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# Commercial Real Estate Uncertainty

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# Commercial Real Estate Uncertainty

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**Abstract**

This paper develops a Commercial Real Estate Uncertainty (CREU) index for the United States based on the forecastability of sector-specific variables, extending the framework of Jurado et al. (2015) and its residential real estate application by Nguyen Thanh et al. (2020). CREU captures variation distinct from existing real estate, macroeconomic, and financial uncertainty measures and aligns more closely with commercial real estate market conditions. The one-quarter-ahead CREU index Granger predicts commercial real estate prices and construction spending and has a significant negative long-run relationship with both. No alternative uncertainty measure satisfies both criteria for construction spending. In a vector autoregression, CREU accounts for approximately 46 percent of construction spendings forecast-error variance at twenty quarters: the largest contribution among the four uncertainty measures. This ranking is robust to alternative identification schemes and index constructions.

*JEL Classification:* D8, E6, R2.

*Keywords:* commercial real estate uncertainty; commercial and non-residential markets

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# 1 Introduction

Uncertainty has received considerable attention as a potential driver of fluctuations in investment and economic activity. A central challenge in this literature is its measurement, as uncertainty is not directly observable. While a number of proxies have been proposed, Jurado et al. (2015) develop a measure that relates uncertainty to the predictability of economic variables. Their approach defines uncertainty as the conditional volatility of the unforecastable component of a variable and aggregates individual uncertainty measures into an index of macroeconomic uncertainty. Subsequent research has applied this framework to particular sectors of the economy, including the real estate market.

This paper constructs and analyzes a time-varying uncertainty measure specific to the commercial real estate sector. In doing so, we follow the uncertainty framework of Jurado et al. (2015) and its application to residential real estate by Nguyen Thanh et al. (2020) and construct a Commercial Real Estate Uncertainty (CREU) index that relates uncertainty to the predictability of commercial real estate variables. We show that, compared with existing measures of Real Estate Uncertainty (REU) by Nguyen Thanh et al. (2020) and both Macro Uncertainty (MU) and Financial Uncertainty (FU) by Jurado et al. (2015), our CREU exhibits distinct time-series variation and is closely related to commercial real estate market conditions. We can summarize our main results as follows.

First, the four measures of uncertainty rise and fall at different points in time. During the Great Recession, all four measures increase, but at the twelve-month horizon CREU rises most strongly and remains the highest of the four until 2011. The COVID-19 recession shows a different pattern: MU and FU rise sharply, whereas the increase in CREU is considerably smaller. CREU does not simply mirror uncertainty in residential real estate, the macroeconomy, or financial markets.

Second, while CREU is more strongly correlated with commercial real estate variables, the other uncertainty measures are more strongly correlated with other aspects of the economy. The correlation of CREU with commercial construction spending is $-0.51$, compared with $-0.23$ for REU, $-0.30$ for MU, and $-0.41$ for FU, whereas its correlation with industrial production growth is $-0.23$, compared with $-0.48$ for MU. Moreover, we ask whether the uncertainty measures are causal, in a temporal sense, for commercial real estate prices and commercial construction spending, as well as for residential real estate and macroeconomic variables. We assess each uncertainty measure using two criteria: rejection of the null hypothesis that its lagged values provide no additional predictive information for the variable, conditional on the other regressors in the model, and rejection of the null hypothesis that its long-run coefficient is zero. At the one-quarter uncertainty horizon, CREU Granger-causes commercial real estate prices and commercial construction spending and has a statistically significant long-run coefficient for both variables. For construction spending, no alternative uncertainty measure meets both criteria. This finding is robust to estimating REU directly at the quarterly frequency and to constructing CREU from a broader set of commercial real estate variables over a shorter sample. For prices, CREU's distinction from the alternative measures is less robust: REU also meets both criteria when estimated directly at the quarterly frequency. CREU additionally meets both criteria for commercial real estate prices at the longer uncertainty horizon. These results establish predictive

relationships and significant long-run associations, rather than structural causality.n.

Finally, we investigate and compare the dynamic responses of key commercial real estate variables to unexpected innovations in the uncertainty measures using vector autoregressions (VARs). Following a CREU shock, the impulse responses of both commercial real estate prices and commercial construction spending turn negative. A decomposition of variance based on the VARs shows that CREU accounts for about 46 percent of the twenty-quarter forecast-error variance of commercial construction spending in the benchmark specification, more than any of the alternative uncertainty measures and considerably more than the federal funds rate, which accounts for about 7 percent at the same horizon. The comparatively large contribution of CREU to commercial construction spending remains under alternative uncertainty constructions and recursive orderings. Moreover, while the explanatory shares of the established uncertainty measures for commercial construction decline substantially when the sample is extended beyond 2017, the corresponding share of CREU remains large.

Our analysis relates to several strands of the literature. The first is the broader literature on economic uncertainty and its effects on investment and economic activity (Bloom 2009; Jurado et al. 2015). A second strand examines uncertainty in real estate markets. Because real estate investment is costly to reverse, greater uncertainty can increase the option value of delaying investment (Titman 1985; Pindyck 1991). For commercial real estate, Sivitanidou and Sivitanides (2000) estimate a model of office-commercial construction that accounts for the opportunity cost of irreversible investment under uncertainty and find evidence consistent with the theory of irreversible investment. Similarly, using commercial real estate data, Holland et al. (2000) examine competing investment models and find evidence favoring an option-based model in which irreversibility and the option to delay affect investment decisions. Related research examines uncertainty and housing investment as well as the effects of macroeconomic uncertainty on housing-market dynamics (Miles 2009; Strobel et al. 2020).

A related strand of the literature applies existing uncertainty measures to real estate outcomes. Gholipour et al. (2021) use a VAR framework and find that shocks to perceived uncertainty reduce both the REIT index and commercial property prices, and Gomez-Gonzalez et al. (2024) examine the effects of U.S. financial and macroeconomic uncertainty shocks on housing markets across countries. Çepni et al. (2020) show that REU has predictive content for the conditional distribution of U.S. home sales growth, and Baek et al. (2024) employ the same index in a smooth-transition VAR and find that its effects on housing prices, housing starts, and construction employment are more pronounced during recessions. Together, this literature suggests that uncertainty is relevant for real estate market dynamics, that its effects may depend on the particular dimension of uncertainty being measured, and that they need not be constant over the business cycle.

Most closely related to our paper is the literature that develops measures of uncertainty specifically for real estate markets. Nguyen Thanh et al. (2020) apply the predictability-based framework of Jurado et al. (2015) to residential real estate and construct a Real Estate Uncertainty (REU) index from housing-market variables. Luo and Tidwell (2026) develop a complementary, news-based measure of real estate uncertainty derived from semantic analysis of newspaper content, whereas, Cao et al. (2025) propose uncertainty proxies for residential and commercial real

estate using implied volatilities from options on real estate exchange-traded funds and show that these measures negatively predict real estate investment activity. Our approach differs from these measures by constructing commercial real estate uncertainty directly from the predictability of commercial real estate variables. CREU therefore extends the predictability-based approach of Jurado et al. (2015) and Nguyen Thanh et al. (2020) to the commercial real estate sector.

We contribute to this literature by providing a predictability-based measure of uncertainty specific to commercial real estate. Such a measure is particularly relevant because investment in this sector is characterized by irreversibility and market conditions are closely linked to financing and credit conditions. Ling et al. (2016), for example, show that changes in credit availability are related to subsequent price movements in commercial real estate, highlighting the importance of financing conditions for CRE asset pricing. Duca and Ling (2020) further show that movements in commercial real estate risk premia and changes in regulatory capital requirements played an important role in the commercial real estate boom and bust. Rather than proxying CREU by broader measures of REU, FU, or MU, CREU measures uncertainty directly from the predictability of commercial real estate variables. Our empirical results show that this distinction is relevant: CREU contains information about commercial real estate market dynamics that is not fully captured by existing uncertainty measures.

## 2 Measuring Commercial Real Estate Uncertainty (CREU)

Most measures of uncertainty in the literature are constructed either from the dispersion or realized volatility of observed variables or from the uncertainty surrounding forecasts of individual time series. For example, Dorofeenko et al. (2014) construct an uncertainty measure based on variation in firm-level total factor productivity to analyze the U.S. house price volatility, while Miles (2009) estimates uncertainty using the conditional standard deviation from a GARCH-in-mean model in analyzing the U.S. housing investments. Such measures capture particular dimensions of uncertainty, but their measurement is typically tied to the behavior of a particular variable or the source of uncertainty.

### 2.1 Framework

We measure uncertainty in the commercial real estate sector from the predictability of a broad set of commercial real estate variables. As in Jurado et al. (2015) and Nguyen Thanh et al. (2020), we define uncertainty associated with commercial real estate variable $y_{jt}$ at time $t$ and forecast horizon $h$ is defined as

$$U_{jt}^{y}(h) = \sqrt{E\left[(y_{j,t+h} - E[y_{j,t+h} \mid I_t])^2 \mid I_t\right]}, \tag{1}$$

where $I_t$ denotes the information available at time $t$. Thus, uncertainty is defined as the conditional volatility of the unforecastable component of a variable rather than the volatility of the variable itself.

We construct individual uncertainty measures for 22 quarterly commercial real estate series. To make the estimation of $E[y_{j,t+h} \mid I_t]$ feasible, the information set is approximated by a

diffusion-index model. In total, 275 time series enter the estimation: the 22 commercial real estate target series listed in Table A2 and 253 additional predictors, of which 112 are macroeconomic and 141 are financial series.[1]

Following the diffusion-index approach of Jurado et al. (2015) and Nguyen Thanh et al. (2020), we summarize the macroeconomic and financial information set by common factors estimated using principal components. The predictor variables are standardized prior to factor extraction. The number of factors is initially selected using the $IC_{p2}$ information criterion of Bai and Ng (2002), with a maximum of eight factors. Because the information criterion can select very few factors in the shorter quarterly sample, we use eight principal components when fewer than four factors are selected. The forecasting information additionally includes the square of the first common factor and the first common factor extracted from the squared predictor series. We collect these terms in the vector $\mathbf{f}_t$.

For each commercial real estate variable, we estimate a factor-augmented forecasting equation of the form

$$y_{jt} = \alpha_j + \sum_{\ell=1}^{2} \rho_{j\ell}\, y_{j,t-\ell} + \sum_{\ell=1}^{2} \boldsymbol{\gamma}'_{j\ell} \mathbf{f}_{t-\ell} + v^{y}_{jt}, \tag{2}$$

where $v^{y}_{jt}$ is the forecast error. Factor predictors are retained when their absolute Newey–West $t$-statistic exceeds 2.575, after which the forecasting equation is re-estimated using the selected predictors. The resulting forecast errors represent the unforecastable components of the individual commercial real estate variables.

To characterize the dynamics of the common factors, each component of $\mathbf{f}_t$ is modeled as an autoregressive process of order two,

$$f_{it} = \delta_i + \sum_{\ell=1}^{2} a_{i\ell}\, f_{i,t-\ell} + v^{f}_{it}, \tag{3}$$

where $v^{f}_{it}$ denotes the corresponding factor innovation. The factor equations are estimated separately using Newey–West standard errors. Together, the dynamics in (2) and (3) determine how innovations are propagated over longer forecast horizons.

We next estimate first-order autoregressive stochastic-volatility processes for the factor innovations and for the forecast errors of the commercial real estate variables. For each commercial real estate variable, the forecast error $v^{y}_{jt}$ is represented as

$$v^{y}_{jt} = \exp\left(\frac{h^{y}_{jt}}{2}\right) \varepsilon^{y}_{jt}, \qquad \varepsilon^{y}_{jt} \sim N(0,1), \tag{4}$$

$$h^{y}_{jt} = \mu_j + \phi_j \left(h^{y}_{j,t-1} - \mu_j\right) + \sigma_j \eta^{y}_{jt}, \qquad \eta^{y}_{jt} \sim N(0,1), \tag{5}$$

where $h^{y}_{jt}$ denotes the latent log variance, $\mu_j$ its long-run level, $\phi_j$ its persistence, and $\sigma_j$ the volatility of the log variance. Analogous stochastic-volatility processes are estimated for the

[1] The predictor set follows Jurado et al. (2015) and combines the FRED-MD macroeconomic database of McCracken and Ng (2016), which standardizes the macroeconomic panel used by Jurado et al. (2015), with the financial series of Ludvigson et al. (2021).

factor innovations $v_{it}^f$. The stochastic-volatility models are estimated by Markov chain Monte Carlo using 50,000 burn-in iterations followed by 50,000 retained draws as in Jurado et al. (2015).[2]

For horizons beyond one quarter, expected future innovation variances are obtained from the estimated stochastic-volatility processes and propagated recursively through the forecasting system. Conditional on the current latent log variance, the expected innovation variance $k$ periods ahead is

$$E_t\left[\exp\left(h_{j,t+k}^y\right)\right] = \exp\left[\mu_j(1-\phi_j^k) + \phi_j^k h_{jt}^y + \frac{\sigma_j^2}{2}\frac{1-\phi_j^{2k}}{1-\phi_j^2}\right]. \tag{6}$$

These expected innovation variances, together with the corresponding variances of the factor innovations, are propagated through the dynamics implied by (2) and (3) to obtain the conditional forecast-error variance at each horizon. Taking its square root yields the individual uncertainty measure $U_{jt}^y(h)$ defined in (1). We calculate these measures for forecast horizons of one through four quarters.

