What Moves Treasury Yields?*

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Abstract

We identify a yield news shock as an innovation that does not move Treasury yields contemporaneously but explains a maximum share of their future variation. Yields do not respond contemporaneously to the news shock as the initial reaction of term premiums and expected short rates offset each other. While the impact on term premiums fades quickly, expected short rates and thus yields decline persistently. As a result, the shock explains a staggering 50 percent of Treasury yield variation several years out. A positive yield news shock is associated with a coincident sharp increase in stock and bond market volatility, a contemporaneous response of leading economic indicators, and is followed by a persistent decline of real activity and inflation which is accommodated by the Federal Reserve. Identified shocks to realized stock market volatility and business cycle news imply similar impulse responses and together capture the bulk of variation of the yield news shock.

Keywords: term structure of interest rates, yield curve, news shocks, volatility shocks, business cycle news, structural dynamic factor models

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1. Introduction

Government bonds play a benchmark role in financial markets and, as such, are key to understanding the transmission of shocks in the economy. While much of the previous literature has studied the factor structure in government bond yields and the interaction of the term structure factors with macroeconomic aggregates, surprisingly little effort has been devoted to understanding the sources of yield curve variation. In this paper, we aim to fill this gap by identifying the shocks that explain essentially all of the yield curve variation, and by studying the macroeconomic and financial market responses associated with these shocks.

The comovement among large panels of macroeconomic and financial time series has been shown to be well captured by a small number of factors which can be consistently estimated by the method of principal components (e.g., Sargent and Sims, 1977; Stock and Watson, 2002a,b, 2016; Bai and Ng, 2002, 2006; Forni, Hallin, Lippi and Reichlin, 2000, 2005). Similarly, the variation of government bond yields of different maturities is also known to be summarized by only a few factors (Garbade, 1996; Litterman and Scheinkman, 1991; Diebold and Li, 2006). We can therefore characterize the common dynamics of macroeconomic variables and Treasury yields in a dynamic factor model (DFM) where the macroeconomic and yield curve factors follow a joint vector autoregression (VAR). This allows us to identify the innovations driving yield curve variation, and to study the responses of a large number of macroeconomic and financial variables to these innovations in a unified framework.

The bulk of the comovement among government bond yields is captured by the first two principal components. The one associated with the largest eigenvalue of the variance-covariance matrix features similar loadings across maturities and is commonly referred to as the level factor. The second component typically has monotonically declining or increasing loadings along the maturity structure and is referred to as the slope factor. Innovations to the level factor thus result in parallel shifts and innovations to the slope factor in a flattening or steepening of the yield curve. Combined, they explain almost all of the short-term variation of yields. However, we show in this paper that these shocks together explain at most half of the variation of Treasury yields several years out.

What drives yield curve variation at these longer horizons? Recent studies have argued that there are factors which help to predict future bond yields but are not (well) spanned by the cross-section of contemporaneous yields. Several approaches have been suggested to identify these unspanned or hidden factors in the term structure of interest rates. Cochrane and Piazzesi (2005) use predictive return regressions to obtain a tent-shaped linear combination of forward rates which has strong forecasting power for future yields, but is only weakly correlated with yields contemporaneously. Ludvigson and Ng (2009) show that macroeconomic factors that are not spanned by yields have strong predictive power for bond returns. Duffee (2011) uses Kalman filtering techniques to identify a linear combination of yields which has almost no immediate but a strong delayed impact on yields. Feunou and Fontaine (2018) propose a class of term stucture models with risk factors that have non-Markovian dynamics and show that these models match well the empirical observation that information in higher order principal components of yields or lagged yields helps predict future yields over and above the factors explaining the cross-section of yields. Joslin, Priebsch and Singleton (2014) find evidence that real economic growth and inflation predict future bond yields while not adding explanatory power to the cross-section of contemporaneous bond yield beyond their first three principal components. Taken together, this evidence strongly suggests the existence of shocks which are orthogonal to the yield curve contemporaneously but which move bond yields with some delay.

