

Lotz, Marton; Ruf, Daniel; Strobel, Johannes

Article — Published Version

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Real Estate Economics

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*Suggested Citation:* Lotz, Marton; Ruf, Daniel; Strobel, Johannes (2023) : Uncertainty premia in REIT returns, Real Estate Economics, ISSN 1540-6229, Wiley, Hoboken, NJ, Vol. 51, Iss. 2, pp. 372-407,  
<https://doi.org/10.1111/1540-6229.12423>

This Version is available at:

<https://hdl.handle.net/10419/287805>

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# Uncertainty premia in REIT returns

Marton Lotz<sup>1</sup> | Daniel Ruf<sup>2</sup>  | Johannes Strobel<sup>3</sup>

<sup>1</sup>Independent

<sup>2</sup>House of Finance, Goethe University, Frankfurt am Main, Germany

<sup>3</sup>Deutsche Bundesbank, Frankfurt am Main, Germany

## Correspondence

Daniel Ruf, House of Finance, Goethe University, Campus Westend, Theodor-W.-Adorno Platz 3, 60629 Frankfurt am Main, Germany.  
Email: [ruf@finance.uni-frankfurt.de](mailto:ruf@finance.uni-frankfurt.de)

## Abstract

We provide a systematic study of how financial and real estate uncertainty affect the aggregate return performance of the U.S. REIT market from 1994 to 2017. A temporal causality analysis reveals a negative uncertainty impact on REIT returns. The asset pricing analysis confirms the predictive relation and suggests that REITs are statistically significantly exposed to changes in market-wide uncertainty, for which investors require a return compensation. We also identify economic state variables to explain time-varying uncertainty exposures as well as periodic hedging characteristics of REITs. Finally, we find evidence that the source of uncertainty matters for compensating expected REIT returns.

## KEYWORDS

asset pricing, REITs, uncertainty

## 1 | INTRODUCTION

The outbreak of the global Covid-19 pandemic in 2020 has renewed awareness of the importance of uncertainty and associated economic and financial turmoil. The rapidly changing events surrounding the pandemic have made financial market conditions largely unpredictable and raised concerns about stock prices (Gormsen and Koijen, 2020). This is reflected in abnormal stock market dynamics (e.g., Cox et al., 2021) and higher uncertainty (Baker et al., 2020). Recalling its hybrid nature, highlighting the resemblance to the stock market, while being exposed to real estate factors (Clayton and MacKinnon, 2003; Hoesli and Oikarinen, 2012), publicly listed real

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estate deserves special attention with respect to uncertainty premia and potential hedge benefits in times of unpredictable financial markets. Few studies focus on how the current pandemic affects the REIT performance, either through higher stock market volatility (Milcheva, 2022) or via the exposure of underlying assets (Ling et al., 2020). Yet, to the best of our knowledge, what is missing is a general understanding of how REITs react to higher uncertainty.

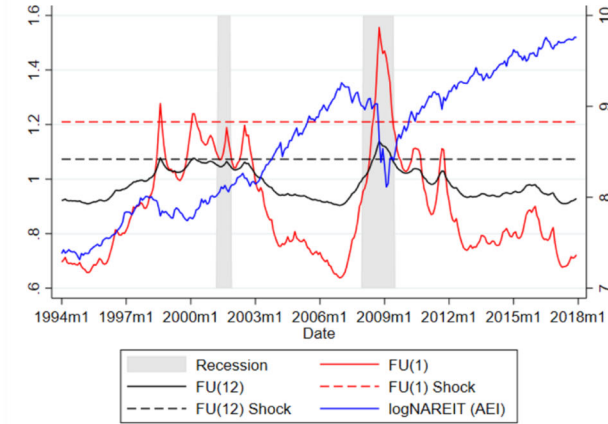
To fill this gap, we provide a systematic study on the impact of two novel uncertainty measures, financial uncertainty (FU) (Ludvigson et al., 2021), as well as real estate uncertainty (REU) (Thanh et al., 2020), on the aggregate REIT market. Specifically, this article analyzes to which extent these two types of uncertainty can account for time-series variation in REIT returns in an asset pricing context. We evaluate whether the source of uncertainty matters and which type of uncertainty is more relevant for REITs. A better understanding on how REIT return predictability is linked to FU is particularly relevant for investors who focus on securitized real estate in their portfolio for risk diversification across asset classes or to benefit from stable cash flows without directly investing in less liquid, private property markets.

As a motivation, Figure 1 illustrates FU and REU indices at a 1-month and 1-year ahead forecast horizon against the log Nareit All Equity REITs Index. Observable uncertainty shocks seem to coincide with more pronounced declines of the REIT index. For instance, FU(1) identifies three uncertainty shocks over the sample period from 1994 to 2017, that is, episodes with the index being at least 1.64 standard deviations above its mean (Bloom, 2009): the 1998 Long-Term Capital Management (LTCM) crisis, the dotcom bubble burst in 2000, and during the 2008–2009 Global Financial Crisis (GFC) (Ludvigson et al., 2021). REU does not react to financial shocks, such as the dotcom bubble burst. However, higher REU, both at the 1-month and 12-month forecast horizon, is also identified during the GFC, which had its origin in the residential housing market bust (e.g., Brunnermeier, 2009; Favilukis et al., 2017). Furthermore, REU is more prolonged and remains elevated, with further peaks around the subsequent U.S. debt ceiling disputes, for example, in 2011.

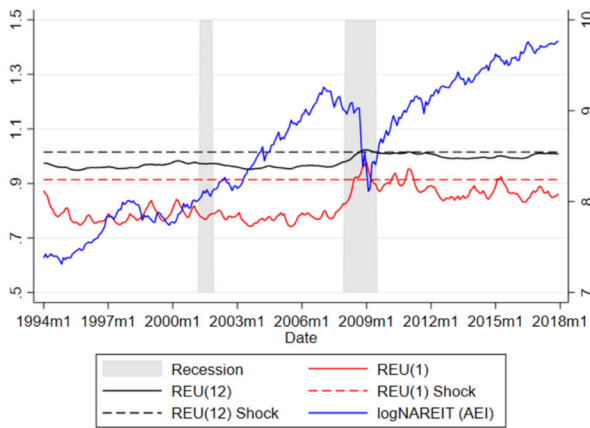
The pricing implications of uncertainty on REITs, to the best of our knowledge, have not yet attracted academic attention. Following the intertemporal capital asset pricing model, proposed by Merton (1973), asset prices and expected returns reflect hedging demand against unfavorable and uncertain stochastic shifts in the economy. For instance, higher uncertainty as a state variable translates into higher default risk, increasing borrowing costs (Bloom, 2014; Gilchrist et al., 2014; Ilut and Schneider, 2014) as well as productivity declines and lower investment and consumption activities (Bloom, 2009; Bloom et al., 2018; Jurado et al., 2015). Assets with negative exposure to unfavorable changes in economic conditions, driven by higher uncertainty, are traded at lower prices and generate on average higher compensating returns. Conversely, assets that benefit from an unexpected change in economic environment are perceived to be safe. Such assets provide a hedge against uncertainty due to a positive exposure, for which investors pay higher prices and accept lower returns (Bali et al., 2017).

We empirically evaluate how REIT returns respond to uncertainty. First, we conduct a simple temporal causality test to study whether both types of uncertainty are significant drivers of REIT performance. We then employ the cross-sectional asset pricing methodology proposed by Fama and MacBeth (1973) to compute the uncertainty premium as market price per uncertainty exposure. We find empirical evidence that, on average, investors demand a negative uncertainty premium for FU as well as REU. We also conduct an unconditional asset pricing analysis to demonstrate that uncertainty serves as return predictor for the aggregate REIT market performance. REITs are negatively exposed to changes in market-wide uncertainty, for which investors demand compensation in terms of higher expected returns over the sample period.

Panel (a) Financial Uncertainty and Equity REIT performance



Panel (b) Real Estate Uncertainty and Equity REIT performance

**FIGURE 1** Uncertainty indices and Nareit All Equity REITs Index

[Color figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

*Note:* The figure shows the development of Financial Uncertainty (FU( $h$ )) in Panel A and Real Estate Uncertainty (REU( $h$ )) in Panel B for monthly forecast horizon  $h = \{1, 12\}$  (lhs axis) and the log Nareit All Equity REITs Index (rhs axis) from 1994M01 to 2017M12. Horizontal dashed lines represent the one-sided 5% threshold for significant uncertainty shocks (5% one-tailed significance level) for the respective series defined as 1.64 standard deviations above the mean (Bloom, 2009). Gray-shaded areas indicate NBER recession periods.

As the impact of uncertainty varies over time, we perform a conditional asset pricing analysis to exhibit unique return dynamics in times of high uncertainty and to identify periodic hedging characteristics of REITs. Our findings reveal that the uncertainty premia for FU and REU, defined as the product of the corresponding market price of uncertainty exposure and its estimated beta, fluctuate over time. Finally, we identify economic state variables, such as residential house price growth, industrial production, and consumer sentiment for FU and the effective federal funds rate for REU, as predictors to explain time-varying uncertainty exposures and implied expected returns. Our findings are also consistent for the core REIT sectors residential, office, industrial, and retail. Hence, we offer new insights for real estate investors, allowing them to

derive informed portfolio and risk management decisions to exploit potential hedge benefits when dealing with uncertainty.

By examining whether FU and REU systematically command REIT return premia, we contribute to the literature on priced economic state variables (Chen et al., 1986; Karolyi and Sanders, 1998; Ling and Naranjo, 1997). Besides, we also build on the conditional asset pricing literature, highlighting the pricing implications of residential housing as a consumption good and predictor for stock returns (Lustig and Van Nieuwerburgh, 2005; Piazzesi et al., 2007).

We further contribute to the burgeoning literature on uncertainty by studying the pricing implications on REITs. For instance, Demiralay and Kilincarslan (2022) study how REITs respond to established uncertainty proxies, such as implied stock market volatility, tail risk, and economic policy uncertainty (EPU). Jurado et al. (2015) propose a novel econometric framework for measuring uncertainty, which is shown to be systematically priced in the stock as well as corporate bond market (Bali et al., 2017, 2021). Similarly, Strobel et al. (2018) focus on the implications of macroeconomic uncertainty on the residential housing market.

This article, however, focuses on FU and REU as REIT return predictors because it is not yet clear, if surging macroeconomic uncertainty is really the exogenous cause or rather the endogenous response to economic turbulences (Ludvigson et al., 2021). This motivates studies such as Ludvigson et al. (2021) and Thanh et al. (2020) to compute measures that explicitly track uncertainty on financial market indicators or the real estate industry. Employing both measures, we acknowledge that uncertainty is an exogenous impulse mechanism that may originate from different sources. For instance, Ludvigson et al. (2021) present FU as exogenous cause of macroeconomic fluctuations, whereas Leamer (2015) argues that the housing market serves as an early warning signal for economic recession periods.

The remainder of the article is organized as follows. Section 2 describes the data and provides the summary statistics. Section 3 presents the methodology and the empirical analysis. The last section concludes.

## 2 | DATA AND SUMMARY STATISTICS

### 2.1 | Uncertainty measures

In our analyses, we use *FU* and *REU* to explain REIT returns. Both indices follow the methodology outlined by Jurado et al. (2015) and are computed as the conditional volatility of the forecast error of a large set of economic variables. The index is constructed to reflect the notion of uncertainty regarding changes in the predictability of developments in the economy. The conditional volatility of the unpredictable component of  $h$ -month ahead forecasted time series  $y_{j,t+h}$  can be expressed as

$$\mathcal{V}_{j,t}^y(h) = \sqrt{E\{(y_{j,t+h} - E(y_{j,t+h}|I_t))^2|I_t\}}. \quad (1)$$

This equation clarifies that the forecast of  $y_{j,t+h}$ ,  $E(y_{j,t+h}|I_t)$  uses only information that is available until time  $t$ .<sup>1</sup> To capture the common variation of the uncertainty measures from different sources,

<sup>1</sup>The conditional volatility  $E\{(y_{j,t+h} - E(y_{j,t+h}|I_t))^2|I_t\}$  is estimated using a stochastic volatility model for  $h = 1$ . For  $h > 1$ , a recursive procedure is used.

multiple time-series forecast errors are then aggregated with individual weights  $\omega_j$

$$UNC(h) = \sum_{j=1}^n \omega_j U_{j,t}^y(h). \quad (2)$$

FU is based on a large set of financial market variables, containing, for example, valuation ratios, dividend, and price information, as well as established stock market factors (Ludvigson et al., 2021). In contrast, REU is derived from construction activity and supply-side variables of the residential housing market, such as housing starts and new built homes (Thanh et al., 2020). FU and REU are available for three different forecast horizons  $h = \{1, 3, 12\}$ , referring to 1-, 3-, and 12-month ahead uncertainty, respectively. In our main regression analyses, we focus on 1-month ahead uncertainty ( $h = 1$ ) to predict the corresponding next month's REIT excess return, therefore allowing for a clean lead-lag relationship. As a robustness check, we also use the other forecast horizons as proxies for very uncertain times, that is, when future market conditions of the next quarter or next year are also highly unpredictable.

Our sample period ranges from 1994M01 to 2017M12. The sample start is predetermined by the modern REIT era, beginning with the 1990s REIT boom (e.g., Clayton and MacKinnon, 2003; Van Nieuwerburgh, 2019), and matches the data availability of additional core sectors. Throughout this article, we use the Nareit All Equity REITs Index as proxy for the aggregate performance of the U.S. REIT market and compare the core sectors residential (RES), office (OFF), industrial (IND), and retail (RET) to study sector-specific heterogeneity. The chosen time series includes several turmoil periods, such as the GFC 2008/2009, allowing us to study the pricing implications of uncertainty on REITs. Our sample is also restricted by the availability of the REU index, which is computed until 2017.<sup>2</sup>

Table 1 presents the descriptive summary of the monthly REIT excess returns and the uncertainty indices. We report mean, standard deviation, minimum and maximum values, as well as test statistics of the augmented Dickey Fuller (ADF) unit root test. We convert the uncertainty measures into factors (referred to as  $\Delta FU$  and  $\Delta REU$ ) by taking the log differences of the level-based time series to mitigate potential concerns of high serial correlation when studying the time-series implications of uncertainty on REITs.<sup>3</sup> FU indicates a higher standard deviation than REU as higher forecast errors from more volatile financial time series also translate into larger fluctuations of the related aggregated uncertainty index (Jurado et al., 2015). Reported min-max values underpin this observation. Furthermore, with increasing  $h$ -step forecast horizon, the volatility declines for each measure. Both uncertainty measures are stationary processes, as shown by the ADF test with one lag and reported  $p$ -value, which rejects the existence of a unit root at a 1% significance level.

<sup>2</sup> We also prefer not to include the current period of the Covid-19 pandemic in our sample. In this context, our data restriction is in line with Ng (2021) who argues that the current health crisis has consequences on economic and financial indicators, but is not considered an economic shock. Consequently, both uncertainty indices must be adjusted during the pandemic accordingly.

