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# Uncertainty and the term structure of interest rates☆

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ABSTRACT

We document a new stylized fact linking uncertainty to the term structure of interest rates: unanticipated increases in uncertainty generate a yield curve that is lower, steeper, and less curved. Using a Yields-Macro Dynamic Nelson–Siegel model applied to U.S. Treasury yields, uncertainty measures, and macroeconomic aggregates, we show that this result is robust across financial, macroeconomic, and policy-related sources of uncertainty. A stylized asset-pricing model provides a structural interpretation, tracing these effects to precautionary motives under investor prudence. Counterfactual analyses show that uncertainty lowers the expected path of short rates while raising term premia, consistent with precautionary and risk-compensation mechanisms. We also develop an efficient Bayesian algorithm for estimating Yields-Macro Dynamic Nelson–Siegel models with constant or time-varying exponential decay parameters.

## 1. Introduction

The term structure of interest rates (also known as the yield curve) refers to the range of bond yields at different terms to maturity. Financial market participants and central bankers pay close attention to the term structure for several reasons. First, the Federal Funds Rate represents the instantaneous rate of return on overnight lending, making short-term yields closely connected to monetary policy. Second, long-term interest rates reflect information about market expectations of future monetary actions (Hansen et al., 2019). Thirdly, the slope of the yield curve, i.e., the difference between long- and short-term rates, provides a robust leading indicator of future macroeconomic activity (Estrella and Hardouvelis, 1991).[1]

In this paper we investigate how the term structure reacts to unexpectedly heightened uncertainty of various forms. Our investigation is motivated by the desire of market participants and policy makers to understand the drivers of yield curve dynamics, together with a vast literature that finds various types of uncertainty have notoriously contractive macroeconomic effects (e.g., Bloom, 2009; Mumtaz and Zanetti, 2013; Jurado et al., 2015; Bloom et al., 2018), and a burgeoning literature exploring how uncertainty impacts the term structure (Creal and Wu, 2017; Castelnuovo, 2019; Tillmann, 2020; Hansen et al., 2019; Shang, 2022).[2]

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[1] While this statement is generally supported by the data, it is not without debate. For instance, Cooper et al. (2020) argue that a yield curve inversion may overstate the probability of a recession when monetary policy is accommodative relative to the neutral federal funds rate.

[2] Castelnuovo (2023) provides a recent review of the literature on the economic effects of uncertainty shocks.

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Specifically, Creal and Wu (2017) develop a term structure model where the second moments of macroeconomic variables and yields can have a first-order effect on their dynamics, and apply this model to investigate the relationship between monetary policy uncertainty and economic fluctuations. Castelnuovo (2019) uses local projections regressions to show that heightened financial uncertainty reduces both short- and long-term interest rates. Tillmann (2020) and Shang (2022) use distinct term-structure models with uncertainty interactions to independently show that high uncertainty about monetary policy decreases the central banks ability to impact the term structure.

We differ from these recent studies in three ways. First, to examine the effects of uncertainty shocks on the yield curve we propose the use of a conceptually simple Yields-Macro dynamic Nelson–Siegel (YM-DNS) model. Originally proposed by Diebold et al. (2006), the YM-DNS model decomposes the yield curve into level, slope, and curvature factors using a DNS representation (Diebold and Li, 2006).[3] Dynamic interactions between these factors and macroeconomic indicators are then jointly modeled as a structural vector autoregression (SVAR) model. In our specification we consider a measure of uncertainty in addition to a broader set of macroeconomic indicators thus controlling for simultaneity in this nexus when examining the impacts of uncertainty shocks on the yield curve. We also show how the latent yield curve factors in these models can be estimated simply and efficiently using a modern precision sampling algorithm, with either a constant or time-varying exponential decay rate parameter.

Second, using a stylized consumption-based asset pricing model of the form in Cochrane (2009), we provide a formal economic mechanism linking uncertainty shocks to movements in the yield curve's level, slope, and curvature. Under investor prudence (i.e., convex marginal utility), a mean-preserving increase in consumption uncertainty raises expected marginal utility and the value of safe payoffs. This decreases bond yields with differing intensities across maturities. Tracing these effects into the Nelson–Siegel representation implies a lower level factor, while the responses of the slope and curvature factors depend on the relative horizon sensitivities of expected marginal utility. In the special case of power utility and log-normal consumption, heightened uncertainty leads to an unambiguously lower level, steeper slope, and less curvature. This mechanism builds on classic result connecting prudence to precautionary motives under uncertainty (Leland, 1968; Sandmo, 1970; Kimball, 1990), by showing that it has direct implications for the term structure's shape through the Nelson–Siegel factor representation.

Third, we study the effects of three distinct types of uncertainty on the term structure of interest rates: the financial uncertainty measure of Ludvigson et al. (2021), the macroeconomic uncertainty measure of Jurado et al. (2015), and, the U.S. economic policy uncertainty (EPU) measure of Baker et al. (2016). Each of these uncertainties have been shown to have significant macroeconomic effects in a variety of empirical studies. Exploring whether these uncertainties elicit similar or different yield curve dynamics therefore has important theoretical consequences. In this sense, the paper is also related to very recent studies on the use of structural macroeconomic models to examine the effects of uncertainty on the yield curve (Leippold and Matthys, 2022; Amisano and Tristani, 2023; Bianchi et al., 2023). We view these studies as complementary in that we use a relatively agnostic and simple econometric model to examine these uncertainty effects. At the very least our results provide a set of stylized facts that can be used to evaluate the fit of structural models with distinct types of uncertainty shocks and the term structure of interest rates.

Our main result is that unexpectedly heightened uncertainty elicits a lower, steeper, and less curved yield curve. This result is found to be robust to a multitude of model specifications, and aligns with the qualitative predictions from our stylized asset pricing model when uncertainty has a relatively stronger impact on near-term marginal utility, and a non-monotonic effect across maturities. More broadly, the lower level and slope factors are consistent with theories of expectations about future macroeconomic conditions and the policy rate (Estrella, 2005). The increased slope factor is also in line with what financial practitioners refer to as a 'bull steepening' of the yield curve; i.e., a situation in which short-term interest rates fall more than long-term rates. The curvature decline reflects a relative reduction in medium-term yields, thereby diminishing the hump-shaped profile of the yield curve typically associated with this component. This result is particularly notable, as the curvature factor has been shown to be relatively unresponsive to other types of shocks within the broader macro-finance literature. The investor prudence mechanism in the stylized model therefore provides a novel possible explanation for its variation over the business cycle.

To further investigate the effects of uncertainty of the term structure, we then look at the impact of uncertainty on the expectations and term premium components of long-term bond yields. This is done by deriving the bond yield implied by the expectations hypothesis and decomposing it into expectations and term premium components for two recent episodes of heightened uncertainty: the Great Recession and the COVID-19 pandemic. In a counterfactual analysis, we find that heightened uncertainty in these two periods systematically lowers the expected path of interest rates while increasing the term premium. While the baseline stylized model studied here isolates the precautionary channel under standard expected-utility preferences, the observed increase in term premia is consistent with richer macro-finance models featuring uncertainty aversion or recursive preferences (e.g., Doh, 2013), in which agents require additional compensation for higher conditional risk. The findings are also consistent with a flight-to-safety mechanism (Caballero and Krishnamurthy, 2008), whereby investors reallocate portfolios toward long-maturity government bonds during periods of elevated uncertainty. Taken together, these results suggest that the precautionary channel highlighted in the stylized model may operate alongside risk-compensation mechanisms emphasized in broader structural settings.

The rest of the paper is organized as follows. Section 2 introduces the empirical Yields-Macro Dynamic Nelson–Siegel model used to examine the link between uncertainty and the yield curve. Section 3 develops a stylized asset-pricing mechanism linking uncertainty to the level, slope, and curvature of the yield curve. Section 4 presents the main empirical results. Section 5 concludes. Technical details of the new Bayesian algorithm used to estimate the Yields-Macro model, together with additional results and robustness checks, are provided in the Online Appendix.

[3] While the DNS framework provides a parsimonious and interpretable representation of the term structure, it does so at the cost of being unable to reconcile the risk-neutral and physical probability measures (see, e.g., Joslin et al., 2011). In contrast, the econometric approach of Creal and Wu (2017) allows for a reconciliation between these measures, without providing such a simple interpretation of the factors. We leave a reconciliation of these two approaches as an interesting avenue of future research.

## 2. Methodology

In this section, we briefly introduce the Yields-Macro (YM) model, discuss how we use this framework to address our research question, and present the data used to estimate the model.

### 2.1. The Yields-Macro (YM) model

Following Nelson and Siegel (1987) and Diebold and Li (2006), we specify a three-component dynamic exponential approximation to the cross-section of treasury yields over time as:

$$y_t(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau}\right) + C_t\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau} - \exp^{-\lambda\tau}\right), \tag{1}$$

where $L_t$, $S_t$, and $C_t$, are respectively interpreted as time-varying level, slope, and curvature yield curve factors, and $\lambda$ is an exponential decay rate parameter that governs the factor loadings on the slope and curvature factors that is often calibrated to maximize the curvature factor loading at a given month to maturity. Since two- or three-year maturities are often used for this purpose, Diebold and Li (2006) calibrate $\lambda = 0.0609$ to maximize the curvature factor at 30 months. The factor dynamics are jointly modeled as a first-order vector autoregressive (VAR) process of the form:

$$\begin{bmatrix} L_t \\ S_t \\ C_t \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \begin{bmatrix} L_{t-1} \\ S_{t-1} \\ C_{t-1} \end{bmatrix} + \begin{bmatrix} \omega_{tL} \\ \omega_{tS} \\ \omega_{tC} \end{bmatrix}. \tag{2}$$

In the Online Appendix, we assess the robustness of the one-lag specification by re-estimating the model with three lags and obtain similar results.

This 'Yields-Only' DNS (YO-DNS) model is a state space model with (1) and (2) representing the measurement and state equations, respectively. Letting $Y_t = \left[y_t(\tau_1), y_t(\tau_2), \ldots, y_t(\tau_N)\right]'$ where $y_t(\tau_i)$ is a bond yield with $\tau_i$ months to maturity, and $f_t = (L_t, S_t, C_t)'$, allows the measurement equation to be expressed more compactly as:

$$Y_t = \Lambda(\lambda) f_t + \varepsilon_t, \varepsilon_t \sim N(0, \Sigma), \tag{3}$$

where $\Sigma = diag(\sigma_1^2, \sigma_2^2, \ldots, \sigma_N^2)$, and the factor loading is a matrix variate function such that

$$\Lambda(\lambda) = \begin{bmatrix} 1 & \frac{1-e^{-\tau_1\lambda}}{\tau_1\lambda} & \frac{1-e^{-\tau_1\lambda}}{\tau_1\lambda} - e^{-\tau_1\lambda_1} \\ 1 & \frac{1-e^{-\tau_2\lambda}}{\tau_2\lambda} & \frac{1-e^{-\tau_2\lambda}}{\tau_2\lambda} - e^{-\tau_2\lambda} \\ \vdots & \vdots & \vdots \\ 1 & \frac{1-e^{-\tau_N\lambda}}{\tau_N\lambda} & \frac{1-e^{-\tau_N\lambda}}{\tau_N\lambda} - e^{-\tau_N\lambda} \end{bmatrix}.$$

Similarly, the state equation in (2) can be written as:

$$f_t = b + B f_{t-1} + \omega_t, \quad \omega_t \sim N(0, \Omega), \tag{4}$$

where $\Omega = diag(\omega_1^2, \omega_2^2, \ldots, \omega_N^2)$. The model is completed by noting that the error terms are distributed as:

$$\begin{bmatrix} \varepsilon_t \\ \omega_t \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \Sigma & 0 \\ 0 & \Omega \end{bmatrix}\right). \tag{5}$$

Since we are interested in determining the impacts of uncertainty on the yield curve, we allow for uncertainty to impact the yield curve, while controlling for other macroeconomic effects. To that end, we follow Diebold et al. (2006) and extend the YO-DNS model to a Yields-Macro DNS (YM-DNS) model that incorporates information from macroeconomic variables into the model. This is done by extending the state vector in (2) to be $f_t = (f_{1t}', f_{2t}')'$, in which $f_{1t} = (L_t, S_t, C_t)'$ is a $3 \times 1$ vector of the latent yield curve factors, and $f_{2t}$ is an $m \times 1$ vector that contains an observable measure of uncertainty and other macroeconomic controls. The definitions of parameters $\theta = \{\Sigma, b, B, \Omega\}$ in (3)–(5) are also modified appropriately. Since our focus is on examining the effects of an uncertainty shock, we follow the common practice of identifying this shock via recursive identification in which the uncertainty measure is placed first in the vector of macroeconomic indicators (see, e.g., Caggiano et al., 2014; Leduc and Liu, 2016, among others). Specified in this manner the YM-DNS model facilitates a joint examination of how the yield curve responds to uncertainty shocks, while controlling for macroeconomic general equilibrium effects relating to the business cycle.

We estimate the YM-DNS model using Bayesian methods, and make two contributions to the broader methodological literature.

First, we show that the latent yield curve factors can be efficiently estimated using the precision sampling approach of Chan and Jeliazkov (2009), which has been shown to be more computationally efficient than Kalman filter based methods when estimating latent states in a variety of state space models (see Chan and Strachan, 2023 and references therein).

Second, we show how to estimate the exponential decay parameter, $\lambda$, using a Griddy–Gibbs step in the Markov chain Monte Carlo (MCMC) algorithm, as opposed to calibrating it as is often done in the literature.