Finally, we aggregate the individual uncertainty measures into the CREU index,

$$CREU_t(h) = \sum_{j=1}^{22} \omega_j U_{jt}^y(h), \qquad \omega_j = \frac{1}{22}, \tag{7}$$

so that each commercial real estate series receives equal weight. Our main analysis focuses on forecast horizons of one, two, and four quarters. To facilitate comparison with the monthly uncertainty measures used in Nguyen Thanh et al. (2020), we denote these horizons by $h = 3$, $h = 6$, and $h = 12$ months, respectively.

## 3 Data

The construction of CREU is based on 22 quarterly time series selected to characterize the U.S. commercial real estate sector and its financing conditions. The variables span five economically relevant dimensions of the commercial real estate market: prices, investment, development, credit, and macroeconomic conditions. Table A2 lists the individual series, their sources, and their transformations. Fifteen series enter the analysis in log differences, while seven series enter in first differences. Together with 112 macroeconomic and 141 financial predictors, a total of 275 time series enter the estimation. The resulting CREU series is available from 1993Q4 to 2025Q4.

Of the 126 FRED-MD series, we exclude the ten housing-market series, two series that also enter our set of commercial real estate target variables (total construction employment and real estate loans at all commercial banks), and two additional construction-related series. These exclusions closely follow the predictor selection used for REU in Nguyen Thanh et al. (2020) and leave 112 macroeconomic predictors. Since several commercial real estate variables are available only at quarterly frequency, we estimate CREU directly at the quarterly frequency. Macroe-

[2] As quarterly commercial real estate uncertainty is expected to evolve gradually because development, financing, and valuation adjust over multiple quarters and our sample contains relatively few observations for estimating latent volatility persistence, we, thus, use $(\phi_j + 1)/2 \sim \text{Beta}(20, 1.5)$ prior on which places more prior mass on persistent log-volatility than the $\text{Beta}(5, 1.5)$ default used in Jurado et al. (2015). We assess the influence of this choice by re-estimating the index under the default and alternative priors: No significant differences were found.

conomic and financial series that are originally available monthly are aggregated to quarterly averages before estimation.

For comparison, we use REU, MU, and FU measures.[3] To ensure that differences in the correlations are not driven by differences in sample composition, all three other indices (REU, MU, and FU) are calculated over the same 129 quarters from 1993Q4 to 2025Q4. We reconstruct REU at the monthly frequency following Nguyen Thanh et al. (2020), extending the underlying data through 2026. To match the quarterly frequency of CREU, we aggregate the resulting monthly REU index to quarterly frequency by taking the average of its monthly observations within each quarter. We apply the same quarterly averaging procedure to the monthly MU and FU measures. Thus, CREU is estimated directly at the quarterly frequency, whereas REU, MU, and FU are constructed at their original monthly frequency and subsequently aggregated to quarterly averages for comparison.

Figures 1 and 2 show the time series of REU, CREU, MU, and FU from 1993Q4 to 2025Q4 for forecast horizons of three and twelve months, respectively. For CREU, these correspond to forecast horizons of one and four quarters. As in Jurado et al. (2015) and Nguyen Thanh et al. (2020), the dashed horizontal lines indicate periods of high uncertainty, defined as observations at least 1.65 standard deviations above the respective mean. Shaded areas indicate NBER recession periods.

The four uncertainty measures exhibit both common and distinct movements over time. At the three-month horizon, their pairwise correlations range from 0.37 to 0.68, while at the twelve-month horizon they range from 0.31 to 0.69. Thus, the measures share a common component but are far from perfectly correlated. Their differences are particularly apparent around major episodes of economic uncertainty.

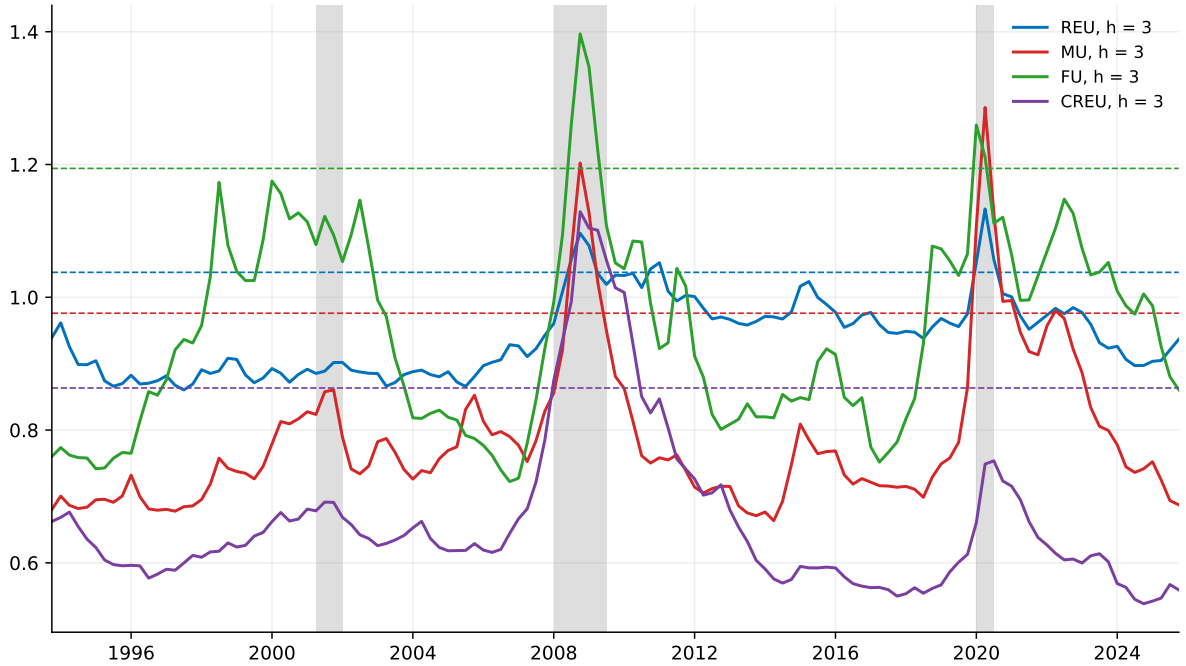
During the Great Recession, all four measures exceed the 1.65 standard deviation threshold at both horizons, and CREU does so by the widest margin at the twelve-month horizon. CREU also remains elevated relative to the other measures until 2011. The persistence of CREU during this period is consistent with the prolonged adjustment in U.S. commercial real estate markets following the financial crisis. Duca and Ling (2020), for example, document a pronounced boom and bust in U.S. commercial real estate prices and show that the bust was initially associated with an increase in general risk premia and subsequently with tighter effective capital requirements in the commercial mortgage-backed securities market. They further find that the subsequent recovery in commercial real estate prices was supported by unusually low real Treasury yields.

The COVID-19 recession shows a markedly different pattern. At the three-month horizon, MU, FU, and REU all rise above their respective thresholds, whereas CREU remains below its own. Thus, CREU does not register an uncertainty shock in 2020 according to the 1.65 standard deviation criterion, despite the sharp increases in broader measures of uncertainty. Taken together with the Great Recession, this difference indicates that CREU does not simply mirror uncertainty in residential real estate, the macroeconomy, or financial markets.

Table 1 further examines the relationship between the uncertainty measures and real estate and macroeconomic variables. Following Nguyen Thanh et al. (2020), we consider house price growth, new housing starts, industrial production growth, and the NBER recession dummy. We

[3]We reconstruct and extend REU by Nguyen Thanh et al. (2020) till 2025Q4. Both MU and FU indices can be found at Sydney Ludvigson's website https://www.sydneyludvigson.com

Figure 1: REU, CREU, MU, and FU from 1993Q4 to 2025Q4, $h = 3$




*Notes:* Dashed horizontal lines indicate 1.65 standard deviations above the mean of each uncertainty series. Shaded areas indicate NBER recession periods. Pairwise correlations among the uncertainty measures range from 0.37 to 0.68.

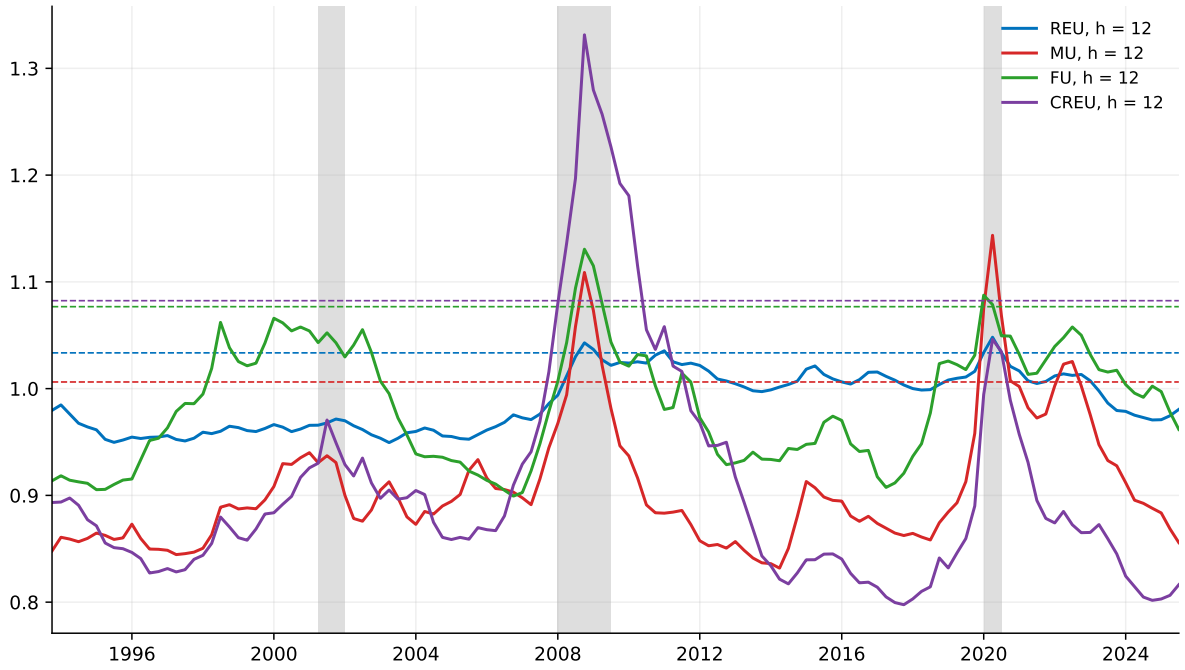
extend this set with two variables that directly capture commercial real estate market conditions: commercial real estate price growth and commercial construction spending growth.

CREU is particularly strongly related to commercial real estate activity. At the three-month horizon, its correlation with commercial construction spending growth is $-0.51$, compared with $-0.23$ for REU, $-0.30$ for MU, and $-0.41$ for FU. At the twelve-month horizon, the corresponding correlations are $-0.49$, $-0.15$, $-0.27$, and $-0.39$. CREU is also negatively correlated with commercial real estate price growth. At the three-month horizon, its correlation is $-0.34$, compared with $-0.23$ for REU, $-0.31$ for MU, and $-0.32$ for FU, while the corresponding correlations at the twelve-month horizon are $-0.34$, $-0.21$, $-0.33$, and $-0.30$, respectively. Thus, the distinction is particularly pronounced for commercial construction spending, while the correlations with commercial real estate price growth are more similar across CREU, MU, and FU.

In contrast, REU and MU are more strongly related to variables from the sectors they are designed to capture. At the three-month horizon, the correlation between REU and new housing starts is $-0.74$, compared with $-0.64$ for CREU, while the correlation between MU and industrial production growth is $-0.48$, compared with $-0.23$ for CREU. CREU is nevertheless strongly related to the aggregate business cycle: its correlation with the NBER recession dummy is 0.53 at the three-month horizon and 0.58 at the twelve-month horizon, compared with 0.36 and 0.26 for REU, respectively. At the same time, CREU is moderately correlated with the alternative uncertainty measures. At the three-month horizon, its correlations with REU, MU, and FU are 0.58, 0.57, and 0.49, respectively. These results suggest that the uncertainty measures contain a common component while retaining information related to their respective economic sectors.

In summary, the time-series evidence and correlations suggest that CREU captures aspects

Figure 2: REU, CREU, MU, and FU from 1993Q4 to 2025Q4, $h = 12$




*Notes:* Dashed horizontal lines indicate 1.65 standard deviations above the mean of each uncertainty series. Shaded areas indicate NBER recession periods. Pairwise correlations among the uncertainty measures range from 0.31 to 0.69.

of uncertainty that differ from those reflected in existing measures of REU, MU, and FU. In particular, CREU is more closely related to commercial construction activity, whereas REU and MU are more strongly associated with housing starts and industrial production growth, respectively. In the following section, we examine these relationships more formally using temporal causality tests and vector autoregressions.

# 4 Empirical Methodology and Results

In this section, we first ask whether the uncertainty measures are causal, in a temporal sense, for house price growth, new housing starts, industrial production growth, the recession dummy, commercial real estate price growth, and commercial construction spending growth. We then compare the dynamic effects of REU, CREU, MU, and FU using vector autoregressions (VARs).