<sup>3</sup> Figure A.1 in the Appendix shows that the uncertainty factors—the first differences of the uncertainty measures in levels—follow AR(1) processes. We include the lagged uncertainty factors from  $t - 1$  in all our regressions to explain REIT returns in period  $t$ . Hence, no information beyond time  $t - 1$  is used to compute the uncertainty measures when estimating the model. We control for the persistence by using Newey and West (1987) adjusted standard errors, which are robust to heteroskedasticity and serial correlation. Furthermore, we apply Breusch–Godfrey LM-tests as well as Durbin–Watson tests for the residuals in our main regressions. Both tests suggest that there is no serial correlation in the residuals.

**TABLE 1** Summary statistics of REIT excess returns and uncertainty factors

<b>Panel A: REIT excess returns</b>						
	<b>Obs</b>	<b>Mean</b>	<b>SD</b>	<b>Min</b>	<b>Max</b>	<b>ADF</b>
AEI	288	0.64	5.65	−38.16	27.01	−13.42***
RES	288	0.73	5.59	−31.08	20.07	−12.97***
OFF	288	0.67	6.17	−38.35	28.10	−12.83***
IND	288	0.61	9.13	−82.61	53.35	−14.81***
RET	288	0.63	6.51	−45.93	36.12	−13.03***
<b>Panel B: Uncertainty factors</b>						
	<b>Obs</b>	<b>Mean</b>	<b>SD</b>	<b>Min</b>	<b>Max</b>	<b>ADF</b>
$\Delta$ FU(1)	288	0.01	2.89	−8.66	9.35	−7.63***
$\Delta$ FU(3)	288	0.01	2.14	−6.31	7.03	−7.41***
$\Delta$ FU(12)	288	0.00	0.65	−1.82	2.26	−6.64***
$\Delta$ REU(1)	288	0.01	1.27	−3.48	4.16	−9.16***
$\Delta$ REU(3)	288	0.01	0.72	−1.87	3.04	−8.39***
$\Delta$ REU(12)	288	0.01	0.17	−0.36	0.75	−6.07***

*Note:* This table shows the summary statistics for excess returns of the Nareit All Equity REITs Index (AEI), core sector indices residential (RES), office (OFF), industrial (IND), and retail (RET), as well as the uncertainty factors for the sample period from 1994M01 to 2017M12. We present mean, standard deviation, as well as minimum and maximum values. ADF refers to the test statistics of the augmented Dickey Fuller unit root test with 1 lag. The corresponding statistical significance for the ADF unit root test is indicated as follows: \* $p < 0.1$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$ .

## 2.2 | Correlation and temporal causality analysis

In a next step, we study the correlation and the temporal causality between the uncertainty measures and the monthly REIT indices. Table 2 presents the correlation of  $\Delta$ FU( $h$ ) and  $\Delta$ REU( $h$ ) with the Nareit returns, respectively. The contemporaneous correlation between uncertainty and REIT returns is consistently negative, ranging from  $-0.29$  ( $\Delta$ FU(1)) to  $-0.08$  ( $\Delta$ REU(1)). We do not document much variation in the correlation with the property sectors, except for residential REITs, which tend to be slightly less correlated with the uncertainty measures. Overall, the correlation structure between REIT returns and  $\Delta$ FU( $h$ ) of different forecast horizons is persistent and substantially larger in absolute magnitude compared to  $\Delta$ REU( $h$ ) factors, whose correlation with REITs becomes slightly stronger with increasing horizon  $h$ . For robustness, the table also presents the correlation between REIT returns and lagged uncertainty factors. Allowing for up to six lags for  $\Delta$ UNC( $h$ ), based on the PACF and ACF time-series decomposition analysis, we show the strongest correlations between  $\Delta$ UNC( $h$ ) factors and REIT returns. The magnitude of the lagged correlation coefficients (with the first lag being dominant) is only marginally larger when compared to the contemporaneous correlation.

To highlight the thematic difference between FU and REU, we also report their weak correlation structure, for example, observing a magnitude of 0.11 for forecast horizon  $h = 1$ .<sup>4</sup> We also document a high correlation (up to 0.99) between different forecast horizons for the same uncertainty measure, further suggesting that in times of high uncertainty, long-term future market conditions, for example, in 1 year, are also highly unpredictable.

<sup>4</sup>The results are shown in Table A.1 in the Appendix to conserve space.



TABLE 2 Correlation analysis

<b>Panel A: Contemporaneous correlations</b>					
	<b>AEI</b>	<b>RES</b>	<b>OFF</b>	<b>IND</b>	<b>RET</b>
$\Delta\text{FU}(1)$	-0.29	-0.21	-0.28	-0.27	-0.25
$\Delta\text{FU}(3)$	-0.29	-0.21	-0.28	-0.27	-0.26
$\Delta\text{FU}(12)$	-0.28	-0.21	-0.27	-0.27	-0.25
$\Delta\text{REU}(1)$	-0.08	-0.08	-0.08	-0.07	-0.08
$\Delta\text{REU}(3)$	-0.14	-0.12	-0.14	-0.13	-0.15
$\Delta\text{REU}(12)$	-0.22	-0.16	-0.21	-0.20	-0.24
<b>Panel B: Strongest correlation—Lagged uncertainty factors</b>					
	<b>AEI</b>	<b>RES</b>	<b>OFF</b>	<b>IND</b>	<b>RET</b>
$\Delta\text{FU}(1)$	-0.30 [1]	-0.25 [4]	-0.30 [1]	-0.31 [1]	-0.28 [1]
$\Delta\text{FU}(3)$	-0.30 [1]	-0.26 [4]	-0.30 [1]	-0.31 [1]	-0.28 [1]
$\Delta\text{FU}(12)$	-0.31 [1]	-0.27 [4]	-0.30 [1]	-0.32 [1]	-0.29 [1]
$\Delta\text{REU}(1)$	-0.11 [1]	-0.12 [1]	-0.11 [1]	-0.13 [4]	-0.12 [2]
$\Delta\text{REU}(3)$	-0.15 [1]	-0.13 [1]	-0.15 [1]	-0.19 [4]	-0.17 [4]
$\Delta\text{REU}(12)$	-0.22 [0]	-0.16 [0]	-0.21 [0]	-0.21 [4]	-0.24 [0]

Note: The table shows the correlation coefficients between the uncertainty factors and the Nareit All Equity REITs Index (AEI) as well as the core sectors residential (RES), office (OFF), industrial (IND), and retail (RET), respectively. The sample ranges from the sample period 1994M01 to 2017M12. Panel A shows the contemporaneous correlation. Panel B shows the strongest correlations coefficients between REIT returns and lagged uncertainty factors. The corresponding lag order of the strongest correlation is reported in squared brackets. The maximum lag order is set to six lags.

Motivated by the correlation analysis, we also test the temporal causality of both uncertainty types on REIT returns. In a preliminary analysis, we estimate the following linear predictive model:

$$x_t = \beta_0 + \sum_{j=1}^L \alpha_j x_{t-j} + \sum_{j=1}^L \beta_j \Delta\text{UNC}_{t-j} + \varepsilon_t, \quad (3)$$

where  $x$  stands for the REIT log return and  $\Delta\text{UNC}$  defines the lagged uncertainty factors  $\Delta\text{REU}(h)$  and  $\Delta\text{FU}(h)$ , respectively. Newey and West (1987) adjusted standard errors (NW hereafter) account for heteroskedasticity and serial correlation. Following the approach of Thanh et al. (2020), we first study the long-term impact (LTI) of an uncertainty shock on REIT returns, defined as linear combination of  $\beta_j$  for lagged uncertainty factors. Second, the Granger causality test is based on a joint significance test of the lagged uncertainty factors. Uncertainty has a significant impact on REIT returns if both the long-run impact and the Granger causality test are statistically significant at least at a 5% significance level.

Table 3 reports the results of the simple temporal causality analysis. For  $L = 3$  lags, the analysis identifies a significant negative causal relationship between FU and REIT returns. Both the LTI and the joint significance test deliver statistically significant results on a 1% level. Furthermore, temporal causality for  $\Delta\text{REU}(12)$  still exceeds the 5% significance level. In contrast,  $\Delta\text{REU}(1)$  and  $\Delta\text{REU}(3)$  are not causal, following our definition. We also perform a robustness test, studying the sensitivity of the causality test to different lag structures of the predictive model. We confirm that the results are not driven by the chosen lag structure.



**TABLE 3** Simple temporal causality analysis

<b>Panel A: All Equity REITs Index (AEI)</b>								
<b>Uncertainty</b>	<b>Lag order <math>L = 3</math></b>				<b>Lag selection (<math>L</math>)</b>			
	<b>LTI</b>		<b>GC</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>
	<b>Sign</b>	<b>p-Value</b>	<b>p-Value</b>		<b>(2)</b>	<b>(4)</b>	<b>(5)</b>	<b>(6)</b>
$\Delta FU(1)$	(-)	0.001	0.006	+	+	+	+	
$\Delta FU(3)$	(-)	0.001	0.005	+	+	+	+	+
$\Delta FU(12)$	(-)	0.001	0.003	+	+	+	+	+
$\Delta REU(1)$	(-)	0.142	0.150					
$\Delta REU(3)$	(-)	0.043	0.092		+			+
$\Delta REU(12)$	(-)	0.037	0.043	+				
<b>Panel B: Sector-specific analysis</b>								
<b>Uncertainty</b>	<b>Residential</b>				<b>Office</b>			
	<b>LTI</b>		<b>GC</b>	<b>C</b>	<b>LTI</b>	<b>GC</b>	<b>C</b>	<b>C</b>
	<b>Sign</b>	<b>p-Value</b>	<b>p-Value</b>		<b>Sign</b>	<b>p-Value</b>	<b>p-Value</b>	
$\Delta FU(1)$	(-)	0.002	0.011	+	(-)	0.002	0.004	+
$\Delta FU(3)$	(-)	0.001	0.009	+	(-)	0.002	0.004	+
$\Delta FU(12)$	(-)	0.001	0.007	+	(-)	0.002	0.004	+
$\Delta REU(1)$	(-)	0.114	0.111		(-)	0.137	0.220	
$\Delta REU(3)$	(-)	0.069	0.127		(-)	0.040	0.112	
$\Delta REU(12)$	(-)	0.094	0.094		(-)	0.053	0.032	
<b>Uncertainty</b>	<b>Industrial</b>				<b>Retail</b>			
	<b>LTI</b>		<b>GC</b>	<b>C</b>	<b>LTI</b>	<b>GC</b>	<b>C</b>	<b>C</b>
	<b>Sign</b>	<b>p-Value</b>	<b>p-Value</b>		<b>Sign</b>	<b>p-Value</b>	<b>p-Value</b>	
$\Delta FU(1)$	(-)	0.007	0.038	+	(-)	0.012	0.037	+
$\Delta FU(3)$	(-)	0.007	0.035	+	(-)	0.010	0.033	+
$\Delta FU(12)$	(-)	0.006	0.029	+	(-)	0.006	0.023	+
$\Delta REU(1)$	(-)	0.115	0.250		(-)	0.107	0.304	
$\Delta REU(3)$	(-)	0.054	0.175		(-)	0.025	0.126	
$\Delta REU(12)$	(-)	0.070	0.203		(-)	0.012	0.037	+

*Note:* This table summarizes the results of the causality analysis of uncertainty factors on REIT returns when the lag order is  $L = 3$ . Panel A shows the results for the All Equity REITs Index. Panel B reports the results for the core sectors residential (RES), office (OFF), industrial (IND), and retail (RET). The sample period ranges from 1994M01 and 2017M12. Long-term impact (LTI) refers to the significance of the sum of coefficients  $\beta_j$  (shown  $p$ -values), and the LTI sign is reported in brackets. Granger Causality (GC) displays the results of the joint significance  $F$ -test of  $\beta_j$  as indicated by the  $p$ -values. The relationship is causal (C) and denoted with a + if both the long-run impact and the Granger causality are significant at least at a 5% level. The table also displays the sensitivity of the causal relationship between the uncertainty factors and the log returns of the NAREIT All Equity REITs Index depending on different lag selections  $L = \{2, \dots, 6\}$ ,  $L = 2$  being the minimum lag order and  $L = 6$  is suggested by PACF and ACF decomposition. Statistical significance is based on Newey and West (1987) standard errors using a maximum lag order of 6 following the NW rule of thumb. Asterisks of \*, \*\*, \*\*\* denote significance on a 10%, 5%, and 1% level, respectively.

We also show similar results across core sectors. Irrespective of the sector,  $\Delta FU(h)$  remains strongly significant. In contrast,  $\Delta REU(h)$  shows no causal impact, except for the retail sector. However, the LTI for  $\Delta REU(3)$  and  $\Delta REU(12)$  is significant across all sectors at a 10% level. For all factors, the sign of LTI is consistently negative across sectors. Concluding the simple causality analysis, FU is a significant driver of REIT returns in a temporal sense, suggesting that the public

real estate market is exposed to uncertainty in the financial market, which seems to be more relevant than REU.

## 2.3 | Additional risk factors and stock-level controls

Van Nieuwerburgh (2019) shows that about half of the variation in REIT returns can be explained by the Carhart (1997) four factor model, extended by bond market risk. This model specification serves as a benchmark for our asset pricing analysis. Therefore, we include the stock market factor (stocks), defined as the monthly value-weighted excess return on all CRSP stocks listed on the NYSE, AMEX, or NASDAQ as proxy for business cycle risk. The bond market factor (bonds) is the monthly excess return of the 10-year constant maturity Treasury bond. The size factor (SMB) replicates a portfolio with long position in small stocks and short position in large stocks. The value factor (HML) mimics a long position on stocks with high book-to-market (BTM) and a short position on low BTM stocks (Fama and French, 1993). Lastly, the momentum (MOM) factor takes a long position in stocks with the highest returns in the last 12 months and shorts losers (Carhart, 1997). The risk-free rate is proxied by the 1-month Treasury bill rate.<sup>5</sup>

To extract the uncertainty premia for FU and REU, we apply the Fama and MacBeth (1973) approach. When estimating uncertainty betas, we additionally control for other predictors. We include the liquidity factor (LIQ), which mimics returns of a portfolio with long positions in stocks with low liquidity beta and a short position on stocks with high liquidity beta (Pástor and Stambaugh, 2003). Following Fama and French (2015), we also use the investment factor (CMA), taking a long (short) position in firms with high (low) investment–asset ratios, whereas the operating profitability factor (RMW) goes long in companies with high operating profitability and shorts low profitability firms.

Motivated by Bali et al. (2017), we also compute monthly individual stock market betas ( $\beta_{i,t}^{stocks}$ ) as controls. Estimates are based on a fixed 60-month rolling window regression of monthly stock excess returns on the stock market factor. Similarly, bond betas ( $\beta_{i,t}^{bonds}$ ) and momentum betas ( $\beta_{i,t}^{Mom}$ ) are calculated, using the bond market factor and momentum factor as explanatory variables conditional on stock market risk. We also calculate *Size* as share price times shares outstanding denoted in million USD, the Amihud (2002) illiquidity ratio, defined as absolute monthly return over the trading volume, and the annual individual BTM ratio (Fama and French, 1993). To control for outliers of individual coefficients  $\beta_{i,t}^{UNC}$ ,  $\beta_{i,t}^{stocks}$ ,  $\beta_{i,t}^{bonds}$ ,  $\beta_{i,t}^{Mom}$ , and BTM, we winsorize the obtained set of monthly time series, eliminating the top and bottom 1% outliers.

