**Quantile Effects of Climate Policy Uncertainty, Economic Policy Uncertainty, and Interest Rates on REIT Returns: Evidence from the U.S.**

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**Abstract**

We investigate the quantile effects of climate policy uncertainty (CPU) on real estate investment trusts (REITs) returns in the United States. We use the quantile autoregressive distributed lags (QARDL) method on the monthly economic policy uncertainty (EPU), the market volatility index (VIX), and interest rates (INT) from March 2006 to April 2023. The results show that the impact coefficients of CPU, EPU, and interest rates on REIT returns are significant in the short and long term. In addition, CPU demonstrates unidirectional causality with REIT returns across all quantiles, whereas REITs only show unidirectional causality with CPU in lower quantiles. Furthermore, EPU and interest rates show bidirectional causality with REIT returns across most quantiles. Policymakers and REIT investors can utilize the relationships and causality between REITs and CPU to update REIT investments, hedge against CPU and REIT stocks, construct a diversified portfolio, and make informed decisions about the price movements of REITs in climate crises.

*Keywords:*REITs;Climate policy uncertainty; Economic policy uncertainty; Interest rates; QARDL

*JEL Codes:*Q5, R3

# **1. Introduction**

Real Estate Investment Trusts (REITs) are investment vehicles that own and operate income-generating real estate properties listed on stock exchanges. They provide a unique opportunity for individual investors to invest in the real estate market and benefit from the returns generated by real estate investments. In the United States, REITs are worth around $4.5 trillion in gross assets, with public REITs comprising approximately $3 trillion in assets. In addition, the equity market capitalization of U.S. REITs exceeds $1.4 trillion[[1]](#footnote-1). However, the United States is vulnerable to climate uncertainties, such as rising sea levels, which is making many coastal areas more prone to flooding. Such events can damage homes and other properties, decreasing property values. The United States has also experienced a rise in extreme weather events, including hurricanes, tornadoes, and wildfires. These events cause significant damage to homes and other properties, leading to decreased property values and increased insurance costs. These calamities will negatively impact real estate (property) across the short- and long-term (Warren-Myers and Hurlimann, 2022). In particular, climate risk is a significant deterrent to building houses in high-risk zones (Hino and Burke, 2020). Both physical and transition-related climate risks adversely affect property prices. Thus, pricing climate risk into the stock markets is essential (Carney, 2015). Investors have recently witnessed an uptick in climate risks and clean energy transition. The risks of climate change affect REIT prices as climate risk affects firms’ investment decisions (Engle et al., 2020).

Although about 150 million Americans own REITs through retirement savings and other investment funds (Nareit, 2023), the REIT market has been largely ignored in prior research on climate uncertainty and REITs. Climate change can increase the frequency and severity of extreme weather events, sea level rise, and other climate-related hazards. This can lead to property damage and reduced demand for properties. As such, the real estate sector becomes increasingly vulnerable to the impacts of climate change. Studies have examined the impacts of climate change on various types of properties, including residential, commercial, and industrial properties, as well as on different regions and markets (André et al., 2020; Huang et al., 2020; Alam, 2022; Addoum et al., 2023).

REIT markets in the United States are subject to extreme volatility due to climate uncertainty. For example, 35 percent of REIT properties in the global REIT market are vulnerable to climate change (King, 2018). New climate policies and regulations can create opportunities for REITs to invest in energy-efficient properties, renewable energy projects, or other environmentally friendly real estate assets that can be more valuable. In contrast, uncertainty about future climate policies and regulations can lead to delays in investment decisions (see Tang et al., 2023; Wang et al., 2024), reducing demand for real estate assets and potentially lowering real estate values. However, there is no precise knowledge or empirical evidence to address climate uncertainty for investors and environmental policymakers. The lack of clear counterstrategies restricts investors and stakeholders in the REIT market from making informed investment decisions early. We, therefore, examine the quantile effects of climate uncertainty on REIT returns. Using the quantile method, we also revisit the effects of EPU and interest rates on REITs. We hypothesize that increased uncertainty in climate policy adversely impacts REIT prices in the United States.

We assert that the sensitivity of REIT returns to climate policy uncertainty varies across different quantiles. This means that the relationship between risk and returns is not uniform across all levels of returns. This is because ─(1) at lower levels of returns, investors may be more sensitive to changes in risk metrics, as they have less room for error. In contrast, at higher levels of returns, investors may be more willing to tolerate higher levels of risk; (2) different types of REITs may have varying degrees of sensitivity to different types of risks. For example, a REIT that invests primarily in office buildings is more sensitive to changes in interest rates than a REIT that invests primarily in shopping centers; (3) the underlying assets of REITs may have varying degrees of liquidity. More liquid assets are less sensitive to changes in risk metrics, as they can be easily bought or sold. Conversely, less liquid assets are more sensitive to changes in risk metrics, as there may be fewer buyers or sellers in the market. Thus, the relationship between risk and returns in REITs is complex and varies across different return quantiles.

Our study differs from previous studies in three key ways. First, this study is the first to examine the effects of climate policy uncertainty on REITs. Furthermore, we uniquely investigated the impacts of interest rates (Fed fund rates) on REITs. We provide the first-ever evidence that climate policy uncertainty affects REIT returns in the United States. Most studies in the extant literature examine the effects of EPU on real estate investment and housing markets (André et al., 2017; Jackson and Orr, 2019; Li and Wu, 2020; Xia et al., 2020; Huang et al., 2020; André et al., 2020; Balcilar et al., 2021; Bossman et al., 2022) and on REITs (Li and Wu, 2020; Charif et al., 2022; Demiralay and Kilincarslan, 2022). Moreover, we utilized the most commonly used REIT index, which includes all equity REITs. It is important to note that equity REITs have distinct risk and return profiles and are typically more exposed to market fluctuations and property values. By examining the effect of climate policy uncertainty on both REIT types, we can provide insights into how different risk factors interact with climate-related regulations or policies. By analyzing the response of REITs to climate policy uncertainty, researchers will gain insights into how different investor groups perceive and react to climate-related risks and uncertainties.