Conceptually, such shocks are similar to news shocks identified in the macroeconomic literature. Using a bivariate VAR of stock prices and total factor productivity (TFP), Beaudry and Portier (2006) document that a shock which affects TFP in the long run is indistinguishable from one that moves stock prices on impact and is orthogonal to contemporaneous TFP. In a similar vein, Barsky and Sims (2011) identify a productivity news shock as the innovation orthogonal to current TFP innovations that best explains variation in future TFP. Their identification strategy maximizes the forecast error variance (FEV) of TFP in a medium-scale VAR subject to some orthogonality constraint, and closely follows the method proposed by Uhlig (2003). We use the same idea to identify a yield news shock which is hidden by contemporaneous Treasury yields but best explains their future variation. More precisely, we extend Uhlig's approach to a DFM framework and identify the innovation that jointly maximizes the equally-weighted forecast error variance shares of the level and slope factors over the next year, but is orthogonal to the innovations which affect the level and slope factor contemporaneously.[1]

Combined, the three shocks explain essentially all of the variation of yields several years out. While the news shock does not move yields initially, it explains a staggering 50 percent of their variation at forecast horizons up to three years out. Consistent with the previous literature on hidden factors in the term structure, the news shock initially moves the expected future short rate and term premium components of Treasury yields in opposite directions. While the term premium response dies out relatively quickly, expected future short rates and with them yields continue to fall over the next several years. The shock is also associated with sharp increases in implied stock and bond market volatility, falling stock prices, and large contemporaneous responses of leading business cycle indicators, followed by a protracted decline of real activity and inflation. The Federal Reserve responds to this decline by persistently lowering the policy rate, which in turn feeds through to persistently lower expected future short rates and Treasury yields.

The sharp contemporaneous response of stock and bond market volatility to the identified

[1]Our identification of a yield news shock as an innovation that maximizes future variation of Treasury yields but is orthogonal to current yields is thus in the tradition of the macroeconomic news shocks literature. Other recent work (see, e.g. Altavilla, Giannone and Modugno, 2017; Gurkaynak, Kisacikoğlu and Wright, 2020) uses high-frequency Treasury yield data and event-study approaches to measure the news embedded in macroeconomic releases.

yield news shock and the following protracted decline of real economic activity suggest that financial market uncertainty may be a key driver of persistent yield curve variation. To verify this conjecture, we explicitly identify shocks that explain a maximum share of near-term variation in measures of implied and realized stock market volatility. We find a striking similarity of the impulse responses to these volatility shocks and the yield news shock, and show that they are highly correlated. In a recent paper, Berger, Dew-Becker and Giglio (2020, henceforth BDG) use a measure of realized stock market volatility along with the option-implied volatility index VXO to disentangle innovations to the realization of volatility from those to uncertainty about future stock prices. They document that it is the shocks to realized rather than those driving expected future volatility that strongly affect macroeconomic aggregates. In line with their results we show that it is also the innovations to contemporaneous volatility and not forward-looking uncertainty that drives persistent yield curve variation.

In addition to hightened financial market volatility, the yield news shock is also associated with a strong contemporaneous response of leading indicator variables which peaks within one year after the shock. Hence, news about the business cycle is another candidate source of persistent yield curve variation. We explicitly identify a business cycle news shock as the innovation that jointly explains a maximum share of the forecast error variances of a set of leading business cycle indicators over the next year. This shock implies similar impulse responses as the yield news and realized volatility shocks, leading to persistently lower expected short rates and thus yields. Moreover, consistent with Angeletos, Collard and Dellas (2020), news about the short-run economic outlook explains large fractions of the forecast error variances of key measures of real activity.

While the realized volatility and business cycle news shocks are positively correlated with one another and with the yield news shock, together they explain only about three quarters of its variation. To understand the residual source of Treasury yield variation, we identify a yield news shock that maximizes the forecast error variance of level and slope over the next year but is orthogonal to shocks to level, slope, realized volatility and business cycle news. Although this shock carries little residual information about volatility and future real activitiy, it still explains economically and statistically significant shares of Treasury yield variation. We show that this residual yield news shock is associated with large movements in international sovereign bond yields, suggesting that a common source of global sovereign bond yield dynamics contributes to persistent Treasury yield variation.

Our analysis is related to various strands of the literature on the forecastability and the economic driving forces of government bond yields. The paper most closely related to ours is Kurmann and Otrok (2013). These authors identify a news shock to the *slope* of the term structure of interest rates and trace its impact on macroeconomic variables in a small-scale VAR. They find that news about the yield curve slope is positively correlated with news about future TFP. While the two analyses are clearly related, there are a number of important differences. First, we identify a news shock which maximizes the forecast error variance of level *and* slope (the first and second principal components of yields) as opposed to only the term structure slope. Since the level factor represents by far the most dominant source of yield curve variation, our yield news shock explains a much larger share of variance of bond yields than the slope news shock of Kurmann and Otrok. The second key difference is that we can trace the impulse responses of a wide range of macroeconomic and financial time series in our DFM approach. This allows for a broad economic interpretation of the identified shocks. Our results imply that financial market volatility and news about the near-term economic outlook are more important drivers of yields than news about future productivity. In a robustness analysis, we identify a slope news shock à la Kurmann and Otrok (2013) and show that it has similar properties as the contemporaneous shock to the slope factor to which our yield news shock is orthogonal by construction.