## 3 | EMPIRICAL RESULTS

### 3.1 | Uncertainty premium in stock returns

In this article, we study the asset pricing implications of uncertainty on REITs. In a preliminary analysis, we first estimate the uncertainty premia or market prices of FU and REU based on the cross-section of U.S. stocks. Since REITs are publicly listed stocks, we first need to derive how uncertainty is priced in the underlying stock market universe. For nontradeable factors, such as

<sup>5</sup> The variable description is given in Table A.2 in the Appendix.

uncertainty, the market price per exposure does not equal the simple time-series average as a unconditional expected value of the risk factor (e.g., see Goyal, 2012 for an overview). Similarly, as the pricing implications of FU and REU have not yet been studied, to the best of our knowledge, there is no available proxy for the corresponding market prices of uncertainty. To overcome this limitation, we follow Bali et al. (2017) who study the cross-sectional pricing implications of macroeconomic uncertainty on stocks. Hence, we conduct the empirical two-step approach of Fama and MacBeth (1973) to compute an estimate for the average uncertainty premium priced in the overall stock market.<sup>6</sup>

For individual stocks, we first estimate monthly uncertainty betas based on a 60-month rolling window time-series regression. Uncertainty betas are computed by regressing the individual monthly stock excess returns ( $er_{i,t}$ ) on the respective, level-based, 1-month ahead uncertainty indices REU(1) and FU(1), using the following model:

$$\begin{aligned}
 er_{i,t-j} = & \beta_{0,i} + \beta_{i,t}^{UNC(1)} UNC(1)_{t-j} + \beta_{i,t}^{stocks} er_{t-j}^{stocks} + \beta_{i,t}^{bonds} er_{t-j}^{bonds} \\
 & + \beta_{i,t}^{SMB} SMB_{t-j} + \beta_{i,t}^{HML} HML_{t-j} + \beta_{i,t}^{MOM} MOM_{t-j} \\
 & + \beta_{i,t}^{RMW} RMW_{t-j} + \beta_{i,t}^{CMA} CMA_{t-j} + \beta_{i,t}^{LIQ} LIQ_{t-j} + \varepsilon_{i,t},
 \end{aligned} \tag{4}$$

where  $i$  indexes the individual stocks,  $t$  refers to the final month of the estimation period, and  $j \in \{0, \dots, 59\}$  indicates the rolling window. We include established return predictors as additional control variables, such as stock market risk ( $er^{stocks}$ ), the bond market factor ( $er^{bonds}$ ), as well as size (SMB), value (HML), momentum (MOM), profitability (RMW), investment (CMA), and liquidity (LIQ) factors. Adding the monthly individual uncertainty betas to other stock-level return predictors such as  $\beta_{i,t}^{stocks}$ ,  $\beta_{i,t}^{bonds}$ ,  $\beta_{i,t}^{Mom}$ , Size, BTM, and the Amihud (2002) illiquidity ratio, we compile a panel dataset of explanatory variables for individual stocks each month. We match them with 1-month ahead individual excess returns as dependent variables ( $er_{i,t+1}$ ).

In a second step, we then run monthly cross-sectional regressions based on the estimated uncertainty betas as well as with additional regressors, using the following predictive model:

$$er_{i,t+1} = \lambda_{0,t} + \lambda_t^{UNC(1)} \beta_{i,t}^{UNC(1)} + \lambda_t^* X_{i,t} + \varepsilon_t, \tag{5}$$

where  $X_{i,t}$  denotes a set of stock-level control variables and  $\lambda_t$  is interpreted as implied monthly risk premium for a certain risk factor. As a final step, we compute the average of the monthly cross-sectional slope coefficients  $\lambda_t^{UNC(1)}$  over the entire sample period to derive  $\lambda^{UNC(1)}$ , a general market-wide average uncertainty premium per uncertainty exposure. As suggested by Petersen (2009), we account for time-series autocorrelation by using NW  $t$ -statistics with six lags when averaging lambdas. The main goal of this analysis is to estimate and test for statistically significant nonzero uncertainty premia ( $\lambda^{UNC(1)}$ ) conditional on other established return predictors, which are included as controls to avoid a potential omitted factor bias.

Table 4 reports the results of the respective lambdas ( $\lambda$ ), that is, the estimated nonzero average market price per uncertainty exposure, derived from the Fama and MacBeth (1973) regressions.

<sup>6</sup> Similar to Bali et al. (2017), we use a set of available stocks, including REITs, to reflect the overall capital market when estimating the market prices of FU and REU. Following their approach, we first remove price outliers with prices below 5USD and above 1000USD for stocks listed on the NYSE, AMEX, and NASDAQ over the sample period and available on CRSP.

TABLE 4 Market price of uncertainty with Fama–MacBeth regression

$\lambda$	FU(1)			REU(1)		
	(1)	(2)	(3)	(4)	(5)	(6)
$\beta^{UNC}$	−0.76*	−0.76*	−0.77*	−0.16*	−0.16*	−0.16*
	[−1.78]	[−1.73]	[−1.74]	[−1.69]	[−1.69]	[−1.70]
$\beta^{stocks}$	0.49**	0.47**	0.47**	0.48**	0.47**	0.47**
	[2.44]	[2.36]	[2.35]	[2.42]	[2.34]	[2.33]
$\beta^{bonds}$	−0.03	−0.03	−0.03	−0.03	−0.03	−0.03
	[−0.66]	[−0.68]	[−0.68]	[−0.63]	[−0.64]	[−0.64]
$\beta^{Mom}$		−0.20***	−0.20***		−0.20***	−0.20***
		[−2.62]	[−2.64]		[−2.70]	[−2.71]
Illiq			−0.00**			−0.00**
			[−2.03]			[−2.05]
Size	−0.30***	−0.30***	−0.30***	−0.30***	−0.30***	−0.30***
	[−6.99]	[−7.00]	[−7.00]	[−6.93]	[−6.93]	[−6.94]
BTM	−0.07	−0.08	−0.08	−0.07	−0.08	−0.07
	[−1.43]	[−1.59]	[−1.49]	[−1.35]	[−1.53]	[−1.43]
Cons	2.64***	2.62***	2.66***	2.64***	2.62***	2.66***
	[8.01]	[8.01]	[7.94]	[7.97]	[7.96]	[7.90]
Avg. $R^2$	4.34	4.67	4.73	4.33	4.66	4.72

Note: This table reports the Fama–MacBeth regression results using estimated  $\beta_{i,t}^{UNC}$  for FU(1) and REU(1), respectively. The sample period ranges from 1994M01 to 2017M12. Parameter  $\lambda_t^{UNC}$  is estimated conditional on common stock-level return predictors. The dependent variable of the cross-sectional regressions are 1-month ahead stock excess returns. Each row stands for the time-series average of slope coefficients of the explanatory variable from the monthly cross-sectional regressions ( $\lambda_t^{var}$ ). The variable of interest is the individual monthly  $\beta_{i,t}^{UNC}$ , at the 1-month ahead forecast horizon. Other stock-level based explanatory variables are used as controls: the monthly stock market beta ( $\beta_{i,t}^{stocks}$ ), bond market beta ( $\beta_{i,t}^{bonds}$ ), momentum factor beta ( $\beta_{i,t}^{Mom}$ ), the Amihud (2002) illiquidity ratio (Illiq), Size ( $\ln$  market capitalization in million dollars), and BTM (stock-specific book-to-market ratio). Avg.  $R^2$  denotes the average coefficient of determination of the monthly cross-sectional regressions. Newey and West (1987)  $t$ -statistics (six lags) are reported in brackets. The corresponding statistical significance is indicated as follows: \* $p < 0.1$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$ .

The corresponding NW  $t$ -statistics are given in the brackets. The estimated uncertainty premia for both measures are negative and statistically significant. The findings suggest that an increase in uncertainty reduces consumption opportunities, for which uncertainty averse investors require a compensation (Bali et al., 2017; Merton, 1973). The market price of FU(1) equals −9.12 percentage points p.a. per uncertainty exposure. The estimated coefficient for FU(1) suggests that an asset with negative uncertainty exposure  $\beta^{FU(1)} < 0$ , that is, performing poorly in times of increasing uncertainty, would earn a compensation of 0.76 percentage points per month (9.12 percentage points p.a.) per FU exposure. In contrast, an asset with positive uncertainty beta  $\beta^{FU(1)} > 0$ , performing well in uncertain times, requires on average lower expected returns. For REU(1), for example, the market price is substantially lower in absolute magnitude, with estimated coefficient of −0.16, but statistically significant with −1.92 percentage points p.a. per uncertainty exposure.

For both uncertainty measures, the estimated lambda is robust for different model specifications. The baseline models include the established stock market and bond market betas as well as stock-level controls, such as size and BTM. We find similar results for the estimated market prices of uncertainty, when we include the momentum beta as additional risk factor exposure or control for stock-level illiquidity (Illiq).

While it is rational to expect a nonzero market price of FU for publicly listed stocks, we provide empirical evidence that REU is also priced in the stock market universe. Since this uncertainty measure is predominantly derived from housing variables, this finding is consistent with Leamer (2015), who argues that the real estate sector serves as an indicator for macroeconomic fluctuations. We will further support this claim in the subsequent analyses when we introduce residential house price growth as a state variable to allow REIT uncertainty premia to move with business cycle movements. Our results are also in line with, for example, Piazzesi et al. (2007) who highlight the role of residential housing as consumption good in asset pricing models for priced stock market risk premia. Overall, our findings show that publicly listed U.S. stock returns reflect a statistically significant nonzero average market price for both FU and REU over the sample period. In the subsequent asset pricing analysis, when we explore the exposure of the REIT sector to uncertainty, we refer to the lambda estimates as unconditional proxies for the market-wide uncertainty premia.

### 3.2 | Unconditional asset pricing analysis

This section further explores the role of uncertainty as return predictor for the aggregate REIT market. REITs would be perceived as safe assets, that is, perform well in times of high uncertainty, when revealing a positive factor exposure. Conditional on the negative uncertainty premium, this would imply lower expected returns accepted by uncertainty-averse investors when investing in the aggregate REIT market. In contrast, a negative uncertainty beta, that is, suggesting a poor performance of the aggregate REIT sector during periods of high uncertainty, would indicate that investors demand a compensation in terms of higher expected returns when investing in REITs. We test for FU and REU as REIT return predictors separately, as well as combined in a simultaneous model specification to disentangle the different sources of uncertainty.

Throughout the asset pricing analysis, we employ the Carhart (1997) four factor model extended by the bond market factor, as suggested by Van Nieuwerburgh (2019). We complement this benchmark model with lagged  $\Delta UNC(1)$  factors as additional explanatory variables to estimate the uncertainty exposure. Including 1-month-lagged versions of  $\Delta UNC(1)$  factors reinforces a causal interpretation in a temporal sense, based on a clean lead-lag relationship, as established in Subsection 2.2. More important, using lagged uncertainty factors directly allows us testing the pricing implications of the 1-month ahead uncertainty on the corresponding REIT market return. We outline the following asset pricing model

$$er_t = \alpha + \beta^{UNC(1)} \Delta UNC(1)_{t-1} + \beta^{stocks} er_t^{stocks} + \beta^{bonds} er_t^{bonds} + \beta^{SMB} SMB_t + \beta^{HML} HML_t + \beta^{MOM} MOM_t + \varepsilon_t, \tag{6}$$

where  $er_t$  stands for the monthly log excess returns on the equity REIT indices in period  $t$  and  $\Delta UNC(1)_{t-1}$  denotes the first lag of the uncertainty factors,  $\Delta REU(1)$  and  $\Delta FU(1)$ , respectively, with 1-month forecast horizon for period  $t$ . Hence, we test the unpredictable uncertainty factors, given all information in period  $t - 1$ , to explain REIT returns conditional on risk factors observed in period  $t$ .

Table 5 shows the results of the unconditional asset pricing analysis with the lagged uncertainty factors as return predictors. In Panel A, we report the betas and the corresponding NW  $t$ -statistics (six lags) for different model specifications using All Equity REITs excess returns. The

TABLE 5 Unconditional asset pricing analysis with  $\Delta FU(1)$  and  $\Delta REU(1)$  factors

	Panel A: All Equity REIT				Panel B: Core sectors			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	AEI	AEI	AEI	AEI	RES	OFF	IND	RET
Constant	-0.19 [-0.64]	-0.17 [-0.60]	-0.18 [-0.63]	-0.16 [-0.59]	0.00 [0.01]	-0.18 [-0.63]	-0.60 [-0.97]	-0.18 [-0.49]
Stocks	0.77*** [6.33]	0.73*** [6.95]	0.76*** [6.38]	0.73*** [6.97]	0.67*** [6.66]	0.81*** [7.94]	1.08*** [4.39]	0.70*** [5.15]
Bonds	0.57*** [3.59]	0.61*** [3.87]	0.57*** [3.57]	0.60*** [3.85]	0.42*** [2.84]	0.49*** [3.08]	0.98*** [2.64]	0.75*** [3.69]
SMB	0.44*** [5.19]	0.44*** [5.28]	0.44*** [5.19]	0.44*** [5.28]	0.36*** [4.82]	0.44*** [4.75]	0.50*** [2.83]	0.51*** [4.79]
HML	0.69*** [5.12]	0.67*** [5.05]	0.68*** [5.15]	0.67*** [5.07]	0.67*** [5.01]	0.73*** [6.53]	0.90*** [3.44]	0.71*** [4.33]
MOM	-0.10 [-1.56]	-0.09 [-1.46]	-0.10 [-1.56]	-0.09 [-1.46]	-0.03 [-0.51]	-0.06 [-0.91]	-0.06 [-0.66]	-0.16* [-1.82]
$\Delta FU(1)$		-0.23** [-2.00]		-0.22* [-1.95]	-0.09 [-1.03]	-0.22* [-1.86]	-0.49 [-1.50]	-0.27* [-1.72]
$\Delta REU(1)$			-0.22 [-1.52]	-0.17 [-1.20]	-0.28 [-1.50]	-0.19 [-1.17]	-0.11 [-0.41]	-0.17 [-0.83]
Adj. $R^2$	52.63	53.84	52.87	53.99	42.54	52.64	42.98	46.19

Note: This table reports the results of the unconditional asset pricing analysis using the 1-month lagged  $\Delta FU(1)$  and  $\Delta REU(1)$  factors as proxy for uncertainty. The dependent variable is the log excess return of the Nareit All Equity REITs Index (AEI) and of the core sectors residential (RES), office (OFF), industrial (IND), and retail (RET). The model-based alpha, denoted as constant, is reported in the first row (as decimal). The  $t$ -statistics are shown in brackets and are calculated based on Newey and West (1987) standard errors with six lags. Adjusted  $R^2$  denotes the adjusted coefficient of determination, expressed in percentage. The analysis considers the sample period from 1994M01 to 2017M12. The corresponding statistical significance is indicated as follows: \* $p < 0.1$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$ .

models suggest a negative relation between the lagged  $\Delta FU(1)$  factor and aggregate REIT returns, which confirms the findings of the simple causality analysis. For instance, column (2) suggests a statistically significant point estimate of  $-0.23$  for  $\Delta FU(1)$  with NW  $t$ -statistics of  $-2.00$ . The negative factor loading implies that REITs on an aggregated level perform poorly during periods of increasing FU, for which an additional return compensation is required. This is also reflected by the model-implied expected return component, stating that  $\Delta FU(1)$  exposure directly contributes  $(-0.23) \times (-0.76) \times 12 = 209.76$  bps p.a. as compensation to the total expected return based on the estimated market price. We find no statistically significant impact of REU, which is surprising given the observed market price of this uncertainty factor. In the subsequent analysis, we show that the uncertainty betas are time-varying, with indicated periods of positive and negative REIT uncertainty exposures over the sample period. Hence, the unconditional model cannot precisely capture the time-varying pattern, leading to a near-zero estimate (e.g., Van Nieuwerburgh, 2019).<sup>7</sup>

<sup>7</sup> For instance, in Table A.3 in the Appendix, we find a negative and statistically significant impact of REU on REITs, when we start the sample period in 1990M1. Although this finding should be taken with caution, it suggests that, on average, a negative time-series relationship between REIT returns and both lagged uncertainty measures might dominate. We do not study the period prior to the modern era, as before the Tax Reform Act of 1986, REIT regulation, and hence, performance, was fundamentally different and not comparable to our sample (see, e.g., Ling and Ryngaert, 1997 for an overview).