Second, we used the quantile ARDL method to explore the effects of climate policy uncertainty, volatility, and economic policy uncertainty on REIT returns. The relationship between risk and returns is not uniform across all levels of returns. However, the QARDL method can capture the sensitivity of REIT returns to risk metrics, which can vary across different return quantiles. Most existing studies use linear methods that fail to capture the effects of climate uncertainty on REITs, as they can vary depending on the quantile or the level of uncertainty.

Third, we examined the causality-in-quantiles between climate uncertainty and REIT returns. Our findings show that CPU unidirectionally Granger causes REIT returns across all quantiles. In contrast, REIT returns only have unidirectional causality with CPU in the lower quantiles. Higher levels of CPU may lead to changes in market conditions and investor sentiment. For example, uncertainty about future climate policies can affect industries related to real estate, influencing investment decisions and market dynamics. Investors may react to changes in climate policy uncertainty by adjusting their portfolios, leading to movements in REIT returns. This is likely due to expectations about how specific policies may impact the real estate sector. Similarly, in lower quantiles (perhaps during periods of relatively low CPU), REIT returns may have a unidirectional influence on the CPU. This clearly indicates that, in less uncertain times, movements in REIT returns will influence or be associated with changes in climate policy uncertainty. During periods of lower CPU, positive or negative developments in the real estate market (reflected in REIT returns) may affect perceptions or decisions related to climate policies. For example, a booming real estate market might lead to expectations of increased construction and energy usage, influencing climate policy considerations.

EPU and interest rates have bidirectional causality with REIT returns across most quantiles. The bidirectional causality between EPU, interest rates, and REIT returns shows a dynamic and interconnected relationship. Changes in economic policy uncertainty and interest rates can influence the real estate market, as reflected in REIT returns. At the same time, the real estate market's performance can provide feedback and influence perceptions of economic policy and interest rate expectations. This bidirectional causality highlights the intricate interplay between broader economic conditions, policy dynamics, and the real estate sector across different quantiles of the data distribution. This causal relationship between CPU, EPU, INT, and REIT returns provides important policy implications for investors, lenders, and policymakers regarding green investments and real estate portfolios. In particular, policymakers and REIT investors, can utilize the asymmetric relationships between REITs and CPU to adjust REIT investments for climate uncertainty. REIT investors and portfolio managers can use the asymmetric and causal relationships between interest rates, EPU, and REITs to hedge against CPU and construct a diversified portfolio.

The remainder of the study is divided into six sections. Section 2 presents an analysis of the existing literature and outlines the research hypothesis. Section 3 describes the empirical methodology of quantile ARDL and Granger causality in quantiles, while Section 4 describes the data. Section 5 discusses the empirical results. Section 6 concludes the study and highlights the policy implications.

# **2. Related studies and hypothesis**

The potential impacts of climate change on various sectors of the economy, including real estate, have recently received increased attention from policymakers, researchers, and industry professionals. The real estate sector is particularly vulnerable to the impacts of climate change due to its dependence on location-specific characteristics such as climate, topography, and proximity to water. Investors and policymakers alike are concerned about potential exposure to climate change. Investors’ reactions to climate uncertainty can lead to extreme volatility and returns in the financial markets. In recent years, there has been growing concern about the impact of climate change on the real estate industry, particularly regarding REITs. Investors are increasingly considering a company’s exposure to climate risk when making investment decisions. Companies that fail to address climate risk may face higher costs of capital and reduced access to financing.

In response to these concerns, many REITs have initiated measures to mitigate their vulnerability to climate risk. This may include investing in sustainable building practices, improving energy efficiency, and reducing greenhouse gas emissions. Furthermore, REITs are beginning to disclose more information about their exposure to climate risk, enabling investors to make more informed decisions. Climate change is a systematic global risk for society. Investors face the less conceivable uncertainty of climate change policy and the uncertainty from price volatility in conventional markets. Finally, the relationship between climate risk and REITs is an increasingly important issue for investors, regulators, and companies in the real estate industry. As the impacts of climate change continue to intensify, this issue will likely become even more critical in the coming decades.

The following sections elaborate on the interrelationship between REITs and CPU, EPU, VIX, and interest rates and develop hypotheses.

## **2.1 Climate policy uncertainty and REIT returns**

In theory, asset prices are equal to investors’ expected discounted cash flows. In the context of REITs, this usually means discounting net operating income at an appropriate capitalization rate that compensates for the inherent investment risks. All else being constant, real estate assets with higher risk must be compensated through higher capitalization rates, resulting in lower prices. Climate policy uncertainty, thus, can impact the performance of the US REIT market. However, the uncertainty surrounding the implementation and enforcement of climate policies can make it difficult for investors to accurately assess the value of real estate assets.

Climate uncertainty can affect REITs in various ways. In general, REIT properties vulnerable to climate change, such as coastal properties, may decline in value as the risk of damage from storms, rising sea levels, and other climate-related events increases. Thus, climate risk is an alarming threat to the financial markets and the global economy (Cevik and Miryugin, 2022). Adverse climate changes directly affect the earth through natural disasters like heat waves, wildfires, droughts, floods, and typhoons. These climate events often occur in different regions where residential or commercial properties are severely affected. Real estate prices typically fall after natural disasters but eventually rebound. Both financial and economic risks can be mutually reinforcing—for instance, weather-related property damage can lead to bank losses, leading to less lending and less investment. Recent evidence suggests that climate events in areas that were minimally exposed to harsh weather can lead to long-term pricing or liquidity declines. An emerging international consensus confirms that climate change is a critical structural risk that long-term investors should proactively consider when constructing climate-hedging portfolios. Many corporate real estate investors have substantial investments in economically important cities and regions increasingly vulnerable to climate change (Clayton et al., 2021). However, real estate prices are affected because investors believe climate change can influence their properties (Baldauf et al., 2020).

Climate change is a cause of major structural shifts in the macroeconomic and financial environment. Climate uncertainty will have far-reaching and disruptive effects on investors (Lin and Wu, 2023). Given the homogeneity of the population, real estate pricing gradients promptly reflect the “new news” (Bunten and Kahn, 2014). Giglio et al. (2021) find that the yield curve of interest rates for climate-hedging investments shows an upward slope but is capped by the risk-free rate. Stroebel and Wurgler (2021) review climate finance and find that asset prices underestimate climate risk. Schulten et al. (2021) find that climate risk is a significant concern for the United States. commercial real estate sector. Warren-Myers et al. (2022) examine the impact of climate uncertainty on real estate and find that the effects of climate change may evolve across regions, increasing both in frequency and intensity.