## 4.1 Granger Causality

In order to examine temporal causality, we first estimate for each dependent variable $x$ the following equation:

$$x_t = \alpha_0 + \sum_{j=1}^{3} \alpha_j x_{t-j} + \sum_{j=1}^{3} \beta_j \text{Uncertainty}_{t-j} + u_t, \tag{8}$$

where $x$ is alternatively house price growth, new housing starts, industrial production growth, the recession dummy, commercial real estate price growth, or commercial construction spending growth, and Uncertainty denotes one of the uncertainty measures. We consider REU, CREU,

Table 1: Correlations of REU, CREU, MU, and FU with Real Estate and Macroeconomic Variables

| | REU(3) | REU(6) | REU(12) | CREU(3) | CREU(6) | CREU(12) | MU(3) | MU(12) | FU(3) | FU(12) | HP Growth | Starts | IP Growth | NBER | CRE Price | CRE Constr. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REU(3) | 1 | | | | | | | | | | | | | | | |
| REU(6) | $0.996^{***}$ | 1 | | | | | | | | | | | | | | |
| REU(12) | $0.966^{***}$ | $0.983^{***}$ | 1 | | | | | | | | | | | | | |
| CREU(3) | $0.578^{***}$ | $0.573^{***}$ | $0.468^{**}$ | 1 | | | | | | | | | | | | |
| CREU(6) | $0.620^{***}$ | $0.613^{***}$ | $0.507^{***}$ | $0.983^{***}$ | 1 | | | | | | | | | | | |
| CREU(12) | $0.604^{***}$ | $0.596^{***}$ | $0.489^{**}$ | $0.986^{***}$ | $0.997^{***}$ | 1 | | | | | | | | | | |
| MU(3) | $0.595^{***}$ | $0.577^{***}$ | $0.507^{***}$ | $0.571^{***}$ | $0.669^{***}$ | $0.643^{***}$ | 1 | | | | | | | | | |
| MU(12) | $0.551^{***}$ | $0.536^{***}$ | $0.471^{**}$ | $0.536^{***}$ | $0.630^{***}$ | $0.607^{***}$ | $0.989^{***}$ | 1 | | | | | | | | |
| FU(3) | $0.369^{**}$ | $0.373^{**}$ | $0.337^{*}$ | $0.487^{***}$ | $0.570^{***}$ | $0.539^{***}$ | $0.683^{***}$ | $0.700^{***}$ | 1 | | | | | | | |
| FU(12) | $0.340^{**}$ | $0.345^{**}$ | $0.313^{*}$ | $0.469^{***}$ | $0.550^{***}$ | $0.519^{***}$ | $0.667^{***}$ | $0.688^{***}$ | $0.996^{***}$ | 1 | | | | | | |
| House Price Growth | $-0.321^{*}$ | $-0.320^{*}$ | $-0.266$ | $-0.478^{***}$ | $-0.436^{***}$ | $-0.460^{***}$ | $-0.123$ | $-0.152$ | $-0.135$ | $-0.116$ | 1 | | | | | |
| New Housing Starts | $-0.737^{***}$ | $-0.748^{***}$ | $-0.731^{***}$ | $-0.639^{***}$ | $-0.600^{***}$ | $-0.605^{***}$ | $-0.134$ | $-0.084$ | $-0.189$ | $-0.161$ | $0.521^{***}$ | 1 | | | | |
| Ind. Prod. Growth | $-0.367^{**}$ | $-0.341^{**}$ | $-0.295^{**}$ | $-0.230$ | $-0.286^{*}$ | $-0.275^{*}$ | $-0.478^{***}$ | $-0.470^{***}$ | $-0.354^{***}$ | $-0.324^{**}$ | 0.147 | 0.190 | 1 | | | |
| Recession Dummy | $0.355^{*}$ | $0.339^{*}$ | 0.264 | $0.531^{***}$ | $0.590^{***}$ | $0.578^{***}$ | $0.603^{***}$ | $0.588^{***}$ | $0.495^{***}$ | $0.472^{***}$ | $-0.316$ | $-0.212$ | $-0.606^{***}$ | 1 | | |
| CRE Price Growth | $-0.232^{*}$ | $-0.232^{*}$ | $-0.206^{*}$ | $-0.336^{**}$ | $-0.337^{***}$ | $-0.336^{***}$ | $-0.314^{**}$ | $-0.329^{***}$ | $-0.318^{***}$ | $-0.302^{***}$ | $0.293^{***}$ | 0.233 | $0.263^{*}$ | $-0.368^{***}$ | 1 | |
| Comm. Constr. Growth | $-0.229$ | $-0.213$ | $-0.151$ | $-0.505^{***}$ | $-0.501^{***}$ | $-0.493^{***}$ | $-0.301$ | $-0.273$ | $-0.413^{***}$ | $-0.388^{**}$ | $0.259^{*}$ | 0.322 | 0.160 | $-0.317^{**}$ | $0.320^{**}$ | 1 |

*Notes:* The table reports correlations of REU (REU($h$)), CREU (CREU($h$)), MU (MU($h$)), and FU (FU($h$)) with house price growth, new housing starts, industrial production growth, the NBER recession dummy, commercial real estate price growth, and commercial construction spending growth. The forecast horizon $h$ is stated in months; CREU(3), CREU(6), and CREU(12) correspond to forecast horizons of one, two, and four quarters, respectively. The one-month horizon is omitted because CREU is estimated directly at the quarterly frequency and therefore has no monthly counterpart.

All correlations are calculated over a common sample of 129 quarters from 1993Q4 to 2025Q4. The beginning of the sample is determined by the availability of CREU, while the end is determined by the availability of MU and FU. CREU is available through 2026Q1. The common sample contains three NBER recessions: the 2001 recession, the Great Recession, and the COVID-19 recession.

All data are quarterly. REU, MU, and FU are quarterly averages of the corresponding monthly uncertainty series. Growth rates are calculated as $100 \times \Delta \ln$ of CPI-deflated series, except for industrial production, which is a real quantity index and therefore enters undeflated. Housing starts enter in logs. FRED mnemonics and transformations are reported in Table A3.

Statistical significance is based on $p$-values from HAC regressions (Newey–West) of the standardized row variable on the standardized column variable. $^{***}$, $^{**}$, and $^{*}$ denote significance at the 1%, 5%, and 10% levels, respectively.

MU, and FU at forecast horizons of three and twelve months. For CREU, these correspond to forecast horizons of one and four quarters, respectively.

In order to test whether an uncertainty measure is causal for the dependent variable $x$, we employ two tests after each estimation. The first is a Granger-causality test with the null hypothesis

$$H_0 : \beta_1 = \beta_2 = \beta_3 = 0. \tag{9}$$

The second test examines whether the long-run effect of a change in uncertainty is significantly different from zero. Given Eq. (8), the long-run effect is

$$\theta = \frac{\beta_1 + \beta_2 + \beta_3}{1 - \alpha_1 - \alpha_2 - \alpha_3}, \tag{10}$$

and we test the null hypothesis

$$H_0 : \theta = 0. \tag{11}$$

As in Nguyen Thanh et al. (2020), we interpret an uncertainty measure as causal for $x$ if both null hypotheses are rejected at the 5 percent significance level.[4] Each regression uses the pairwise maximal sample available for the respective uncertainty measure and dependent variable.

Tables 2 and 3 summarize the results of the causality analysis. In line with the correlation analysis, the uncertainty measures differ in their relationships with the real estate and macroeconomic variables. REU is causal for new housing starts at both horizons, with negative long-run coefficients, and for industrial production growth at the twelve-month horizon. MU is causal for industrial production growth at both horizons and for the recession dummy at the twelve-month horizon. FU is causal for industrial production growth and the recession dummy at both horizons. None of these three uncertainty measures is causal for either commercial real estate price growth or commercial construction spending growth at either horizon.

FU provides an instructive contrast. Its lags are jointly significant for commercial construction spending at both horizons, with $p$-values of 0.015 and 0.029, but the corresponding long-run coefficients are not significant at the 5 percent level ($p = 0.110$ and $p = 0.137$). FU therefore carries short-run predictive content for commercial construction spending without meeting our definition of temporal causality.

The results for CREU are markedly different for the commercial real estate variables. At the three-month horizon, CREU is causal for both commercial real estate price growth and commercial construction spending growth. For commercial real estate prices, the Granger-causality test rejects the null hypothesis with a $p$-value of 0.009, while the long-run coefficient is negative and significant with a $p$-value of 0.042. For commercial construction spending, the corresponding $p$-values are below 0.001 and 0.035. Thus, CREU is the only one of the four uncertainty measures that satisfies both causality criteria for either commercial real estate variable at the three-month horizon.

[4] We use Newey–West standard errors that are robust to heteroskedasticity and autocorrelation in all estimations, with a maximum lag order of three. The standard errors of the long-run coefficients are calculated using the delta method.

At the twelve-month horizon, CREU remains causal for commercial real estate price growth, with $p$-values of 0.005 for the Granger-causality test and 0.037 for the long-run coefficient test. For commercial construction spending, the Granger-causality null continues to be rejected with a $p$-value below 0.001, whereas the long-run coefficient is significant only at the 10 percent level ($p = 0.060$). CREU therefore does not satisfy both criteria for commercial construction spending at the 5 percent level at this horizon. All long-run coefficients of CREU for the two commercial real estate variables are negative, so that higher CREU is associated with lower commercial real estate prices and lower commercial construction spending.

CREU is also related to variables outside the commercial real estate sector. It is causal for new housing starts and the recession dummy at both horizons, with a negative long-run coefficient for housing starts and a positive one for the recession dummy. In contrast, CREU is not causal for house price growth or industrial production growth at either horizon.

The house price row warrants a separate comment, since it is the most notable case in which our results depart from Nguyen Thanh et al. (2020), who find REU to be causal for house price growth. In our estimations, REU at the twelve-month horizon and FU at both horizons reject the Granger-causality null for house price growth, yet none of the four measures rejects the long-run coefficient null at any horizon. Moreover, all eight estimated long-run coefficients in this row are positive, in contrast to the negative unconditional correlations reported in Table 1. Both observations point to instability in the estimated long-run coefficient for this dependent variable: house price growth has a first-order autocorrelation of 0.83, so that the denominator of Eq. (10) is close to zero, and the three lags of the uncertainty measures are correlated among themselves at 0.93 to 0.98. The implied long-run coefficients for this row are therefore sensitive to the lag specification and should be interpreted with caution.

The absence of corresponding results for MU and FU may reflect differences in their construction. MU and FU aggregate uncertainty across large sets of macroeconomic and financial variables, so that the contribution of any single sector is diluted in the aggregate. CREU, by contrast, is constructed from variables directly related to the commercial real estate sector, and REU is specifically designed to capture uncertainty in residential real estate. The stronger predictive content of CREU for the commercial real estate variables is therefore consistent with the sector-specific nature of the measure, although we do not test this explanation directly.

We assess the robustness of the causality results along two dimensions, reported in Table A9 in the Appendix. First, CREU is estimated directly at the quarterly frequency, whereas the benchmark REU is estimated at the monthly frequency and aggregated to quarterly averages. To remove this asymmetry, we re-estimate REU directly at the quarterly frequency over the same estimation window as CREU. Under this construction, REU(3) satisfies both causality criteria for commercial real estate prices, with $p$-values of 0.045 for the Granger-causality test and 0.016 for the long-run coefficient test, but remains non-causal for commercial construction spending at both horizons. Second, we reconstruct CREU from 27 target series over the shorter window 2007Q4–2026Q1, adding five series whose coverage does not extend back to 1993Q4. CREU(3) remains causal for both commercial real estate prices and commercial construction spending.

Taken together, the temporal causality results indicate that CREU contains distinct predictive information for commercial real estate activity in the benchmark specification. At the

three-month horizon, CREU is the only uncertainty measure that satisfies both causality criteria for either commercial real estate variable in the benchmark results. For commercial construction spending, this finding is also robust to both alternative constructions considered above. For commercial real estate prices, by contrast, the distinction between CREU and REU is sensitive to how REU is constructed.

### 4.2 Vector Autoregressions

We use VARs to investigate and compare the dynamic responses of key real estate market variables to unexpected innovations in REU, CREU, MU, and FU. We estimate separate VARs for residential and commercial real estate. Our benchmark commercial real estate VAR is ordered as follows:

$$\begin{pmatrix} \text{federal funds rate} \\ \text{10-year Treasury rate} \\ \text{S\&P 500 growth} \\ \log(\text{industrial production}) \\ \text{uncertainty} \\ \log(\text{CRE price}) \\ \log(\text{commercial construction spending}) \end{pmatrix}. \tag{12}$$

The residential real estate VAR replaces the two commercial real estate variables with log house prices, log housing starts, and log residential construction employment. In each case, uncertainty is specified to be either REU(3), CREU(3), MU(3), or FU(3). The interest rates, stock market, and industrial production are included to capture broader financial and macroeconomic conditions, while the remaining variables capture activity in the respective real estate sector. The variables entering the VARs, their sample periods, and their sources are listed in Table A5.

Since there is no unambiguous theoretical ordering of uncertainty, we follow the argument of Bloom (2014) that uncertainty may contain both exogenous and endogenous components: it can increase in response to exogenous events but may also rise endogenously in response to deteriorating economic conditions. Accordingly, in our benchmark identification we order macroeconomic and financial variables before uncertainty and real estate variables after uncertainty. This ordering allows uncertainty to respond contemporaneously to macroeconomic and financial conditions, while real estate market variables respond contemporaneously to innovations in uncertainty.