Ludvigson et al. (2021) argue that the origin of uncertainty matters and different sources may have a different economic impact. We investigate the simultaneous effect of lagged  $\Delta FU(1)$  and  $\Delta REU(1)$  on REIT returns. The results are presented in column (4), suggesting a negative beta coefficient for the lagged  $\Delta FU(1)$  with a magnitude of  $-0.22$ , which is statistically significant with NW  $t$ -statistics of  $-1.95$  conditional on  $\Delta REU(1)$ . The captured effect of  $\Delta FU(1)$  therefore remains robust when including  $\Delta REU(1)$  as additional predictor. We conjecture that REITs are priced closer to changes in FU. For instance, a stronger representation of lasting FU episodes over the sample period, like the LTCM crisis, the dotcom bubble burst or the GFC, may offer a potential explanation. Both the REU and FU measures identify the GFC as a significant uncertainty episode, which eventually causes additional difficulties to distinguish and attribute the effects to the respective uncertainty measures. In the next section, we therefore discuss the implications arising from conditional asset pricing models, allowing the uncertainty beta to fluctuate over time. To study the impact of both uncertainty measures, conditional models might be more suitable than unconditional asset pricing models, for which the uncertainty beta is assumed to be constant over the sample period.

The model specifications also suggest a statistically significant exposure to the general stock market and the Fama and French (1993) factors, which is in line with early studies such as Peterson and Hsieh (1997). The strong exposure to bond market risk confirms the bond-like character of REITs, supporting the findings of Van Nieuwerburgh (2019) who shows that from the mid-2000s on, REITs seem to be priced closer to interest rate risk. Alpha values remain statistically insignificant near zero. We acknowledge that the interpretation of the alpha should be considered with caution when nontradeable uncertainty factors are included in the model. However, zero-abnormal REIT returns also hold for the benchmark pricing model, shown in column (1), which is only based on tradeable factors.

In Panel B, we also study the cross-sectional differences between the core sectors residential (RES), office (OFF), industrial (IND), and retail (RET) with respect to uncertainty. The regression models indicate no significant exposure to REU in general. However, we document a negative impact of FU on the office and retail sectors, which confirms our intuition. For instance, office markets, occupied by the financial service sector, are highly exposed to financial market fluctuations and periods of financial distress (see, e.g., Lizieri et al., 2000). Similarly, FU can affect the real economic activity (Caggiano et al., 2021), and therefore, the retail sector, whereas long-term lease contracts might protect the industrial sector (Van Nieuwerburgh, 2019). Our findings are also consistent with Demiralay and Kilincarslan (2022), who argue that the apartment sector is less sensitive to alternative uncertainty measures, such as the Chicago Board Options Exchange-implied volatility (VIX) or EPU as measured by Baker et al. (2016), due to its stable demand base.

### 3.3 | Do REIT uncertainty exposures vary over time?

The previous section suggests that REITs are in general negatively exposed to changes in FU. However, the recent literature shows that uncertainty exposures are strongest, when the perceived level of uncertainty is highest (see, e.g., Bloom, 2009, 2014; Ludvigson et al., 2021). These findings hint at time-varying asset pricing implications of changes in uncertainty and REIT return predictability, which are not captured by the unconditional methodology. In this section, we therefore test for time-series fluctuations in uncertainty exposures and corresponding return compensations. Furthermore, we dedicate special attention to potential episodic hedge



characteristics, that is, when uncertainty betas turn from negative to positive over the sample period.

We estimate monthly uncertainty betas based on a 60-month rolling window regression approach while controlling for the other risk factors as follows:

$$er_{t-j} = \alpha_t + \beta_t^{UNC} \Delta UNC(1)_{(t-1)-j} + \beta_t^{stocks} xr_{t-j}^{stocks} + \beta_t^{bonds} xr_{t-j}^{bonds} + \beta_t^{SMB} SMB_{t-j} + \beta_t^{HML} HML_{t-j} + \beta_t^{MOM} MOM_{t-j} + \varepsilon_{t-j}, \quad (7)$$

where  $j$  takes up the values from 0 to 59, and  $\beta_t^*$  denotes the monthly beta coefficient estimated from a rolling window with data of the last 60 months. Estimates at the beginning of the sample period are considered when at least 24 observations are available in the regression window. Consequently, the set of time-varying  $\beta_t^*$  is available from 1996M01. This monthly rolling window approach is repeated until 2017M12.

Panel A of Figures 2 and 3 illustrates the monthly uncertainty betas using the lagged  $\Delta FU(1)$  and  $\Delta REU(1)$  factors, respectively. In Panel B, we also show the implied expected return compensation based on the full sample average market prices for uncertainty (with  $FU(1) = -0.76$  and  $REU(1) = -0.16$  percentage points per month from the Fama and MacBeth (1973) regressions). On average, uncertainty betas seem to be predominantly negative, which is in line with the results of the causality test and the unconditional asset pricing models. This implies that REITs perform poorly when FU increases, for which uncertainty-averse investors require additional return compensation. Specifically, negative FU betas seem to be related to specific financial market shocks, such as the LTCM crisis in 1998 and the GFC episode in 2008/2009 (Ludvigson et al., 2021).

More interesting is the period of the early 2000s, which incorporates the securitization-driven commercial real estate boom prior to the housing market burst in 2007 (e.g., Duca and Ling, 2020). During this period, uncertainty betas are mainly positive, implying an episode of potential hedge characteristics against FU. Our findings are also in line with the previous literature. For instance, the observed positive uncertainty betas are consistent with the results of Van Nieuwerburgh (2019) who shows that REIT returns tend to be less connected to stock markets during the early 2000s.

Required return compensations for  $\Delta FU(1)$  exposure peak at about 4 percentage points p.a. during the GFC, immediately following the bankruptcy of Lehman Brothers in September 2008. In contrast, during the REIT boom phase of the 1990s investors were willing to accept about 1–2 percentage point p.a. lower expected returns in exchange for holding presumably safe REIT assets.

Taking lagged  $\Delta REU(1)$  as proxy for uncertainty, we show the betas and the required return compensation in Panels A and B of Figure 3. The estimated uncertainty betas generally reveal a negative factor loading. We also find that investors demand higher compensating expected returns during the real estate boom period of the 2000s, which was accompanied by low interest rates, a rapid expansion of subprime mortgages, and the CMBS market (Brunnermeier, 2009). Surprisingly, the most substantial positive factor exposure is observed during the GFC period and its aftermath. This might be driven by a positive hedging demand, as uncertainty-averse investors perceive REITs as safer assets compared to housing investments. In general, investors require up to 0.50 percentage points p.a. higher expected returns for being exposed to  $\Delta REU(1)$  prior to the housing bubble burst and the subsequent GFC period. During the housing bubble burst and the GFC, uncertainty-averse investors are willing to accept about 1–2 percentage points lower expected returns for holding REITs assets, respectively.

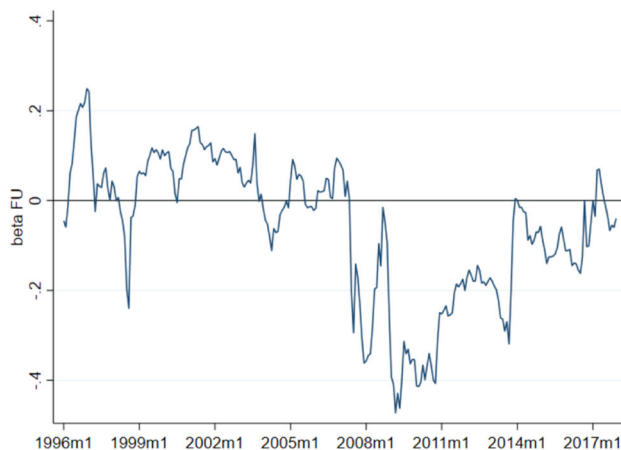
We also provide simple regressions to study how uncertainty betas respond to specific uncertainty shocks. For instance, as suggested by Muir (2017), risk premia are expected to be higher

**FIGURE 2** Time-varying  $\Delta FU(1)$  betas of REITs and implied return contribution

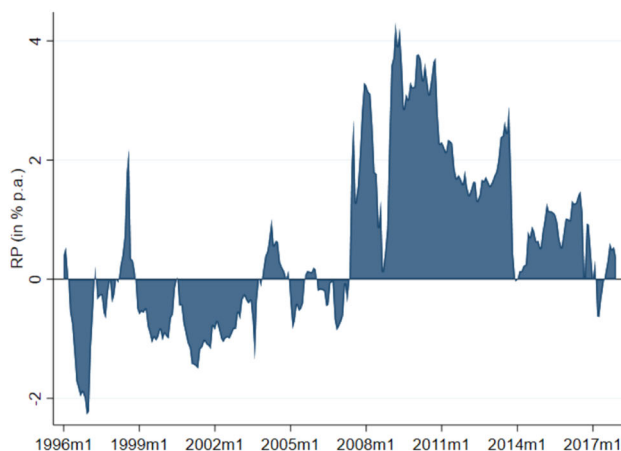
[Color figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

*Note:* In Panel A, the figure shows the estimated time-varying monthly uncertainty betas using the 1-month lagged  $\Delta FU(1)$  factor based on a 60-month rolling window regression (with a required minimum of 24 observations within the estimation window). In Panel B, the figure depicts the corresponding model-implied expected risk premium for the uncertainty exposure (in % p.a.), defined as the product of the monthly  $\Delta FU(1)$  beta and the annualized Fama and MacBeth (1973) market price of uncertainty. The sample period ranges from 1996M01 to 2017M12.

Panel (a) Estimated rolling window beta  $\Delta FU(1)$

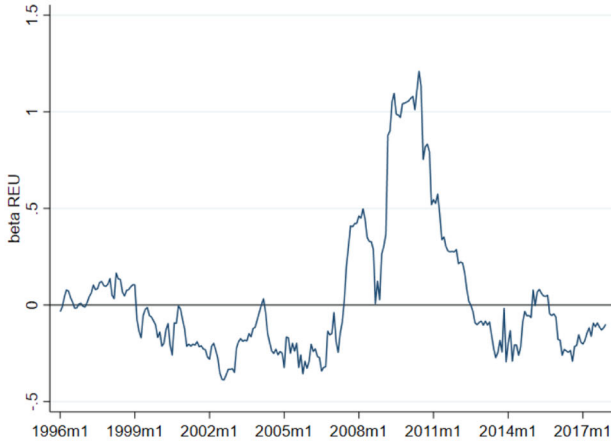


Panel (b) Implied risk premium (in % p.a.)

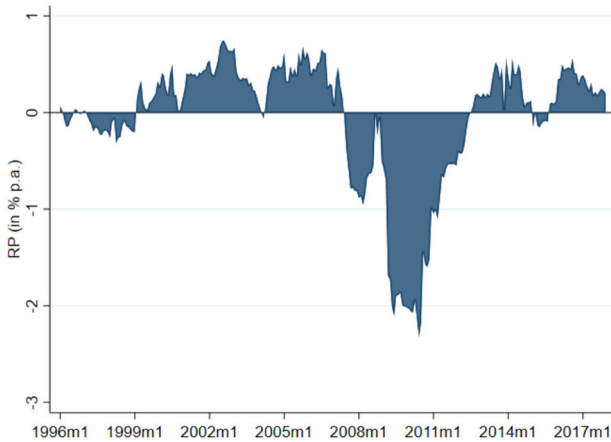


during crisis episodes. Given the observed negative market prices, this would be in line with observed negative REIT uncertainty betas. In Table 6, we present the results. FU betas are negative and statistically significant during financial crisis episodes, such as the LTCM crisis in 1998 and during the GFC 2008/2009 after the Lehman bankruptcy. Hedge episodes of the REIT market can be observed during the dotcom bubble burst, which was mainly driven by overvalued technology stocks (Ofek and Richardson, 2003), and the financial turmoil period following the 9/11 terrorist attacks in 2001. Furthermore, we observe, on average, a negative uncertainty beta, as indicated by the statistically significant constant term. For REU, uncertainty betas become negative during the economic downturn, following the dotcom bubble burst and the 9/11 terrorist attacks in the early 2000s. As hedge periods with positive uncertainty betas, we identify the GFC 2008/2009 and the episode around the U.S. debt ceiling dispute in 2011 (Baker et al., 2016).

To summarize, our analysis relates the time-varying behavior of REIT uncertainty exposures to specific turmoil periods. However, we prefer to interpret these results as rather descriptive. We do not claim to fully explain the volatile pattern of the estimated uncertainty betas. By construction,

Panel (a) Estimated rolling window beta  $\Delta\text{REU}(1)$ 

Panel (b) Implied risk premium (in % p.a.)

**FIGURE 3** Time-varying  $\Delta\text{REU}(1)$  betas of REITs and implied return contribution

[Color figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

*Note:* In Panel A, the figure shows the estimated time-varying monthly uncertainty betas using the 1-month lagged  $\Delta\text{REU}(1)$  factor based on a 60-month rolling window regression (with a required minimum of 24 observations within the estimation window). In Panel B, the figure depicts the corresponding model-implied expected risk premium for the uncertainty exposure (in % p.a.), defined as the product of the monthly  $\Delta\text{REU}(1)$  beta and the annualized Fama and MacBeth (1973) market price of uncertainty. The sample period ranges from 1996M01 to 2017M12.

uncertainty is defined as conditional volatility of the unforecastable component of multiple time-series variables, which can be driven by many observable and unobservable factors. However, in the next section, we attempt to study the predictive behavior of uncertainty betas and implied risk premia in a more systematic way, which also allows to derive general implications.