REITs can anticipate changes in CPU because of their close ties to the real estate market and their sensitivity to regulatory changes. Because climate policy can significantly impact property values and operating costs, REITs actively monitor policy developments and adjust their strategies accordingly. Investors conduct in-depth analyses of regulatory trends and reflect their expectations in REIT prices. According to the efficient market hypothesis, asset prices, including those of REITs, incorporate all available information. As REITs are publicly traded and closely monitored by investors, their prices reflect collective expectations about future economic and policy conditions, including expected changes in climate policy. This means that REIT prices can serve as forward-looking indicators, capturing the market expectations of future climate policy uncertainty. Through these mechanisms, REITs serve as forward-looking indicators of expected changes in climate policy uncertainty. Based on the preceding discussion, we propose the following hypothesis:

H1: Climate policy uncertainty negatively affects REIT returns.

## **2.2 Economic policy uncertainty and REIT returns**

The real estate market is susceptible to fluctuations in economic conditions, including interest rates, inflation, and employment levels. Such alterations can influence the value of real estate assets, which, in turn, can impact the value of REITs. EPU reflects the overall uncertainties in an economy, including the real estate sector. Aggregate uncertainty has become a topic of empirical studies, with a focus on macroeconomic dynamics. In particular, there has been a great deal of focus on the relationships between economic uncertainty and investment. In the United States, the real estate sector is dominant and is linked to the financial sector. The discrepancy between expectations about the effects and causes of housing and credit market operations and the actual news releases can be attributed to inherent uncertainties in economic policy. EPU can represent the herding behavior in the REIT markets (Huang et al., 2020).

André et al. (2020) examined whether EPU can predict fluctuations in housing return and found that EPU directly impacts housing and financial markets. Bossman et al. (2022) demonstrate that real estate investments are detrimental to information flows from global economic policy uncertainties. Antonakakis et al. (2015) identified time-varying negative correlations which showed a marked increase in highly volatile and uncertain periods. Chow et al. (2017) posit that EPU exerts an influence on housing return. In their study, Li and Wu (2020) examined the impact of EPU on Chinese real estate development and concluded that EPU adversely affects real estate development. Similarly, a study conducted in China by Xia et al. (2020) revealed that persistent EPU information affects real estate markets in the long term. Aye and Poon (2018) found a time-varying causality between EPU and real estate prices in emerging countries. Balcilar et al. (2021), using the GMM and VAR methods, found that increased EPU leads to decreased housing prices. Huang et al. (2020) showed a positive correlation between housing price fluctuation and EPU, indicating that EPU influences greater variations in housing prices. Demiralay and Kilincarslan (2022) investigate the effects of different uncertainty metrics and discover that EPU negatively affects REIT returns. Charif et al. (2022) investigated the effect of EPU on REITs and found that EPU significantly impacts REIT returns and volatility.

REITs can anticipate changes in EPU owing to their close integration with the economic environment, investor behavior, and strategic positioning. Their performance is directly affected by the economic policies that impact property values and rental income. Investors in REITs conduct detailed analyses of potential policy changes and reflect these expectations on REIT prices, making them early indicators of EPU. REITs also employ strategic risk management and engage with policymakers to stay informed about potential changes, allowing them to adjust their strategies proactively. This combination of factors enables REITs to anticipate and signal changes in economic policy uncertainty effectively. Based on the preceding discussion, we propose the following hypothesis:

H2: Economic policy uncertainty negatively affects REIT returns.

## **2.3 Volatility and REIT returns**

In terms of investment, the degree of interconnection and extent to which one market becomes susceptible to another financial market are of paramount importance. In their study, Curcio et al. (2012) examined the relationship between stock market volatility and real estate returns. Market volatility (VIX) is an important criterion in the decision-making process for real estate investments, particularly in times of uncertainty. Changes in stock market volatility are significant predictors of real estate market returns (Beracha et al., 2019). Liow and Huang (2018) find that REITs’ volatility connects rapidly to other markets. Investor sentiment directly and dynamically affects REIT movement, leading to market volatility (Pillada and Rangasamy, 2023). However, the authors did not mention whether these effects are asymmetric, which requires further investigation. Kang et al. (2023) show that U.S. sectoral real estate returns are vulnerable to the “30-day forward-looking market expectations” of the VIX. Monteiro et al. (2023) identify an asymmetric relationship between the volatility of U.S. industries and other markets. The authors posit that the markets are interconnected, and volatility is transmitted across markets. In studying the effects of the global pandemic on financial markets, Milcheva (2022) found that the U.S. real estate sector was the most affected. Alam (2022) examined how housing sector volatility affects REIT equity returns in the United States and confirmed that housing risk volatility affects REITs. Lesame et al. (2021) state that REIT markets are highly dynamic and strongly correlated with uncertainty. The evidence of volatility is linked to the dynamics and performance of the real estate sector. The relationship between volatility and REIT returns is an important consideration for investors who are invested in the REIT market. Understanding how volatility affects REIT returns can assist investors in deciding when to buy or sell REITs and manage their investment risk.

VIX can anticipate changes in REITs because they are closely tied to broader market conditions and investors’ expectations. Their performance is sensitive to economic indicators and market stability, prompting investors to adjust their REIT holdings based on anticipated volatility. These adjustments in REIT prices reflect the collective investor expectation of future market conditions. Thus, VIX acts as an early indicator of market volatility, often anticipating changes in the REIT return. Based on the above discussion, we propose the following hypothesis.

H3: Volatility affects REIT returns and shows unidirectional causality.

## **2.4 Interest rates can affect REIT returns**

Interest rates can significantly impact REITs in the United States (Demirer et al., 2020). REITs are investment vehicles that own and operate income-generating real estate properties. REITs often use debt financing to acquire and develop their property. When interest rates are low, REITs can access financing at lower costs, boosting their profitability and potentially increasing their ability to acquire more properties (Weis et al., 2021). Conversely, higher interest rates can increase borrowing costs and limit borrowers’ ability to pursue new opportunities.