To conserve space, we defer details of the MCMC algorithm to the Online Appendix. There we also show how the algorithm can be extended to estimate a time-varying exponential decay rate parameter, $\lambda_t$, $t = 1, \ldots, T$ in a similar spirit to Koopman et al. (2010). However, as shown there, using a constant decay parameter results in a clean interpretation of the term structure and yield curve

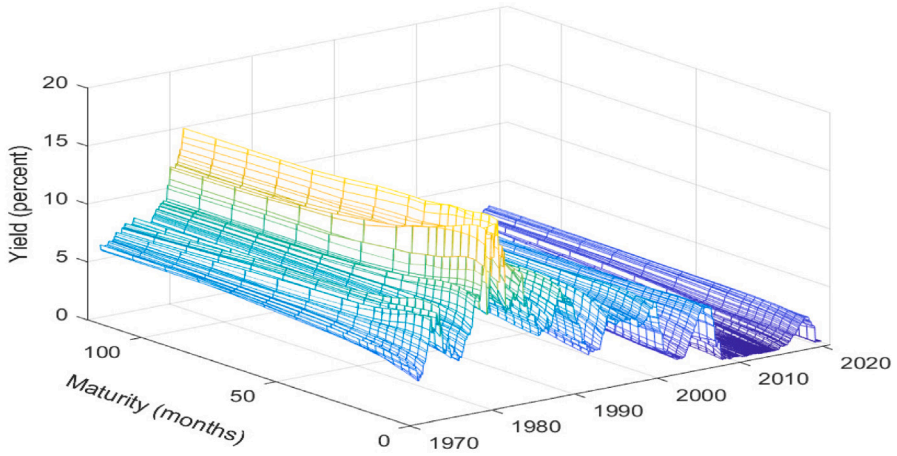


**Fig. 1.** Yield Curves from August 1971 to December 2020 at maturities of 3, 6, 9, 12, 15, 18, 21, 24, 30, 36, 48, 60, 72, 84, 96, 108, and 120 months.

factor responses to uncertainty shocks, while the time-varying case is more complex. We therefore use a constant decay parameter for our main results, and consider the time-varying case as robustness. Nonetheless, given the recently established usefulness of allowing for a time-varying exponential decay rate parameter in forecasting applications (Lee, 2025), having an efficient way to estimate this parameter should be useful to researchers working in this closely related literature.

### 2.2. Data

*Yield curve data.* Following Diebold and Li (2006), the yield curve is modeled using zero-coupon U.S. Treasury maturities of 3, 6, 9, 12, 15, 18, 21, 24, 30, 36, 48, 60, 72, 84, 96, 108, and 120 months. However, we use monthly data from 1971M8 to 2020M12 drawn from the recently constructed dataset of Liu and Wu (2021), who show that their yield curve dataset provides a more accurate representation of the raw data compared to alternative measures.

The data is plotted in Fig. 1, and descriptive statistics are presented in Table 1. There a few stylized facts about yield curves that are consistent with other datasets (e.g., Diebold and Rudebusch, 2013; Diebold et al., 2006). First, the yield curve has a large amount of temporal variation, and takes on a variety of shapes: upward sloping, downward sloping (inverted), concave and convex. Second, the yield curve is increasing and concave on average.[4] Third, short rates tend to be more volatile, less persistent, and have greater range, than long rates.

*Uncertainty data.* We consider three extremely popular types of uncertainty: the financial uncertainty measure of Ludvigson et al. (2021), the macroeconomic uncertainty measure of Jurado et al. (2015), and the economic policy uncertainty (EPU) measure of Baker et al. (2016). The EPU begins in January 1985, while the other two measures extend back to the start of our sample in August 1971. The indexes are shown in Fig. 2. The measures are clearly positively correlated and tend to rise during periods of recession. For instance, significant spikes are observed during the recessions of the early 1990s and 2000s, the 2008 Great Recession, and the COVID-19 pandemic. However, they also show independent variation. For example, while the financial and macroeconomic uncertainty indexes declined after the 2008 Great Recession, the EPU remained elevated until 2014, partly due to the 2011 debt ceiling crisis. The financial uncertainty also exhibits a distinct spike during the Black Monday event in October 1987, and both the EPU and financial uncertainty indexes spike during the 2011 debt ceiling crisis, while the macroeconomic uncertainty index remains unaffected. Given these differences, we examine the effects of uncertainty shocks using three distinct YM-DNS specifications, each incorporating one of the uncertainty indexes.

*Macroeconomic data.* We use data on four macroeconomic indicators: capacity utilization (CU), unemployment rate (UE), CPI inflation (CPI), and the shadow federal funds rate (SFFR) of Wu and Xia (2016). The first three indicators are sourced from the St. Louis Fed's FRED database, and the SFFR is from the Federal Reserve Bank of Atlanta. CU and CPI are converted to monthly growth rates so that all variables are expressed in percentage terms.

The first three variables: CU, UE, and CPI, provide a minimal set for capturing the real and nominal sides of the business cycle. We include the SFFR as an additional macroeconomic variable for three reasons. First, as shown in Diebold and Li (2006), the sum of the level and slope factors equates to the instantaneous short rate in the DNS model, thus linking monetary policy changes directly to the yield curve. Second, monetary policy is known to respond endogenously to the adverse business cycle effects of uncertainty

[4] Following Diebold et al. (2006) scholars often define the empirical proxy of the yield curve slope as $S_t = y_t(3) - y_t(24)$, so that $S_t > 0$ implies a downward sloping curve. Here we define $S_t = y_t(24) - y_t(3)$, so that $S_t > 0$ implies a positive slope.

**Table 1**
Descriptive statistics of yield curves.

| Maturity (months) | Mean | Std. dev. | Minimum | Maximum | $\hat{\rho}(1)$ | $\hat{\rho}(12)$ | $\hat{\rho}(30)$ |
|---|---|---|---|---|---|---|---|
| 3 | 4.609 | 3.501 | 0.024 | 15.946 | 0.989 | 0.858 | 0.656 |
| 6 | 4.767 | 3.552 | 0.049 | 16.133 | 0.990 | 0.867 | 0.674 |
| 9 | 4.881 | 3.565 | 0.082 | 16.107 | 0.990 | 0.873 | 0.690 |
| 12 | 4.967 | 3.562 | 0.103 | 15.962 | 0.990 | 0.878 | 0.705 |
| 15 | 5.040 | 3.558 | 0.109 | 15.901 | 0.990 | 0.883 | 0.720 |
| 18 | 5.105 | 3.556 | 0.114 | 15.943 | 0.991 | 0.887 | 0.733 |
| 21 | 5.160 | 3.544 | 0.120 | 15.910 | 0.991 | 0.890 | 0.743 |
| 24 | 5.206 | 3.520 | 0.124 | 15.719 | 0.991 | 0.892 | 0.752 |
| 30 | 5.299 | 3.475 | 0.114 | 15.545 | 0.991 | 0.897 | 0.767 |
| 36 | 5.400 | 3.442 | 0.123 | 15.569 | 0.991 | 0.900 | 0.776 |
| 48 | 5.580 | 3.370 | 0.172 | 15.475 | 0.992 | 0.902 | 0.790 |
| 60 | 5.713 | 3.286 | 0.231 | 15.195 | 0.992 | 0.903 | 0.799 |
| 72 | 5.848 | 3.233 | 0.313 | 14.989 | 0.992 | 0.905 | 0.804 |
| 84 | 5.947 | 3.169 | 0.382 | 14.950 | 0.992 | 0.902 | 0.806 |
| 96 | 6.034 | 3.117 | 0.445 | 14.941 | 0.992 | 0.905 | 0.808 |
| 108 | 6.105 | 3.067 | 0.488 | 14.945 | 0.992 | 0.905 | 0.810 |
| 120 | 6.163 | 2.996 | 0.530 | 14.939 | 0.992 | 0.900 | 0.809 |
| Level | 5.326 | 3.292 | 0.249 | 15.278 | 0.992 | 0.895 | 0.758 |
| Slope | 1.554 | 1.385 | −4.358 | 3.756 | 0.948 | 0.484 | −0.098 |
| Curvature | −0.360 | 0.970 | −2.695 | 2.765 | 0.927 | 0.637 | 0.377 |

Note: Descriptive statistics for monthly yields at different maturities. The final three columns are sample autocorrelations at lags of 1, 12 and 30 months. The empirical yield curve level, slope and curvature are respectively defined as $L_t = \frac{y_t(3)+y_t(24)+y_t(120)}{3}$, $S_t = y_t(24) - y_t(3)$, and $C_t = 2y_t(24) - y_t(3) - y_t(120)$.

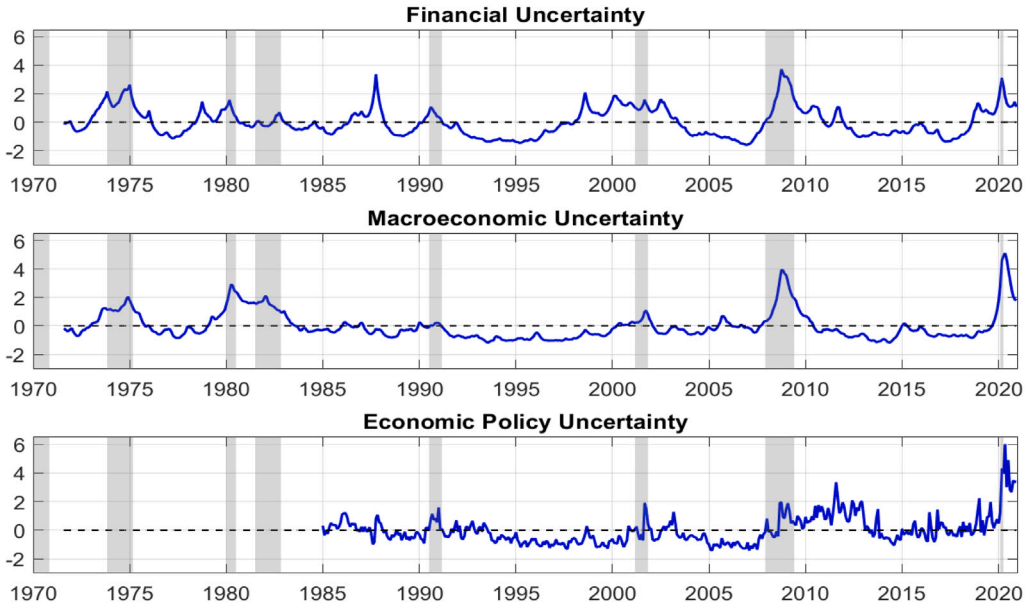


**Fig. 2.** Uncertainty Measures.
**Notes**: The panels plot the time series of financial uncertainty, macroeconomic uncertainty and economic policy uncertainty. Shaded areas are NBER recession dates.

shocks (e.g., Castelnuovo and Pellegrino, 2018). Controlling for monetary policy therefore helps us isolate the mechanism through which uncertainty affects the yield curve. Finally, we use the SFFR instead of the effective federal funds rate (FFR) since it accounts for the two effective lower bound (ELB) periods—during and after the Great Recession (2008M12–2015M12) and again during the COVID-19 pandemic (2020M11–2020M12). The resulting series are shown in Fig. 3.

## 3. A stylized model of uncertainty and the term structure of interest rates

Before presenting the results of our empirical investigation into the effects of uncertainty shocks on the term structure of interest rates, we first derive qualitative predictions connecting uncertainty to the Nelson–Siegel factor representation of the yield curve.

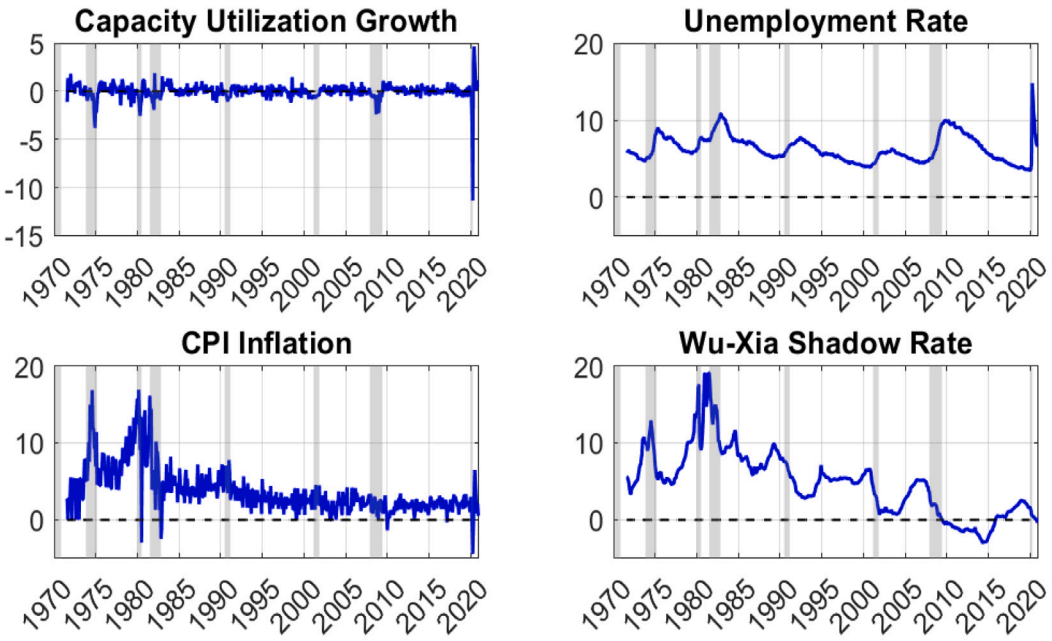


**Fig. 3.** Macroeconomic Indicators.
**Notes**: Shaded areas are NBER recession dates.

The objective is to establish a transparent mechanism linking uncertainty shocks to movements in the level, slope, and curvature of the term structure.

We consider a stylized consumption-based asset pricing model with exogenous consumption uncertainty, in which bond prices admit a stochastic discount factor representation (see Cochrane, 2009). The model deliberately abstracts from general equilibrium dynamics and richer macro-finance mechanisms that are known to match broader empirical regularities like long-run risks (Bansal and Yaron, 2004), consumption habits (Wachter, 2006), adaptive learning (Piazzesi et al., 2006), liquidity shortages (Caballero and Krishnamurthy, 2008), recursive preferences (Van Binsbergen et al., 2012), or combinations of such features (e.g., Doh, 2013).

The main mechanism is as follows: Under the assumption of investor prudence (i.e., convex marginal utility), a mean-preserving increase in consumption uncertainty raises expected marginal utility and increases the value of safe payoffs. As a result, bond prices rise and yields fall, with differential effects across maturities. Mapping these effects into a Nelson–Siegel representation of the term structure implies that heightened uncertainty is associated with a lower level factor, while the responses of the slope and curvature depend on how expected marginal utility aggregates across investment horizons. In a parametric example with power utility and log-normal consumption, we show that heightened uncertainty is associated with an unambiguously lower level, a steeper slope, and reduced curvature. This mechanism builds on classic results in economics linking prudence to precautionary motives under uncertainty (Leland, 1968; Sandmo, 1970; Kimball, 1990), into asset pricing implications for bond yields through the Nelson–Siegel factor representation.