### 3.4 | Conditional asset pricing analysis

In this section, we identify a set of economic state variables that can predict the time variation of uncertainty betas. Following the conditional asset pricing methodology, changes in risk premia can be attributed to business cycle fluctuations. More specifically, we study whether potential state variables explain a rotation in REIT uncertainty, that is, identified market conditions when the beta becomes positive and therefore offers potential hedge benefits.

**TABLE 6** Time-varying uncertainty betas during crisis episodes

	(1) FU	(2) REU
LTCM crisis 1998	-0.19*** [-8.06]	0.05 [1.10]
Dotcom burst 2000	0.11*** [4.24]	-0.10* [-1.78]
9/11 attacks 2001	0.17*** [6.93]	-0.23*** [-4.54]
GFC 2008/2009	-0.26*** [-4.43]	0.70*** [3.35]
debt ceiling crisis 2011	-0.14*** [-6.14]	0.30*** [6.01]
Constant	-0.05** [-2.16]	-0.01 [-0.16]
Adj.R <sup>2</sup>	20.74	24.82

*Note:* This table reports simple regressions to explain the time variation of the estimated uncertainty betas (FU and REU, respectively) using dummy variables for the following crisis episodes (defined as follows): the LTCM crisis in 1998 (1998M08–1998M12), the dotcom bubble burst in 2000 (2000M04–2000M12), the 9/11 terrorist attack 2001 (2001M09–2001M12), the GFC 2008/2009, following the Lehman bankruptcy (2008M09–2009:M12), and the 2011 U.S. debt ceiling dispute (2011:M07–2011:M08). The *t*-statistics are shown in brackets and are calculated based on Newey and West (1987) standard errors with six lags. Adjusted R<sup>2</sup> denotes the adjusted coefficient of determination, expressed in percentage. The analysis considers the sample period from 1996M01 to 2017M12. The corresponding statistical significance is indicated as follows: \**p*<0.1; \*\**p*<0.05; \*\*\**p*<0.01.

We estimate the following conditional asset pricing model by introducing interaction terms between the uncertainty factors and state variable  $c_{t-1}$ . We regress

$$er_t = \alpha + \beta^{UNC(1)} \Delta UNC(1)_{t-1} + (\lambda + \delta^{UNC(1)} \Delta UNC(1)_{t-1}) c_{t-1} + \beta^* X_t + \varepsilon_t, \tag{8}$$

where  $er_t$  stands for monthly log REIT excess returns,  $\Delta UNC(1)_{t-1}$  denotes the first lag of the uncertainty factors,  $\Delta REU(1)$  and  $\Delta FU(1)$ , respectively, and  $c_{t-1}$  is defined as a state variable given information available in period  $t - 1$ . Matrix  $X_t$  captures additional and already established risk factors. For a specific state variable to predict the rotation in the uncertainty beta, leading to a potential hedge characteristic of REITs, we expect parameter  $\beta^{UNC(1)}$  to be negative, but the interaction term  $\delta^{UNC(1)}$  to be positive.

The results are presented in Table 7. While FU uncertainty is confirmed to have a negative impact on REIT returns in general, positive U.S. house price growth and changes in industrial production predict a rotation in FU exposure of REITs in the next period. For instance, compared to the estimated FU factor loading of -0.26, the interaction term between FU and lagged house price growth is positive and statistically significant with a magnitude of 0.54. We also show that interaction terms between the state variables and REU are insignificant. Hence, the identified state variables predict potential FU hedge episodes, but not for REU. Our findings are in line with the established literature, using housing as a consumption proxy to explain time-

TABLE 7 Conditional asset pricing analysis with  $\Delta FU(1)$  and  $\Delta REU(1)$  factors

State variable	$\Delta hp$		$\Delta ip$		$\Delta SENT$		$ffr$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta FU(1)$	-0.26**	-0.27**	-0.23***	-0.23**	-0.22*	-0.21*	-0.23*	-0.35*
	[-2.48]	[-2.52]	[-2.61]	[-2.54]	[-1.89]	[-1.88]	[-1.77]	[-1.78]
$\Delta REU(1)$	-0.10	-0.04	-0.16	-0.17	-0.12	-0.12	-0.50**	-0.49**
	[-0.70]	[-0.21]	[-1.10]	[-1.08]	[-0.85]	[-0.84]	[-2.15]	[-2.08]
$\Delta hp$	0.13	0.20						
	[0.24]	[0.37]						
$\Delta FU(1) \times \Delta hp$	0.54***	0.57***						
	[2.74]	[2.77]						
$\Delta REU(1) \times \Delta hp$		-0.28						
		[-0.90]						
$\Delta ip$			0.97***	0.96***				
			[2.66]	[2.65]				
$\Delta FU(1) \times \Delta ip$			0.20***	0.19***				
			[3.26]	[2.75]				
$\Delta REU(1) \times \Delta ip$				0.07				
				[0.17]				
$\Delta SENT$					0.01	0.01		
					[0.29]	[0.28]		
$\Delta FU(1) \times \Delta SENT$					0.03*	0.03*		
					[1.88]	[1.69]		
$\Delta REU(1) \times \Delta SENT$						0.01		
						[0.22]		
$ffr$							-0.01	-0.02
							[-0.06]	[-0.14]
$\Delta REU(1) \times ffr$							0.12*	0.11*
							[1.93]	[1.83]
$\Delta FU(1) \times ffr$								0.05
								[1.22]
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. $R^2$	57.19	57.31	56.93	56.93	54.78	54.79	54.39	54.74

Note: This table reports the results of the conditional asset pricing analysis using the 1-month lagged  $\Delta FU(1)$  and  $\Delta REU(1)$  factors as proxy for uncertainty. The dependent variable is the log excess return of the Nareit All Equity REITs Index (AEI). As 1-month lagged state variables, we use the Case-Shiller house price growth ( $\Delta hp$ ), change in industrial production ( $\Delta ip$ ), change in consumer sentiments ( $\Delta SENT$ ), and the federal funds rate ( $ffr$ ). Additional risk factors (Stocks, Bonds, SMB, HML, MOM) are used as controls. The  $t$ -statistics are shown in brackets and are calculated based on Newey and West (1987) standard errors with six lags. Adjusted  $R^2$  denotes the adjusted coefficient of determination, expressed in percentage. The analysis considers the sample period from 1994M01 to 2017M12. The corresponding statistical significance is indicated as follows: \* $p < 0.1$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$ .

varying asset prices and risk premia (Lettau and Ludvigson, 2001; Lustig and Van Nieuwerburgh, 2005).<sup>8</sup>

<sup>8</sup>We also support Leamer (2015) who states that the housing market as leading economic indicator reflects the business cycle. For instance, Table A.4 in the Appendix reports the correlation structure between the state variables and REIT

We also document consumer sentiment as potential predictor for time-varying FU exposures. For instance, Lemmon and Portniaguina (2006) use this variable as proxy for investor confidence. This finding is also consistent with our intuition and might be capable of capturing the more volatile pattern in uncertainty exposures. For instance, fluctuations in the outlook of market conditions or periods of financial distress might lead to time-varying FU premia required by investors due to changes in perceived consumer sentiment.

In contrast, we identify the effective federal funds rate as unique predictor for REU betas. Higher interest rates lead to increases in the cost of financing residential housing investments. Hence, REITs as an alternative investment become more attractive during these times, as suggested by positive REU exposure, offering stable rental cash flow streams. For instance, the effective fed funds rate is capable of predicting the negative REU betas observed in the early 2000s, when interest rates were lowered as a response to the dotcom bubble burst and the 9/11 terrorist attacks prior to the housing bubble burst when subprime mortgages started to default because of increased interest rates (Brunnermeier, 2009). Again, our findings hint at separate drivers of potential FU and REU beta rotations, as the interaction term between the effective fed funds rate and FU is not statistically significant.

In Table 8, we also replicate our analysis for the different core sectors. Overall, we find similar results, establishing house price growth and changes in industrial production as statistically significant state variables for FU exposures in all sectors. Compared to the unconditional asset pricing exercise, we also observe a negative and statistically significant impact of FU on the industrial sector, which might be even more sensitive to business cycle fluctuations than the office or retail sector. In contrast, we find no statistically significant negative impact of FU in the residential sector. However, positive house price growth or changes in industrial production might indicate potential hedge characteristics. We document heterogeneous results for investor sentiment as a state variable, which seems to mostly explain variation in FU premia for the office and retail sector. Similarly, the fed funds rate as a state variable tends to drive hedge implications against REU in the REIT residential and retail sectors.

### 3.5 | Which uncertainty factor dominates?

Lastly, we evaluate the simultaneous model-implied expected return contribution of both time-varying uncertainty factors and compare them to the dynamics of other risk factors. Specifically, the estimated REU betas suggest a strong positive exposure of REIT returns during the GFC 2008/2009 after the burst of the residential housing bubble, mirroring the negative exposure to FU, which might have an offsetting effect. In this section, we are therefore dedicated to further understand which uncertainty factor dominates.

Using estimated factor risk premia, that is, market prices of uncertainty as well as unconditional time-series averages as risk premia for additional factors, we compute expected returns. Following Van Nieuwerburgh (2019), we exploit the full-sample market prices per uncertainty exposure from the Fama and MacBeth (1973) approach to overcome data limitations arising from the 60-month rolling window when estimating the time-varying factor loadings in addition to the risk premia.

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returns as well with both uncertainty measures. To illustrate the relevance of the residential housing sector for indirect real estate, we document a correlation of 17.6% (13.5%) between (lagged) house price growth and REIT returns.

TABLE 8 Conditional asset pricing analysis for different core sectors

<b>Panel A: Conditional on house price growth as a state variable</b>								
	RES		OFF		IND		RET	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta hp$	0.11	0.11	0.10	0.22	0.11	0.34	0.53	0.55
	[0.18]	[0.20]	[0.17]	[0.37]	[0.11]	[0.38]	[0.75]	[0.76]
$\Delta FU(1)$	-0.12	-0.12	-0.27**	-0.28**	-0.62**	-0.64**	-0.33**	-0.33**
	[-1.28]	[-1.30]	[-2.40]	[-2.47]	[-2.23]	[-2.22]	[-2.44]	[-2.43]
$\Delta REU(1)$	-0.23	-0.23	-0.12	-0.00	0.09	0.32	-0.06	-0.04
	[-1.20]	[-0.91]	[-0.63]	[-0.02]	[0.32]	[0.84]	[-0.30]	[-0.18]
$\Delta FU(1) \times \Delta hp$	0.37***	0.37***	0.55**	0.60**	1.58**	1.68**	0.81***	0.81***
	[3.20]	[3.36]	[2.54]	[2.57]	[2.57]	[2.52]	[3.16]	[3.01]
$\Delta REU(1) \times \Delta hp$		-0.02		-0.49		-0.97		-0.07
		[-0.04]		[-1.01]		[-1.22]		[-0.17]
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. $R^2$	44.08	44.08	55.46	55.77	53.33	53.88	52.00	52.01
<b>Panel B: Conditional on industrial production as a state variable</b>								
	RES		OFF		IND		RET	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta ip$	1.11**	1.09**	0.90**	0.94**	1.26*	1.38**	1.22***	1.21***
	[2.46]	[2.43]	[2.46]	[2.56]	[1.71]	[2.11]	[2.71]	[2.62]
$\Delta FU(1)$	-0.10	-0.10	-0.23**	-0.23**	-0.51**	-0.52**	-0.29**	-0.29**
	[-1.24]	[-1.21]	[-2.37]	[-2.38]	[-2.33]	[-2.37]	[-2.42]	[-2.34]
$\Delta REU(1)$	-0.27	-0.29	-0.18	-0.15	-0.07	0.04	-0.15	-0.16
	[-1.38]	[-1.37]	[-1.08]	[-0.78]	[-0.29]	[0.14]	[-0.74]	[-0.81]
$\Delta FU(1) \times \Delta ip$	0.13*	0.12*	0.18**	0.19**	0.75***	0.79***	0.28***	0.27***
	[1.93]	[1.68]	[2.38]	[2.22]	[4.20]	[4.04]	[3.46]	[2.99]
$\Delta REU(1) \times \Delta ip$		0.17		-0.25		-0.88		0.12
		[0.47]		[-0.47]		[-0.81]		[0.24]
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. $R^2$	45.05	45.10	54.70	54.78	51.19	51.64	50.13	50.14
<b>Panel C: Conditional on investor sentiment as a state variable</b>								
	RES		OFF		IND		RET	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta SENT$	-0.01	-0.01	0.02	0.02	-0.06	-0.06	0.00	0.00
	[-0.20]	[-0.22]	[0.35]	[0.36]	[-0.69]	[-0.70]	[0.08]	[0.05]
$\Delta FU(1)$	-0.09	-0.09	-0.22*	-0.22*	-0.51	-0.50	-0.27*	-0.27*
	[-1.03]	[-0.99]	[-1.78]	[-1.78]	[-1.48]	[-1.48]	[-1.70]	[-1.71]
$\Delta REU(1)$	-0.24	-0.24	-0.13	-0.14	-0.03	-0.03	-0.10	-0.10
	[-1.26]	[-1.26]	[-0.79]	[-0.82]	[-0.10]	[-0.09]	[-0.54]	[-0.52]
$\Delta FU(1) \times \Delta SENT$	0.02	0.02	0.03**	0.03**	0.04	0.04	0.03*	0.03
	[1.05]	[0.95]	[1.99]	[1.96]	[0.96]	[0.84]	[1.80]	[1.56]
$\Delta REU(1) \times \Delta SENT$		0.01		-0.01		0.02		0.02
		[0.29]		[-0.20]		[0.41]		[0.40]

(Continues)



TABLE 8 (Continued)

Panel C: Conditional on investor sentiment as a state variable								
	RES		OFF		IND		RET	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	yes
Adj.R <sup>2</sup>	42.97	42.98	53.54	53.55	43.56	43.58	47.01	47.05
Panel D: Conditional on fed funds rate as a state variable								
	RES		OFF		IND		RET	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ffr	-0.06	-0.06	0.11	0.10	0.14	0.11	0.01	0.00
	[-0.51]	[-0.55]	[0.98]	[0.92]	[0.72]	[0.60]	[0.10]	[0.02]
ΔFU(1)	-0.09	-0.15	-0.25*	-0.38*	-0.53	-0.97*	-0.29	-0.45
	[-0.91]	[-1.13]	[-1.91]	[-1.91]	[-1.49]	[-1.80]	[-1.61]	[-1.64]
ΔREU(1)	-0.66**	-0.65**	-0.32	-0.30	-0.57	-0.53	-0.61*	-0.59*
	[-2.12]	[-2.10]	[-1.12]	[-1.04]	[-1.34]	[-1.18]	[-1.87]	[-1.81]
ΔFREU(1)×ffr	0.14*	0.13*	0.05	0.04	0.17*	0.14	0.16**	0.15*
	[1.87]	[1.83]	[0.71]	[0.55]	[1.71]	[1.32]	[2.06]	[1.95]
ΔFU(1)×ffr		0.03		0.06		0.18*		0.07
		[0.75]		[1.32]		[1.90]		[1.23]
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj.R <sup>2</sup>	43.17	43.27	52.86	53.22	43.41	45.16	46.75	47.23

Note: This table reports the results of the conditional asset pricing analysis using the 1-month lagged ΔFU(1) and ΔREU(1) factors as proxy for uncertainty. As dependent variables, we use the log excess return of the REIT indices for the different core sectors residential (RES), office (OFF), industrial (IND), and retail (RET). Panels A–D show the results for the following 1-month lagged state variables: the Case–Shiller house price growth (Δhp), change in industrial production (Δip), change in consumer sentiments (ΔSENT), and the federal funds rate (ffr). Additional risk factors (Stocks, Bonds, SMB, HML, MOM) are used as controls. The *t*-statistics are shown in brackets and are calculated based on Newey and West (1987) standard errors with six lags. Adjusted R<sup>2</sup> denotes the adjusted coefficient of determination, expressed in percentage. The analysis considers the sample period from 1994M01 to 2017M12. The corresponding statistical significance is indicated as follows: \**p*<0.1; \*\**p*<0.05; \*\*\**p*<0.01.