Furthermore, REITs are known for their dividend distributions, that attract investors seeking income. When interest rates are low, the yields of fixed-income investments, such as bonds or treasury securities, are lower. Lower interest rates make REITs more attractive for income-seeking investors, driving up demand for REIT shares and pushing prices higher. Conversely, when interest rates rise, the yields on fixed-income investments become more competitive, leading some investors to reallocate their portfolios away from REITs and toward other income-generating assets.

Given that the interest rates and REIT prices are interconnected, the anticipation of interest rate hikes or cuts can lead to changes in REIT prices before the actual rate change occurs. It is, therefore, clear that movements in REIT returns can signal anticipated changes in interest rates. Similarly, REITs, as leading indicators for broader economic trends, reflect changes in interest rates and other market conditions. Thus, REITs and interest rates are interdependent and can show bidirectional causality.

H4: Changes in interest rate affect REIT returns and show bidirectional causality.

# **3. Method**

## **3.1 Quantile ARDL method**

We use the quantile ARDL method (Cho et al., 2015) to investigate the quantile effects of CPU on REIT returns. The sensitivity of REIT returns to these risk metrics varies across different return quantiles. This means that the relationship between risk and returns is not uniform across all levels of REIT returns and is likely to be more sensitive to risk metrics during low-return periods when investors tend to be more risk-averse. The quantile autoregressive distributed lag (QARDL) method allows for nonlinear and dynamic analysis of the relationship between climate uncertainty and REIT returns. It can capture the asymmetric effects of climate uncertainty on REIT returns, meaning it can differentiate between positive and negative impacts. This is crucial because the impact of climate uncertainty on REITs varies depending on the magnitude or level of uncertainty.

Furthermore, it is important to note that REITs can be volatile in the short term, with their returns subject to fluctuations in real estate markets, interest rates, and other factors. This makes them a significant investment for both short and long-term alike. By considering short-term effects, investors can better understand the risks associated with investing in REITs and make informed decisions on whether to include them in their investment portfolio. Over the long term, REITs provide investors with a steady income stream through dividends while offering the potential for capital appreciation. Moreover, understanding the short- and long-term effects of REITs can help investors diversify their portfolios and potentially improve their long-term returns. The QARDL method allows for consideration of both short- and long-term effects, making it an ideal tool for examining the dynamic relationship between climate uncertainty and REIT returns. The Wald test was also used to validate the consistency of co-integrating coefficients across quantiles. This determines long- and short-term symmetry.

The baseline ARDL-ECM can be expressed by Eq. (1) as follows.

(1)

here, p, q, r, s, and w are the lag orders determined by the Schwarz information criteria (SIC) and is the error term.

We write the QARDL error correction model in Eq. (2):

(2)

where ∆QREIT is the τth quantile of REIT prices and τ specifies given quantiles in [0,1].

To empirically analyze the relationship, we use the following quantiles in this study.

Moreover, we test the short- and long-run asymmetry using the Wald test. The short-run symmetry for equation (2) is tested by using the following null hypotheses:

## **3.2 Quanitle Granger causality method**

The quantile Granger causality test helps to identify whether the influence of one time series on another varies across different levels of the data. This is particularly useful when the relationship between variables is nonlinear or varies under different conditions. It also provides insights into how the causal link between variables may change across different quantiles of the data. To investigate causality within different quantiles of REIT returns and CPU, EPU, and INT, we use the quantile Granger causality approach introduced by Tröster (2018). This method extends traditional causality tests (Granger, 1969) by examining the relationship at various quantiles of the data. It captures potential nonlinearities and conditional dependencies that exist in the dynamic interplay between these variables. The results at different quantiles offer insights into the robustness of REIT's causal relationships with chosen variables under different market or economic conditions.

A series Granger causes series if the past values of provide future information about and past values of itself can predict Granger (1969)*.* Following Tröster et al. (2018)*,* we use an explanatory vector , where the notation of indicates the past group of . We define the null hypothesis of the Granger non-causality from to in Eq. (3) as follows:

for all (3)

where is the conditional distribution function of given . Eq. (3) is the null hypothesis of Granger non-causality. Since the conditional distribution estimation may be complicated, many studies proposed tests for Granger non-causality in the mean. In this context, does not Granger-cause in mean, if

(4)

where and are the means of the and , respectively.

Granger non-causality in the mean of Eq. (4) can be easily extended to higher-order moments. However, causality in the mean (or in higher moments) ignores the possible dependence in the conditional tails of the distribution. In contrast, the null hypothesis of Granger non-causality in the distribution of Eq. (3) does not inform us about the level of causality if Eq. (3) is rejected. Therefore, we tested for Granger non-causality in conditional quantiles, as it determines the pattern of causality and provides a sufficient condition for testing the null hypothesis in Eq. (3), given that the quantiles fully characterize the distribution. Let and be the -quantiles of . Now we can rewrite the Eq. (3) as shown in Eq. (5):

, a. s., for all (5)

where is a compact set such that , and the conditional -quantiles of satisfy the following restrictions.

, a. s., for all (6)

, a. s., for all

Given an explanatory vector , then , where

y] is an indicator function of the event that is less than or equal to y. Thus, the null hypothesis of Granger non-causality in Eq. (5) is equivalent to Eq. (7):

, a. s., for all (7)

where the left-hand side of Eq. (7) is equal to the τ-quantile of . We apply the parametric model to estimate the τ-th quantile of . We assume that is correctly specified by a parametric quantile model m(., θ(τ)) belonging to a family of functions . Then, under the null hypothesis in Eq. (7), τ-the conditional quantile, , is correctly specified by a parametric quantile model that uses only the restricted information set . We can rewrite the null hypothesis of non-Granger-causality in Eq. (7) as follows:

, a. s., for all (8)

Versus

, a. s., for all (9)

where correctly specifies the true conditional quantile , for all . We can rewrite Eq. (8) as , a. s., for all . Then, we can characterize the null hypothesis in Eq. (9) by a sequence of unconditional moment restrictions:

, for all . (10)

where exp()] is a weighting function for all with r ≤ d, and is the imaginary root. The test statistic is a sample analog of

(11)

where is a constant estimator of , for all . Next, we apply the test statistic proposed by Tröster (2018):