Our paper is also related to the literature on the role of uncertainty for term premium dynamics in estimated New Keynesian models. Bianchi, Kung and Tirskikh (2018) propose a model with time-varying uncertainty about aggregate demand and supply. They find that both types of uncertainty shocks result in a steepening of the yield curve which arises due to both lower short rates and higher term premiums for longer-term bonds. Andreasen (2019) builds a model with autoregressive stochastic volatility which generates a link between current inflation and future uncertainty. His model matches the time series dynamics of Treasury yields and term premiums as implied by the flexible no-arbitrage model of Adrian, Crump and Moench (2013, henceforth ACM), and further reproduces the predictive power of the term spread for bond returns. Finally, Amisano and Tristani (2019) propose a model with regime shifts in the conditional variance of productivity shocks. In their model, an increase in uncertainty also raises term premiums and lowers expected real rates via a precautionary savings motive. Combined, the two effects explain a sizable share of variance of longer-term yields. Consistent with our empirical results, in these theories increased uncertainty leads to a drop in economic activity, lower short-term interest rates and initially higher term premiums. A similar finding is documented by Castelnuovo (2019), who uses local projections to show that financial uncertainty lowers both short and long rates, with the short rate responses being stronger. However, none of the aforementioned papers discusses the spanning (or, rather, the lack thereof) of shocks to volatility by contemporaneous yields, which is a key insight of our paper. Moreover, this literature also does not differentiate between contemporaneous shocks to volatility and those to expectations of future volatility, which we show to have very different effects on yields and other financial market indicators.

Our econometric approach builds on the literature that extends structural VAR methods to DFMs (e.g., Giannone, Reichlin and Sala, 2004; Forni, Giannone, Lippi and Reichlin, 2009; Forni and Gambetti, 2010; Stock and Watson, 2016; Bjørnland and Thorsrud, 2016). Using a DFM, we consistently estimate the common and idiosyncratic components of a large number of variables. We then apply structural VAR methods to the innovations of the estimated factors to identify structural shocks based on a rich information set, and without the confounding influence of measurement errors and idiosyncratic variations.

The remainder of the paper is organized as follows. Section 2 presents the DFM, describes the identification approach of Uhlig (2003), and extends it to the DFM setup for identifying news shocks. Section 3 presents our empirical application to yield news shocks, describes the data, and details the estimation and model selection. Our empirical results, including several robustness analyses, are presented in Section 4. Section 5 concludes.

2. Econometric Methodology

In this section, we present our econometric methodology. We first describe the dynamic factor model (DFM) which we use to summarize the joint dynamics of the Treasury yield curve and the U.S. macroeconomy. We then discuss our identification of shocks, which extends prior work on structural VARs following Uhlig (2003) to DFMs.

2.1. Model

We model the variation of a large number of macroeconomic and financial variables as well as Treasury yields using the DFM given by

$$X_t = \Lambda F_t + e_t, \tag{1}$$

for $t = 1, ..., T$, where X_t denotes the $N \times 1$ vector of observed time series, the factors in the $r \times 1$ vector F_t capture the common sources of variation among the variables X, Λ is the matrix of factor loadings, and e_t is a vector of idiosyncratic components. We further assume that the factors F_t follow a VAR

$$\Phi(L)F_t = \eta_t, \tag{2}$$

where $\Phi(L) = I - \Phi_1 L - \cdots - \Phi_p L^p$ is a lag polynomial matrix, and η_t is the vector of factor innovations with mean zero and variance-covariance matrix Σ_η. From Equations (1) and (2), we obtain the reduced-form moving average representation which expresses X_t in terms of current and past values of innovations

$$X_t = \Lambda \Phi(L)^{-1} \eta_t + e_t. \tag{3}$$

Dynamic factor models of this form were first popularized by Stock and Watson (2002a,b) and have since become a workhorse tool to study the joint dynamics of large sets of macroeconomic and financial time series.