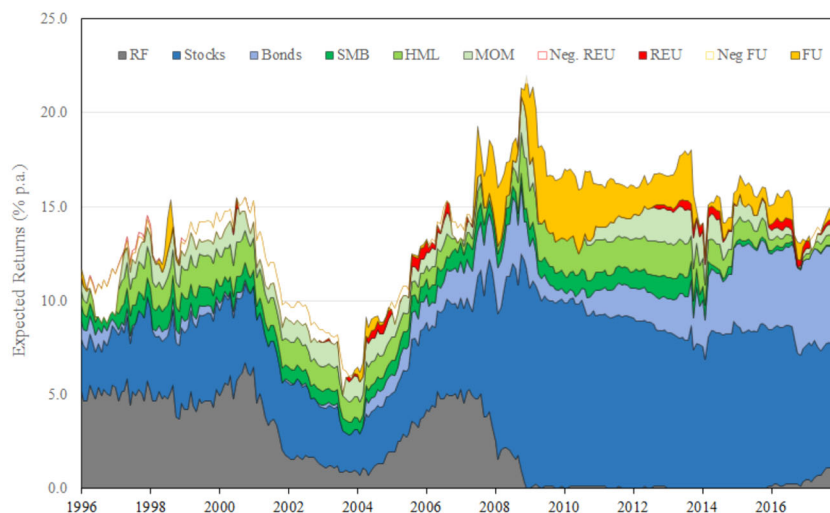
Expected returns are calculated as follows:

$$r_t = E[r_{t+1}] = E[r_t^f] + \beta^{UNC(1)}\lambda^{UNC(1)} + \beta^{stocks}\lambda^{stocks} + \beta^{bonds}\lambda^{bonds} + \beta^{SMB}\lambda^{SMB} + \beta^{HML}\lambda^{HML} + \beta^{MOM}\lambda^{MOM} + \varepsilon_t, \tag{9}$$

where  $r_t$  stands for the expected total return implied by the factor model,  $E[r_t^f]$  denotes the average risk-free rate over the entire sample period,  $\lambda^{UNC}$  denotes the annualized average market price for REU(1) and FU(1), respectively, and  $\lambda^*$  of the remaining traded factors are the annualized average excess returns over the full sample period.<sup>9</sup>

Figure 4 illustrates the expected returns based on the rolling window model with lagged ΔFU(1) and ΔREU(1) as uncertainty proxies. We include both measures simultaneously to mitigate potential concerns that the time-varying exposure of each uncertainty factor, when tested separately, might capture the variation of the other omitted uncertainty measure. Baseline results regarding the compensation for stock and bond market risk as well as other established risk factors, such as

<sup>9</sup> An overview of market prices of risk for employed factors is provided in Table A.5 in the Appendix.



**FIGURE 4** Expected REIT return decomposition including  $\Delta FU(1)$  and  $\Delta REU(1)$

[Color figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

*Note:* This figure plots the model-implied expected return on US Equity REITs based on the uncertainty extended 60-month rolling window regression (with a required minimum of 24 observations within the estimation window) from 1996M1 to 2017M12. Rolling window estimates use log excess returns of the Nareit All Equity REITs Index (AEI) as a dependent variable. Independent variables include the one-month lagged  $\Delta REU(1)$  and  $\Delta FU(1)$  factors as well as the stock market risk (Stocks), bond market risk (Bonds), Size (SMB), Value (HML), and Momentum (MOM) factors as control variables. Expected returns are computed as the sum of the monthly rolling window beta estimates multiplied with the annualized full sample average excess returns of the factor. For FU and REU, we use the estimated Fama and MacBeth (1973) market prices of uncertainty, respectively. Instead of alpha values, annualized monthly risk-free rates are considered.

size, value, and momentum, are in line with the findings of Van Nieuwerburgh (2019). During the first half of the sample, expected returns are mainly driven by the unusually high risk-free rate, which diminishes and completely disappears after the GFC. Risk premia for other factors, mainly for stock and bond market risk, offset the vanishing impact of the time value of money. These findings serve as common ground for comparing the additional impact of uncertainty episodes.

Taking  $\Delta FU(1)$  as proxy for uncertainty, we identify three substantial exposure periods in which investors demand an uncertainty premium as compensation in terms of higher expected returns: during the LTCM crisis 1998, the housing market bust 2007, the subsequent GFC, as well as its aftermath, which is the longest and most substantial period. During the late-1990s REIT boom and throughout the emergence and burst of the dotcom bubble, along the securitization boom of the early 2000s, the REIT market is perceived as safe with respect to FU and reveals a negative expected return contribution due to positive uncertainty exposures. For instance, for the moderate hedge episode around the dotcom bubble, it is reasonable to assume that the surging demand for internet stocks distorted their fundamental valuation, accompanied by higher FU, whereas REITs were considered as safe assets. The observed episodes with hedge potentials against FU are not offset by required compensated returns for corresponding REU.

Next, we turn to the return contribution of lagged  $\Delta REU(1)$ . We observe several episodes of priced negative REU exposure, when investors demand a higher uncertainty premium, coinciding with the debt-driven commercial real estate boom and the rapid expansion of the CMBS market. Recalling Figure 3, the return contribution of  $\Delta REU(1)$  is substantially negative around the GFC in 2008/2009, suggesting a temporary hedge opportunity. However, taking into account the offset-

**TABLE 9** Conditional pricing models with alternative uncertainty measures as controls

	$\Delta hp$		$\Delta ip$		$\Delta SENT$		$ffr$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta FU(1)$	-0.28**	-0.29***	-0.25***	-0.25**	-0.23**	-0.23**	-0.24*	-0.36*
	[-2.54]	[-2.58]	[-2.58]	[-2.49]	[-2.01]	[-2.00]	[-1.88]	[-1.85]
$\Delta REU(1)$	-0.10	-0.03	-0.16	-0.16	-0.13	-0.12	-0.48**	-0.47**
	[-0.69]	[-0.18]	[-1.10]	[-1.02]	[-0.86]	[-0.85]	[-2.06]	[-1.99]
$\Delta hp$	0.10	0.17						
	[0.18]	[0.31]						
$\Delta FU(1) \times \Delta hp$	0.54***	0.57***						
	[2.71]	[2.73]						
$\Delta REU(1) \times \Delta hp$		-0.30						
		[-0.91]						
$\Delta ip$			0.91**	0.91**				
			[2.47]	[2.49]				
$\Delta FU(1) \times \Delta ip$			0.21***	0.21**				
			[3.05]	[2.56]				
$\Delta REU(1) \times \Delta ip$				0.03				
				[0.07]				
$\Delta SENT$					0.01	0.01		
					[0.19]	[0.18]		
$\Delta FU(1) \times \Delta SENT$					0.03*	0.03*		
					[1.88]	[1.70]		
$\Delta REU(1) \times \Delta SENT$						0.01		
						[0.20]		
$ffr$							-0.01	-0.02
							[-0.08]	[-0.16]
$\Delta REU(1) \times ffr$							0.11*	0.10*
							[1.83]	[1.73]
$\Delta FU(1) \times ffr$								0.05
								[1.18]
$\Delta VIX$	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
	[0.87]	[0.92]	[1.08]	[1.02]	[0.44]	[0.43]	[0.73]	[0.80]
$\Delta EPU$	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	[0.70]	[0.66]	[0.62]	[0.61]	[0.80]	[0.81]	[0.70]	[0.55]
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. $R^2$	57.43	57.56	57.21	57.21	54.95	54.96	54.59	54.91

*Note:* This table reports the results of the conditional asset pricing analysis using the 1-month lagged  $\Delta FU(1)$  and  $\Delta REU(1)$  factors as a proxy for uncertainty. The dependent variable is the log excess return of the Nareit All Equity REITs Index (AEI). As 1-month lagged state variables, we use the Case-Shiller house price growth ( $\Delta hp$ ), change in industrial production ( $\Delta ip$ ), change in consumer sentiments ( $\Delta SENT$ ), and the federal funds rate ( $ffr$ ). Additional risk factors (Stocks, Bonds, SMB, HML, MOM) are used as controls. As additional control variables, we include changes in the VIX ( $\Delta VIX$ ) and changes in Economic Policy Uncertainty ( $\Delta EPU$ ) from Baker et al. (2016) that are used as alternative uncertainty measures. The  $t$ -statistics are shown in brackets and are calculated based on Newey and West (1987) standard errors with six lags. Adjusted  $R^2$  denotes the adjusted coefficient of determination, expressed in percentage. The analysis considers the sample period from 1994M01 to 2017M12. The corresponding statistical significance is indicated as follows: \* $p < 0.1$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$ .

TABLE 10 Conditional pricing model with diversified REIT index

	$\Delta hp$		$\Delta ip$		$\Delta SENT$		$ffr$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta FU(1)$	-0.21**	-0.21**	-0.20**	-0.20**	-0.19**	-0.19**	-0.20**	-0.23
	[-2.15]	[-2.24]	[-2.41]	[-2.34]	[-2.19]	[-2.31]	[-2.01]	[-1.45]
$\Delta REU(1)$	-0.26	-0.19	-0.30*	-0.31	-0.26	-0.26	-0.48*	-0.48*
	[-1.52]	[-0.87]	[-1.76]	[-1.61]	[-1.56]	[-1.62]	[-1.79]	[-1.77]
$\Delta hp$	0.24	0.32						
	[0.34]	[0.45]						
$\Delta FU(1) \times \Delta hp$	0.28*	0.31**						
	[1.75]	[1.97]						
$\Delta REU(1) \times \Delta hp$		-0.30						
		[-0.71]						
$\Delta ip$			1.17***	1.15***				
			[2.63]	[2.66]				
$\Delta FU(1) \times \Delta ip$			0.02	0.01				
			[0.43]	[0.25]				
$\Delta REU(1) \times \Delta ip$				0.15				
				[0.33]				
$\Delta SENT$					0.02	0.02		
					[0.35]	[0.39]		
$\Delta FU(1) \times \Delta SENT$					0.03**	0.03**		
					[2.12]	[2.48]		
$\Delta REU(1) \times \Delta SENT$						-0.03		
						[-0.68]		
$ffr$							0.00	0.00
							[0.03]	[0.01]
$\Delta REU(1) \times ffr$							0.07	0.06
							[1.02]	[1.00]
$\Delta FU(1) \times ffr$								0.02
								[0.43]
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. $R^2$	54.82	54.94	55.44	55.47	54.60	54.67	54.06	54.09

Note: This table reports the results of the conditional asset pricing analysis using the 1-month lagged  $\Delta FU(1)$  and  $\Delta REU(1)$  factors as proxy for uncertainty. The dependent variable is the log excess return of the Diversified REIT Index. As 1-month lagged state variables, we use the Case-Shiller house price growth ( $\Delta hp$ ), change in industrial production ( $\Delta ip$ ), change in consumer sentiments ( $\Delta SENT$ ), and the federal funds rate ( $ffr$ ). Additional risk factors (Stocks, Bonds, SMB, HML, MOM) are used as controls. The  $t$ -statistics are shown in brackets and are calculated based on Newey and West (1987) standard errors with six lags. Adjusted  $R^2$  denotes the adjusted coefficient of determination, expressed in percentage. The analysis considers the sample period from 1994M01 to 2017M12. The corresponding statistical significance is indicated as follows: \* $p < 0.1$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$ .

ting effects in terms of compensating returns required for FU, this effect disappears. Hence, our findings indicate that FU is the dominant factor, which might be related to the fact that REITs are publicly traded and are therefore more exposed to FU fluctuations than to REU.

### 3.6 | Robustness tests

In this section, we discuss several robustness tests. First, in Table 9, we replicate our results when we additionally control for alternative measures of uncertainty. Following Demiralay and Kilincarslan (2022), we include the VIX to capture implied stock market volatility and EPU. However, in contrast to our preferred uncertainty measures, established proxies such as the VIX do not remove the forecastable component to purely reflect uncertainty as a forecast error (Jurado et al., 2015). The asset pricing analysis shows that both 1-month ahead FU and REU still serve as predictors for REIT returns when competing against contemporaneous alternative uncertainty measures. Consistent with our main findings, the already established state variables suggest potential rotations in the estimated uncertainty betas and corresponding risk premia.

Overall, our results suggest homogeneity among the different REIT sectors with respect to uncertainty. To some extent, and depending on specific market conditions, we find weak evidence for potential hedge benefits when investing in residential REITs. However, in Table 10, we also replicate our results when using the Nareit-diversified REIT index as alternative performance measure. Hence, we demonstrate the persistence of uncertainty exposure as well as relevance of both FU and REU even when potential idiosyncratic, sector-specific shocks might be diversified away. Furthermore, we find no evidence of potentially offsetting uncertainty effects from investing in multiple REIT sectors, further supporting our intuition of synchronous fluctuations in sector-specific uncertainty premia.<sup>10</sup>

We offer further corroborative evidence for our findings when we use uncertainty factors of 3- and 12-month ahead forecast horizons to predict next period's REIT returns. Following the argumentation of Bali et al. (2017), we use the  $\Delta\text{UNC}(3)$  and  $\Delta\text{UNC}(12)$  factors to test the predictive behavior of next month's REIT returns in times of high uncertainty, that is, when the magnitude of future uncertainty as long-term horizon forecast error is large. We report the results in Tables A.6 and A.7 in the Appendix. Specifically, lagged house price growth, changes in industrial production, and the effective fed funds rate can still explain changes in uncertainty betas and implied time-varying expected REIT returns in highly uncertain times. Consumer sentiment fails to predict time-varying uncertainty premia when long-term future market conditions are rather unpredictable.

## 4 | CONCLUSION

We systematically study the impact of uncertainty on the aggregate U.S. REIT market as well as the core sectors residential, office, industrial, and retail from 1994 to 2017. First, our results suggest that REITs are exposed to changes in uncertainty. We find a negative market price for REU and FU in a cross-sectional asset pricing analysis. Furthermore, we show that, on average, both uncertainty factors imply significantly negative factor loadings. Consequently, uncertainty-averse investors require a compensation in terms of expected returns.