We use quarterly data and two lags in the benchmark specification. As in Jurado et al. (2015) and Nguyen Thanh et al. (2020), the data are not filtered, which avoids using information from the entire sample in constructing the series that enter the system. The S&P 500 enters in growth rates rather than log levels because the VAR is unstable when the stock market enters in log levels. In the benchmark specification, the largest eigenvalue of the companion matrix ranges from 0.949 to 0.983 across the estimated VARs. The estimation sample varies slightly across uncertainty measures depending on data availability.[5]

[5]Table A6 in the Appendix reports the Schwarz information criterion for lag lengths of one to four. Two lags minimize the criterion in all specifications except those including CREU, where one lag yields a marginally lower value (0.53 compared with 0.81 in the residential VAR and 2.98 compared with 3.10 in the commercial VAR). We retain two lags throughout to maintain a common specification across uncertainty measures. Among the four

Table 2: Summary of the Granger causality analysis (REU, CREU, MU and FU).

| Dependent Variable | REU(3) | REU(12) | CREU(3) | CREU(12) | MU(3) | MU(12) | FU(3) | FU(12) |
|---|---|---|---|---|---|---|---|---|
| House Price Growth | 0.141 | $0.022^{**}$ | 0.420 | 0.659 | 0.611 | 0.453 | $0.006^{***}$ | $0.004^{***}$ |
| New Housing Starts | $0.019^{**}$ | $0.001^{***}$ | $0.042^{**}$ | $0.002^{***}$ | $0.001^{***}$ | $0.000^{***}$ | $0.003^{***}$ | $0.002^{***}$ |
| Ind. Prod. Growth | 0.113 | $0.014^{**}$ | 0.111 | $0.064^{*}$ | $0.009^{***}$ | $0.002^{***}$ | $0.007^{***}$ | $0.006^{***}$ |
| Recession Dummy | 0.640 | 0.124 | $0.006^{***}$ | $0.003^{***}$ | $0.058^{*}$ | $0.001^{***}$ | $0.004^{***}$ | $0.002^{***}$ |
| CRE Price Growth | 0.344 | 0.781 | $0.009^{***}$ | $0.005^{***}$ | 0.404 | 0.379 | 0.214 | 0.216 |
| Comm. Constr. Growth | 0.685 | 0.852 | $0.000^{***}$ | $0.000^{***}$ | $0.097^{*}$ | 0.118 | $0.015^{**}$ | $0.029^{**}$ |

*Notes:* The table displays, for each uncertainty measure, the result of the Granger causality analysis of whether the lags of that uncertainty measure are jointly significant in explaining the dependent variable. The entries are $p$-values of an $F$-test of $\beta_1 = \beta_2 = \beta_3 = 0$ in Eq. (8), estimated with Newey–West standard errors as in Table 3.

Following Nguyen Thanh et al. (2020), an uncertainty measure is called causal for a variable when both this test and the long-run coefficient test reject at the 5% level. On that criterion, CREU(3) is causal for housing starts, the recession dummy, commercial real estate prices, and commercial construction spending, and CREU(12) for housing starts, the recession dummy, and commercial real estate prices. REU is causal for housing starts at both horizons and, at the twelve-month horizon, for industrial production. MU(3) is causal for industrial production only and MU(12) for industrial production and the recession dummy, while FU is causal for industrial production and the recession dummy at both horizons.

$^{***}$, $^{**}$, and $^{*}$ denote significance at the 1%, 5%, and 10% levels, respectively.

Table 3: Summary of the long-run impact causality analysis (REU, CREU, MU and FU).

| Dependent Variable | REU(3) | REU(12) | CREU(3) | CREU(12) | MU(3) | MU(12) | FU(3) | FU(12) |
|---|---|---|---|---|---|---|---|---|
| House Price Growth | (+) [0.623] | (+) [0.546] | (+) [0.949] | (+) [0.784] | (+) [0.849] | (+) [0.981] | (+) [0.239] | (+) [0.247] |
| New Housing Starts | (−) [0.016]** | (−) [0.009]*** | (−) [0.009]*** | (−) [0.011]** | (−) [0.339] | (−) [0.306] | (−) [0.448] | (−) [0.477] |
| Ind. Prod. Growth | (−) [0.041]** | (−) [0.021]** | (−) [0.476] | (−) [0.204] | (−) [0.008]*** | (−) [0.001]*** | (−) [0.002]*** | (−) [0.002]*** |
| Recession Dummy | (+) [0.261] | (+) [0.829] | (+) [0.000]*** | (+) [0.000]*** | (+) [0.001]*** | (+) [0.000]*** | (+) [0.002]*** | (+) [0.000]*** |
| CRE Price Growth | (−) [0.181] | (−) [0.356] | (−) [0.042]** | (−) [0.037]** | (−) [0.148] | (−) [0.128] | (−) [0.100] | (−) [0.095]* |
| Comm. Constr. Growth | (−) [0.599] | (−) [0.707] | (−) [0.035]** | (−) [0.060]* | (−) [0.201] | (−) [0.165] | (−) [0.110] | (−) [0.137] |

*Notes:* The table summarizes the results of the long-run causality analysis of whether the long-run coefficients of the uncertainty measures are significant in explaining the house price growth rate, housing starts, the industrial production growth rate, the NBER recession dummy, and two commercial real estate variables. The sign of the long-run coefficient is presented in round brackets and the respective $p$-value in square brackets.

Estimation follows Eq. (8) with three lags, on quarterly data. Each regression uses the pairwise maximal sample. After allowing for three lags this leaves 129 to 221 observations for the REU columns, 127 for the CREU columns, and 125 to 256 for MU and FU. The long-run coefficient is $\theta = \sum_j \beta_j / (1 - \sum_j \alpha_j)$ as in Eq. (10); its standard error is obtained by the delta method from a Newey–West covariance matrix with maximum lag order three.

The house price row should be read with caution. House price growth has a first-order autocorrelation of 0.83, so that $1 - \sum_j \alpha_j$ is close to zero, and the three lags of the uncertainty measures are correlated among themselves at 0.93 to 0.98. The implied long-run coefficients for this row are therefore sensitive to the lag specification.

$^{***}$, $^{**}$, and $^{*}$ denote significance at the 1%, 5%, and 10% levels, respectively.

Figure 3, one of our main results, shows the impulse responses of commercial real estate prices and commercial construction spending to a one-standard-deviation innovation in each uncertainty measure. The responses to a CREU shock are negative of both commercial real estate prices and commercial construction spending. The response of commercial real estate prices initially increases slightly before turning negative, but becomes increasingly negative over the first several quarters, and subsequently begins to recover. Commercial construction spending follows a similar pattern: after a small initial response, it declines, reaches its largest negative response at intermediate horizons, and then moves back toward zero.

The responses following shocks to the alternative uncertainty measures differ in their timing and persistence. Since the uncertainty measures enter these VARs in their original units, a one-standard-deviation innovation corresponds to a different absolute change for each measure: the unconditional standard deviations are 0.058 for REU(3), 0.121 for CREU(3), 0.114 for MU(3), and 0.148 for FU(3). The magnitudes of the impulse responses are therefore not directly comparable across the four uncertainty shocks.[6]

### 4.2.1 Decomposition of Variance

To study the quantitative importance of uncertainty shocks for fluctuations in real estate markets, Table 4, the other main finding, reports forecast-error variance decompositions for the residential and commercial real estate variables. We compare the fractions of forecast-error variance explained by REU(3), CREU(3), MU(3), and FU(3). As a benchmark, we also report the fraction explained by the federal funds rate in each VAR.

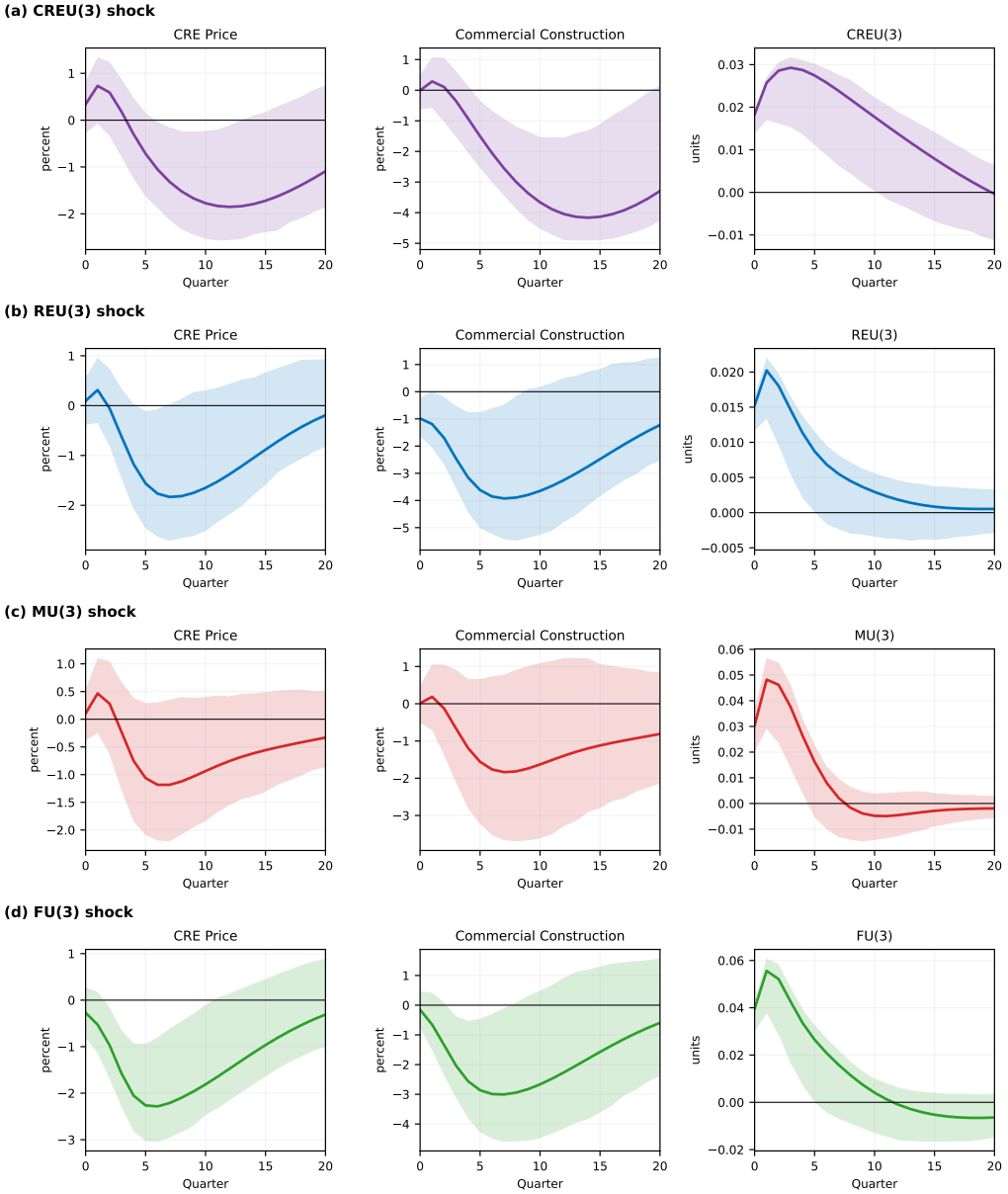
The results for commercial construction spending are particularly pronounced. At a forecast horizon of four quarters, CREU accounts for only 0.36 percent of its forecast-error variance. But its contribution subsequently increases to 11.26 percent at eight quarters, 31.01 percent at twelve quarters, and 46.38 percent at twenty quarters. At the twenty-quarter horizon, REU, MU, and FU account for 25.85, 5.17, and 14.07 percent, respectively. Thus, at longer horizons CREU accounts for a substantially larger fraction of the forecast-error variance of commercial construction spending than any of the alternative uncertainty measures. The corresponding contribution of the federal funds rate in the CREU VAR is 7.40 percent at the same horizon. Figure A3 shows the responses to a federal funds rate shock alongside those to CREU and MU shocks within the same VARs.

The leading role of CREU for commercial construction spending is also robust to the two alternative constructions described in Section 4.1, as reported in Table A10 in the Appendix. For example, when REU is estimated directly at the quarterly frequency, its share of the twenty-quarter forecast-error variance of commercial construction spending is 15.5 percent, compared with 46.4 percent for CREU. When CREU is instead constructed from 27 target series over the shorter sample, its share falls to 24.1 percent but remains the largest among the four uncertainty measures. Given that the latter VARs contain only 72 to 75 observations, the corresponding

uncertainty specifications, the CREU VAR has the lowest criterion value at every lag length in both panels. For this comparison, all four uncertainty measures are standardized to zero mean and unit variance before entering the VARs, ensuring a common scale across the uncertainty specifications.

[6] We use the forecast-error variance decomposition to assess the relative quantitative importance of the different uncertainty shocks.

Figure 3: Impulse response functions of commercial real estate prices, commercial construction spending and uncertainty to a CREU (Panel a), REU (Panel b), MU (Panel c) and FU (Panel d) shock.




*Notes:* Estimation based on quarterly data from 1993Q2 to 2026Q1, depending on the uncertainty measure, with 128 to 130 observations per VAR. Responses are orthogonalised impulse responses to an innovation of one standard deviation in the respective uncertainty measure, shown over 20 quarters. Shaded areas are 95% confidence bands from 1,000 residual bootstrap replications.

The specification follows Eq. (12), ordered (federal funds rate, ten-year Treasury rate, S&P 500 growth, log industrial production, uncertainty, log CRE price, log commercial construction spending). Two lags are used and the data are unfiltered. The commercial real estate series are cumulated from their growth rates and are measured in percent; uncertainty is measured in units.

The size of a one-standard-deviation shock differs across measures, since the unconditional standard deviations are 0.058 for REU(3), 0.121 for CREU(3), 0.114 for MU(3), and 0.148 for FU(3). The magnitudes of the impulse responses are therefore not directly comparable across the four uncertainty shocks.