### 3.1. General model

Consider a general consumption-based asset pricing framework in which the price of an asset $P_t$ satisfies the Euler pricing condition:

$$P_t = \mathbb{E}_t\left[M_{t+1} X_{t+1}\right], \tag{6}$$

for any payoff $X_{t+1}$, where the stochastic discount factor (SDF), $M_{t+1}$, is given by the investors intertemporal rate of substitution:

$$M_{t+1} = \beta \frac{u'(c_{t+1})}{u'(c_t)}, \tag{7}$$

with $\beta \in (0,1)$ denoting the subjective discount factor and $u(c_t)$ utility of consumption. This representation is consistent with a wide range of equilibrium environments (see Cochrane, 2009 for various examples).

The utility function is assumed to satisfy three conditions: (i) increasing marginal utility, $u'(c) > 0$; (ii) risk aversion, $u''(c) < 0$; and (iii) prudence $u'''(c) > 0$. The third condition, prudence, implies convex marginal utility and therefore a precautionary motive under uncertainty (Leland, 1968; Sandmo, 1970; Kimball, 1990).

An uncertainty shock is defined as a mean-preserving spread of future consumption. That is, higher uncertainty corresponds to an increase in the dispersion of the consumption distribution, denoted $\sigma^2$, holding $E_0[c_t]$ fixed. This mirrors the standard definition

of uncertainty shocks in the applied macroeconomics literature, where uncertainty is often measured as the conditional volatility of forecast errors, such as in the widely used macroeconomic uncertainty measure of Jurado et al. (2015), discussed in the previous section.

To connect this general framework to the term structure of interest rates, let $P_0^{(n)}$ denote the time 0 price of a real zero-coupon bond that pays one unit of consumption at time $n$, so that $P_n^{(n)} = 1$. Using (6) this price satisfies the standard asset pricing condition:

$$P_0^{(n)} = E_0\left[\prod_{j=1}^{n} M_j\right], \tag{8}$$

and the corresponding continuously compounded yield $y_0^{(n)}$ is given by:

$$y_0^{(n)} = -\frac{1}{n}\ln P_0^{(n)}. \tag{9}$$

Substituting (7) into (8) and using the result in (9) gives the general expression for the yields:

$$y_0^{(n)} = -\ln\beta + \frac{1}{n}\ln u'(c_0) - \frac{1}{n}\ln E_0\left[u'(c_n)\right]. \tag{10}$$

This shows that yields are determined by three components: A time-preference term, $-\ln\beta$, which is positive when $\beta < 1$; a normalization term, $\frac{1}{n}\ln u'(c_0)$, reflecting marginal utility at time 0; and a precautionary savings component, $-\frac{1}{n}\ln E_0[u'(c_n)]$, which lowers yields since an increase in uncertainty raises $E_0[u'(c_n)]$ under prudence. In the next subsection, we consider a parametric log-normal specification for consumption; for now, however, we keep the analysis general.

To obtain a simple analogue of the Nelson–Siegel factorization of the yield curve presented in Section 2, consider a stylized three-maturity setup, $n = 1, 2, 3$, and define level, slope, and curvature factors as linear combinations of these yields[5]:

$$\text{Level} \equiv y_0^{(3)}, \tag{11}$$

$$\text{Slope} \equiv y_0^{(3)} - y_0^{(1)}, \tag{12}$$

$$\text{Curvature} \equiv \frac{1}{2}\left(y_0^{(1)} + y_0^{(3)}\right) - y_0^{(2)}. \tag{13}$$

In this representation, the level factor is proxied by the longest-maturity yield, the slope factor captures the steepness of the yield curve, and the curvature factor measures deviations from linearity in the yield curve by capturing whether intermediate-maturity yields lie above or below the average of short- and long-maturity yields.

Using the generic yield representation in (9) gives the following expressions for the factors:

$$\begin{aligned}
\text{Level} &= -\ln\beta + \frac{1}{3}\ln u'(c_0) - \frac{1}{3}\ln E_0\left[u'(c_3)\right], \\
\text{Slope} &= -\frac{2}{3}\ln u'(c_0) + \ln E_0\left[u'(c_1)\right] - \frac{1}{3}\ln E_0\left[u'(c_3)\right], \\
\text{Curvature} &= \frac{1}{6}\ln u'(c_0) - \frac{1}{2}\ln E_0\left[u'(c_1)\right] + \frac{1}{2}\ln E_0\left[u'(c_2)\right] - \frac{1}{6}\ln E_0\left[u'(c_3)\right].
\end{aligned} \tag{14}$$

This decomposition shows that time preference affects only the level factor, while slope and curvature depend exclusively on expectations of future marginal utility. Differences in factor loadings across maturities therefore imply that changes in consumption uncertainty affect level, slope, and curvature in distinct ways. To see how, differentiate each of these factors with respect to consumption uncertainty, $\sigma^2$, to get:

$$\begin{aligned}
\frac{\partial\,\text{Level}}{\partial\sigma^2} &= -\frac{1}{3}\frac{1}{E_0[u'(c_3)]}\frac{\partial}{\partial\sigma^2}E_0\left[u'(c_3)\right], \\
\frac{\partial\,\text{Slope}}{\partial\sigma^2} &= \frac{1}{E_0[u'(c_1)]}\frac{\partial}{\partial\sigma^2}E_0\left[u'(c_1)\right] - \frac{1}{3}\frac{1}{E_0[u'(c_3)]}\frac{\partial}{\partial\sigma^2}E_0\left[u'(c_3)\right], \\
\frac{\partial\,\text{Curvature}}{\partial\sigma^2} &= -\frac{1}{2}\frac{1}{E_0[u'(c_1)]}\frac{\partial}{\partial\sigma^2}E_0\left[u'(c_1)\right] + \frac{1}{2}\frac{1}{E_0[u'(c_2)]}\frac{\partial}{\partial\sigma^2}E_0\left[u'(c_2)\right] - \frac{1}{6}\frac{1}{E_0[u'(c_3)]}\frac{\partial}{\partial\sigma^2}E_0\left[u'(c_3)\right].
\end{aligned} \tag{15}$$

Since marginal utility, $u'(c)$, is a convex function of consumption, Jensen's inequality implies:

$$E_0\left[u'(c_t)\right] \;\geq\; u'\left(E_0[c_t]\right). \tag{16}$$

An uncertainty shock is defined as a mean-preserving increase in the dispersion of consumption, indexed by the variance parameter $\sigma^2$. By construction, such a shock leaves the mean of consumption unchanged, so that $E_0[c_t]$ is invariant to $\sigma^2$. As a result, the right-hand side of the inequality does not depend on $\sigma^2$, while the left-hand side increases weakly as dispersion rises. Intuitively, when marginal utility is convex, low-consumption realizations raise marginal utility by more than high-consumption realizations reduce

[5] This three-maturity representation is not intended as a literal DNS derivation, but as a transparent mapping that isolates the effects of uncertainty on level, slope, and curvature movements. In the literature, the Nelson–Siegel slope factor is often defined as the short-term yield minus the long-term yield, however we reverse this convention so that positive values indicate a steeper yield curve.

it. Increasing uncertainty therefore tilts the distribution of marginal utility toward higher values, even though average consumption is unchanged. Formally, this implies that:

$$\frac{\partial}{\partial\sigma^2} E_0\left[u'(c_t)\right] \;\geq\; 0, \qquad t = 1, 2, 3, \tag{17}$$

with strict inequality for a nondegenerate increase in dispersion.

It therefore follows that the level response is non-positive:

$$\frac{\partial\,\text{Level}}{\partial\sigma^2} \leq 0, \tag{18}$$

and strictly negative when $\frac{\partial}{\partial\sigma^2} E_0[u'(c_3)] > 0$.

The slope response is positive whenever the short-horizon increase in $\ln E_0[u'(c_t)]$ dominates the long-horizon increase, i.e., when:

$$\frac{1}{E_0[u'(c_1)]}\frac{\partial}{\partial\sigma^2} E_0\left[u'(c_1)\right] > \frac{1}{3}\frac{1}{E_0[u'(c_3)]}\frac{\partial}{\partial\sigma^2} E_0\left[u'(c_3)\right]. \tag{19}$$

The curvature response is negative whenever the response at the two-period horizon lies between those at the one- and three-period horizons:

$$\frac{1}{E_0[u'(c_1)]}\frac{\partial}{\partial\sigma^2} E_0\left[u'(c_1)\right] \;\geq\; \frac{1}{E_0[u'(c_2)]}\frac{\partial}{\partial\sigma^2} E_0\left[u'(c_2)\right] \;\geq\; \frac{1}{E_0[u'(c_3)]}\frac{\partial}{\partial\sigma^2} E_0\left[u'(c_3)\right]. \tag{20}$$

Intuitively, the slope rises when uncertainty raises short-horizon expected marginal utility relatively more than long-horizon expected marginal utility, and curvature falls when the response of expected marginal utility declines smoothly across horizons, reducing the hump-shaped behavior of intermediate maturities.

In summary, these minimal assumptions are sufficient to deliver clear qualitative implications for the yield curve. An increase in uncertainty raises the expected marginal utility of future consumption through precautionary saving, which increases the price of long-maturity bonds and therefore lowers the level of the yield curve. In contrast, the responses of the slope and curvature depend on how uncertainty affects expected marginal utility at different horizons. If uncertainty has a relatively stronger impact on near-term marginal utility, short-maturity yields fall more than long-maturity yields, steepening the curve. Conversely, if uncertainty primarily affects longer-horizon marginal utility, long yields decline more strongly, flattening or inverting the curve. Curvature responses arise when the effects of uncertainty are non-monotonic across horizons, causing intermediate-maturity yields to move differently from the average of short- and long-maturity yields.

### 3.2. A parametric example

To obtain closed-form expressions and transparent yield-curve implications, we consider a tractable special case with power utility:

$$u(c) = \begin{cases} \dfrac{c^{1-\gamma}}{1-\gamma}, & \gamma \neq 1, \\ \log c, & \gamma = 1, \end{cases} \tag{21}$$

And log-normal consumption:

$$\ln c_t = \mu_t - \tfrac{1}{2}\sigma^2 + \sigma\varepsilon_t, \qquad \varepsilon_t \sim \mathcal{N}(0,1). \tag{22}$$

In this setting $E[c_t] = e^{\mu_t}$, so increases in the variance $\sigma^2$ correspond exactly to mean-preserving increases in consumption uncertainty.

Using (9) permits closed-form expression for yields:

$$y_0^{(n)} = -\ln\beta + \frac{\gamma}{n}\left(\mu_n - \ln c_0\right) - \frac{\gamma(1+\gamma)}{2n}\sigma^2, \qquad n = 1, 2, 3. \tag{23}$$

Using (14) gives the factor expressions:

$$\begin{aligned} \text{Level} &= y_0^{(3)} = -\ln\beta + \frac{\gamma}{3}(\mu_3 - \ln c_0) - \frac{\gamma(1+\gamma)}{6}\sigma^2, \\ \text{Slope} &= y_0^{(3)} - y_0^{(1)} = \gamma\left(\frac{\mu_3}{3} - \mu_1 + \frac{2}{3}\ln c_0\right) + \frac{\gamma(1+\gamma)}{3}\sigma^2, \\ \text{Curvature} &= \frac{1}{2}\left(y_0^{(1)} + y_0^{(3)}\right) - y_0^{(2)} = \gamma\left(\frac{1}{2}\mu_1 + \frac{1}{6}\mu_3 - \frac{1}{2}\mu_2 - \frac{1}{6}\ln c_0\right) - \frac{\gamma(1+\gamma)}{12}\sigma^2. \end{aligned} \tag{24}$$

Differentiating with respect to $\sigma^2$ gives:

$$\begin{aligned} \frac{\partial\,\text{Level}}{\partial\sigma^2} &= -\frac{\gamma(1+\gamma)}{6} < 0, \\ \frac{\partial\,\text{Slope}}{\partial\sigma^2} &= \frac{\gamma(1+\gamma)}{3} > 0, \\ \frac{\partial\,\text{Curvature}}{\partial\sigma^2} &= -\frac{\gamma(1+\gamma)}{12} < 0, \end{aligned} \tag{25}$$

**Table 2**
Uncertainty and the yield curve.

| Uncertainty measure | Posterior median | 95% credible interval |
|---|---|---|
| Financial | 0.043 | (0.03,0.05) |
| Macroeconomic | 0.045 | (0.04,0.05) |
| Economic Policy | 0.039 | (0.03,0.05) |

since $\gamma > 0$. Heightened uncertainty is therefore predicted to elicit a lower, steeper, and less curved yield curve. Economically, this arises because increased uncertainty raises expected marginal utility through precautionary motives, increasing the value of safe long-term payoffs and lowering yields. The slope steepens as short-maturity yields decline more strongly than long-maturity yields, while curvature falls as the response of yields becomes more linear across maturities; that is, intermediate-maturity yields move closer to the average of short- and long-maturity yields. These results establish a direct structural link between uncertainty shocks and the Nelson–Siegel level, slope, and curvature factors. These qualitative predictions provide a benchmark for the empirical analysis, though the strength and statistical significance of each channel ultimately depend on the data. In the next section, we evaluate these predictions empirically using the Yields-Macro Dynamic Nelson–Siegel framework described above.

## 4. Main results

We present our results in five subsections. First, we examine the posterior estimates of the yield curve. Second, we formally assess whether uncertainty impacts the yield curve using the Savage–Dickey density ratio. Third, we analyze the impact of an uncertainty shock on the yield curve while controlling for effects in the broader macroeconomy. Fourth, we assess how an uncertainty shock affects the entire term structure of interest rates. Finally, we investigate how uncertainty directly influences the expectations channel and the term premium. All results are based on 10,000 posterior simulations, following a burn-in period of 1000 draws.

In the Online Appendix, we report a range of sensitivity checks, including the exclusion of the pandemic period, the specification of the monetary policy measure, treatment of effective lower bound (ELB) periods, the inclusion of financial conditions measures, different variable orderings for identification, the construction of a common uncertainty factor, alternative lag lengths in the state equation, and a time-varying exponential decay parameter. While some quantitative differences emerge, the qualitative conclusion that uncertainty shocks lead to an increase in the slope, a reduction in the level and curvature factors, and a broad deterioration in macroeconomic conditions, is generally robust across all specifications. One exception is that the reduction in the level factor is sensitive to some of the robustness checks. Specifically, when we end the sample in 2007M12, specify three lags in the state equation, and specify a time-varying exponential decay rate parameter, then the credible bands for the level response almost always include zero, implying that the effect is not statistically meaningful. This means that while the slope and curvature responses are consistently robust, the evidence for a decline in the level factor depends on whether ELB periods are included in the sample, specification of the state equation lag length, and the specification of the exponential decay rate parameter. A full set of results for each specification is provided in the Online Appendix.