Second, REITs do exhibit time-varying uncertainty characteristics that can be related to specific distress periods as well as state variables to proxy business cycle movements. Hence, REIT returns tend to be negatively exposed to uncertainty, but the magnitude of the exposure fluctuates

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<sup>10</sup> To some extent, synchronous variation in uncertainty premia across sectors, as suggested by the conditional asset pricing analysis, also mitigates potential concerns that aggregate uncertainty effects on equity REITs are driven by large idiosyncratic shocks from a specific sector (see, e.g., Gabaix, 2011).

over time. REU betas become positive during the GFC, suggesting that investors would accept lower expected returns; however, this effect is offset by the exposure to FU with required positive compensating returns. Similarly, estimated FU betas also suggest episodic hedge characteristics in certain episodes of financial distress, mostly unrelated to the real estate sector, such as the dot-com bubble burst, but in contrast to REU, the positive exposure remains economically significant. In summary, we find evidence that the source of uncertainty matters. Lastly, it seems that FU has a stronger return contribution in direct comparison to REU, and hence, is a stronger predictor of REIT returns.

Our findings matter especially in the context of portfolio and risk management, as they help form expectations for times of high uncertainty. Investors and REIT managers can strategically time indirect real estate investments as protection against uncertainty shocks by exploiting identified economic state variables to predict time-varying periods of positive REIT exposure. For instance, by observing changes in house prices or industrial production, investors can time REIT holdings for diversification benefits against FU. REIT managers or retail investors exposed to real estate investment risk can hedge against REU by tracking the effective fed funds rate, while also protecting their portfolio against financial uncertainty. The understanding of how FU affects REIT returns is particularly important for investors who focus on securitized real estate to overcome limitations and trading frictions of private real estate. Furthermore, considering the ongoing unresolved pandemic situation, market-wide uncertainty may sustain in the short to medium-term, which highlights the importance of future academic research on uncertainty.

## ACKNOWLEDGMENTS

For helpful and valuable comments, we are indebted to the editor, Wenlan Qian, two anonymous referees, as well as Donglin He. We also thank Sydney Ludvigson for making available the FU index.

## ORCID

Daniel Ruf  <https://orcid.org/0000-0002-6045-1802>

## REFERENCES

- Amihud, Y. (2002). Illiquidity and stock returns: Cross-section and time series effects. *Journal of Financial Markets*, 5(1), 31–56.
- Baker, S. R., Bloom, N., & Davis, S. J. (2016). Measuring economic policy uncertainty. *Quarterly Journal of Economics*, 131(4), 1593–1636.
- Baker, S. R., Bloom, N., Davis, S. J., & Terry, S. J. (2020). *Covid-induced economic uncertainty*. NBER Working Paper 26983.
- Bali, T. G., Brown, S. J., & Tang, Y. (2017). Is economic uncertainty priced in the cross-section of stock returns? *Journal of Financial Economics*, 126(3), 471–489.
- Bali, T. G., Subrahmanyam, A., & Wen, Q. (2021). The macroeconomic uncertainty premium in the corporate bond market. *Journal of Financial and Quantitative Analysis*, 56(5), 1653–1678.
- Bloom, N. (2009). The impact of uncertainty shocks. *Econometrica*, 77(3), 623–685.
- Bloom, N. (2014). Fluctuations in uncertainty. *Journal of Economic Perspectives*, 28(2), 153–176.
- Bloom, N., Floetotto, M., Jaimovich, N., Saporta-Eksten, I., & Terry, S. J. (2018). Really uncertain business cycles. *Econometrica*, 86(3), 1031–1065.
- Brunnermeier, M. K. (2009). Deciphering the liquidity and credit crunch 2007–2008. *Journal of Economic Perspectives*, 23(1), 77–100.
- Caggiano, G., Castelnuovo, E., Delrio, S., & Kima, R. (2021). Financial uncertainty and real activity: The good, the bad, and the ugly. *European Economic Review*, 136, 103750.
- Carhart, M. M. (1997). On persistence in mutual fund performance. *Journal of Finance*, 52(1), 57–82.

- Chen, N., Roll, R., & Ross, S. (1986). Economic forces and the stock market. *Journal of Business*, 59(3), 383–403.
- Clayton, J., & MacKinnon, G. (2003). The relative importance of stock, bond and real estate factors in explaining REIT returns. *Journal of Real Estate Finance and Economics*, 27(1), 39–60.
- Cox, J., Greenwald, D. L., & Ludvigson, S. (2021). *What explains the COVID-19 stock market?* NBER Working Paper 27784.
- Davis, J. L., Fama, E. F., & French, K. R. (2000). Characteristics, covariances, and average returns: 1929 to 1997. *Journal of Finance*, 55(1), 389–406.
- Demiralay, S., & Kilincarslan, E. (2022). Uncertainty measures and sector-specific REITs in a regime-switching environment. *Journal of Real Estate Finance and Economics*, <https://doi.org/10.1007/s11146-022-09898-w>
- Duca, J., & Ling, D. (2020). The other (commercial) real estate boom and bust: The effects of risk premia and regulatory capital arbitrage. *Journal of Banking and Finance*, 112, 105317.
- Fama, E. F., & French, K. R. (1993). Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics*, 33(1), 3–56.
- Fama, E. F., & French, K. R. (2015). A five-factor asset pricing model. *Journal of Financial Economics*, 116(1), 1–22.
- Fama, E. F., & MacBeth, J. D. (1973). Risk, return, and equilibrium: Empirical tests. *Journal of Political Economy*, 81(3), 607–636.
- Favilukis, J., Ludvigson, S. C., & Van Nieuwerburgh, S. (2017). The macroeconomic effects of housing wealth, housing finance and limited risk sharing in general equilibrium. *Journal of Political Economy*, 125(1), 140–223.
- Gabaix, X. (2011). The granular origins of aggregate fluctuations. *Econometrica*, 79(3), 733–772.
- Gilchrist, S., Sim, J. W., & Zakrajsek, E. (2014). *Uncertainty, financial frictions, and investment dynamics*. NBER Working Paper 20038.
- Gormsen, N. J., & Koijen, R. S. J. (2020). Coronavirus: Impact on stock prices and growth expectations. *Review of Asset Pricing Studies*, 10(4), 574–597.
- Goyal, A. (2012). Empirical cross-sectional asset pricing: A survey. *Financial Markets and Portfolio Management*, 26, 3–38.
- Hoesli, M., & Oikarinen, E. (2012). Are REITs real estate? Evidence from international sector level data. *Journal of International Money and Finance*, 31(7), 1823–1850.
- Ilut, M., & Schneider, M. (2014). Ambiguous business cycles. *American Economic Review*, 104(8), 2368–2399.
- Jurado, K., Ludvigson, S. C., & Ng, S. (2015). Measuring uncertainty. *American Economic Review*, 105(3), 1177–1216.
- Karolyi, G. A., & Sanders, A. B. (1998). The variation of economic risk premiums in real estate returns. *Journal of Real Estate Finance and Economics*, 17(3), 245–262.
- Leamer, E. E. (2015). Housing really is the business cycle: What survives the lessons of 2008-09? *Journal of Money, Credit and Banking*, 47(1), S43–S50.
- Lemmon, M., & Portniaguina, E. (2006). Consumer confidence and asset prices: Some empirical evidence. *Review of Financial Studies*, 19(4), 1499–1529.
- Lettau, M., & Ludvigson, S. (2001). Resurrecting the (C)CAPM: A cross-sectional test when risk premia are time-varying. *Journal of Political Economy*, 109(6), 1238–1287.
- Ling, D. C., & Naranjo, A. (1997). Economic risk factors and commercial real estate returns. *Journal of Real Estate Finance and Economics*, 15(3), 283–307.
- Ling, D. C., & Ryngaert, M. (1997). Valuation uncertainty, institutional involvement, and the underpricing of IPOs: The case of REITs. *Journal of Financial Economics*, 43(3), 433–456.
- Ling, D. C., Wang, C., & Zhou, T. (2020). A first look at the impact of COVID-19 on commercial real estate prices: Asset-level evidence. *Review of Asset Pricing Studies*, 10(4), 669–704.
- Lizieri, C., Baum, A., & Scott, P. (2000). Ownership, occupation, and risk: A view of the City of London Office Market. *Urban Studies*, 37(7), 1109–1129.
- Ludvigson, S. C., Ma, S., & Ng, S. (2021). Uncertainty and business cycles: Exogenous impulse or endogenous response? *American Economic Journal: Macroeconomics*, 13(4), 369–410.
- Lustig, H., & Van Nieuwerburgh, S. (2005). Housing collateral, consumption insurance, and risk premia: An empirical perspective. *Journal of Finance*, 60(3), 1167–1219.
- Merton, R. C. (1973). An intertemporal capital asset pricing model. *Econometrica*, 41(5), 867–887.
- Milcheva, S. (2022). Volatility and the cross-section of real estate equity returns during COVID-19. *Journal of Real Estate Finance and Economics*, 65, 293–320.
- Muir, T. (2017). Financial crises and risk premia. *Quarterly Journal of Economics*, 132(2), 765–809.



- Newey, W. K., & West, K. D. (1987). A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica*, *55*(3), 703–708.
- Ng, S. (2021). *Modeling macroeconomic variation after COVID-19*. NBER Working Paper 29060.
- Ofek, E., & Richardson, M. (2003). DotCom Mania: The rise and fall of internet stock prices. *Journal of Finance*, *58*(3), 1113–1137.
- Pástor, L., & Stambaugh, R. F. (2003). Liquidity risk and expected stock returns. *Journal of Political Economy*, *111*(3), 642–685.
- Petersen, M. A. (2009). Estimating standard errors in finance panel data sets: Comparing approaches. *Review of Financial Studies*, *22*(1), 435–480.
- Peterson, J. D., & Hsieh, C.-H. (1997). Do common risk factors in the returns on stocks and bonds explain returns on REITs. *Real Estate Economics*, *25*(2), 321–345.
- Piazzesi, M., Schneider, M., & Tuzel, S. (2007). Housing, consumption and asset pricing. *Journal of Financial Economics*, *83*(3), 531–569.
- Strobel, J., Thanh, B. N., & Lee, G. (2018). Effects of macroeconomic uncertainty and labor demand shocks on the housing market. *Real Estate Economics*, *48*(2), 345–372.
- Thanh, B. N., Strobel, J., & Lee, G. (2020). A new measure of real estate uncertainty shocks. *Real Estate Economics*, *48*(3), 744–771.
- Van Nieuwerburgh, S. (2019). Why are REITS currently so expensive? *Real Estate Economics*, *47*(1), 18–65.

**How to cite this article:** Lotz, M., Ruf, D., & Strobel, J. (2023). Uncertainty premia in REIT returns. *Real Estate Economics*, *51*, 372–407. <https://doi.org/10.1111/1540-6229.12423>

APPENDIX A

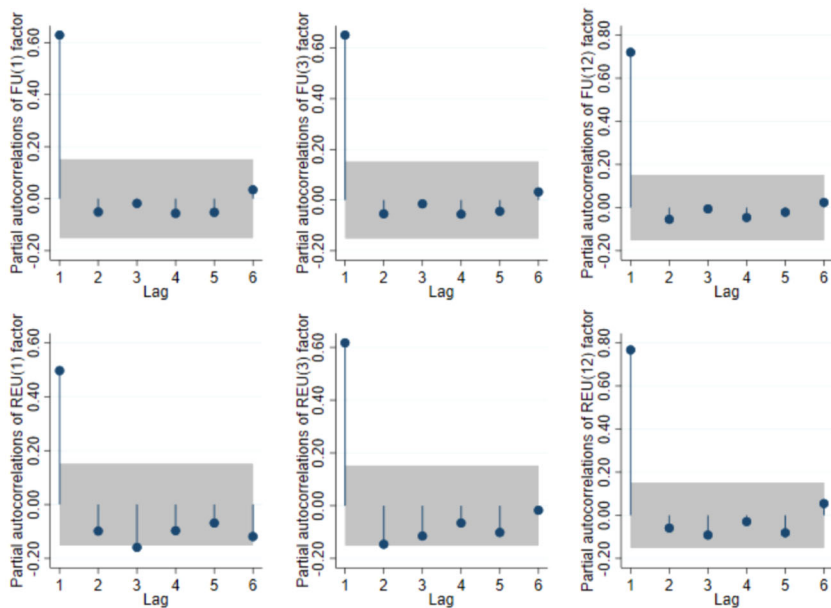


FIGURE A.1 Partial autocorrelations for UNC factors

[Color figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

Note: This figure shows the partial autocorrelations and corresponding confidence band at a 5% significance level for the uncertainty factors  $\Delta FU(h)$  and  $\Delta REU(h)$ , respectively, for the three different forecast horizons  $h = \{1, 3, 12\}$ , referring to 1-month, 3-month, and 12-month ahead uncertainty, respectively. The sample period ranges from 1994M1 to 2017M12.

TABLE A.1 Correlation between uncertainty factors

	$\Delta FU(1)$	$\Delta FU(3)$	$\Delta FU(12)$	$\Delta REU(1)$	$\Delta REU(3)$	$\Delta REU(12)$
$\Delta FU(1)$	1.000					
$\Delta FU(3)$	0.999	1.000				
$\Delta FU(12)$	0.983	0.989	1.000			
$\Delta REU(1)$	0.112	0.114	0.130	1.000		
$\Delta REU(3)$	0.257	0.260	0.280	0.949	1.000	
$\Delta REU(12)$	0.413	0.420	0.442	0.686	0.832	1.000

Note: This table shows the contemporaneous correlations between the uncertainty factors with different forecast horizons (1 month, 3 months, and 12 months-ahead) for the sample period from 1994M01 to 2017M12.