Table 4: Decomposition of variance: relative importance of REU, CREU, MU and FU and of the federal funds rate.

| | REU(3) | | CREU(3) | | MU(3) | | FU(3) | |
|---|---|---|---|---|---|---|---|---|
| Horizon | Unc. | ffr | Unc. | ffr | Unc. | ffr | Unc. | ffr |
| **Panel A: residential real estate** | | | | | | | | |
| Sample | 1993Q1–2026Q2 | | 1993Q4–2026Q1 | | 1993Q1–2025Q4 | | 1993Q1–2025Q4 | |
| $n$ | 132 | | 128 | | 130 | | 130 | |
| *Variance decomposition: Housing Prices* | | | | | | | | |
| $k = 1$ | 3.47 | 0.01 | 6.94 | 0.00 | 1.59 | 0.03 | 0.16 | 0.14 |
| $k = 4$ | 10.24 | 0.05 | 4.79 | 0.06 | 5.99 | 0.02 | 1.90 | 0.02 |
| $k = 8$ | 6.91 | 0.10 | 4.39 | 0.72 | 2.10 | 0.03 | 1.11 | 0.08 |
| $k = 12$ | 4.62 | 0.23 | 4.68 | 2.03 | 1.00 | 0.06 | 4.64 | 0.07 |
| $k = 20$ | 3.14 | 0.39 | 5.84 | 4.92 | 0.82 | 0.06 | 12.73 | 0.89 |
| *Variance decomposition: Housing Starts* | | | | | | | | |
| $k = 1$ | 0.37 | 5.49 | 1.12 | 2.53 | 0.08 | 3.23 | 0.64 | 2.02 |
| $k = 4$ | 18.67 | 2.39 | 12.69 | 0.72 | 14.05 | 1.26 | 5.19 | 0.74 |
| $k = 8$ | 15.29 | 1.61 | 17.71 | 0.94 | 9.10 | 1.19 | 2.84 | 1.82 |
| $k = 12$ | 11.45 | 1.24 | 19.00 | 2.23 | 5.96 | 1.01 | 4.88 | 1.93 |
| $k = 20$ | 8.60 | 0.93 | 18.11 | 5.39 | 4.89 | 0.80 | 14.09 | 3.16 |
| *Variance decomposition: Construction Employment* | | | | | | | | |
| $k = 1$ | 0.16 | 18.20 | 0.70 | 15.45 | 0.00 | 16.11 | 1.35 | 13.22 |
| $k = 4$ | 12.33 | 14.13 | 9.89 | 9.43 | 18.01 | 9.98 | 6.53 | 7.13 |
| $k = 8$ | 16.38 | 7.44 | 17.06 | 3.27 | 15.38 | 5.41 | 5.44 | 5.07 |
| $k = 12$ | 13.20 | 4.47 | 19.03 | 1.93 | 8.88 | 3.48 | 2.84 | 3.89 |
| $k = 20$ | 8.55 | 2.37 | 18.48 | 3.84 | 4.29 | 2.12 | 8.33 | 3.59 |
| **Panel B: commercial real estate** | | | | | | | | |
| Sample | 1993Q2–2026Q1 | | 1993Q4–2026Q1 | | 1993Q2–2025Q4 | | 1993Q2–2025Q4 | |
| $n$ | 130 | | 128 | | 129 | | 129 | |
| *Variance decomposition: CRE Prices* | | | | | | | | |
| $k = 1$ | 0.09 | 2.46 | 1.16 | 2.24 | 0.10 | 2.94 | 0.70 | 1.90 |
| $k = 4$ | 1.06 | 11.26 | 2.58 | 6.70 | 0.70 | 9.42 | 8.44 | 4.85 |
| $k = 8$ | 10.57 | 15.78 | 5.95 | 8.54 | 4.83 | 13.32 | 27.47 | 6.98 |
| $k = 12$ | 16.54 | 13.94 | 14.94 | 6.43 | 7.01 | 12.63 | 34.53 | 6.20 |
| $k = 20$ | 17.99 | 11.83 | 22.30 | 4.43 | 7.74 | 10.96 | 34.18 | 5.33 |
| *Variance decomposition: Commercial Construction* | | | | | | | | |
| $k = 1$ | 7.25 | 0.01 | 0.00 | 0.01 | 0.00 | 0.03 | 0.16 | 0.04 |
| $k = 4$ | 11.49 | 10.81 | 0.36 | 4.69 | 0.44 | 8.14 | 5.69 | 3.90 |
| $k = 8$ | 21.85 | 20.45 | 11.26 | 14.28 | 3.64 | 18.12 | 13.54 | 10.57 |
| $k = 12$ | 25.42 | 19.11 | 31.01 | 12.72 | 4.84 | 19.05 | 15.18 | 10.99 |
| $k = 20$ | 25.85 | 14.72 | 46.38 | 7.40 | 5.17 | 15.49 | 14.07 | 8.58 |

*Notes:* Fraction of forecast-error variance, in percent, due to either uncertainty or the federal funds rate (ffr). Separate VARs are estimated in which uncertainty is REU(3), CREU(3), MU(3), or FU(3). Each block shows the fraction of forecast-error variance of the variable named in the block title at horizon $k$ explained by the uncertainty measure or by the federal funds rate of that VAR. Sample and number of observations are stated in the first two rows of each panel. The specification follows Eq. (12), with eight variables in Panel A and seven in Panel B. The S&P 500 enters in growth rates rather than log levels, since in log levels the largest eigenvalue of the companion matrix exceeds unity; in the present specification it ranges from 0.949 to 0.983. Two lags are used and the data are unfiltered. Horizons $k = 1$, 4, and 20 correspond to the 3-, 12-, and 60-month horizons of Nguyen Thanh et al. (2020); $k = 8$ and $k = 12$ are added to show the dynamics between the one- and five-year horizons. Panel A uses the residential variables (log house price, log housing starts, log residential construction employment), Panel B the commercial ones (log CRE price, log commercial construction spending), which are cumulated from their growth rates.

estimates should be interpreted with caution.

For commercial real estate prices, uncertainty also becomes more important at longer horizons, although the relative importance of the individual uncertainty measures differs. At twenty quarters, CREU accounts for 22.30 percent of the forecast-error variance of commercial real estate prices, compared with 17.99 percent for REU and 7.74 percent for MU. FU accounts for the largest share, at 34.18 percent. Hence, the particularly strong relative contribution of CREU is concentrated in commercial construction spending rather than commercial real estate prices.

The residential real estate results provide an additional comparison. At the twenty-quarter horizon, CREU accounts for 18.11 percent of the forecast-error variance of housing starts and 18.48 percent of residential construction employment. The corresponding shares for REU are 8.60 and 8.55 percent, while those for MU are 4.89 and 4.29 percent. For house prices, however, the contribution of CREU is considerably smaller, at 5.84 percent.

As a further robustness check, we examine whether these results depend on the extension of the estimation period beyond the sample used by Nguyen Thanh et al. (2020). Table A7 in the Appendix compares the forecast-error variance decompositions for a sample ending in 2017Q4 with those from the full sample. For commercial construction spending at the twenty-quarter horizon, the contribution of REU declines from 49.9 to 25.9 percent, that of MU from 44.4 to 5.2 percent, and that of FU from 33.9 to 14.1 percent when the sample is extended. The contribution of CREU also declines, from 55.8 to 46.4 percent, but remains large in the extended sample. Thus, although the estimated variance share is sample-dependent, CREU continues to account for a large fraction of the forecast-error variance of commercial construction spending in the extended sample.

For other robustness checks, we also examine the sensitivity of the results to the recursive identification by alternatively ordering uncertainty first and last. The main result for commercial construction spending is robust to both alternative orderings. At the twenty-quarter horizon, CREU accounts for 46.4 percent of its forecast-error variance under the benchmark ordering, compared with 46.4 percent when uncertainty is ordered last and 45.1 percent when it is ordered first. The estimated response of commercial construction spending to a CREU shock is also similar across the three orderings. The results for commercial real estate prices and the residential variables are more sensitive to the recursive identification. Table A8 and Figure A4 in the Appendix report the corresponding results.

Overall, the VAR results complement the temporal causality analysis. Innovations in CREU are followed by negative responses in both commercial real estate prices and commercial construction spending, and the variance decomposition indicates a particularly important role for CREU in fluctuations in commercial construction spending at longer horizons. At the same time, the results for commercial real estate prices show that the relative importance of CREU is not uniform across commercial real estate variables.

# 5 Conclusion

This paper constructs and analyzes a novel measure of uncertainty for the U.S. commercial real estate sector that complements existing measures of REU, MU, and FU. Our Commercial Real Estate Uncertainty (CREU) index is based on the predictability of commercial real estate

variables. Rather than relying on the volatility of a single observable series, following Jurado et al. (2015) and Nguyen Thanh et al. (2020), CREU measures uncertainty from the conditional volatility of the unforecastable components of a broad set of variables related to commercial real estate. The resulting index therefore provides a sector-specific measure of uncertainty that captures dimensions of the commercial real estate market not fully reflected in existing uncertainty measures.

Our empirical results support this distinction. Although CREU is positively correlated with REU, MU, and FU, the four measures differ substantially over time and in their relationships with real estate and macroeconomic variables. In particular, CREU is more strongly correlated with commercial construction spending than any of the alternative uncertainty measures, whereas MU is more strongly correlated with industrial production growth. CREU is therefore particularly closely related to conditions in the commercial real estate sector rather than simply reflecting uncertainty in the economy as a whole.

The temporal causality analysis provides further evidence of the distinct information contained in CREU. At the three-month forecast horizon, CREU is both Granger-causal for and has a significant negative long-run effect on commercial real estate prices and commercial construction spending. For commercial construction spending, none of the alternative uncertainty measures satisfies both criteria, a result that is robust to estimating REU directly at the quarterly frequency and to constructing CREU from a broader set of commercial real estate variables over a shorter sample. For commercial real estate prices, the distinction is less robust: when REU is estimated directly at the quarterly frequency, it also satisfies both criteria. In the benchmark specification, CREU continues to satisfy both criteria for commercial real estate prices at the twelve-month horizon, whereas for commercial construction spending the long-run coefficient is significant only at the 10 percent level. CREU is also causal for new housing starts and the recession dummy at both horizons, but not for house price growth or industrial production growth. These results suggest that CREU contains predictive information that is particularly relevant for commercial real estate activity rather than serving as a general measure of economy-wide uncertainty.

The VAR analysis reinforces the evidence for commercial construction spending. Following an unexpected increase in CREU, the estimated responses of both commercial real estate prices and commercial construction spending turn negative. At a twenty-quarter horizon, CREU accounts for 46.38 percent of the forecast-error variance of commercial construction spending in the benchmark specification, compared with 25.85 percent for REU, 5.17 percent for MU, and 14.07 percent for FU. This result is robust to alternative recursive orderings, with corresponding shares of 46.4 and 45.1 percent when uncertainty is ordered last and first, respectively. CREU also retains the largest share among the four uncertainty measures under the alternative uncertainty constructions. Moreover, although the estimated variance shares are sensitive to the estimation period, CREU continues to account for a large fraction of the forecast-error variance of commercial construction spending when the sample is extended beyond 2017. For commercial real estate prices, the evidence is less uniform: at the twenty-quarter horizon, FU accounts for a larger share of their forecast-error variance than CREU.

The negative relationship between CREU and commercial construction is consistent with the

real-options view of investment under uncertainty. Using commercial real estate data, Holland et al. (2000) find evidence in favor of option-based investment models in which irreversibility and the option to delay are important for investment decisions. Related evidence from real estate development shows that greater uncertainty delays investment (Bulan et al. 2009). In this interpretation, an increase in uncertainty raises the value of waiting before committing to an irreversible development project, providing a potential mechanism for the negative response of commercial construction to CREU.

The negative response of commercial real estate prices also raises questions about the channels through which uncertainty affects property valuations. Dorofeenko et al. (2014), for example, obtain a positive response of house prices to supply-side uncertainty in a structural housing model, whereas our estimated response of commercial real estate prices to CREU is negative. The latter finding is consistent with empirical evidence that commercial property prices decline following shocks to broader measures of economic uncertainty (Gholipour et al. 2021). Commercial real estate valuations are also closely related to required risk premia and financing conditions (Duca and Ling 2020). Our analysis, however, does not identify which mechanism drives the price response to CREU. Distinguishing among supply- and demand-side channels, changes in required risk premia, and financing conditions therefore provides a natural direction for further research.

In summary, our results indicate that measuring uncertainty specifically at the level of the commercial real estate sector provides information that is not fully captured by existing measures of REU, MU, or FU. This distinction is particularly pronounced for commercial construction spending, for which CREU exhibits both temporal predictive content and substantial quantitative importance in the VAR analysis, with the central findings remaining under alternative constructions and recursive identification schemes. CREU therefore provides a basis for further research on the role of uncertainty in commercial real estate investment, development, financing, and valuation, as well as on the usefulness of sector-specific uncertainty measures more generally.