### 4.1. Posterior estimates of the yield curve

Given our interest in quantifying the impact of uncertainty on the yield curve's slope and curvature, accurate estimation of the exponential decay parameter $\lambda$ in (3) is critical. A new feature of our algorithm is that it facilitates the estimation of $\lambda$, rather than calibrating it, as is commonly done in the literature.

When estimating $\lambda$, we specify a uniform prior with bounded support. The lower bound is set at $a = 0.01$ and the upper bound at $b = 0.1$, corresponding to curvature peaks between approximately 10 years ($\lambda = 0.01$) and 19 months ($\lambda = 0.10$). The choice of $b = 0.1$ is conservative, as it covers the calibrated values $\lambda = 0.0609$ and $\lambda = 0.077$ used by Diebold and Li (2006), Diebold et al. (2006), respectively. Under this prior, the conditional posterior density has bounded and non-standard support. We therefore sample from this conditional density using a Griddy–Gibbs step (Ritter and Tanner, 1992). Further estimation details are provided in the Online Appendix.

The posterior median estimate for the exponential decay parameter in each model is provided in Table 2. Overall, we find the results to be robust to the choice of uncertainty indicator used in the model. This is despite the fact that the model including the EPU index is estimated on a shorter sample than the alternative uncertainty measures. The 95% credible intervals lie entirely within the range $[0.03, 0.05]$, indicating that the parameter is precisely estimated. The median estimates are found to be within the range of 0.039–0.045, which means that the data suggests that the curvature factor is maximized between 41-47 months to maturity. Diebold and Li (2006), Diebold et al. (2006) calibrate $\lambda$ at 0.0609 and 0.077, which correspond to maturities of approximately 30 and 24 months, respectively. Both of these values are beyond the empirical range of our estimated posterior distribution, underscoring the importance of estimating this parameter when interpreting yield-curve dynamics.

To illustrate the practical importance of estimating the exponential decay rate parameter, Figs. 4 and 5 report the impulse response functions (IRFs) of each variable to an EPU shock when calibrating $\lambda$ to 0.0609 (Diebold and Li, 2006) and 0.077 (Diebold et al., 2006), respectively. While the baseline IRFs will be discussed in the next section, we here highlight the fact that calibrating $\lambda$ to these values, as is often done in the literature, results in the slope response no longer being credibly different from zero. This means that if we were to calibrate the values then we would conclude that EPU shocks do not impact the slope of the yield curve.

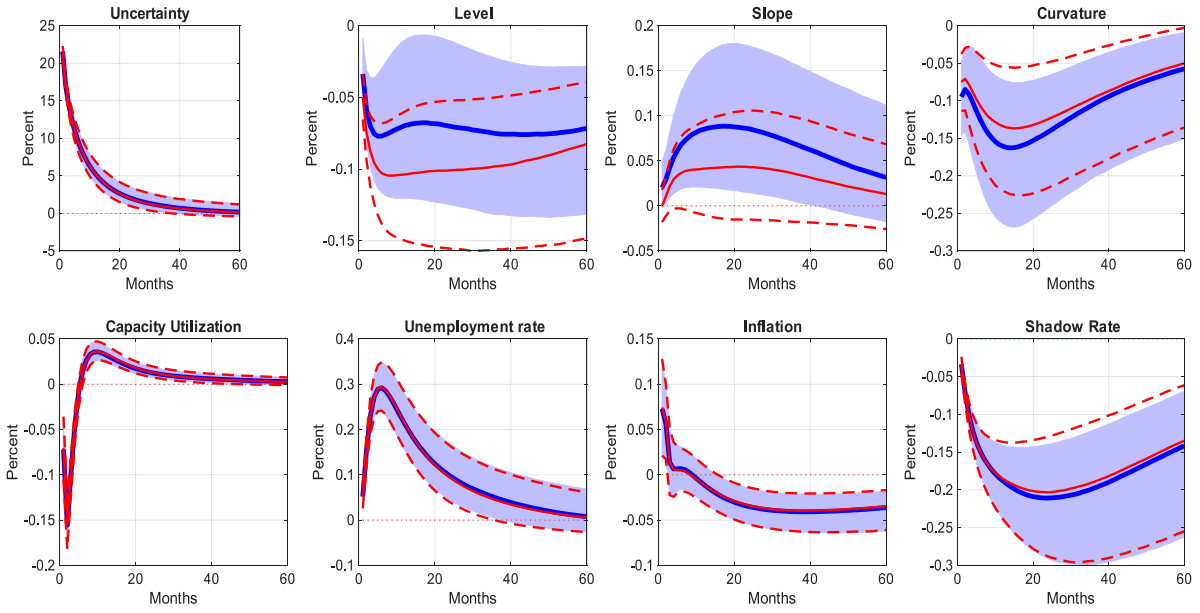


**Fig. 4.** Impulse response to an EPU shock calibrating $\lambda = 0.0609$.
**Notes**: Posterior median estimates and the 95% credible set from the main model specification are represented by the solid (blue) line and the shaded (blue) area, respectively, while the corresponding results from the robustness check are shown as dotted (red) lines. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Calibration also distorts the responses of the other factors: the magnitude of the level response is overstated, while the magnitude of the curvature response is understated. These findings further highlight the importance of estimating this parameter when assessing the effects of uncertainty on the yield curve.

That said, two caveats are worth noting. First, the results in these figures indicate that whether we calibrate or estimate the decay parameter does not significantly affect the identification of the uncertainty shock or its transmission to the macroeconomy. Second, while we find that similar results hold for both macroeconomic and financial uncertainty, the slope response remains credibly different from zero in both cases (due to the similarity of these results we have deferred them to the Online Appendix). Therefore, the key takeaway when examining the effects of uncertainty shocks on the yield curve is that estimating the rate parameter serves as an important safeguard against model misspecification.

The posterior estimates of the yield curve factors are also found to be extremely robust to the choice of uncertainty metric used in the model. We therefore present the results obtained using the financial uncertainty indicator here, and provide the results using the macroeconomic uncertainty index and economic policy uncertainty index, along with a comparison of the results, in the Online Appendix.

The estimated posterior median of the yield curve factors (solid line), along with the associated 95% credible intervals (shaded region), are presented in Fig. 6. The narrow 95% credible intervals indicate that the factors are estimated very precisely. We find that the factors capture several stylized features of empirical yield curves, as discussed in Section 2.2. The level factor, which can be interpreted as capturing the long-term component of interest rates, exhibits a pronounced decline beginning in the 1980s. This is consistent with the literature on the natural rate of interest ($r^*$), which has also declined over this period (Laubach and Williams, 2003). Explanations for this decline include demographic shifts, weak productivity growth, global factors, and greater monetary policy credibility (see, e.g., Rachel and Smith, 2015; Laubach and Williams, 2016; Holston et al., 2017, among others). While our model does not attempt to separately identify $r^*$, the downward trend in the latent level factor aligns closely with these results. We also see that the slope factor tends to become negative prior to recessions, which is in line with the view that yield curve inversions are a leading indicator of the business cycle (Estrella and Hardouvelis, 1991).

To investigate the empirical reliability of these estimated factors, in Fig. 7 we compare the posterior median estimates of the yield curve factors against their empirical counterparts that were used earlier in Table 1. The results show that our estimated factors track their empirical counterpart reasonably well. The estimated correlation coefficients between each factor and its empirical counterpart are 0.8707, 0.8930 and 0.8906, respectively. These high correlations are in line with estimates in both Diebold and Li (2006), Diebold et al. (2006), and suggest a very high degree of co-movement between the factors and their empirical counterparts. The descriptive statistics in Table 3 are also close to those reported in Table 1, thereby lending further support toward their credible interpretation as level, slope and curvature factors.

As a final determination of the validity of the factors interpretation, we also investigate whether important cross-variable correlations are in line with theoretical predictions. Economic theory suggests that the yield curve level is related to the level of expected inflation, and that the yield curve slope is linked to real activity (Estrella, 2005). We therefore calculated the correlations

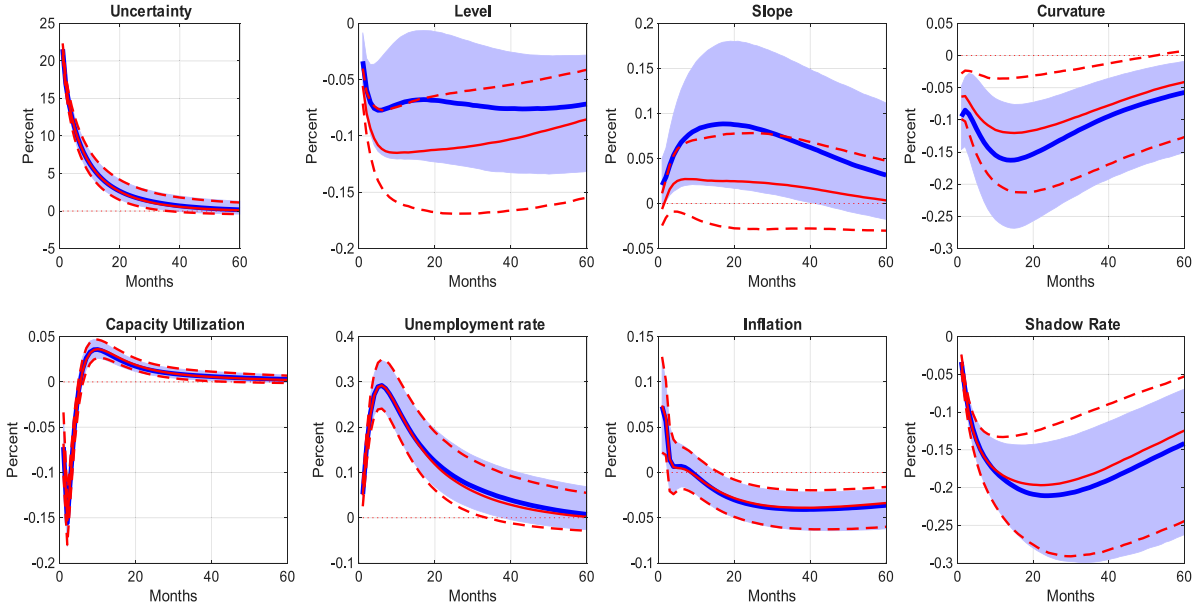


**Fig. 5.** Impulse response to an EPU shock calibrating $\lambda = 0.077$.
**Notes**: Posterior median estimates and the 95% credible set from the main model specification are represented by the solid (blue) line and the shaded (blue) area, respectively, while the corresponding results from the robustness check are shown as dotted (red) lines. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

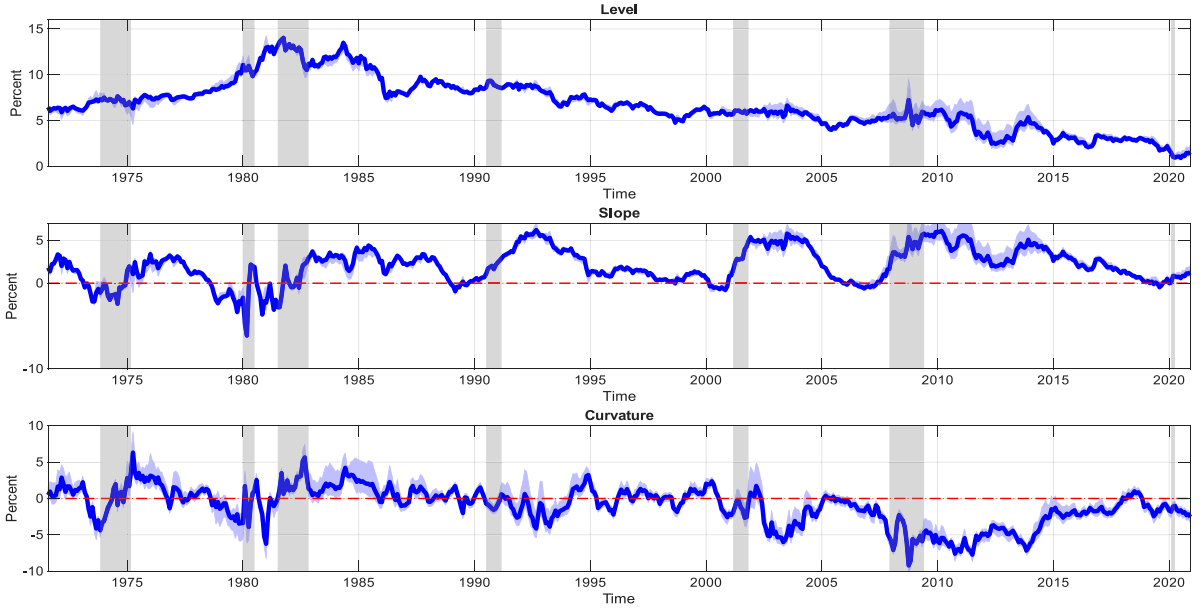


**Fig. 6.** Posterior estimates of the Slope, Level and Curvature factors.
**Notes**: The solid line is the posterior median and the shaded region the associated 95% credible interval.

between $L_t$ and the University of Michigan's 1-year ahead inflation expectations, and between $S_t$ and capacity utilization as an indicator of macroeconomic activity. The correlation between $L_t$ and inflation expectations is 0.50 suggesting a link between the movements in the yield curve level and inflation expectations that is consistent with the Fisher equation. The correlation between $S_t$ and capacity utilization is 0.58, which suggests that the slope yield curve closely follows the economy's cyclical behavior. Similar values for these correlations are reported in Diebold et al. (2006).