TABLE A.2 Variable definition

Variables	Description	Source
<b>Nareit Real Estate Indices</b>		
Nareit REIT index	Monthly total return indices for the aggregate U.S. REIT market (Nareit AEI) and core sectors residential (RES), office (OFF), industrial (IND), and retail (RET) from 1994M01 to 2017M12.	Nareit
<b>Uncertainty indices</b>		
REU(h)	The index tracks the market-wide real estate uncertainty, constructed by Thanh et al. (2020) and following the methodology of Jurado et al. (2015), from 1994M01 to 2017M12 for three forecast horizons: 1 month, 3 months, and 12 months-ahead real estate uncertainty, denoted by h.	Johannes Strobel's website
FU(h)	The index tracks the market-wide financial uncertainty, constructed by Ludvigson et al. (2021) and following the methodology of Jurado et al. (2015), from 1994M01 to 2017M12 for three forecast horizons: 1 month, 3 months, and 12 months-ahead financial uncertainty, denoted by h.	Sydney Ludvigson's website
EPU	Newspaper-based economic policy uncertainty index, developed by Baker et al. (2016), and proposed by Demiralay and Kilincarslan (2022) as alternative uncertainty proxy.	FRED Economic Data St.Louis FED
VIX	The Chicago Board Options Exchange (CBOE) Volatility Index reflects the implied volatility of S&P 500 at-the-money options and is proposed by Demiralay and Kilincarslan (2022) as alternative uncertainty proxy.	FRED Economic Data St.Louis FED
<b>Traditional risk factors</b>		
rf	Risk-free rate is expressed by the 1-month Treasury bill rate from Ibbotson Associates.	Kenneth French's data library
Stock market	Monthly value-weighted excess returns on all CRSP stocks listed on the NYSE, AMEX, or NASDAQ.	Kenneth French's data library
Bond market	Monthly excess returns of the 10-year constant maturity Treasury bonds.	CRSP (WRDS)
SMB	Size factor displays excess return of a mimicking portfolio long on small stocks and short on large stocks (Fama and French, 1993).	Kenneth French's data library
HML	Value factor as excess return of a mimicking portfolio long on high book-to-market (BTM) stocks and short on low BTM stocks (Fama and French, 1993)	Kenneth French's data library
MOM	Momentum factor as excess return of a mimicking portfolio long on stocks with the highest returns in the last 12 months (winners) and short on losers (Carhart, 1997).	Kenneth French's data library

(Continues)

TABLE A.2 (Continued)

Variables	Description	Source
CMA	Investment factor as excess return of a mimicking portfolio long on firms with high investment–asset ratios and short on stocks of low investment–asset ratio firms (Fama and French, 2015).	Kenneth French’s data library
RMW	Operating profitability factor displays excess return of a mimicking portfolio long on companies with high operating profitability and short on low profitability firms (Fama and French, 2015).	Kenneth French’s data library
LIQ	Liquidity factor displays excess return of a mimicking portfolio long on stocks with low liquidity beta and short on stocks with high liquidity beta (Pástor and Stambaugh, 2003).	Lubos Pastor’s data library
<b>Conditional pricing model state variables</b>		
$\Delta h$	Monthly house price growth, defined as log-difference, based on the S&P/Case-Shiller U.S. National Home Price Index.	FRED Economic Data St.Louis FED
$\Delta ip$	Monthly growth rate, defined as log-difference, of the U.S. industrial production index.	FRED Economic Data St.Louis FED
$\Delta SENT$	Monthly growth rate, defined as log-difference, of the U.S. Consumer Sentiment Index.	FRED Economic Data St.Louis FED
$ffr$	Effective federal funds rate (in % p.a.), based on last business day of month.	FRED Economic Data St.Louis FED
<b>Stock-level control variables</b>		
Uncertainty beta	Monthly uncertainty beta estimated on stock level based on a 60 months rolling window regression, following Bali et al. (2017). Estimates are considered when at least 24 observations are available within the estimation window (winsorized at 1%).	Own calculation
Stock beta	Monthly stock market betas ( $\beta_{i,t}^{Stocks}$ ) estimated with a 60 month rolling window regression of individual stock excess returns on the stock market factor, if at least 24 observations are available in the estimation window (winsorized at 1%).	Own calculation
Bond beta	Monthly bond betas ( $\beta_{i,t}^{Bonds}$ ) are calculated with a 60 month rolling window regression of individual stock returns regressed on the bond market factor conditional on the stock market factor. Estimates are considered if at least 24 observations are available in the estimation window (winsorized at 1%).	Own calculation

(Continues)

TABLE A.2 (Continued)

Variables	Description	Source
Momentum beta	Monthly momentum betas ( $\beta_{i,t}^{Mom}$ ) estimated with a fixed 60-month rolling window regression of individual stock excess returns on the momentum factor (MOM), if at least 24 observations are available in the estimation window (winsorized at 1%).	Own calculation
Illiq	The Amihud (2002) illiquidity measure is calculated for each stock as monthly ratio of absolute stock market return and trading volume.	Own calculation
Size	Defined as share price times shares outstanding (in million USD). Natural logarithm is used to control for skewness and kurtosis (Fama and French, 1993).	CRSP (WRDS)
BTM	Individual book-to-market ratio is calculated (at the end of June). Negative book-to-market ratios are eliminated. Natural logarithm of the positive individual BTM ratios is calculated (Davis et al., 2000).	COMPUSTAT (WRDS)

TABLE A.3 Unconditional asset pricing analysis with extended sample period

	All Equity REIT			
	(1)	(2)	(3)	(4)
Constant	-0.18 [-0.70]	-0.17 [-0.69]	-0.17 [-0.68]	-0.17 [-0.67]
Stocks	0.74*** [6.61]	0.70*** [7.16]	0.73*** [6.70]	0.70*** [7.22]
Bonds	0.54*** [3.94]	0.57*** [4.22]	0.53*** [3.89]	0.56*** [4.16]
SMB	0.44*** [5.81]	0.44*** [5.87]	0.45*** [5.84]	0.44*** [5.88]
HML	0.65*** [4.95]	0.63*** [4.85]	0.65*** [5.02]	0.63*** [4.92]
MOM	-0.10* [-1.68]	-0.09 [-1.55]	-0.10* [-1.74]	-0.09 [-1.60]
$\Delta FU(1)$		-0.21** [-2.04]		-0.20* [-1.91]
$\Delta REU(1)$			-0.24** [-2.31]	-0.19* [-1.81]
Adj. $R^2$	52.08	53.15	52.49	53.40

Note: This table reports the results of the unconditional asset pricing analysis using the 1-month lagged  $\Delta FU(1)$  and  $\Delta REU(1)$  factors as proxy for uncertainty. The dependent variable is the log excess return of the Nareit All Equity REITs Index (AEI). The model-based alpha, denoted as constant, is reported in the first row (as decimal). The  $t$ -statistics are shown in brackets and are calculated based on Newey and West (1987) standard errors with six lags. Adjusted  $R^2$  denotes the adjusted coefficient of determination, expressed in percentage. The analysis considers the sample period from 1990M01 to 2017M12. The corresponding statistical significance is indicated as follows: \* $p < 0.1$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$ .

**TABLE A.4** Correlation of REIT returns and Uncertainty indices with return predictors

<b>Panel A: Common risk factors</b>							
	<b>AEI</b>	<b>RES</b>	<b>OFF</b>	<b>IND</b>	<b>RET</b>	<b>ΔFU(1)</b>	<b>ΔREU(1)</b>
Stocks	0.563	0.495	0.571	0.514	0.490	−0.352	−0.010
Bonds	0.010	−0.014	−0.036	0.037	0.036	0.017	0.031
SMB	0.275	0.232	0.271	0.209	0.259	−0.070	0.015
HML	0.278	0.281	0.275	0.223	0.270	−0.043	−0.073
MOM	−0.278	−0.220	−0.260	−0.216	−0.288	0.255	0.151
<b>Panel B: State variables</b>							
	<b>AEI</b>	<b>RES</b>	<b>OFF</b>	<b>IND</b>	<b>RET</b>	<b>ΔFU(1)</b>	<b>ΔREU(1)</b>
ΔHP	0.176	0.151	0.176	0.184	0.193	−0.148	−0.047
ΔIP	0.012	0.021	0.059	−0.027	0.012	−0.007	−0.033
ΔSENT	0.257	0.225	0.221	0.277	0.251	−0.160	0.005
ffr	−0.007	−0.013	0.042	0.024	−0.007	0.201	0.006
<b>Panel C: Lagged state variables (<math>L = 1</math>)</b>							
	<b>AEI</b>	<b>RES</b>	<b>OFF</b>	<b>IND</b>	<b>RET</b>	<b>ΔFU(1)</b>	<b>ΔREU(1)</b>
ΔHP	0.135	0.118	0.132	0.149	0.163	−0.116	−0.068
ΔIP	0.275	0.271	0.253	0.293	0.271	−0.083	0.009
ΔSENT	0.043	0.015	0.054	0.006	0.030	−0.082	0.008
ffr	−0.016	−0.012	0.034	0.008	−0.021	0.205	0.005

*Note:* This table shows the contemporaneous correlations between returns of the All Equity REIT Index (AEI), residential (RES), office (OFF), industrial (IND), and retail (RET) core sectors and uncertainty factors  $\Delta FU(1)$  and  $\Delta REU(1)$  with the standard risk factors and state variables for the sample period from 1994M01 to 2017M12. Risk factors are excess returns on Stocks, Bonds, as well as SMB, HML, and Momentum (MOM). State variables are house price growth ( $\Delta HP$ ) based on the S&P/Case-Shiller Home Price Index, changes in industrial production ( $\Delta IP$ ) and consumer sentiment ( $\Delta SENT$ ), and the effective federal funds rate (ffr).

**TABLE A.5** Implied market prices of employed risk factors

<b>Estimated risk premia</b>		
	<b>Monthly</b>	<b>p.a.</b>
Rf	0.20	2.38
Stocks	0.67	8.04
Bonds	0.26	3.08
SMB	0.16	1.92
HML	0.19	2.31
MOM	0.41	4.96
$\Delta FU(1)$	−0.76	−9.12
$\Delta REU(1)$	−0.16	−1.92

*Note:* This tables reports the market prices, which are used in the conditional asset pricing analysis. We report the average monthly and annualized time-series averages for the following variables: Rf denotes the risk-free rate. Risk premia for Stocks, Bonds, SMB, HML, and MOM factors are calculated as time-series average of the excess returns (tradeable factors) over the sample period. Risk premia for  $\Delta FU(1)$  and  $\Delta REU(1)$  refer to the estimated Fama and MacBeth (1973) risk premium components, respectively. Time-series averages are calculated over the sample period from 1994M01 to 2017M12 and are assumed to be unconditionally applicable.

TABLE A.6 Conditional pricing analysis with  $\Delta$ FU(3) and  $\Delta$ REU(3) factors

	$\Delta$ hp		$\Delta$ ip		$\Delta$ SENT		ffr	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta$ FU(3)	-0.34**	-0.36**	-0.30**	-0.30**	-0.28*	-0.28*	-0.29*	-0.42*
	[-2.39]	[-2.46]	[-2.54]	[-2.41]	[-1.85]	[-1.84]	[-1.73]	[-1.67]
$\Delta$ REU(3)	-0.10	0.03	-0.25	-0.23	-0.21	-0.20	-1.12**	-1.06**
	[-0.34]	[0.08]	[-0.92]	[-0.83]	[-0.80]	[-0.77]	[-2.45]	[-2.41]
$\Delta$ hp	0.14	0.25						
	[0.25]	[0.44]						
$\Delta$ FU(3) $\times$ $\Delta$ hp	0.70***	0.79***						
	[2.64]	[2.65]						
$\Delta$ REU(3) $\times$ $\Delta$ hp		-0.59						
		[-1.03]						
$\Delta$ ip			0.97***	0.98***				
			[2.66]	[2.66]				
$\Delta$ FU(3) $\times$ $\Delta$ ip			0.26***	0.27**				
			[3.18]	[2.04]				
$\Delta$ REU(3) $\times$ $\Delta$ ip				-0.13				
				[-0.17]				
$\Delta$ SENT					0.01	0.01		
					[0.29]	[0.23]		
$\Delta$ FU(3) $\times$ $\Delta$ SENT					0.04*	0.03		
					[1.79]	[1.33]		
$\Delta$ REU(3) $\times$ $\Delta$ SENT						0.03		
						[0.55]		
ffr							0.00	-0.01
							[0.00]	[-0.08]
$\Delta$ REU(3) $\times$ ffr							0.29**	0.26**
							[2.46]	[2.32]
$\Delta$ FU(3) $\times$ ffr								0.05
								[0.98]
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. $R^2$	56.94	57.10	56.84	56.85	54.71	54.75	54.77	54.97

Note: This table reports the results of the conditional asset pricing analysis using the 1-month lagged  $\Delta$ FU(3) and  $\Delta$ REU(3) factors as proxy for uncertainty. The dependent variable is the log excess return of the Nareit All Equity REITs Index (AEI). As 1-month lagged state variables, we use the Case-Shiller house price growth ( $\Delta$ hp), change in industrial production ( $\Delta$ ip), change in consumer sentiments ( $\Delta$ SENT), and the federal funds rate (ffr). Additional risk factors (Stocks, Bonds, SMB, HML, MOM) are used as controls. The  $t$ -statistics are shown in brackets and are calculated based on Newey and West (1987) standard errors with six lags. Adjusted  $R^2$  denotes the adjusted coefficient of determination, expressed in percentage. The analysis considers the sample period from 1994M01 to 2017M12. The corresponding statistical significance is indicated as follows: \* $p < 0.1$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$ .



**TABLE A.7** Conditional pricing analysis with  $\Delta$ FU(12) and  $\Delta$ REU(12) factors

	$\Delta$ hp		$\Delta$ ip		$\Delta$ SENT		ffr	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta$ FU(12)	-1.01**	-1.13**	-0.93**	-0.95**	-0.84*	-0.84*	-0.83*	-0.99
	[-2.27]	[-2.30]	[-2.53]	[-2.19]	[-1.87]	[-1.87]	[-1.65]	[-1.39]
$\Delta$ REU(12)	0.16	0.71	-0.67	-0.60	-1.28	-1.20	-6.39**	-6.16***
	[0.11]	[0.43]	[-0.47]	[-0.42]	[-0.86]	[-0.81]	[-2.52]	[-2.66]
$\Delta$ hp	0.19	0.32						
	[0.33]	[0.52]						
$\Delta$ FU(12) $\times$ $\Delta$ hp	2.06**	2.37**						
	[2.33]	[2.26]						
$\Delta$ REU(12) $\times$ $\Delta$ hp		-1.89						
		[-0.75]						
$\Delta$ ip			0.98***	1.02**				
			[2.62]	[2.23]				
$\Delta$ FU(12) $\times$ $\Delta$ ip			0.76***	0.86				
			[3.00]	[1.19]				
$\Delta$ REU(12) $\times$ $\Delta$ ip				-0.62				
				[-0.16]				
$\Delta$ SENT					0.02	0.01		
					[0.34]	[0.20]		
$\Delta$ FU(12) $\times$ $\Delta$ SENT					0.11	0.08		
					[1.53]	[1.09]		
$\Delta$ FU(12) $\times$ $\Delta$ SENT						0.16		
						[0.65]		
ffr							-0.01	-0.01
							[-0.05]	[-0.09]
$\Delta$ REU(12) $\times$ ffr							1.77***	1.67***
							[2.63]	[2.67]
$\Delta$ FU(12) $\times$ ffr								0.07
								[0.41]
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. $R^2$	56.30	56.37	56.63	56.64	54.59	54.63	55.34	55.37

*Note:* This table reports the results of the conditional asset pricing analysis using the 1-month lagged  $\Delta$ FU(12) and  $\Delta$ REU(12) factors as proxy for uncertainty. The dependent variable is the log excess return of the Nareit All Equity REITs Index (AEI). As 1-month lagged state variables, we use the Case–Shiller house price growth ( $\Delta$ hp), change in industrial production ( $\Delta$ ip), change in consumer sentiments ( $\Delta$ SENT), and the federal funds rate (ffr). Additional risk factors (Stocks, Bonds, SMB, HML, MOM) are used as controls. The *t*-statistics are shown in brackets and are calculated based on Newey and West (1987) standard errors with six lags. Adjusted  $R^2$  denotes the adjusted coefficient of determination, expressed in percentage. The analysis considers the sample period from 1994M01 to 2017M12. The corresponding statistical significance is indicated as follows: \* $p < 0.1$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$ .