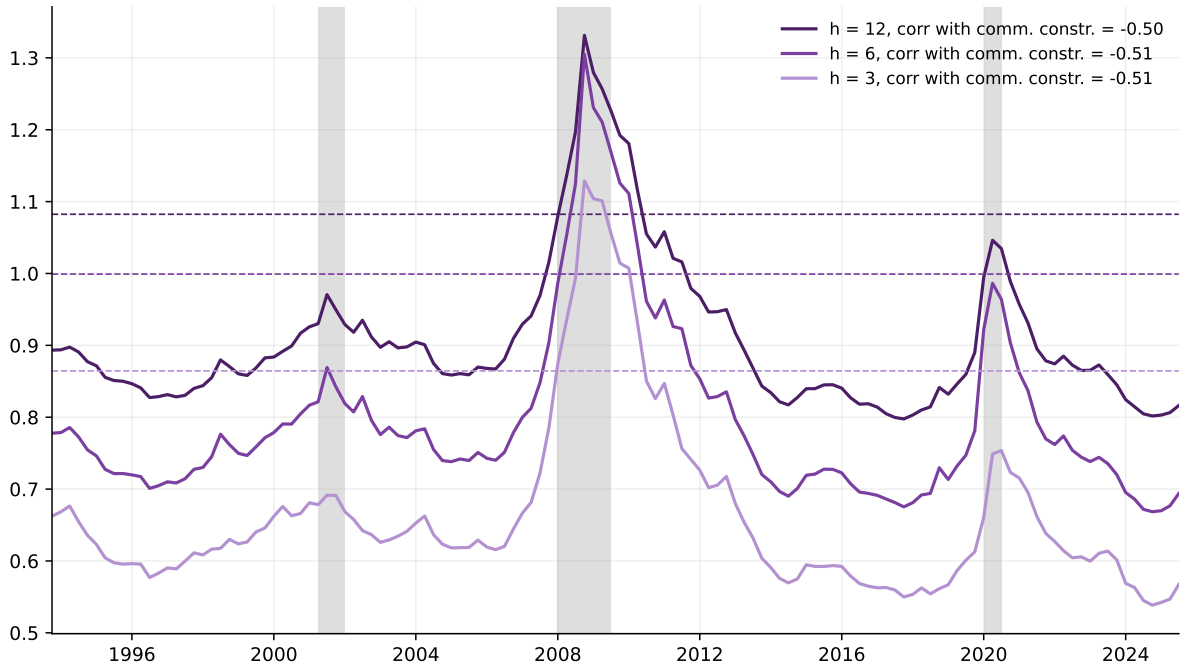
# Appendix

Table A1: Correlations using pairwise maximal samples.

| | REU(3) | REU(6) | REU(12) | CREU(3) | CREU(6) | CREU(12) | MU(3) | MU(12) | FU(3) | FU(12) | HP Growth | Starts | IP Growth | NBER | CRE Price | CRE Constr. | Sample | $n$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REU(3) | 1 | | | | | | | | | | | | | | | | 1970Q2–2026Q2 | 225 |
| REU(6) | $0.983^{***}$ | 1 | | | | | | | | | | | | | | | 1970Q2–2026Q2 | 225 |
| REU(12) | $0.876^{***}$ | $0.949^{***}$ | 1 | | | | | | | | | | | | | | 1970Q2–2026Q2 | 225 |
| CREU(3) | $0.577^{***}$ | $0.572^{***}$ | $0.468^{**}$ | 1 | | | | | | | | | | | | | 1993Q4–2026Q1 | 130 |
| CREU(6) | $0.619^{***}$ | $0.612^{***}$ | $0.506^{***}$ | $0.983^{***}$ | 1 | | | | | | | | | | | | 1993Q4–2026Q1 | 130 |
| CREU(12) | $0.603^{***}$ | $0.595^{***}$ | $0.489^{**}$ | $0.986^{***}$ | $0.997^{***}$ | 1 | | | | | | | | | | | 1993Q4–2026Q1 | 130 |
| MU(3) | $0.592^{***}$ | $0.511^{***}$ | $0.324^{**}$ | $0.571^{***}$ | $0.669^{***}$ | $0.643^{***}$ | 1 | | | | | | | | | | 1960Q3–2025Q4 | 262 |
| MU(12) | $0.532^{***}$ | $0.442^{***}$ | $0.247^{*}$ | $0.536^{***}$ | $0.630^{***}$ | $0.607^{***}$ | $0.964^{***}$ | 1 | | | | | | | | | 1960Q3–2025Q4 | 262 |
| FU(3) | $0.344^{***}$ | $0.306^{**}$ | 0.200 | $0.487^{***}$ | $0.570^{***}$ | $0.539^{***}$ | $0.627^{***}$ | $0.580^{***}$ | 1 | | | | | | | | 1960Q3–2025Q4 | 262 |
| FU(12) | $0.325^{***}$ | $0.285^{**}$ | 0.176 | $0.469^{***}$ | $0.550^{***}$ | $0.519^{***}$ | $0.642^{***}$ | $0.609^{***}$ | $0.994^{***}$ | 1 | | | | | | | 1960Q3–2025Q4 | 262 |
| House Price Growth | $-0.298^{*}$ | $-0.285^{*}$ | $-0.202$ | $-0.474^{***}$ | $-0.432^{***}$ | $-0.455^{***}$ | $-0.098$ | $-0.130$ | $-0.098$ | $-0.081$ | 1 | | | | | | 1987Q2–2026Q1 | 156 |
| New Housing Starts | $-0.717^{***}$ | $-0.746^{***}$ | $-0.720^{***}$ | $-0.639^{***}$ | $-0.600^{***}$ | $-0.605^{***}$ | $-0.176$ | $-0.138$ | $-0.170$ | $-0.149$ | $0.522^{***}$ | 1 | | | | | 1960Q3–2026Q1 | 263 |
| Ind. Prod. Growth | $-0.405^{***}$ | $-0.374^{***}$ | $-0.303^{***}$ | $-0.230$ | $-0.286^{*}$ | $-0.275^{*}$ | $-0.475^{***}$ | $-0.444^{***}$ | $-0.361^{***}$ | $-0.347^{***}$ | 0.160 | $0.318^{***}$ | 1 | | | | 1960Q3–2026Q1 | 263 |
| Recession Dummy | $0.375^{***}$ | $0.305^{***}$ | 0.147 | $0.531^{***}$ | $0.591^{***}$ | $0.579^{***}$ | $0.587^{***}$ | $0.556^{***}$ | $0.450^{***}$ | $0.445^{***}$ | $-0.354^{*}$ | $-0.267^{**}$ | $-0.590^{***}$ | 1 | | | 1960Q3–2026Q1 | 263 |
| CRE Price Growth | $-0.176^{*}$ | $-0.165$ | $-0.114$ | $-0.338^{**}$ | $-0.339^{***}$ | $-0.338^{***}$ | $-0.186^{*}$ | $-0.164^{*}$ | $-0.199^{**}$ | $-0.189^{*}$ | $0.332^{***}$ | 0.208 | $0.173^{**}$ | $-0.214^{**}$ | 1 | | 1960Q3–2026Q1 | 263 |
| Comm. Constr. Growth | $-0.231$ | $-0.215$ | $-0.153$ | $-0.501^{***}$ | $-0.497^{***}$ | $-0.489^{***}$ | $-0.302$ | $-0.275$ | $-0.413^{***}$ | $-0.389^{**}$ | $0.257^{*}$ | 0.321 | 0.159 | $-0.316^{**}$ | $0.315^{**}$ | 1 | 1993Q2–2026Q1 | 132 |

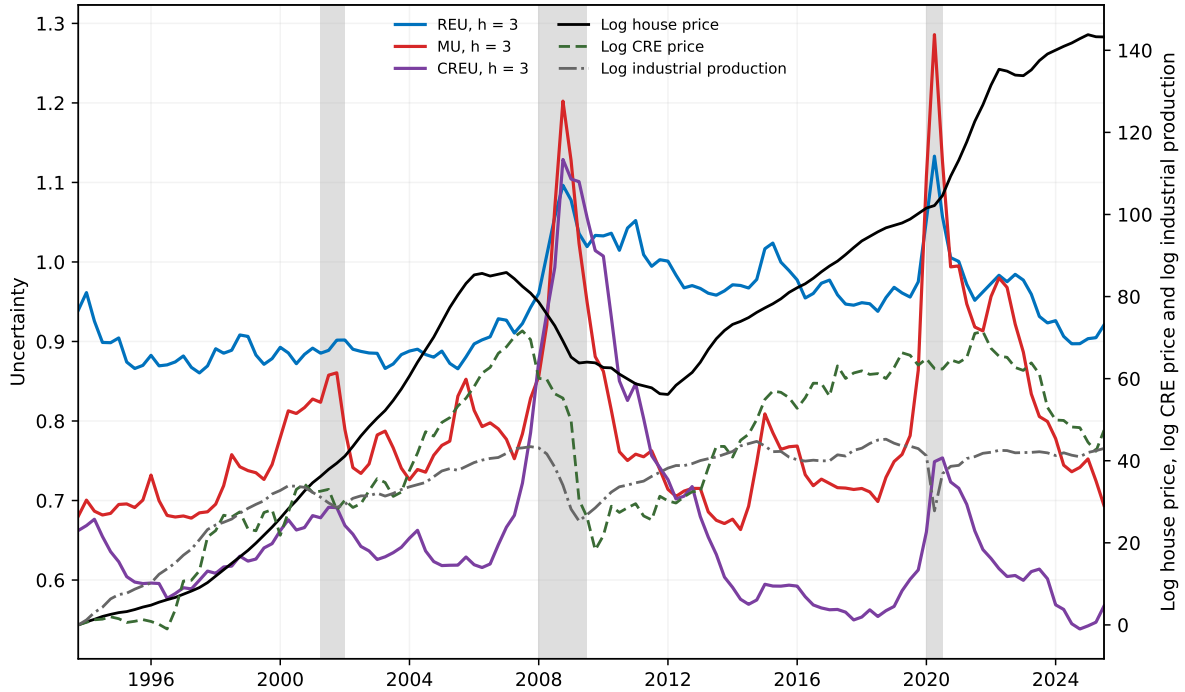
*Notes:* As Table 1, but without imposing a common sample. Each coefficient uses the pairwise maximal number of quarters for which both variables are observed. The final two columns report the availability and number of observations of the row variable. REU is available from 1970Q2 to 2026Q2, CREU from 1993Q4 to 2026Q1, and MU and FU from 1960Q3 to 2025Q4. Coefficients are therefore not comparable across rows. $p$-values are obtained as in Table 1. $^{***}$, $^{**}$, and $^{*}$ denote significance at the 1%, 5%, and 10% levels, respectively.

Figure A1: CREU at different forecast horizons.



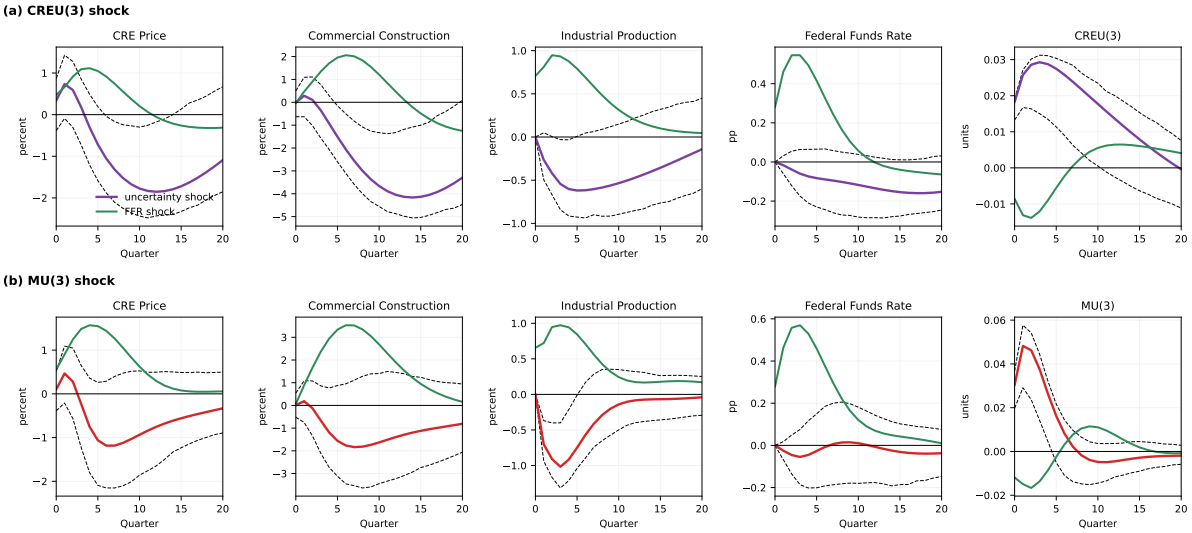

*Notes:* Dashed horizontal lines indicate 1.65 standard deviations above the mean of each series. Shaded areas indicate NBER recession periods. The legend reports the correlation of each series with commercial construction spending growth.

Figure A2: Uncertainty and real estate market variables.



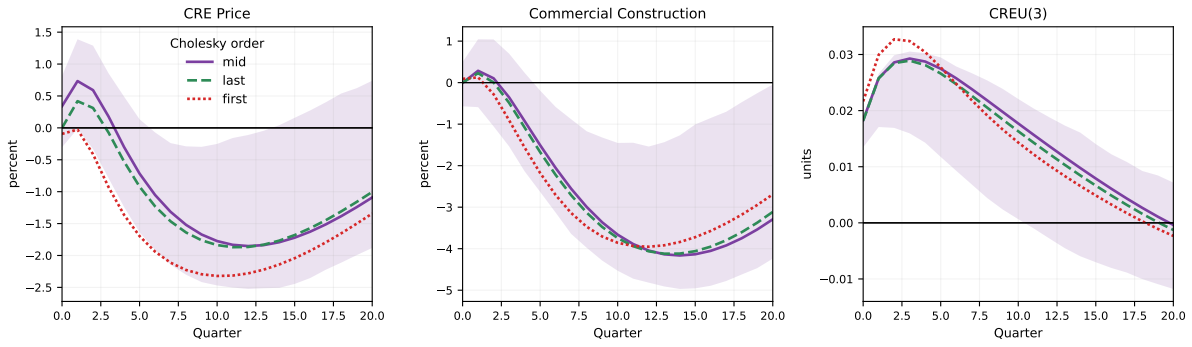

*Notes:* Shaded areas indicate NBER recession periods. Uncertainty is measured on the left axis and the log series on the right axis. The forecast horizon is $h = 3$ throughout. The log series are cumulated from the corresponding growth rates and normalized to zero in 1993Q4.