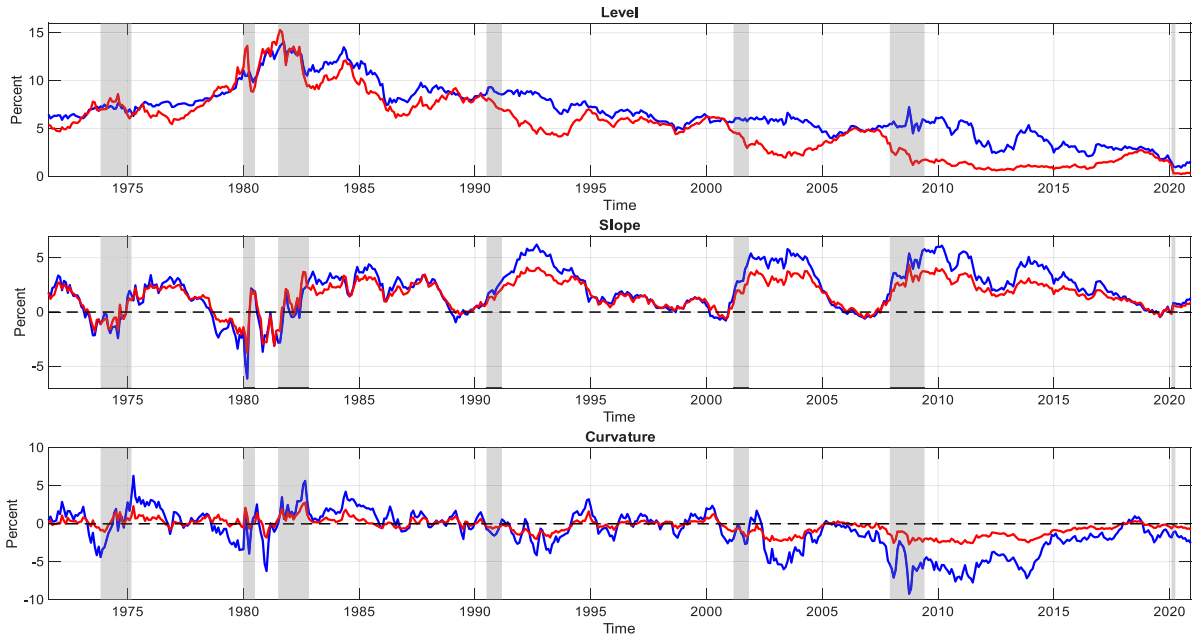


**Fig. 7.** Estimated yield curve factors (blue) and empirical proxies (red). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

**Table 3**
Descriptive statistics of yield curves.

| Factor | Mean | Std. dev. | Minimum | Maximum | $\hat{\rho}(1)$ | $\hat{\rho}(12)$ | $\hat{\rho}(30)$ |
|---|---|---|---|---|---|---|---|
| Level | 6.969 | 2.532 | 1.636 | 14.450 | 0.993 | 0.885 | 0.734 |
| Slope | 2.393 | 2.156 | −7.401 | 4.715 | 0.975 | 0.605 | 0.068 |
| Curvature | −1.391 | 2.789 | −9.371 | 7.373 | 0.928 | 0.598 | 0.372 |

Notes : Descriptive statistics are for the estimated factors (posterior median). The final three columns are sample autocorrelations at lag lengths of 1, 12 and 30 months.

### 4.2. Does uncertainty impact the yield curve?

To formally assess whether uncertainty has statistically meaningful effects on the yield curve we utilize the Savage–Dickey density ratio (SDR); a variant of the Bayes Factor (BF) that is useful when testing the credibility of equality constraints on a subset of one or more of the parameters in a model. Here we determine whether or not the lagged coefficients on the uncertainty term for all the variables (except for uncertainty) are jointly different from zero. Let the vector of lagged coefficient on the uncertainty term for these variables be defined as $\mathbf{b}_{UNC}$. The SDR associated with this restriction is given by

$$BF = \frac{p(\mathbf{b}_{UNC} = \mathbf{0})}{p(\mathbf{b}_{UNC} = \mathbf{0}|\mathbf{y})}, \tag{26}$$

where $BF$ denotes the Bayes factor. The numerator is the marginal prior density of $\mathbf{b}_{UNC}$ evaluated at zero, and the denominator is the marginal posterior density evaluated at zero. If $\mathbf{b}_{UNC} \neq 0$, then the numerator will be larger than the denominator, implying that larger values of (26) provide substantial evidence that $\mathbf{b}_{UNC}$ is jointly different from zero, and vice-versa.

The resulting Bayes Factors are reported in Table 4. A numerical interpretation of the results can be made via the popular rules of thumb proposed by Kass and Raftery (1995). According to their interpretation, the strength of evidence provided by the $BF$ for values between $1-3.2$ are 'not worth more than a bare mention', $3.2-10$ are 'substantial', $10-100$ are 'strong', and anything greater than 100 is 'decisive'. Our results show that there is 'strong' evidence that financial and macroeconomic uncertainty each have a credible impact on the yield curve, and 'decisive' evidence for EPU. While the general conclusion that uncertainty has a credible impact on the yield curve is novel, our result that EPU has a relatively large impact on the yield curve is in line with recent results that high policy uncertainty reduces the Federal Reserve's policy effectiveness (Tillmann, 2020; Shang, 2022).

### 4.3. How does uncertainty impact the yield curve?

To assess how uncertainty shocks impact the yield curve we examine IRFs to a one standard deviation shock from each of the three uncertainty measures: financial, macroeconomic and economic policy. The IRFs are presented in Figs. 8–10. In each case the thick line represents the posterior median and the shaded region is the associated 68% credible interval.

**Table 4**
Uncertainty and the yield curve.

| Uncertainty measure | BF |
|---|---|
| Financial | 37.10 |
| Macroeconomic | 14.36 |
| Economic Policy | 129.57 |

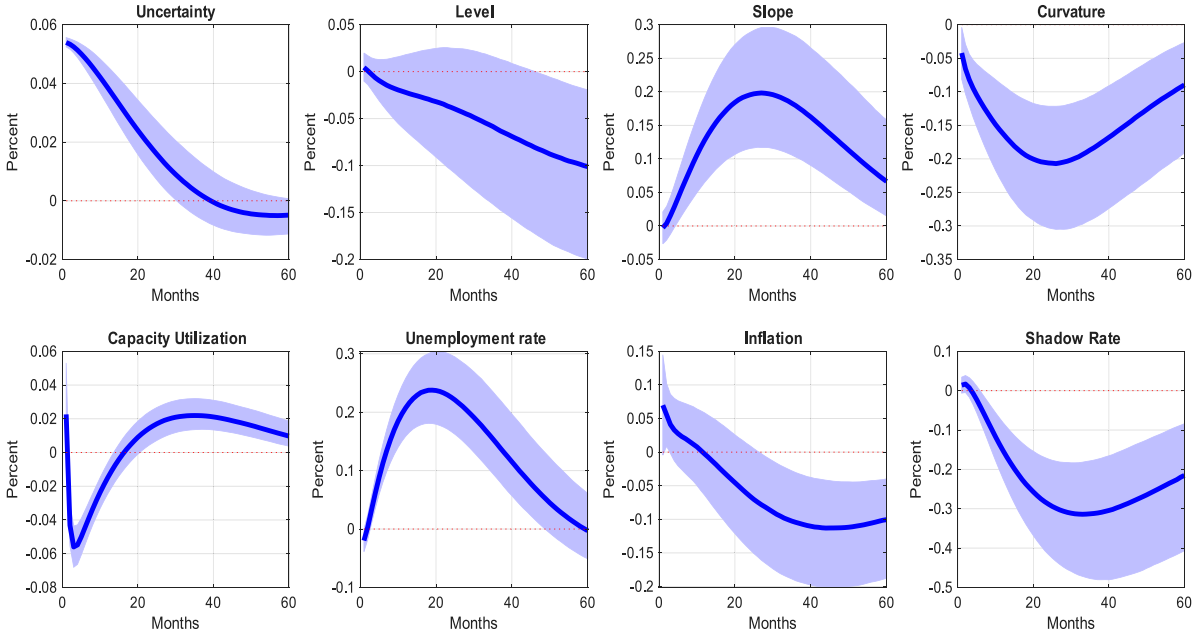


**Fig. 8.** Impulse Response to a Financial Uncertainty Shock.
**Notes**: The solid line is the posterior median and the shaded region the associated 68% credible interval.

We find that uncertainty shocks elicit a similar transmission mechanism across each of the three figures. In each case, the uncertainty shock has a negative impact on the yield curve's level and curvature factors, while increasing the slope. This response is consistent with the precautionary mechanism developed in Section 3, in which heightened uncertainty raises expected marginal utility and increases the value of safe payoffs, with relatively stronger effects on short-horizon expected marginal utility.

At the same time, higher uncertainty also elicits general deterioration of macroeconomic conditions; an increase in unemployment and an overshooting effect within capacity utilization. These macroeconomic responses are consistent with the findings of numerous studies in the broader literature on the macroeconomic effects of uncertainty shocks (e.g., Bloom, 2009; Caggiano et al., 2014, 2022; Basu and Bundick, 2017). The general mechanism is that higher uncertainty raises the real option value of waiting to invest. This results in firms temporarily pausing their hiring and investment decisions while they 'wait-and-see' the Fed's policy response, and the broader macroeconomic effects. The resulting decline in job creation raises unemployment and initially reduces capacity utilization, followed by an overshooting as the economy recovers. Such precautionary behavior by firms has been identified as a major cause of U.S. business cycles (Bloom, 2009; Bloom et al., 2018). Importantly, these macroeconomic responses operate alongside the asset-pricing channel emphasized in Section 3, implying that both investor prudence and real-side macroeconomic dynamics jointly shape the observed movements in the term-structure.

One notable difference in the responses across uncertainty measures is that the level factor response to a macroeconomic uncertainty shock quickly reverts to its pre-shock value, while the negative responses following a financial uncertainty or EPU shocks are relatively persistent. A possible explanation for this difference is given by the Fisher effect, which posits that a prolonged decrease in the level factor is consistent with the interpretation of market participants decreasing their expectations of future inflation, and vice-versa. Indirect evidence of such behavior is provided in the CPI inflation response. In that case, the financial uncertainty and EPU shocks elicit an initial temporary increase in inflation followed by persistent decrease, while the macroeconomic uncertainty shock has a more persistent hump-shaped increase in inflation. Both of these responses lend empirical support to the Fisher effect.

This raises the question of why inflation responds differently to the various types of uncertainty shock. As discussed in the recent survey by Castelnuovo (2023), the inflationary effect of uncertainty shocks is uncertain, which relates to a debate surrounding the theoretical classification of uncertainty shocks as aggregate demand shocks or aggregate supply shocks. If unexpectedly heightened uncertainty moves inflation and output (here proxied by capacity utilization) in the same direction then it is classified as aggregate demand shock. In contrast, if the uncertainty shock moves inflation and output in opposite directions then it is classified as an

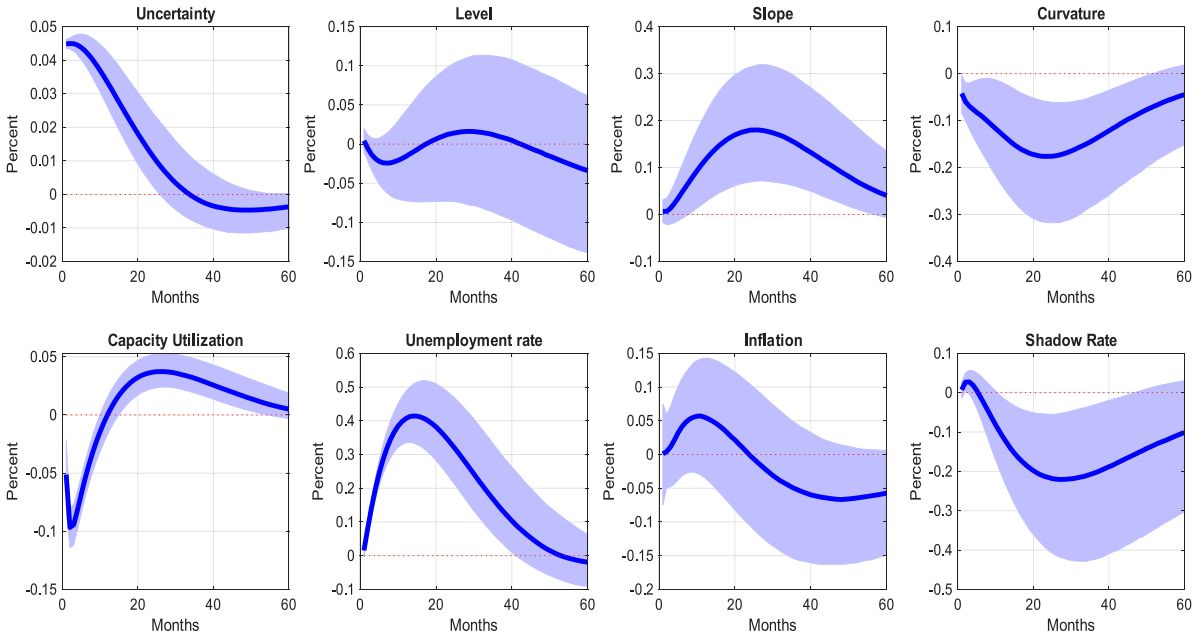


**Fig. 9.** Impulse Response to a Macroeconomic Uncertainty Shock.
**Notes**: The solid line is the posterior median and the shaded region the associated 68% credible interval.

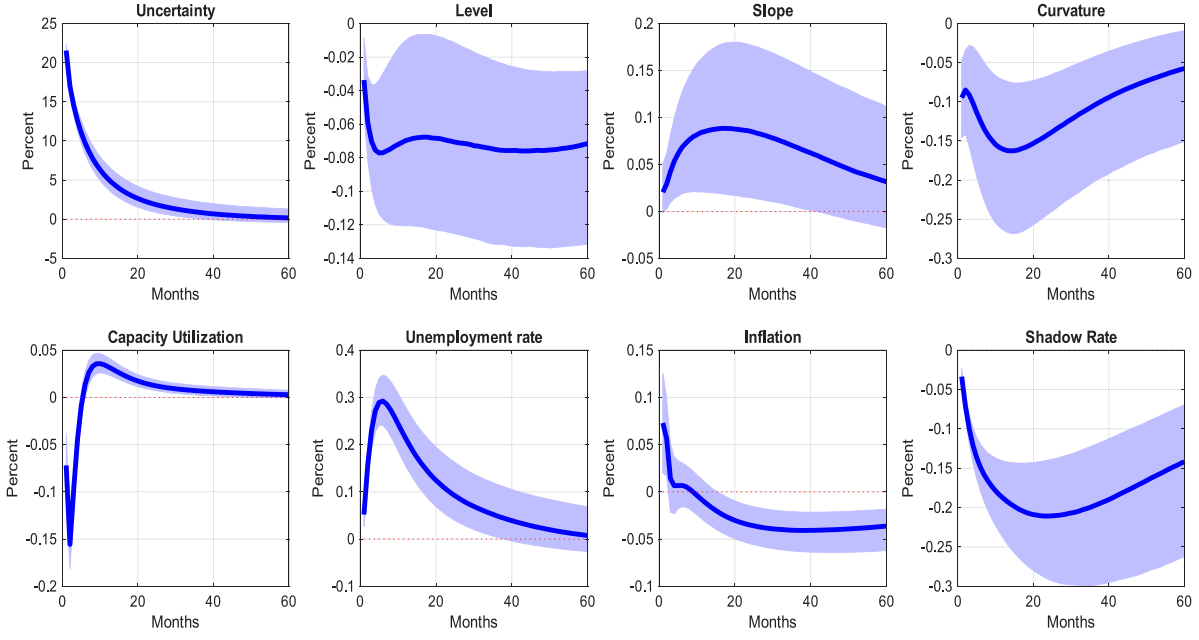


**Fig. 10.** Impulse Response to an EPU Shock.
**Notes**: The solid line is the posterior median and the shaded region the associated 68% credible interval.

aggregate supply shock. Using this classification our results are broadly in line with the financial and EPU shocks falling into the category of aggregate demand shocks, however the classification of macroeconomic uncertainty is less clear. To our mind, this is not too surprising given that financial markets and economic policy are generally believed to be closely related to demand conditions in the economy, while the primary origins of business cycle fluctuation have been debated for over a century. On the one hand, the neoclassical perspective of the business cycle is that macroeconomic fluctuations are primarily driven by supply-side shocks. On the other hand, the New Keynesian perspective is that demand side factors play a more pertinent role. Given the relatively modest response of inflation to the macroeconomic uncertainty shock, the results here are more in line with results from New-Keynesian

models which predict that macroeconomic uncertainty has a demand side effect on inflation due to its origins in countercyclical markups and sticky prices (e.g., Leduc and Liu, 2016; Basu and Bundick, 2017; Bianchi et al., 2023).