(12)

Where is the conditional distribution function of a d-variate standard normal random vector, follows a uniform discrete distribution over a grid of in n equally spaced points , and the vector of weights is drawn from a standard normal distribution. The test statistic in Eq. (12), can be estimated using its sample analog. Let ψ be a *T x n* matrix with elements , where is the function  
 Then, we applied the following test statistic:

(13)

where ***W*** is the T × T matrix with elements , and denotes the j-th column of Ψ. We reject the null hypothesis of Granger non-causality in distribution whenever we observe large values of *ST* in Eq. (13). To apply the *ST* test in Eq. (13), we specify three different QAR models m (·), for all , under the null hypothesis of non-Granger-causality in Eq. (8) as follows:

(14)

where the parameters are estimated by maximum likelihood in an equally spaced grid of quantiles and is the inverse of a standard normal distribution function. To verify the sign of the causal relationship between the variables, we estimated the quantile autoregressive models in Eq. (14), including lagged variables of another variable. For simplicity, we presented the results using only a QAR(3) model with the lagged values of the other variable as follows:

(15)

# **4. Data**

We used monthly data on all Equity REITs (REIT), climate policy uncertainty (CPU), economic policy uncertainty (EPU), the CBOE Volatility Index (VIX), and interest rates (1-year Fed Fund Rates) from March 2006 to April 2023. The availability of the data determines the data duration. We collected the CPU and EPU data from <https://policyuncertainty.com>. REIT data was extracted from the Nareit website (<https://www.reit.com>). The data of the CBOE Volatility Index, a popular stock market volatility measure based on S&P 500 index options, is collected from https://www.cboe.com. The Fed fund rates are extracted from <https://fred.stlouisfed.org/>. The series is log-transformed. We calculate the monthly rate of changes (R) in each variable using the , where ‘S’ is the data series, and ‘t’ is the point of time.

Table 1. Descriptive statistics.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | REIT | CPU | EPU | VIX | INT |
| Mean | 0.1515 | 0.7142 | 0.3686 | 0.1590 | 0.0248 |
| Maximum | 26.6234 | 123.2682 | 68.4249 | 85.2587 | 91.6290 |
| Minimum | -38.4336 | -170.1375 | -64.3027 | -61.4278 | -256.4949 |
| Std. Dev. | 6.7068 | 38.3260 | 19.7677 | 23.3548 | 27.0860 |
| Skewness | -1.4042 | 0.2763 | 0.2185 | 0.4834 | -4.2245 |
| Kurtosis | 10.4668 | 4.5012 | 4.4016 | 3.7690 | 43.1769 |
| Jarque-Bera | 543.607\*\*\* | 21.8618\*\*\* | 18.414\*\*\* | 13.0378\*\* | 19.102\*\* |

Notes: \*\*\*p<0.01. REIT (Equity REIT returns), CPU (climate policy uncertainty), EPU (economic policy uncertainty), VIX (CBOE volatility index), and INT (1-Year Fed Fund Rates).

Table 1 contains the descriptive statistics of all the data. The data show that REIT prices, interest rates, and VIX have negative skewness and high kurtosis, while EPU and CPU have positive skewness. CPU shows higher deviations, followed by INT. The Jarque-Bera (J.B.) test statistics, which are significant at the 1% and 5% levels, indicate non-Gaussian distributions for the VIX data series.

Figure 1. Plots of changes in each time series, March 2006─ April 2023.



Figure 1 shows that REIT, CPU, EPU, and VIX share an upward trend during the study period. It can be observed that all five series exhibited extreme volatility from 2020 to 2023 due to the COVID-19 pandemic and geopolitical crises between Russia and Ukraine. Higher levels of economic uncertainty can lead to increased market volatility, which could affect REIT prices. Similarly, higher CPU could affect REITs. Real estate assets may be subject to climate-related risks, such as extreme weather events, rising sea levels, and changes in temperature and precipitation patterns.

Next, we conducted the unit root test to confirm that the time series were stationary. We tested the null hypothesis of non-stationarity for each series using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. I(0) indicates that the series is in order of zero, i.e., level stationary, while I(1) indicates that the series is integrated in order of 1, i.e., stationary after the first difference.

Table 2. Unit root test results.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variables | ADF | | PP | |
|  | I(0) | I(1) | I(0) | I(1) |
| REIT | -5.4522\*\*\* | -16.8879\*\*\* | -13.4683\*\*\* | -37.4745\*\*\* |
| CPU | -15.1373\*\*\* | -8.5529\*\*\* | -16.5300\*\*\* | -19.7677\*\*\* |
| EPU | -11.8852\*\*\* | -10.2742\*\*\* | -26.0802\*\*\* | -18.0409\*\*\* |
| VIX | -18.0500 | -13.1703\*\*\* | 0.7226 | -13.1857\*\*\* |
| INT | -9.3368\*\*\* | -12.0340\*\*\* | -9.1977\*\*\* | -55.9576\*\*\* |

Notes: \*\*\*p< 0.01, \*\*p<0.05, and \*p< 0.1. REIT (Equity REIT returns), CPU (climate policy uncertainty), EPU (economic policy uncertainty), VIX (CBOE volatility index), and INT (1-Year Fed Fund Rates).

Table 2 shows the test statistics from the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests indicate that all data series are stationary at level, i.e., I(0), except for VIX. The VIX is stationary at first-difference stationary, i.e., I(1). Therefore, the combination of the level- and first-differenced stationary variables and no second-differenced stationary variables makes them fit for the ARDL model (Shin et al., 2014).