Figure A3: Impulse responses to uncertainty and federal funds rate shocks.




*Notes:* Dashed lines are 95% confidence bands around the uncertainty shock, obtained from 1,000 residual bootstrap replications. Both shocks are orthogonalised innovations of one standard deviation. Estimation is based on the same VAR specification as in Figure 3, over 20 quarters. Responses of the commercial real estate series and industrial production are in percent, the federal funds rate in percentage points, and uncertainty in units. The third column shows industrial production rather than the S&P 500, which enters the system in growth rates and is therefore not informative as a level response.

Figure A4: Impulse response functions under alternative Cholesky orderings.




*Notes:* Orthogonalised impulse responses of commercial real estate prices, commercial construction spending, and CREU(3) to an innovation of one standard deviation in CREU(3), shown over 20 quarters under the three recursive identification schemes defined in Table A8. Only the recursive identification changes across specifications; the estimation sample and reduced-form VAR are identical. The shaded area denotes the 95% confidence band for the benchmark ordering, obtained from 1,000 residual bootstrap replications. Confidence bands for the alternative orderings are omitted for readability.

Table A2: Commercial real estate variables used to construct CREU.

| No. | Code (FRED) | Transf. | Description |
|---|---|---|---|
| 1 | BAA10Y | $\Delta$ | Moody's BAA corporate bond yield relative to 10-year Treasury (credit spread) |
| 2 | DGS10 | $\Delta$ | 10-year Treasury constant maturity rate |
| 3 | NFCI | $\Delta$ | Chicago Fed National Financial Conditions Index |
| 4 | CES2023620001 | $\Delta \ln$ | All employees: nonresidential building construction |
| 5 | PLODGCONS | $\Delta \ln$ | Total construction spending: lodging |
| 6 | PNRESCONS | $\Delta \ln$ | Total private construction spending: nonresidential |
| 7 | PRCOMCONS | $\Delta \ln$ | Total private construction spending: commercial |
| 8 | PRHLTHCONS | $\Delta \ln$ | Total private construction spending: health care |
| 9 | PROFCONS | $\Delta \ln$ | Total private construction spending: office |
| 10 | REALLN | $\Delta \ln$ | Real estate loans, all commercial banks |
| 11 | USCONS | $\Delta \ln$ | All employees: construction (total) |
| 12 | WPUSI012011 | $\Delta \ln$ | Producer price index: inputs to construction industries |
| 13 | CORSREACBS | $\Delta$ | Charge-off rate on commercial real estate loans, all banks |
| 14 | NCOALLSCRELEXFACB | $\Delta$ | Net charge-offs on commercial real estate loans |
| 15 | QBPBSNLNNCOMREAL | $\Delta \ln$ | Noncurrent commercial real estate loans (nonperforming) |
| 16 | BOGZ1FA106300011Q | $\Delta \ln$ | Nonfinancial corporate business: commercial real estate (flow) |
| 17 | BOGZ1FL010000386Q | $\Delta$ | Commercial real estate price index, year-over-year growth |
| 18 | BOGZ1FL075035503Q | $\Delta \ln$ | Value of commercial real estate (financial accounts) |
| 19 | BOGZ1FL103165505Q | $\Delta \ln$ | Nonfinancial corporate business: commercial mortgages |
| 20 | BOGZ1FL113165505Q | $\Delta \ln$ | Nonfinancial noncorporate business: commercial mortgages |
| 21 | DRCRELEXFACBS | $\Delta$ | Delinquency rate on commercial real estate loans, all banks |
| 22 | MMMFFAQ027S | $\Delta \ln$ | Money market mutual fund assets |

*Notes:* The table lists the 22 commercial real estate target variables used to construct CREU($h$). All series are obtained from FRED, are quarterly, and are available over the 1993Q4–2026Q1 sample. $\Delta \ln$ denotes the first difference of the natural logarithm; $\Delta$ denotes the first difference in levels and is used for the seven rate, spread, and index series that can take non-positive values or approach zero. The initial data set contains 33 series; four macroeconomic duplicates (INDPRO, CPIAUCSL, FEDFUNDS, UNRATE) are excluded because they are already contained in the predictor set, and seven series are excluded because they do not cover the full sample period, leaving 22 target series and a balanced quarterly panel.

Table A3: Dependent variables used in the correlation and causality analyses.

| Variable | Code (FRED) | Transf. | Period | Description |
|---|---|---|---|---|
| House Price Growth | CSUSHPISA | $\Delta \ln \times 100$ | 1987Q2–2026Q1 | S&P/Case-Shiller U.S. National Home Price Index |
| New Housing Starts | HOUST | $\ln \times 100$ | 1960Q3–2026Q1 | Total new privately owned housing units started |
| Ind. Prod. Growth | INDPRO | $\Delta \ln \times 100$ | 1960Q3–2026Q1 | Industrial production index |
| Recession Dummy | USREC | level | 1960Q3–2026Q1 | NBER-based recession indicator |
| CRE Price Growth | BOGZ1FL075035503Q | $\Delta \ln \times 100$ | 1960Q3–2026Q1 | Commercial real estate price/value series |
| Comm. Constr. Growth | PRCOMCONS | $\Delta \ln \times 100$ | 1993Q2–2026Q1 | Total private construction spending: commercial |

*Notes:* The table lists the dependent variables used in the correlation and causality analyses. Growth rates are first differences of natural logarithms, multiplied by 100; the deflated variants divide the nominal series by the consumer price index (CPIAUCSL) before taking the growth rate. Housing starts enter in logs and the recession dummy in levels. All series are from FRED and are quarterly.

Table A4: Correlations with additional measures of uncertainty.

| | CREU(3) | CREU(12) | FU(3) | FU(12) | Policy | VIX | HP Growth | Starts | IP Growth | NBER | CRE Price | CRE Constr. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CREU(3) | 1 | | | | | | | | | | | |
| CREU(12) | $0.986^{***}$ | 1 | | | | | | | | | | |
| FU(3) | $0.487^{***}$ | $0.539^{***}$ | 1 | | | | | | | | | |
| FU(12) | $0.469^{***}$ | $0.519^{***}$ | $0.996^{***}$ | 1 | | | | | | | | |
| Policy | $0.214^{*}$ | $0.276^{**}$ | $0.397^{***}$ | $0.389^{***}$ | 1 | | | | | | | |
| VIX | $0.572^{***}$ | $0.624^{***}$ | $0.812^{***}$ | $0.802^{***}$ | $0.382^{***}$ | 1 | | | | | | |
| House Price Growth | $-0.478^{***}$ | $-0.460^{***}$ | $-0.135$ | $-0.116$ | $-0.104$ | $-0.181$ | 1 | | | | | |
| New Housing Starts | $-0.639^{***}$ | $-0.605^{***}$ | $-0.189$ | $-0.161$ | $-0.351^{*}$ | $-0.238$ | $0.521^{***}$ | 1 | | | | |
| Ind. Prod. Growth | $-0.230$ | $-0.275^{*}$ | $-0.354^{***}$ | $-0.324^{**}$ | $-0.232$ | $-0.349^{**}$ | 0.147 | 0.190 | 1 | | | |
| Recession Dummy | $0.531^{***}$ | $0.578^{***}$ | $0.495^{***}$ | $0.472^{***}$ | 0.200 | $0.531^{***}$ | $-0.316$ | $-0.212$ | $-0.606^{***}$ | 1 | | |
| CRE Price Growth | $-0.336^{**}$ | $-0.336^{***}$ | $-0.318^{***}$ | $-0.302^{***}$ | $-0.188^{**}$ | $-0.240^{**}$ | $0.293^{***}$ | 0.233 | $0.263^{*}$ | $-0.368^{***}$ | 1 | |
| Comm. Constr. Growth | $-0.505^{***}$ | $-0.493^{***}$ | $-0.413^{***}$ | $-0.388^{**}$ | $-0.181^{**}$ | $-0.405^{***}$ | $0.259^{*}$ | 0.322 | 0.160 | $-0.317^{**}$ | $0.320^{**}$ | 1 |

*Notes:* The table reports correlations over the common sample 1993Q4–2025Q4 (129 quarters). Policy denotes the Economic Policy Uncertainty index of Baker et al. (2016) (USEPUINDXM) and VIX the CBOE Volatility Index (VIXCLS), both obtained from FRED and aggregated to quarterly averages. $p$-values are obtained from HAC (Newey–West) regressions. $^{***}$, $^{**}$, and $^{*}$ denote significance at the 1%, 5%, and 10% levels, respectively.

Table A5: Variables used in the analysis.

| Variable | Period | Source |
|---|---|---|
| All Employees: Construction: Residential Building | 1993Q4–2026Q1 | FRED |
| Commercial Real Estate Uncertainty | 1993Q4–2026Q1 | own construction |
| Real Estate Uncertainty | 1993Q4–2026Q2 | own construction |
| Macro Uncertainty | 1993Q4–2025Q4 | Jurado et al. (2015) |
| Financial Uncertainty | 1993Q4–2025Q4 | Ludvigson et al. (2021) |
| S&P/Case-Shiller U.S. National Home Price Index | 1993Q4–2026Q1 | FRED |
| Housing Starts | 1993Q4–2026Q1 | FRED |
| Commercial Real Estate Price | 1993Q4–2026Q1 | FRED |
| Commercial Construction Spending | 1993Q4–2026Q1 | FRED |
| Federal Funds Rate | 1993Q4–2026Q2 | FRED |
| 10-Year Treasury Rate | 1993Q4–2026Q2 | FRED |
| Industrial Production | 1993Q4–2026Q1 | FRED |
| S&P 500 | 1993Q4–2026Q2 | Yahoo Finance (`^GSPC`) |
| Economic Policy Uncertainty | 1993Q4–2025Q4 | FRED |
| VIX | 1993Q4–2025Q4 | FRED |

*Notes:* The table lists the variables used in the analysis, their sample periods, and sources. All series are quarterly; monthly series are aggregated by simple averaging. The period column reports the availability of each variable; the estimation sample of each VAR is determined by the shortest series in that system and is reported in Table 4. Economic Policy Uncertainty and the VIX enter the correlation analysis only and not the vector autoregressions. The S&P 500 is retrieved from Yahoo Finance (ticker `^GSPC`) using the `quantmod` package in R, because the FRED series SP500 covers only the most recent ten years.

Table A6: VAR goodness-of-fit — Schwarz information criterion.

| Number of Lags in VAR | No Uncertainty | REU(3) | CREU(3) | MU(3) | FU(3) |
|---|---|---|---|---|---|
| *Panel A: residential real estate* | | | | | |
| 1 Lag | 4.39 | 1.99 | 0.53 | 2.23 | 2.19 |
| 2 Lags | 4.05 | 1.95 | 0.81 | 1.99 | 1.99 |
| 3 Lags | 5.24 | 3.48 | 2.18 | 3.22 | 3.38 |
| 4 Lags | 6.59 | 5.07 | 4.07 | 4.97 | 5.15 |
| *Panel B: commercial real estate* | | | | | |
| 1 Lag | 6.63 | 4.26 | 2.98 | 4.49 | 4.41 |
| 2 Lags | 6.39 | 4.20 | 3.10 | 4.21 | 4.29 |
| 3 Lags | 7.31 | 5.15 | 4.08 | 5.13 | 5.46 |
| 4 Lags | 8.19 | 6.41 | 5.35 | 6.42 | 6.66 |

*Notes:* The table displays the Schwarz information criterion for VAR estimations with and without an uncertainty measure, for different lag lengths, over the period 1993Q4 to 2025Q4. Panel A uses the residential variables and Panel B the commercial real estate variables. Lower values indicate a lower Schwarz information criterion.

All four uncertainty measures are standardized to zero mean and unit variance before entering the VARs for this comparison, ensuring a common scale across the uncertainty specifications. Comparisons between the specification without uncertainty and those including an uncertainty measure should be interpreted with caution because the number of equations differs. Comparisons among the four uncertainty specifications are based on VARs of the same dimension.