Since the slope factor is here defined as long-rate minus short-rate, this increase in slope factor suggests the yield curve has steepened in response to the uncertainty shock. Such a steepening can be caused by short-term interest rates falling more quickly than long-term rates. Alternatively, a steepening may also occur if long-term interest rates rise faster than short-term interest rates. Financial practitioners often refer to these two distinct scenarios as a 'bull steepening', and 'bear steepening', respectively, since their occurrence is indicative of overall market sentiment.[6] Over time, however, the decrease in the policy rate causes macroeconomic conditions to improve. As the economy recovers, expectations about compensation for longer-term securities improve, and the slope of the yield curve gradually reverts to its normal state. The resulting effect is a U-shaped response in the slope factor. This result is also in line with recent results in Amisano and Tristani (2023) and Bianchi et al. (2023) who respectively find that macroeconomic uncertainty shocks steepen the slope of the yield curve, albeit with different methodologies to the one used here. Similar results for financial uncertainty shocks are also reported in Castelnuovo (2019).

While the reductions in the level and slope factors are consistent with the existing literature, a new and distinctive result in this paper is that uncertainty shocks also have a significant negative impact on the curvature factor. This is especially notable since the macro-finance literature has not established a credible association between curvature and shocks from macroeconomic variables. As shown in Section 3, a possible mechanism is given by investor prudence. That is, higher uncertainty raises expected marginal utility and the value of safe payoffs. This leads to a general decrease in the level factor of the yields, with a possibly increased slope factor and reduced curvature factor depending on the relative horizon sensitivities of expected marginal utility. More broadly, the paper therefore relates to the theoretical macroeconomics literature with Epstein–Zin preferences (e.g., Doh, 2013), which suggest that agents are uncertainty averse and demand compensation for higher risk, and also with a flight-to-safety mechanism (Caballero and Krishnamurthy, 2008), whereby investors faced with uncertainty will reallocate portfolios toward long-maturity government bonds. Specifically, following an uncertainty shock, rational agents may anticipate a deterioration in macroeconomic conditions. This expectation, combined with heightened risk aversion, induces investors to shift demand toward relatively safe assets, like long-term government bonds. With comparatively less demand at medium maturities, the yield curve becomes flatter around its hump, leading to a reduction in curvature. Further evidence of this mechanism is provided in Section 4.5 where we derive the bond yields into expectations and associated term premium channels.

To dig deeper into the effects of uncertainty on the yield curve factors, Figs. 11–13 present the impulse responses of selected maturities to an uncertainty shock, decomposed via the respective yield curve factors. Specifically, we trace the effect of an uncertainty shock on individual maturities using the measurement equation. For example, a decline in the curvature factor resulting from heightened uncertainty can be used to assess its impact on short-, medium-, and long-term maturities. A similar approach is employed to evaluate the influence of the level and slope factors on the yield curve.

We find that the level factor reflects an unconditional parallel shift in the yield curve across all maturities, and that the slope factor is primarily responsible for the reduction of short-term yields relative to the long-end of the curve, which is consistent with a bull steepening. The curvature factor has its strongest effect on medium-term maturities relative to both short- and long-term yields, which is consistent with the uncertainty aversion and flight-to-safety mechanisms discussed above. We return to this point in Section 4.5 where we dig deeper into the expectations and term premium channels during the Great Recession and COVID-19 pandemic.

### *4.4. How does uncertainty impact the term structure?*

To further investigate how the yield curve responds to uncertainty shocks, we also examine how the entire term structure reacts to such shocks. Computationally, this is done by premultiplying the impulse response vector by the factor loading $\Lambda(\lambda)$ in (3). Since the impulse responses are of the entire term structure, they can be viewed as functional IRFs in the spirit of Inoue and Rossi (2021). The main difference is that Inoue and Rossi (2021) investigate the response of a functional variable, i.e., the term structure, to a functional monetary policy shock, while we consider the response of the same functional variable to a scalar uncertainty shock.

The IRFs associated with a one standard deviation uncertainty shock are shown in Figs. 14–16. Panel A shows the median response, and panel B shows the median response together with the corresponding 68% credible intervals for the six selected yield maturities. We see that all responses are credibly different from zero.

In line with our results in the previous section, we see that the level of the term structure is typically lowered after a positive uncertainty shock. There is also a general monotonic impact in terms of the relative magnitude in the level effects at different dates-to-maturity, with short-term yields falling much more than long-term yields. This result provides further support for our aforementioned finding that uncertainty elicits a general steepening of the yield curve, and our associated interpretation of the uncertainty shock generating a bull steepening of the yield curve. There is also evidence of reduced curvature at all maturities, however some heterogeneity exists in the magnitude of the effects; larger effects at medium-term maturities, and short-term maturities reverting to zero substantially faster than the long-end. Thus, while uncertainty shocks decrease the relative curvature across the entire yield curve, there is important heterogeneity in the responses of yields at different dates-to-maturity.

[6] Practitioners also often discuss the existence of so called 'bear flattening': When short-term rates rise faster than long-term interest rates, and 'bull flattening': When long-term rates fall faster than short-term rates. However neither of these scenarios are consistent with a steepening of the yield curve. The term 'flattening' here should also be interpreted with respect to the relative slope of the yield curve as opposed to its curvature.

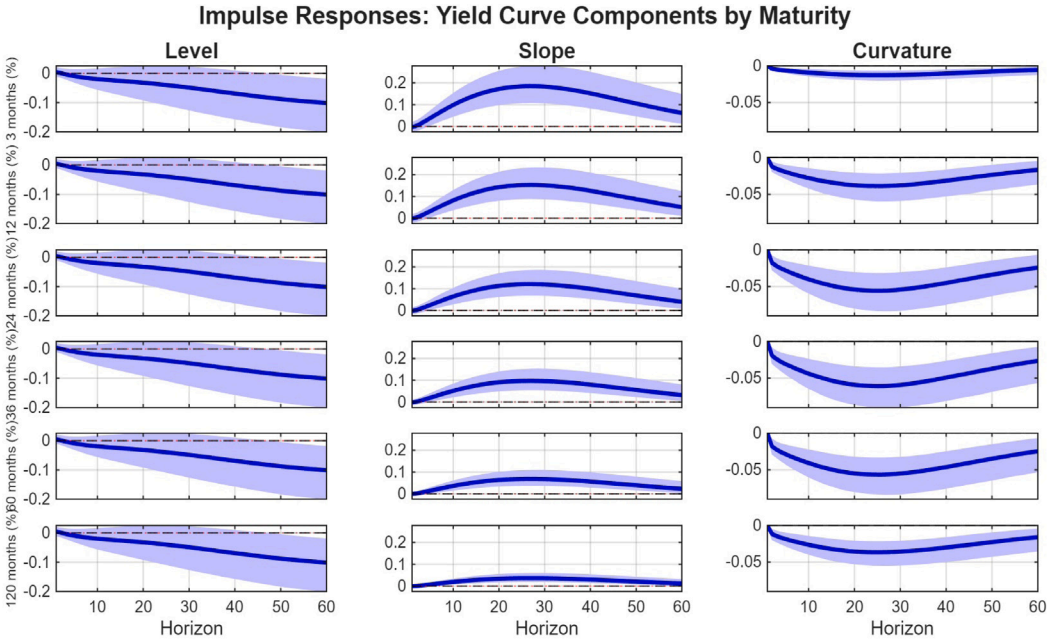


**Fig. 11.** Term Structure Response to a Financial Uncertainty Shock: Evidence from Selected Maturities (3 m, 12 m, 24 m, 36 m, 60 m, 120 m).
**Notes**: The solid line is the posterior median and the shaded region the associated 68% credible interval.

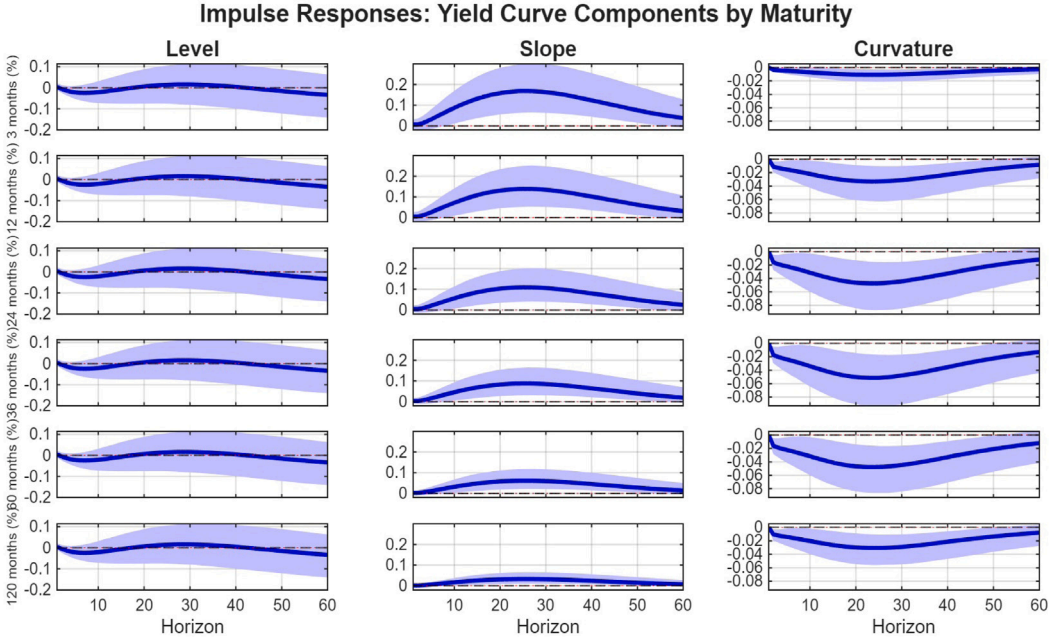


**Fig. 12.** Term Structure Response to a Macroeconomic Uncertainty Shock: Evidence from Selected Maturities (3 m, 12 m, 24 m, 36 m, 60 m, 120 m).
**Notes**: The solid line is the posterior median and the shaded region the associated 68% credible interval.

Another area of heterogeneity in the responses of yields at different dates-to-maturity occurs across the various uncertainty measures. Specifically, while we find that each of the uncertainty shocks has a similar impact on the yields at the short-end — a sharp drop, followed by a gradual increase — we find a large degree of heterogeneity in the responses at the long-end of the curve. Financial uncertainty results in a gradual decline in uncertainty that is extremely persistent, macroeconomic uncertainty elicits more of a horizontally translated S-shaped response, and EPU elicits a U-shaped response; albeit with a long right-tail due to the high

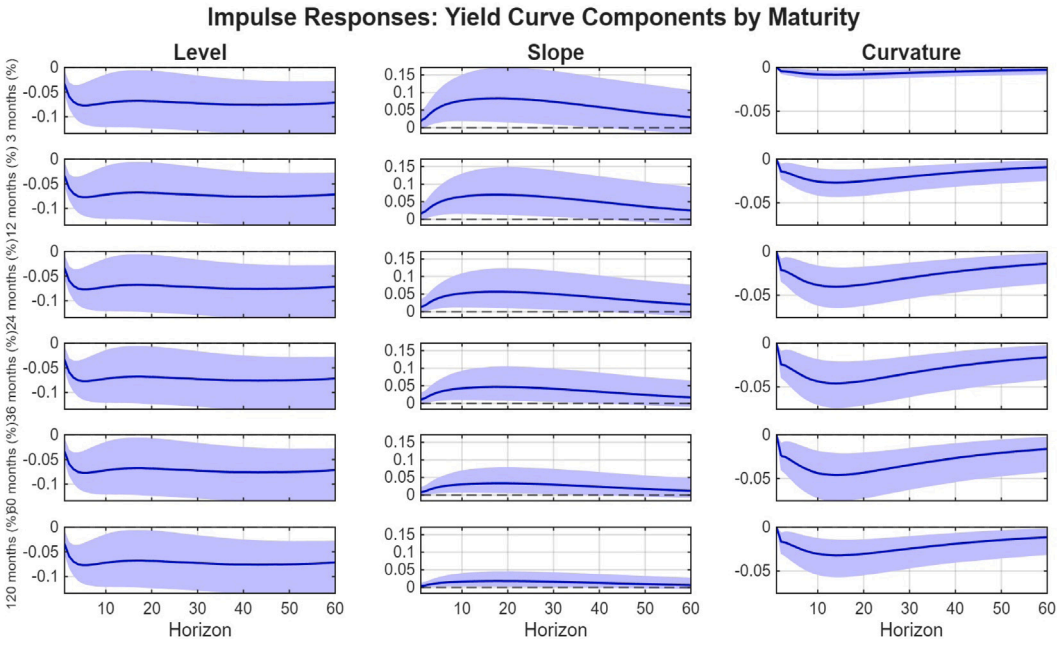


**Fig. 13.** Term Structure Response to a EPU Shock: Evidence from Selected Maturities (3 m, 12 m, 24 m, 36 m, 60 m, 120 m).
**Notes**: The solid line is the posterior median and the shaded region the associated 68% credible interval.

degree of persistence in the shocks effects. A possible reason for these heterogeneous effects of uncertainty at the long-end of the yield curve is that they be influenced by the Fed's policy communication. This is because the Fed is likely better able to communicate away uncertainty relating to future paths of policy, relative to the future paths of macroeconomic and financial conditions (Hansen et al., 2019). Policy uncertainty may therefore have a relatively smaller impact on long-rates compared to other forms of uncertainty.