# **5. Results and discussion**

## **5.1 Long-term quantile effects on U.S. real estate investment trust (REIT)**

In examining the impact of climate policy uncertainty on REIT returns across various quantiles, our findings in Table 3 reveal a negative relationship in the long term in the 0.05, 0.9, and 0.95 quantiles. Notably, the pronounced adverse effect observed at these quantiles aligns with our expectations of higher risk in the face of climate events. This finding can be attributed to the real estate sector's substantial global contribution of over 40% to CO2 emissions (Carlin, 2023). In addition, these findings are consistent with earlier empirical studies (Engle et al., 2020; Baldauf et al., 2020; Clayton et al., 2021), reinforcing the notion that CPU can potentially impact investors' interests in real estate. However, from the 0.1 to 0.4 and 0.6 to 0.8 quantiles, the results show positive effects of CPU on REITs, which partially contradicts our initial hypothesis. It is possible that during the periods corresponding to the 0.1 to 0.4 and 0.6 to 0.8 quantiles, investors perceive climate policy uncertainty as an opportunity rather than a risk, leading to increased investment in REITs. Additionally, climate policy uncertainty may interact with other market conditions in a way that positively affects REIT returns during specific quantiles. Housing policies aligned with environmental regulations, stock market performance, and GDP can also influence REIT returns.

Further results show that economic policy uncertainty (EPU) consistently negatively influences REIT returns across all quantiles. Investors are acutely aware of the potential long-term implications of economic policy uncertainty, which is why this consistent negative relationship exists. The underlying cause can be traced to economic policy news uncertainty and investor expectations. Our findings confirm the findings of existing research (Xia et al., 2020; Ling et al., 2020; Balcilar et al., 2021), which shows the impact of EPU on real estate investments.

Moreover, the results show a unique pattern in the long-term impact of the volatility index (VIX) on REIT returns. Notably, the negative impact of VIX on REIT returns is discernible across all quantiles except for 0.05, 0.3, and 0.5. This positive effect directly results from heightened uncertainty (as reflected by a higher VIX), which prompts investors to invest in tangible assets like real estate, including REITs. This flight to safety increases demand for REITs and potentially leads to positive returns during periods of higher volatility. This nuanced observation suggests a complex interplay between market volatility and real estate dynamics. Investors' heightened awareness is a pivotal factor in comprehending the volatility witnessed in stock markets. This, in turn, can manifest in the pricing of real estate assets. The translation of market shocks into real estate valuations equips investors with valuable insights, facilitating more informed decision-making regarding investments exposed to the uncertainties of climate-related factors. Furthermore, this dynamic contributes to portfolio risk diversification, a strategic move with financial stability and ecological sustainability implications.

The results show that interest rates both positively and negatively affect REIT returns in the long term. Interest rates negatively affect REIT returns, particularly at quantiles 0.2, 0.5, 0.6, and 0.95. Furthermore, the impact is more pronounced at lower quantiles, particularly in the 0.05 to 0.1 range. Lower interest rates cause higher borrowing costs for REITs and vice versa. Similarly, when interest rates rise, other investment options, such as bonds or fixed-income securities, may become more attractive to investors seeking income. This can lead to a shift in investor preferences away from REITs, potentially reducing demand for REIT shares and putting downward pressure on their prices in the long term. Thus, reduced demand for properties, lower rental income, and potential property value declines can negatively impact REITs in the long term. In addition to CPU, EPU, VIX, and interest rates, other economic forces such as inflation, credit market conditions, demographic trends, and stock market performance can affect REIT prices.

Table 3. Results of quantile effects on US REIT returns (March 2006─April 2023).

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Constant | ECT | Long-term estimates | | | | Short-term estimates | | | |
|  | *α*\*(τ) | *ρ*\*(τ) | *β*CPU(τ) | *β*EPU(τ) | *βVIX*(τ) | *βINT*(τ) | *c*CPU(τ) | *d*EPU(τ) | *e*VIX(τ) | *fINT*(τ) |
| 0.05 | 4.918\*\*\* | -0.870\*\*\* | -0.116\*\* | -0.062\*\*\* | 0.038\*\*\* | 0.982\*\*\* | -0.106\*\* | -0.032\*\* | -0.038\*\* | 0.506\*\* |
| (1.773) | (0.032) | (0.013) | (0.020) | (0.012) | (0.194) | (0.013) | (0.007) | (0.001) | (0.271) |
| 0.1 | 4.778\*\*\* | -0.730\*\*\* | 0.055\*\* | -0.058\*\* | -0.016 | 0.576\*\*\* | 0.044\*\*\* | -0.044\* | 0.032\*\* | -0.079 |
| (1.179) | (0.021) | (0.017) | (0.032) | (0.245) | (0.135) | (0.001) | (0.026) | (0.016) | (0.128) |
| 0.2 | 4.767\*\*\* | -0.940\*\* | 0.018\*\* | -0.048\* | -0.187\*\* | -0.421 | 0.018\*\*\* | -0.048\*\* | -0.101\*\* | -0.029 |
| (0.681) | (0.078) | (0.009) | (0.030) | (0.062) | (0.916) | (0.016) | (0.024) | (0.070) | (0.066) |
| 0.3 | 4.713\*\*\* | -0.869\*\*\* | 0.013\*\*\* | -0.046\*\*\* | 0.044\*\*\* | 0.367 | 0.0726 | -0.032\*\* | -0.076\*\* | 0.048\*\*\* |
| (0.528) | (0.022) | (0.006) | (0.023) | (0.012) | (0.897) | (0.094) | (0.013) | (0.092) | (0.017) |
| 0.4 | 5.060\*\*\* | -0.490\*\*\* | 0.072\*\*\* | -0.032\* | -0.076 | 0.463\*\*\* | 0.024\*\* | -0.019\*\* | 0.013 | 0.636\*\*\* |
| (0.502) | (0.093) | (0.006) | (0.022) | (0.105) | (0.104) | (0.007) | (0.002) | (0.102) | (0.061) |
| 0.5 | 4.345\*\*\* | -0.740\*\*\* | 0.065\*\*\* | -0.025\*\* | 0.069\*\* | -0.465\*\*\* | 0.886\*\*\* | -0.116\*\* | -0.029\*\* | 0.017\*\*\* |
| (0.390) | (0.032) | (0.015) | (0.019) | (0.031) | (0.106) | (0.044) | (0.038) | (0.026) | (0.004) |
| 0.6 | 4.218\*\*\* | -0.652\*\*\* | 0.047\*\*\* | -0.005 | -0.077\*\*\* | -0.322\*\* | -0.046\*\* | -0.050\*\* | -0.077\*\*\* | 0.471\*\*\* |
| (0.445) | (0.019) | (0.005) | (0.018) | (0.095) | (0.106) | (0.005) | (0.009) | (0.015) | (0.075) |
| 0.7 | 4.122 | -0.894\*\*\* | 0.029\*\*\* | -0.052\* | -0.085\* | 0.330 | -0.030\*\*\* | -0.105\*\* | -0.089\*\*\* | 0.111 |
| (0.403) | (0.031) | (0.003) | (0.039) | (0.087) | (0.096) | (0.004) | (0.039) | (0.002) | (0.085) |
| 0.8 | 4.740 | -0.835\*\*\* | 0.019\*\*\* | -0.080\*\*\* | -0.031\*\*\* | 0.348\*\* | -0.013\*\*\* | -0.015\*\* | -0.064\* | 0.190\*\*\* |
| (0.383) | (0.076) | (0.005) | (0.016) | (0.006) | (0.348) | (0.004) | (0.009) | (0.045) | (0.001) |
| 0.90 | 4.906 | -0.976\*\*\* | -0.152\*\* | -0.041\*\* | -0.174\*\*\* | 0.408\*\*\* | -0.059\*\*\* | -0.011\*\* | -0.034\*\* | 0.420\*\*\* |
| (0.807) | (0.072) | (0.011) | (0.020) | (0.032) | (0.1063) | (0.014) | (0.019) | (0.020) | (0.086) |
| 0.95 | 4.505 | -0.916\*\*\* | -0.099\*\* | -0.088\*\*\* | -0.040\*\*\* | -0.450\*\*\* | -0.991\*\*\* | -0.087\*\*\* | 0.040\* | 0.183\*\*\* |
| (1.364) | (0.103) | (0.018) | (0.051) | (0.014) | (0.117) | (0.007) | (0.016) | (0.031) | (0.076) |

