.1108/JKM-05-2025-0756>
- Zeng, H. (2026). Risk transmission and diversification strategies between US real estate investment trusts (REITs) and green finance indices. *Kybernetes*, 55(1), 128–154. <https://doi.org/10.1108/K-12-2023-2653>
- Zeng, H., Abedin, M. Z., Ahmed, A. D., & Lucey, B. (2025a). Quantile and time-frequency risk spillover between climate policy uncertainty and grains commodity markets. *Journal of Futures Markets*, 45(6), 659–682. <https://doi.org/10.1002/fut.22583>
- Zeng, H., Abedin, M. Z., Zhou, X., & Lu, R. (2024). Measuring the extreme linkages and time-frequency co-movements among artificial intelligence and clean energy indices. *International Review of Financial Analysis*, 92, Article 103073. <https://doi.org/10.1016/j.irfa.2024.103073>
- Zeng, H., Benkraiem, R., Abedin, M. Z., & Hajek, P. (2025b). Transitioning to sustainability: Dynamic spillovers between sustainability indices and Chinese stock market. *European Financial Management*, 31, 1742–1770. <https://doi.org/10.1111/eufm.12560>
- Zhang, D., Lei, L., Ji, Q., & Kutan, A. M. (2019). Economic policy uncertainty in the US and China and their impact on the global markets. *Economic Modelling*, 79, 47–56. <https://doi.org/10.1016/j.econmod.2018.09.028>