### *4.5. How does uncertainty affect the expectations channel and the term premium?*

To further assess how expectations and uncertainty aversion shape the transmission of uncertainty to the yield curve, we decompose long-term yields into expectations and term premium components using the expectations hypothesis (EH). Under the EH, the yield on a long-term bond equals the average of expected future short-term interest rates. A deviation between this expectation and observed long-term yield is referred to as the term premium, representing the additional compensation investors require for bearing interest rate risk over longer horizons.

Following Bianchi et al. (2009), among others, the yield on a longer-term bond consistent with the expectations hypothesis, is effectively the conditional expectation at time $t$ of the average future short-term interest rates, given all currently available information:

$$y_t(\tau)^{EH} = \frac{1}{\tau}\sum_{i=0}^{\tau-1}\mathbb{E}_t[y_{t+i}(1)], \tag{27}$$

and the term premium is defined as the difference between the observed and EH-implied yields:

$$TP_t(\tau) = y_t(\tau) - y_t(\tau)^{EH}. \tag{28}$$

Any unexpected uncertainty shock at time $t$ can alter investors perceptions about future rates and affect the current yield. To assess this sensitivity, we consider taking the first-order derivative of the expected future short rate with respect to an uncertainty shock, $\delta$, which quantifies how changes in perceived future uncertainty influence current bond yields and market expectations:

$$\begin{aligned}\frac{\partial y_t^{EH}(\tau)}{\partial \delta} &= \frac{1}{\tau}\sum_{i=0}^{\tau-1}\mathbb{E}_t\left[\frac{\partial y_{t+i}(1)}{\partial \delta}\right], \\ &= \frac{1}{\tau}\sum_{i=0}^{\tau-1}\mathbb{E}_t\left[\Lambda(\lambda)\frac{\partial f_{t+i}}{\partial \delta}\right],\end{aligned} \tag{29}$$

where regularity of the model permits the interchange of the differential and integral. If uncertainty changes by $\delta$ at time $t$, the partial derivative above corresponds to the standard impulse response functions of an uncertainty shock, tracing how a structural disturbance propagates through the yield curve factors and affects the expectations component of long-term yields.

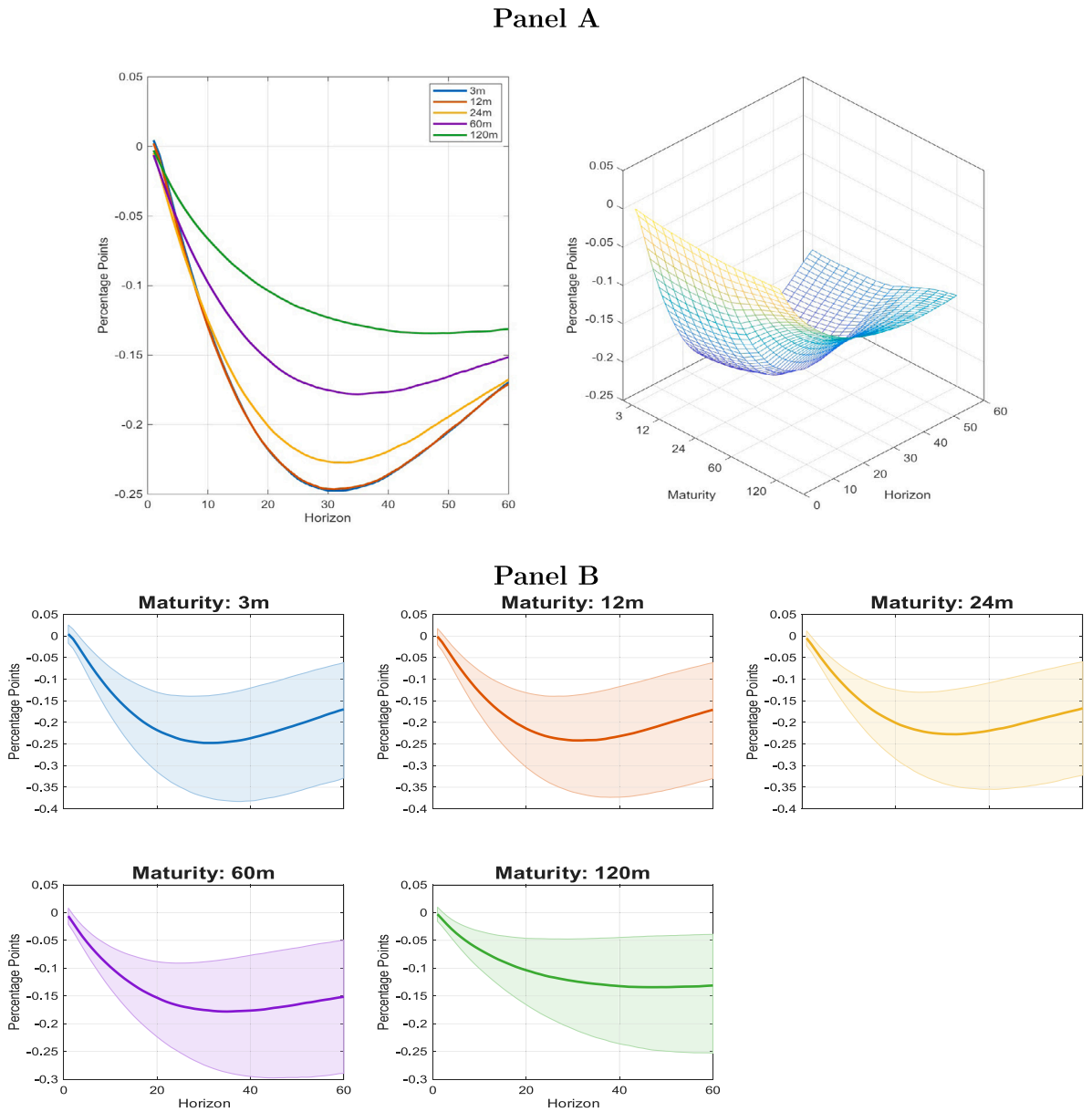


**Fig. 14.** Functional Impulse Response Functions to a Financial Uncertainty Shock.
**Notes**: Panel A plots the posterior median of the functional impulse response function for six selected maturities as well as for the full range of maturities. Panel B plots the posterior median of the functional impulse response function for each of the six selected maturities individually; the associated shaded region represents the 68% credible set.

To assess the role of uncertainty in shaping both the expectations component and the term premium, we focus on the 10-year bond yield during two key episodes of heightened uncertainty: September 2008 (the onset of the Great Recession) and June 2020 (the COVID-19 pandemic). As shown earlier in Fig. 2, these periods are associated with relatively high levels of financial, macroeconomic and policy uncertainties over the sample period. We refer to the EH-consistent yield and term premium using each of the three different uncertainty measures without a shock as the baseline estimates. The above simulated counterfactual exercise (CF) at time $t = 1$ is then computed by increasing uncertainty by one-unit, holding all other model components fixed, and recalculating the EH-implied yields and term premia under this scenario.[7]

[7] Since the mean of the raw EPU index is approximately 100, we implement the counterfactual analysis by increasing the EPU index by 100 units at time $t = 1$.

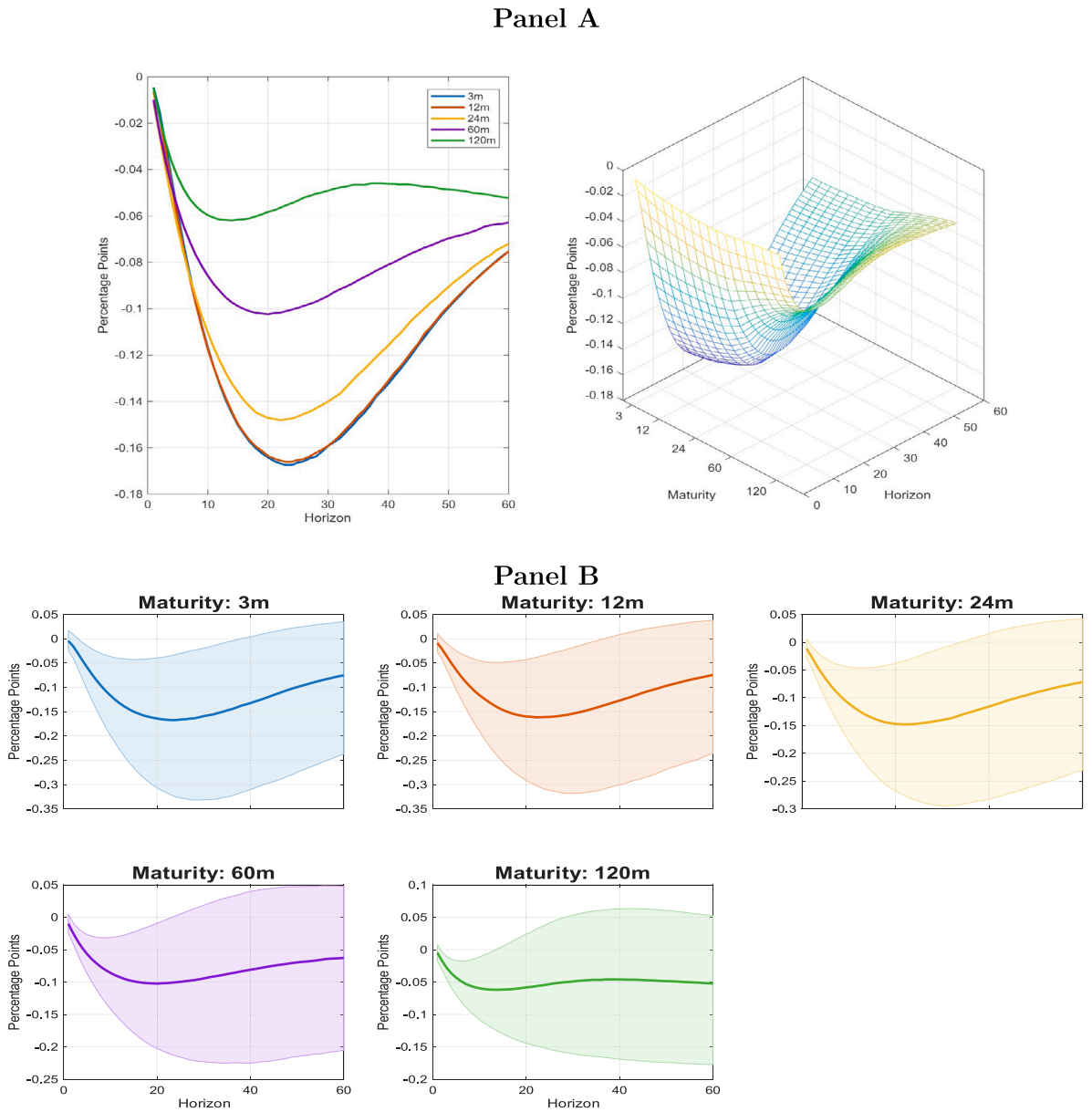


**Fig. 15.** Functional Impulse Response Functions to a Macroeconomic Uncertainty Shock.
**Notes**: Panel A plots the posterior median of the functional impulse response function for six selected maturities as well as for the full range of maturities. Panel B plots the posterior median of the functional impulse response function for each of the six selected maturities individually; the associated shaded region represents the 68% credible set.

Table 5 reports posterior median and 68% credible interval estimates from both the baseline (Base) and counterfactual (CF) exercises. In the baseline results, we observe that during the Great Recession, a substantial portion of the 10-year yield was accounted for by the term premium, reflecting heightened compensation for risks associated with holding long-term bonds. This indicates that risk compensation was a dominant driver of long-term interest rates during that period. In contrast, during the COVID-19 pandemic, the 10-year yield was primarily driven by expectations of future short-term interest rates, pointing to a more prominent role for the expectations component. Notably, the term premium was negative, indicating that investors were willing to accept yields below those implied by expected short-term rates, consistent with a flight-to-safety mechanism (Caballero and Krishnamurthy, 2008).

Turning to the counterfactual analysis, we find that increases in financial, macroeconomic, and policy uncertainty consistently lead to lower expectations of future short-term interest rates and higher term premia. This implies that heightened uncertainty simultaneously depresses the expected path of policy rates while increasing the compensation investors require for bearing duration risk. The decline in expected short rates aligns closely with the precautionary savings mechanism developed in Section 3. By contrast,