Table A7: Decomposition of variance: estimation window ending in 2017Q4 compared with the full sample.

| | REU(3) | | CREU(3) | | MU(3) | | FU(3) | |
|---|---|---|---|---|---|---|---|---|
| Horizon | 1993–2017 | 1993–2026 | 1993–2017 | 1993–2026 | 1993–2017 | 1993–2026 | 1993–2017 | 1993–2026 |
| **Panel A: residential real estate** | | | | | | | | |
| *Housing Prices* | | | | | | | | |
| $k = 1$ | 0.7 | 3.5 | 8.1 | 6.9 | 2.5 | 1.6 | 0.0 | 0.2 |
| $k = 4$ | 12.8 | 10.2 | 10.4 | 4.8 | 9.5 | 6.0 | 8.1 | 1.9 |
| $k = 8$ | 21.1 | 6.9 | 17.5 | 4.4 | 10.4 | 2.1 | 7.4 | 1.1 |
| $k = 12$ | 29.6 | 4.6 | 22.0 | 4.7 | 13.6 | 1.0 | 5.3 | 4.6 |
| $k = 20$ | 37.9 | 3.1 | 25.8 | 5.8 | 17.1 | 0.8 | 3.2 | 12.7 |
| *Housing Starts* | | | | | | | | |
| $k = 1$ | 0.7 | 0.4 | 1.1 | 1.1 | 1.1 | 0.1 | 0.0 | 0.6 |
| $k = 4$ | 26.4 | 18.7 | 25.3 | 12.7 | 20.2 | 14.1 | 7.5 | 5.2 |
| $k = 8$ | 30.3 | 15.3 | 38.6 | 17.7 | 19.4 | 9.1 | 9.0 | 2.8 |
| $k = 12$ | 32.5 | 11.4 | 40.8 | 19.0 | 19.3 | 6.0 | 7.5 | 4.9 |
| $k = 20$ | 35.3 | 8.6 | 39.7 | 18.1 | 19.9 | 4.9 | 5.9 | 14.1 |
| *Construction Employment* | | | | | | | | |
| $k = 1$ | 0.1 | 0.2 | 1.3 | 0.7 | 0.1 | 0.0 | 5.2 | 1.4 |
| $k = 4$ | 9.7 | 12.3 | 13.9 | 9.9 | 7.6 | 18.0 | 1.0 | 6.5 |
| $k = 8$ | 22.3 | 16.4 | 30.0 | 17.1 | 14.3 | 15.4 | 2.9 | 5.4 |
| $k = 12$ | 27.7 | 13.2 | 37.7 | 19.0 | 16.0 | 8.9 | 3.4 | 2.8 |
| $k = 20$ | 36.3 | 8.6 | 40.7 | 18.5 | 18.9 | 4.3 | 2.9 | 8.3 |
| **Panel B: commercial real estate** | | | | | | | | |
| *CRE Prices* | | | | | | | | |
| $k = 1$ | 1.5 | 0.1 | 0.0 | 1.2 | 0.0 | 0.1 | 3.8 | 0.7 |
| $k = 4$ | 2.3 | 1.1 | 0.8 | 2.6 | 3.0 | 0.7 | 14.6 | 8.4 |
| $k = 8$ | 20.6 | 10.6 | 10.6 | 6.0 | 20.1 | 4.8 | 30.6 | 27.5 |
| $k = 12$ | 35.6 | 16.5 | 21.4 | 14.9 | 26.5 | 7.0 | 33.2 | 34.5 |
| $k = 20$ | 44.8 | 18.0 | 30.4 | 22.3 | 29.1 | 7.7 | 30.9 | 34.2 |
| *Commercial Construction* | | | | | | | | |
| $k = 1$ | 12.8 | 7.2 | 0.3 | 0.0 | 5.9 | 0.0 | 0.4 | 0.2 |
| $k = 4$ | 19.6 | 11.5 | 3.2 | 0.4 | 27.6 | 0.4 | 15.0 | 5.7 |
| $k = 8$ | 34.8 | 21.9 | 25.5 | 11.3 | 41.4 | 3.6 | 30.8 | 13.5 |
| $k = 12$ | 43.4 | 25.4 | 44.5 | 31.0 | 43.1 | 4.8 | 34.0 | 15.2 |
| $k = 20$ | 49.9 | 25.9 | 55.8 | 46.4 | 44.4 | 5.2 | 33.9 | 14.1 |

*Notes:* Fraction of forecast-error variance explained by the respective uncertainty measure, in percent. The shorter estimation window ends in 2017Q4; the full-sample results correspond to Table 4. The specification, ordering, and lag length are identical across estimation windows. Panel A contains 98 and 130 observations and Panel B 97 and 129 observations in the short and full samples, respectively.

Table A8: Decomposition of variance under three Cholesky orderings.

| | REU(3) | | | CREU(3) | | | MU(3) | | | FU(3) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Horizon | Bench. | Last | First | Bench. | Last | First | Bench. | Last | First | Bench. | Last | First |
| **Panel A: residential real estate** | | | | | | | | | | | | |
| *Housing Prices* | | | | | | | | | | | | |
| $k = 1$ | 3.5 | 0.0 | 6.4 | 6.9 | 0.0 | 11.8 | 1.6 | 0.0 | 3.4 | 0.2 | 0.0 | 0.1 |
| $k = 4$ | 10.2 | 2.5 | 12.9 | 4.8 | 0.1 | 11.0 | 6.0 | 1.9 | 8.3 | 1.9 | 3.5 | 7.5 |
| $k = 8$ | 6.9 | 1.2 | 7.6 | 4.4 | 0.1 | 8.0 | 2.1 | 0.7 | 2.9 | 1.1 | 1.3 | 2.5 |
| $k = 12$ | 4.6 | 0.6 | 5.0 | 4.7 | 0.0 | 7.0 | 1.0 | 1.3 | 1.2 | 4.6 | 3.3 | 2.3 |
| $k = 20$ | 3.1 | 0.3 | 3.7 | 5.8 | 0.3 | 6.8 | 0.8 | 2.0 | 0.6 | 12.7 | 10.5 | 6.7 |
| *Housing Starts* | | | | | | | | | | | | |
| $k = 1$ | 0.4 | 0.0 | 11.2 | 1.1 | 0.0 | 9.7 | 0.1 | 0.0 | 7.9 | 0.6 | 0.0 | 0.6 |
| $k = 4$ | 18.7 | 11.5 | 26.3 | 12.7 | 2.5 | 20.1 | 14.1 | 10.5 | 18.8 | 5.2 | 10.0 | 8.9 |
| $k = 8$ | 15.3 | 8.2 | 19.3 | 17.7 | 4.2 | 20.7 | 9.1 | 6.2 | 12.0 | 2.8 | 5.8 | 4.8 |
| $k = 12$ | 11.4 | 5.6 | 13.9 | 19.0 | 4.7 | 18.5 | 6.0 | 4.2 | 7.8 | 4.9 | 5.4 | 5.1 |
| $k = 20$ | 8.6 | 4.1 | 10.3 | 18.1 | 4.5 | 14.4 | 4.9 | 4.2 | 6.4 | 14.1 | 13.2 | 12.7 |
| *Construction Employment* | | | | | | | | | | | | |
| $k = 1$ | 0.2 | 0.0 | 19.3 | 0.7 | 0.0 | 18.8 | 0.0 | 0.0 | 15.9 | 1.4 | 0.0 | 2.0 |
| $k = 4$ | 12.3 | 7.8 | 40.9 | 9.9 | 2.5 | 36.9 | 18.0 | 15.7 | 43.9 | 6.5 | 13.6 | 10.6 |
| $k = 8$ | 16.4 | 9.1 | 35.2 | 17.1 | 4.3 | 36.3 | 15.4 | 11.9 | 31.4 | 5.4 | 12.1 | 9.0 |
| $k = 12$ | 13.2 | 6.4 | 24.8 | 19.0 | 4.7 | 30.3 | 8.9 | 6.2 | 18.1 | 2.8 | 6.2 | 4.6 |
| $k = 20$ | 8.6 | 3.5 | 14.7 | 18.5 | 4.4 | 21.3 | 4.3 | 3.4 | 8.7 | 8.3 | 7.8 | 6.7 |
| **Panel B: commercial real estate** | | | | | | | | | | | | |
| *CRE Prices* | | | | | | | | | | | | |
| $k = 1$ | 0.1 | 0.0 | 1.2 | 1.2 | 0.0 | 0.1 | 0.1 | 0.0 | 2.1 | 0.7 | 0.0 | 0.2 |
| $k = 4$ | 1.1 | 0.9 | 9.6 | 2.6 | 0.7 | 2.6 | 0.7 | 0.5 | 7.6 | 8.4 | 5.4 | 9.9 |
| $k = 8$ | 10.6 | 9.9 | 29.8 | 6.0 | 6.7 | 18.6 | 4.8 | 5.3 | 22.5 | 27.5 | 23.2 | 28.9 |
| $k = 12$ | 16.5 | 15.0 | 38.1 | 14.9 | 16.5 | 32.5 | 7.0 | 7.6 | 27.2 | 34.5 | 30.5 | 34.6 |
| $k = 20$ | 18.0 | 16.4 | 39.6 | 22.3 | 22.7 | 39.2 | 7.7 | 8.2 | 28.2 | 34.2 | 31.0 | 34.7 |
| *Commercial Construction* | | | | | | | | | | | | |
| $k = 1$ | 7.2 | 0.0 | 6.9 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.6 | 0.2 | 0.0 | 0.1 |
| $k = 4$ | 11.5 | 2.0 | 19.9 | 0.4 | 0.5 | 1.5 | 0.4 | 0.5 | 5.7 | 5.7 | 3.8 | 4.3 |
| $k = 8$ | 21.9 | 9.6 | 34.1 | 11.3 | 13.2 | 20.2 | 3.6 | 4.0 | 14.1 | 13.5 | 10.8 | 9.5 |
| $k = 12$ | 25.4 | 11.9 | 35.9 | 31.0 | 33.5 | 40.1 | 4.8 | 5.2 | 15.2 | 15.2 | 12.5 | 9.7 |
| $k = 20$ | 25.9 | 11.9 | 32.6 | 46.4 | 46.4 | 45.1 | 5.2 | 5.5 | 13.4 | 14.1 | 11.6 | 8.6 |

*Notes:* Fraction of forecast-error variance explained by the respective uncertainty measure, in percent, as in Table 4, under three recursive identification schemes. "Bench." is the benchmark ordering, in which uncertainty is placed after the macroeconomic and financial variables and before the real estate variables. "Last" places uncertainty after the real estate variables, so that uncertainty may respond contemporaneously to innovations in all other variables in the system, whereas the other variables do not respond contemporaneously to innovations in uncertainty. "First" places uncertainty before all other variables and represents the opposite recursive ordering.

Only the recursive identification changes across the three specifications. Within each uncertainty measure, the estimation sample and reduced-form VAR are identical across orderings. Sample periods differ across uncertainty measures because of differences in data availability and are reported in Table 4.

Table A9: Causality for the commercial real estate variables under alternative specifications.

| | REU(3) | REU(12) | CREU(3) | CREU(12) |
|---|---|---|---|---|
| *Benchmark* | | | | |
| CRE price growth | 0.344 / 0.181 | 0.781 / 0.356 | **0.009 / 0.042** | **0.005 / 0.037** |
| Comm. constr. growth | 0.685 / 0.599 | 0.852 / 0.707 | **0.000 / 0.035** | 0.000 / 0.060 |
| *REU estimated at the quarterly frequency, 1993Q4–2026Q1* | | | | |
| CRE price growth | **0.045 / 0.016** | 0.119 / 0.024 | — | — |
| Comm. constr. growth | 0.183 / 0.242 | 0.071 / 0.236 | — | — |
| *CREU from 27 target series, 2007Q4–2026Q1* | | | | |
| CRE price growth | — | — | **0.006 / 0.018** | 0.143 / 0.110 |
| Comm. constr. growth | — | — | **0.006 / 0.026** | 0.001 / 0.098 |

*Notes:* Each cell reports the $p$-value of the Granger-causality test followed by the $p$-value of the long-run coefficient test, estimated as in Tables 2 and 3. Entries in bold satisfy both criteria at the 5% level. A dash indicates that the respective uncertainty measure is not part of the alternative construction reported in that block. In the second block, REU is estimated directly from quarterly data over the same estimation window as CREU. In the third block, CREU additionally includes CREACBM027SBOG, PCU5311205311202, PCU5311205311203, TLMFGCONS, and PNFIC1, which restricts the estimation window to 2007Q4–2026Q1 and leaves 71 observations per regression.

Table A10: Forecast-error variance decomposition under alternative uncertainty constructions.

| | CRE Prices | | Commercial Construction | |
|---|---|---|---|---|
| Uncertainty Measure | Unc. | ffr | Unc. | ffr |
| *Benchmark* | | | | |
| REU(3) | 17.99 | 11.83 | 25.85 | 14.72 |
| CREU(3) | 22.30 | 4.43 | 46.38 | 7.40 |
| MU(3) | 7.74 | 10.96 | 5.17 | 15.49 |
| FU(3) | 34.18 | 5.33 | 14.07 | 8.58 |
| *REU estimated at the quarterly frequency, 1993Q4–2026Q1* | | | | |
| Quarterly REU(3) | 15.45 | 6.83 | 15.51 | 8.93 |
| *Shorter estimation window from 2007, CREU from 27 target series* | | | | |
| REU(3) | 2.28 | 19.36 | 3.68 | 34.91 |
| CREU(3) | 20.14 | 6.82 | 24.11 | 7.98 |
| MU(3) | 2.93 | 13.99 | 2.38 | 29.65 |
| FU(3) | 13.16 | 9.64 | 12.84 | 25.63 |

*Notes:* The table reports the fraction of the twenty-quarter forecast-error variance explained by the respective uncertainty measure and the federal funds rate (ffr), in percent. The benchmark results reproduce the corresponding entries from Table 4. In the second block, REU is estimated directly from quarterly data over the same estimation window as CREU; the results for CREU, MU, and FU are unaffected and coincide with the benchmark. In the third block, CREU is constructed from 27 target series, and all four VARs are estimated over the shorter window beginning in 2007, so that the results for REU, MU, and FU also differ from the benchmark. The VAR specification, lag length, variable transformations, and recursive identification otherwise follow the benchmark specification. The VARs in the third block contain only 72 to 75 observations and should therefore be interpreted with caution.

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