Notes: REIT (Equity REIT), CPU (climate policy uncertainty), EPU (economic policy uncertainty), VIX (CBOE volatility index), and INT (1-Year Fed Fund Rates). \*\*\*p< 0.01, \*\*p<0.05, and \*p< 0.1. Standard errors are presented in the parentheses.

## **5.2** **Short-term quantile effects on U.S. real estate investment trusts (REITs)**

Table 3 presents the short-term quantile estimates derived from the quantile ARDL model, which shows the relationship between CPU and REIT returns. Notably, the short-term effect of CPU on REIT returns shows a negative relationship within the higher quantiles, specifically in the 0.6 to 0.95 range. However, the effects become more nuanced in the lower quantiles, particularly in the 0.1 to 0.5 range, displaying positive trends, except for the 0.05 quantile. This intriguing pattern aligns with findings from prior empirical studies, as reported by Giglio et al. (2021), Stroebel and Wurgler (2021), and Warren-Myers et al. (2022), providing additional support for the observed dynamics. This finding results from investors' rapid yet sporadic reactions to short-term fluctuations in real estate prices, influenced by the prevailing uncertainty in climate policy. The uncertainty associated with climate change has a wide-ranging impact on equity REITs. Firstly, REITs specializing in properties vulnerable to climate-related risks may witness a decline in value due to the increased threat of damage from storms and rising sea levels. Secondly, REITs invested in properties expected to benefit from the shift toward a low-carbon economy, such as renewable energy and green buildings, may experience an uptick in value. The intricate interplay of these factors contributes to the observed mixed effects at lower quantiles. The variability in reactions among investors is due to the difference in awareness and concern about climate change. While some investors are indifferent to climate uncertainty, others are enthusiastic about green investments. Consequently, when CPU increases (decreases), climate-aware investors tend to decrease (increase) their REIT investments. This intricate interplay results in the mixed effects of CPU on REIT prices at lower quantiles.

The short-term results show that EPU has a persistent negative impact on REIT returns across all quantiles. This outcome is consistent with prior research findings, as corroborated by studies conducted by Antonakakis et al. (2015), André (2017), and Bossman (2022). This finding can be explained by the fact that EPU can lead to uncertainty in the real estate market, interest rate uncertainty, and increased credit risk. These factors can lead to lower demand for REITs and lower prices, resulting in negative short-term returns. However, it is important to note that REITs can still offer attractive returns for investors in the long term, especially if they weather short-term market volatility. The results demonstrate that changes in economic policy uncertainty have a negative impact on real estate prices across all quantiles. The effect is more pronounced in higher quantiles, particularly in the 0.8 to 0.95 range. This finding can be explained by the diffuse uncertainty transmission channels through investors’ sentiments. Real estate, an important economic sector in the U.S., instantly reacts to any negative economic news and thus involves investors, regulators, and policymakers.

Our analysis of the short-term effects of VIX on REIT returns reveals a mixed effect on REITs across all quantiles. The findings indicate that investors’ responses to VIX linked with REIT prices are heterogeneous. This is likely due to the growing awareness among U.S. investors about climate policy uncertainty and the volatility of real estate markets or funds. Such heterogeneous effects in the short term are to be expected, given that climate uncertainty and induced market volatility from geopolitical threats have recently changed investors’ sentiments (Tang et al., 2023). Further results show that REITs are sensitive to interest rate fluctuations. Changes influence their stock prices, market expectations, and investor sentiment. Interest rates positively affect REIT returns across all quantiles except for quantiles 0.1 and 0.2 in the short term. The magnitude of the effects is higher at higher quantiles, specifically in the 0.6 to 0.95 range. Lower interest rates create positive sentiment as they reduce borrowing costs for REITs and make them relatively more attractive than other income-generating investments. From 2006 to 2016, interest rates showed a downward trend, which created positive sentiments among REIT investors.

In addition, the error correction terms (ECT) indicate that the estimated speed of adjustment coefficients, *ρ*\*(τ), are significant and negative across all quantiles. The results confirm that the deviations return to the long-term equilibrium among the variables under study. Notably, the speed of adjustment (-0.9761) is highest at the 0.90th quantile and lowest (-0.4902) at the 0.40th quantile. We also checked the constancy of the estimated parameters from the QARDL models. The results show that the long- and short-term parameters are stable across different time periods.