2.2. Identifying News Shocks in Dynamic Factor Models

As in structural VARs, we assume that the innovations η_t summarizing the joint dynamics among the variables in X_t are linear combinations of structural shocks, denoted by the $r \times 1$ vector ν_t:

$$\eta_t = H \nu_t. \tag{4}$$

The structural shocks ν_t have the variance-covariance matrix Σ_ν. Under the unit standard deviation normalization ($\Sigma_\nu = I$), one can write any matrix H as $H = Chol(\Sigma_\eta)Q$ where Q is a $r \times r$ orthonormal matrix ($Q'Q = I$), and $Chol$ denotes the Cholesky factorization. This implies the structural moving average representation

$$X_t = C(L)Q\nu_t + e_t, \text{ with } C(L) = \Lambda\Phi(L)^{-1}Chol(\Sigma_\eta), \tag{5}$$

where the impulse response function of X_t with respect to the ith shock is given by $C(L)Q_i$ with Q_i denoting the ith column of Q. Any potential mapping from the structural shocks ν_t to the innovations η_t can thus be captured by a choice of the matrix Q. In the application below, we seek to identify as few shocks as possible that summarize the common dynamics of Treasury yields. We then study the responses of the yields and the macroeconomic and financial variables with respect to these shocks.

In DFMs, because the factors and their loadings are unobserved, the space spanned by the factors is identified, but the factors themselves are not ($\Lambda F_t = \Lambda G^{-1}GF_t$, where G is any invertible $r \times r$ matrix). Therefore, a normalization must be imposed. In our application of DFMs to the identification of a yield news shock, we use the following normalization

$$X_t = \begin{bmatrix} Y_t \\ X_{\bullet t} \end{bmatrix} = \begin{bmatrix} \Lambda_{YY} & 0_{n\times(r-m)} \\ \Lambda_{\bullet Y} & \Lambda_{\bullet\bullet} \end{bmatrix} \begin{bmatrix} F_t^Y \\ F_{m+1:rt} \end{bmatrix} + e_t. \tag{6}$$

Here, Y_t denotes the $n \times 1$ vector of Treasury yields we associate with the $m \times 1$ vector of factors F_t^Y with loadings Λ_{YY}, and $X_{\bullet t}$ denotes the remaining macroeconomic and financial variables which are driven by F_t^Y and an additional set of factors $F_{m+1:rt}$ with the corresponding loadings $\Lambda_{\bullet Y}$ and $\Lambda_{\bullet\bullet}$. This block-lower-triangular normalization has also been used in Coroneo, Giannone and Modugno (2016).

We seek to identify a news shock which explains the maximum share of variation of Y_t. A similar identification approach has been proposed for an individual variable by Uhlig (2003) in the context of structural VARs, and has been applied to identify news shocks about future TFP (Barsky and Sims, 2011; Forni, Gambetti and Sala, 2014), shocks to the yield curve slope (Kurmann and Otrok, 2013), and technology shocks (Francis, Owyang, Roush and DiCecio, 2014), among others.

To disentangle the news shock from other sources of variation, we would like to ensure that the shock of interest is contemporaneously orthogonal to other identified shocks. Hence, we need to impose additional short-run timing restrictions. Under the normalization in Equation (6), the moving average representation of the factor VAR is

$$F_t = \begin{bmatrix} F_t^Y \\ F_{m+1:rt} \end{bmatrix} = \begin{bmatrix} D_Y(L) \\ D_{m+1:r}(L) \end{bmatrix} Q\nu_t = D(L)Q\nu_t, \tag{7}$$

where $D(L) = \Phi(L)^{-1}Chol(\Sigma_\eta)$, and the second expression partitions the lag polynomial similarly to F_t. Let D_k denote the kth lag matrix in $D(L)$ such that $D_{k,i}Q_j$ is the effect of the jth shock on the ith element of F_t^Y after k periods.

We seek to identify a news shock that explains a maximum share of forecast error variance of the factors indexed by 1,...,q but does not move these factors contemporaneously. Hence, we identify the q+*1*st shock (the q+*1*st column of Q) as the news shock by solving the following optimization problem:

$$\underset{Q_{q+1}}{\text{argmax}} \sum_{i=1}^{q} \frac{\sum_{k=0}^{h-1} \left(D_{k,i}Q_{q+1}\right)^2}{\text{var}\left(F_{it+h}^Y | F_t, F_{t-1}, \ldots\right)}, \tag{8}$$

subject to two constraints: (*i*) $Q'_{q+1}Q_{q+1} = 1$, (*ii*) $H_{ij} = 0$, for $i = 1, \ldots, q$ and $j = q+1, \ldots, r$. The first constraint ensures that Q_{q+1} is an orthonormal vector. The second constraint imposes the restrictions on the matrix H so that the q+*1*st shock does not affect the factors 1,...,q within the same period. Following Uhlig (2003), the solution of this problem is characterized by an eigenvector associated with the first eigenvalue of the lower $(r-q)\times(r-q)$ block of the matrix $\sum_{k=0}^{h-1}\left(D'_{k,1:q}S_{q\times q}D_{k,1:q}\right)$, where $D_{k,1:q}$ denotes the first q rows of D_k, and $S_{q\times q}$ is a diagonal matrix with entries $\frac{1}{\text{var}\left(F_{it+h}^Y|F_t,F_{t-1},\ldots\right)}$ for $i = 1, .., q$.[2]