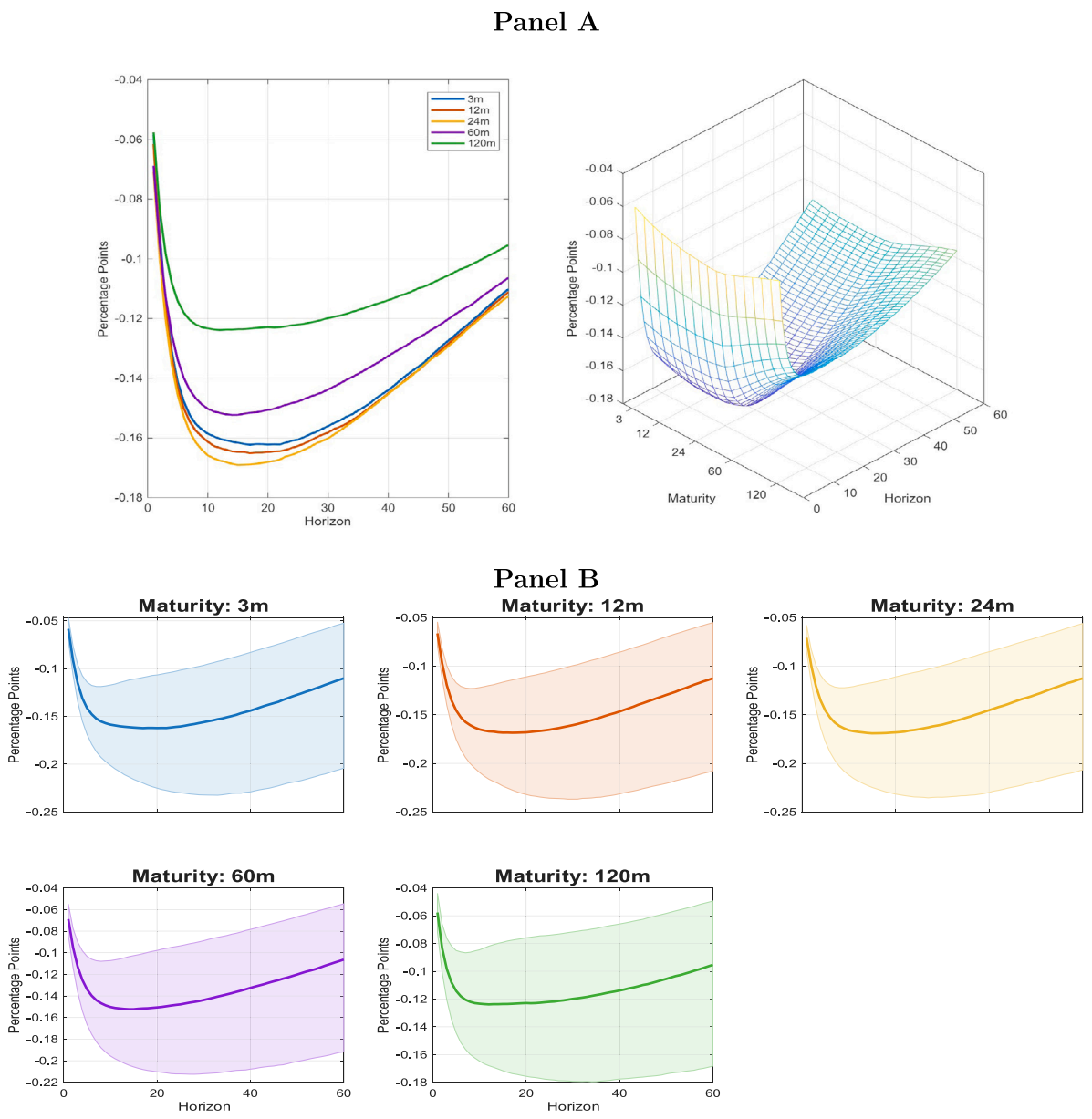


**Fig. 16.** Functional Impulse Response Functions to an EPU Shock.
**Notes**: Panel A plots the posterior median of the functional impulse response function for six selected maturities as well as for the full range of maturities. Panel B plots the posterior median of the functional impulse response function for each of the six selected maturities individually; the associated shaded region represents the 68% credible set.

the rise in term premia points to additional risk-compensation channels consistent with uncertainty-aversion mechanisms in models with Epstein–Zin preferences (e.g., Doh, 2013). In such settings, rising uncertainty strengthens agents' aversion to long-horizon risks, thereby increasing the compensation required to bear those risks.

## 5. Conclusion

How does uncertainty affect the term structure of interest rates? To address this question, we developed a flexible Yields-Macro Dynamic Nelson–Siegel (YM-DNS) model that shows the impact of uncertainty shocks on the yield curve while controlling for macroeconomic conditions. We made two extensions to the current state-of-the-art Bayesian algorithm used to estimate such models. First, we demonstrated how the exponential decay rate parameter of the yields can be sampled as part of the algorithm using a

**Table 5**
Posterior estimates of baseline and counterfactual yields at the 10-Year maturity.

| Indexes | Financial Uncertainty | | Macro Uncertainty | | EPU | |
|---|---|---|---|---|---|---|
| | Base | CF | Base | CF | Base | CF |
| | | | **September 2008** | | | |
| Observed | 4.26 | 4.26 | 4.26 | 4.26 | 4.26 | 4.26 |
| EH | 0.88 (−3.15,4.20) | −1.74 (−7.08,2.02) | 1.36 (−3.12,5.10) | −0.44 (−0.44,4.03) | 1.33 (−0.94,3.24) | 1.02 (−1.37,2.91) |
| Term Premium | 3.38 (0.05,7.40) | 6.00 (2.24,11.33) | 2.90 (−0.84,7.38) | 4.70 (0.23,10.70) | 2.93 (1.02,5.20) | 3.24 (1.35,5.63) |
| | | | **June 2020** | | | |
| Observed | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 |
| EH | 1.07 (−2.87,4.64) | −1.66 (−6.67,2.14) | 0.49 (−4.18,4.34) | −1.31 (−7.61,3.45) | 1.65 (−0.71,3.73) | 1.30 (−1.14,3.41) |
| Term Premium | −0.42 (−3.99,3.52) | 2.31 (−1.49,4.83) | 0.16 (−3.69,4.83) | 1.96 (−2.80,8.26) | −1.00 (−3.08,1.36) | −0.78 (−2.76,1.79) |

**Notes** : 'Observed' here refers to the realized 10-year Treasury yield. The baseline (Base) yield consistent with the Expectations Hypothesis (EH) consistent is computed from Eq. (27), and the associated term premium is derived from Eq. (28). The counterfactual (CF) is computed by first simulating equation (29) from the model given an uncertainty shock, and then recomputing both the EH yield and the term premium. Both baseline and counterfactual results are computed using Monte Carlo methods from each MCMC draw, with reported values being posterior medians and 68% credible intervals in parentheses.

Griddy–Gibbs step. Second, we showed that the latent yield curve factors can be sampled simply and efficiently using a modern precision sampling algorithm, with either a constant or time-varying exponential decay rate parameter.

Our main insight is that unanticipated increases in uncertainty generally produce a yield curve that is lower, steeper, and less curved. These responses are consistent with investor prudence and precautionary behavior. More broadly, the yield curve effects were accompanied by a deterioration in economic conditions, followed by a monetary easing response and subsequent overshooting in real activity; a pattern consistent with the wait-and-see behavior emphasized in uncertainty driven business cycle models. We show that these results are generally robust across three common measures of financial, macroeconomic, and policy uncertainty, and a wide range of sensitivity checks.

The decline in the curvature factor is particularly notable, as this component is typically weakly responsive to macroeconomic shocks. We show that this result can be traced to investor prudence and heightened precautionary behavior. A counterfactual analysis that decomposes long-term yields into expectations and term-premium components, also indicated that uncertainty depresses expected future short-term interest rates while simultaneously raising the term premium, consistent with uncertainty-aversion and flight-to-safety mechanisms.

Taken together, these findings show the importance of accounting for uncertainty when modeling the term structure of interest rates. They also highlight the importance of developing richer macro-finance models that integrate uncertainty into term structure modeling.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.euroecorev.2026.105352.

## Data availability

I have provided a link to the replication file on Zenodo which contains the dataset used in the paper.

## References

Amisano, G., Tristani, O., 2023. Monetary policy and long-term interest rates. Quant. Econ. 14 (2), 689–716.
Baker, S.R., Bloom, N., Davis, S.J., 2016. Measuring economic policy uncertainty. Q. J. Econ. 131 (4), 1593–1636.
Bansal, R., Yaron, A., 2004. Risks for the long run: A potential resolution of asset pricing puzzles. J. Financ. 59 (4), 1481–1509.
Basu, S., Bundick, B., 2017. Uncertainty shocks in a model of effective demand. Econometrica 85 (3), 937–958.
Bianchi, F., Kung, H., Tirskikh, M., 2023. The origins and effects of macroeconomic uncertainty. Quant. Econ. 14 (3), 855–896.
Bianchi, F., Mumtaz, H., Surico, P., 2009. The great moderation of the term structure of UK interest rates. J. Monet. Econ. 56 (6), 856–871.
Bloom, N., 2009. The Impact of Uncertainty Shocks. Econometrica 77 (3), 623–685.
Bloom, N., Floetotto, M., Jaimovich, N., Saporta-Eksten, I., Terry, S.J., 2018. Really uncertain business cycles. Econometrica 86 (3), 1031–1065.
Caballero, R.J., Krishnamurthy, A., 2008. Collective risk management in a flight to quality episode. J. Financ. 63 (5), 2195–2230.
Caggiano, G., Castelnuovo, E., Groshenny, N., 2014. Uncertainty shocks and unemployment dynamics in US recessions. J. Monet. Econ. 67, 78–92.
Caggiano, G., Castelnuovo, E., Nodari, G., 2022. Uncertainty and monetary policy in good and bad times: A replication of the vector autoregressive investigation by Bloom (2009). J. Appl. Econometrics 37 (1), 210–217.
Castelnuovo, E., 2019. Yield curve and financial uncertainty: Evidence based on US data. Aust. Econ. Rev. 52 (3), 323–335.

Castelnuovo, E., 2023. Uncertainty before and during COVID-19: A survey. J. Econ. Surv. 37 (3), 821–864.
Castelnuovo, E., Pellegrino, G., 2018. Uncertainty-dependent effects of monetary policy shocks: A new-Keynesian interpretation. J. Econom. Dynam. Control 93, 277–296.
Chan, J.C., Jeliazkov, I., 2009. Efficient simulation and integrated likelihood estimation in state space models. Int. J. Math. Model. Numer. Optim. 1 (1–2), 101–120.
Chan, J.C., Strachan, R.W., 2023. Bayesian state space models in macroeconometrics. J. Econ. Surv. 37 (1), 58–75.
Cochrane, J.H., 2009. Asset pricing: Revised edition. Princeton University Press.
Cooper, D., Fuhrer, J.C., Olivei, G., 2020. Predicting recessions using the yield curve: The role of the stance of monetary policy. Fed. Reserv. Bank Boston Res. Pap. Ser. Curr. Policy Perspect. Pap. 87522.
Creal, D.D., Wu, J.C., 2017. Monetary policy uncertainty and economic fluctuations. Internat. Econom. Rev. 58 (4), 1317–1354.
Diebold, F.X., Li, C., 2006. Forecasting the term structure of government bond yields. J. Econometrics 130 (2), 337–364.
Diebold, F.X., Rudebusch, G.D., 2013. Yield curve modeling and forecasting: the dynamic Nelson-Siegel approach. Princeton University Press.
Diebold, F.X., Rudebusch, G.D., Aruoba, S.B., 2006. The macroeconomy and the yield curve: a dynamic latent factor approach. J. Econometrics 131 (1–2), 309–338.
Doh, T., 2013. Long-Run Risks in the Term Structure of Interest Rates: Estimation. J. Appl. Econometrics 28 (3), 478–497.
Estrella, A., 2005. Why Does the Yield Curve Predict Output and Inflation? Econ. J. 115 (505), 722–744.
Estrella, A., Hardouvelis, G.A., 1991. The Term Structure as a Predictor of Real Economic Activity. J. Financ. 46 (2), 555–576.
Hansen, S., McMahon, M., Tong, M., 2019. The long-run information effect of central bank communication. J. Monet. Econ. 108, 185–202.
Holston, K., Laubach, T., Williams, J.C., 2017. Measuring the natural rate of interest: International trends and determinants. J. Int. Econ. 108, S59–S75.
Inoue, A., Rossi, B., 2021. A new approach to measuring economic policy shocks, with an application to conventional and unconventional monetary policy. Quant. Econ. 12 (4), 1085–1138.
Joslin, S., Singleton, K.J., Zhu, H., 2011. A new perspective on Gaussian dynamic term structure models. Rev. Financ. Stud. 24 (3), 926–970.
Jurado, K., Ludvigson, S.C., Ng, S., 2015. Measuring uncertainty. Am. Econ. Rev. 105 (3), 1177–1216.
Kass, R.E., Raftery, A.E., 1995. Bayes factors. J. Amer. Statist. Assoc. 90 (430), 773–795.
Kimball, M.S., 1990. Precautionary Saving in the Small and in the Large. Econometrica 58 (1), 53–73.
Koopman, S.J., Mallee, M.I., Van der Wel, M., 2010. Analyzing the term structure of interest rates using the dynamic Nelson–Siegel model with time-varying parameters. J. Bus. Econom. Statist. 28 (3), 329–343.
Laubach, T., Williams, J.C., 2003. Measuring the natural rate of interest. Rev. Econ. Stat. 85 (4), 1063–1070.
Laubach, T., Williams, J.C., 2016. Measuring the natural rate of interest redux. Bus. Econ. 51 (2), 57–67.
Leduc, S., Liu, Z., 2016. Uncertainty shocks are aggregate demand shocks. J. Monet. Econ. 82, 20–35.
Lee, S.-H., 2025. An Alternative Approach for Determining the Time-Varying Decay Parameter of the Nelson-Siegel Model. Comput. Econ. 65 (5), 2965–2990.
Leippold, M., Matthys, F., 2022. Economic policy uncertainty and the yield curve. Rev. Financ. 26 (4), 751–797.
Leland, H.E., 1968. Saving and Uncertainty: The Precautionary Demand for Saving. Q. J. Econ. 82 (3), 465–473.
Liu, Y., Wu, J.C., 2021. Reconstructing the yield curve. J. Financ. Econ. 142 (3), 1395–1425.
Ludvigson, S.C., Ma, S., Ng, S., 2021. Uncertainty and business cycles: exogenous impulse or endogenous response? Am. Econ. J.: Macroecon. 13 (4), 369–410.
Mumtaz, H., Zanetti, F., 2013. The impact of the volatility of monetary policy shocks. J. Money Credit. Bank. 45 (4), 535–558.
Nelson, C.R., Siegel, A.F., 1987. Parsimonious Modeling of Yield Curves. J. Bus. 473–489.
Piazzesi, M., Schneider, M., Benigno, P., Campbell, J.Y., 2006. Equilibrium yield curves. NBER Macroecon. Annu. 21, 389–472.
Rachel, L., Smith, T., 2015. Secular Drivers of the Global Real Interest Rate. Bank of England Working Paper 571. Bank of England.
Ritter, C., Tanner, M.A., 1992. Facilitating the Gibbs sampler: the Gibbs stopper and the griddy-Gibbs sampler. J. Amer. Statist. Assoc. 87 (419), 861–868.
Sandmo, A., 1970. The Effect of Uncertainty on Saving Decisions. Rev. Econ. Stud. 37 (3), 353–360.
Shang, F., 2022. The effect of uncertainty on the sensitivity of the yield curve to monetary policy surprises. J. Econom. Dynam. Control 137, 104355.
Tillmann, P., 2020. Monetary policy uncertainty and the response of the yield curve to policy shocks. J. Money, Credit. Bank. 52 (4), 803–833.
Van Binsbergen, J.H., Fernández-Villaverde, J., Koijen, R.S., Rubio-Ramírez, J., 2012. The term structure of interest rates in a DSGE model with recursive preferences. J. Monet. Econ. 59 (7), 634–648.
Wachter, J.A., 2006. A consumption-based model of the term structure of interest rates. J. Financ. Econ. 79 (2), 365–399.
Wu, J.C., Xia, F.D., 2016. Measuring the macroeconomic impact of monetary policy at the zero lower bound. J. Money, Credit. Bank. 48 (2–3), 253–291.