Table 4. Results of the Wald test for the constancy of the parameters.

|  |  |  |  |
| --- | --- | --- | --- |
| Variables | Wald-statistics | p-values | Decision |
| *ρ* | 5.7043 | 0.2902 | No instability |
| *βCPU* | 10.0230 | 0.0838 | No instability |
| *βEPU* | 3.7288 | 0.0542 | No instability |
| *βVIX* | 4.0232 | 0.0911 | No instability |
| *βINT* | 7.0891 | 0.0622 | No instability |
| *ci* | 5.0394 | 0.4301 | No instability |
| *di* | 6.3842 | 0.2835 | No instability |
| *ei* | 7.9203 | 0.0109 | No instability |
| *fi* | 5.7382 | 0.1743 | No instability |

Notes: CPU (climate policy uncertainty), EPU (economic policy uncertainty), VIX (CBOE volatility index), and INT (1-Year Fed Fund Rates).Null Hypothesis (H0): The parameter is constant over time.

Table 4 shows the null hypothesis that the parameters cannot be rejected at a 5% significance level. Thus, failing to reject the null hypothesis indicates that the parameters are stable across different time periods. This finding also indicates that the models are suitable to estimate the coefficients.

## **5.2 Causality analysis**

A causal relationship provides crucial insights into the dynamics of time series data. We, therefore, investigate the causal relationship between climate policy uncertainty and US REIT returns. Table 5 demonstrates the causal relationship between the two variables at different quantiles. The results show that climate policy uncertainty Granger causes real estate prices across all quantiles. However, there is a causal relationship between REIT returns and climate policy uncertainty only in higher quantiles, i.e., from 0.5 to 0.95. This finding indicates that climate policy uncertainty can predict REIT returns and, thus, can be utilized as a policy instrument to manage REIT prices. It means that the effect of climate policy uncertainty on REIT returns is homogeneous across the entire distribution. Climate risk can significantly impact REITs, increasing costs and reducing property values. Extreme weather conditions, such as hurricanes, floods, and droughts, can cause significant damage to buildings and infrastructure. This damage leads to costly repairs and reduced property values. The changing climate will also affect the demand for specific properties, such as beachfront properties, and reduce property values.

Regarding economic policy uncertainty, the results show bidirectional Granger causality with REIT returns across all quantiles. This finding is in line with the previous evidence from Aye and Poon (2018) and Balcilar et al. (2021). Interest rates can and do predict REIT returns across all quantiles. Likewise, REITs significantly influence interest rates in almost all quantiles. It is evident that increases and decreases in interest rates can Granger cause REIT returns through changes in property demand, rental income, and property value. These findings provide crucial policy information about the post-pandemic scenarios. For example, the causal effect of climate uncertainty on U.S. REITs provides valuable insights for making informed decisions regarding real estate investment. Additionally, the causal relationship between interest rates and REIT prices can further inform investors about the implications of their investments in financial assets.

Table 5. Results of quantile Granger causality test.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Quantiles | ∆REIT⇏∆CPU | ∆CPU⇏∆REIT | ∆EPU⇏∆REIT | ∆REIT⇏∆EPU | ∆INT⇏∆REIT | ∆REIT⇏∆INT |
| [0.05;0.95] | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.009 |
| 0.05 | 0.059 | 0.000 | 0.000 | 0.000 | 0.000 | 0.378 |
| 0.10 | 0.096 | 0.000 | 0.000 | 0.000 | 0.237 | 0.000 |
| 0.20 | 0.342 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.30 | 0.928 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.40 | 0.791 | 0.000 | 0.000 | 0.000 | 0.000 | 0.902 |
| 0.50 | 0.059 | 0.000 | 0.000 | 0.211 | 0.506 | 0.000 |
| 0.60 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.70 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.80 | 0.000 | 0.026 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.90 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.95 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.109 |

Notes: The p-values of the test statistics are reported in the table. ‘⇏’indicates Granger non-causality.∆CPU (changes in climate policy uncertainty), ∆EPU (changes in economic policy uncertainty), ∆REIT (Equity REIT returns), and ∆INT (changes in 1-Year Fed Fund Rates).

# **6. Conclusion and policy implications**

We investigated the quantile effects of climate policy uncertainty, interest rates, economics policy uncertainty, and volatility on REIT returns in the United States. We used monthly data from March 2006 to April 2023 and employed the quantile ARDL method. The findings provide striking evidence of short- and long-term effects of CPU and EPU on REIT returns across all quantiles, indicating a dynamic relationship between climate policy and economic policy uncertainty with REIT returns. This finding provides policy information about the dynamics of CPU and EPU. Investors can utilize the negative relationship between real estate prices and CPU and EPU. Furthermore, VIX has short- and long-term effects on REIT returns across all quantiles except for 0.1 and 0.4 quantiles. Interest rates have short-term positive effects, while the long-term effects are mixed across different quantiles. Further results from Granger causality-in-quantiles show that CPU can predict REIT returns across all quantiles, and REIT can predict CPU in lower quantiles. EPU and REIT returns show bidirectional causality, while interest rates have bidirectional causality with REIT returns across most quantiles.

These findings have significant implications for investors and policymakers. Regarding climate policy uncertainty, the policy implications for REITs will significantly impact REIT operations and financial performance. As governments worldwide adopt more stringent measures to address the impacts of climate change, REITs will undoubtedly face increased regulatory and financial risks. In addition, the policy implications of climate policy uncertainty for REITs highlight the need for the industry to consider the long-term financial and regulatory risks posed by climate uncertainty. The findings on the asymmetric relationships between REIT returns, climate policy uncertainty, volatility, and economic policy uncertainty provide essential insights for addressing climate change with REIT investment. Policymakers and REIT investors, in particular, can utilize the asymmetric relationships between REITs and CPU to update REIT investments according to climate uncertainty. REIT investors and portfolio managers can use the asymmetric and causal relationships between interest rates, EPU, and REITs to hedge against CPU and construct a diversified portfolio. The dynamic interactions between interest rates, CPU, and REIT returns provide investors and policymakers with the information they need to make informed decisions about the price movements of REITs during climate crises.

Future research can examine whether positive and negative changes in EPU, technology sector stocks, and CPU have symmetric effects on REIT prices in the United States. In addition, variables like monetary policy shocks, property technology stock, and green finance can be included. Furthermore, future studies can consider a group of countries to extend the literature instead of a single country.

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**Data availability**: The data used in this study are available at reasonable request from the corresponding author.  
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