3. Empirical Implementation

In this section, we first discuss our implementation of the aforementioned approach to identify a yield news shock, i.e. a shock which contains news about future yield curve variation but cannot be seen in contemporaneous yields. We then describe the data used in our empirical analysis, summarize the individual steps to obtain estimates and standard errors, and discuss model selection.

3.1. Yield News Shock

We aim to identify a yield news shock as a shock which does not move yields contemporaneously but has a strong impact on future yields. Our approach translates the notion of "unspanned" (Joslin, Priebsch and Singleton, 2014) or "hidden" (Duffee, 2011) factors in the term structure of

[2]To see this, use Equation (8) to write the objective function as $trace\left[S_{q\times q}\sum_{k=0}^{h-1}\left(D_{k,1:q}Q_{q+1}\right)\left(D_{k,1:q}Q_{q+1}\right)'\right] = Q'_{q+1}\left[\sum_{k=0}^{h-1}\left(D'_{k,1:q}S_{q\times q}D_{k,1:q}\right)\right]Q_{q+1}$. The goal is to solve the optimization problem subject to the two constraints. Under constraint (*ii*), $H = \begin{bmatrix} H_{11} & 0_{q\times(r-q)} \\ H_{21} & H_{22} \end{bmatrix}$ where H_{11}, H_{21} and H_{22} are three unrestricted $q\times q$, $(r-q)\times q$ and $(r-q)\times(r-q)$, respectively. Then, $H = Chol(\Sigma_\eta)Q$ and that Q is an orthonormal matrix imply $Q = \begin{bmatrix} Q_{11} & 0_{q\times(r-q)} \\ 0_{(r-q)\times q} & Q_{22} \end{bmatrix}$, where Q_{11} and Q_{22} are $q\times q$ and $(r-q)\times(r-q)$. Finally, under constraint (*i*), solving the optimization problem obtains $Q_3 = \begin{bmatrix} 0_{q\times 1} \\ v \end{bmatrix}$ where v is an eigenvector associated with the first eigenvalue of the lower $(r-q)\times(r-q)$ block of $\sum_{k=0}^{h-1}\left(D'_{k,1:q}S_{q\times q}D_{k,1:q}\right)$.

interest rates into a shock rather than a factor identification strategy. Specifically, we identify a yield news shock as the innovation that maximizes the sum of the forecast error variance shares of the first two principal components of Treasury yields over the next 12 months. In line with the naming convention in the term structure literature, we label these "level" and "slope". We ensure that the yield news shock is orthogonal to contemporaneous variation in yields by imposing the restriction that the shock does not contemporaneously affect level and slope using the contemporaneous zero restrictions on the matrix H. As the two factors explain nearly all of the unconditional variance of yields, the contemporaneous zero restrictions imply that our identified yield news shock is essentially unspanned by yields within the same period. We jointly consider the yield news shock with two recursively identified shocks to the level and slope. These latter shocks induce contemporaneous changes in the level and slope and as such by construction maximize current instead of future variation in yields. We label these a "level" and a "slope" shock, respectively.

Several authors (Duffee, 2011; Joslin, Priebsch and Singleton, 2014; Coroneo, Giannone and Modugno, 2016) have pointed out that macroeconomic information might help to identify factors that are not spanned by yields contemporaneously but have forecasting power for future yields. To assess the importance of macroeconomic information in identifying a yield news shock, we apply our identification approach in two specifications. The first is an only-yields DFM with factors extracted exclusively from yields. The second is a macro-yields specification where we augment the set of yields with a large number of macroeconomic and financial variables and estimate a second set of factors driving these variables (in addition to the comovement explained by the yield factors).

As we impose the block-lower-triangular normalization (6) on the factor loadings Λ in the macro-yields model, the yield factors have the same interpretation across these two specifications. Let level and slope be the first two factors. Then, identification of a yield news shock is implemented by solving the problem in Equation (8) subject to the zero restrictions on H which rule out a contemporaneous response of the level and slope factors to the news shock. Specifically, using the notation in (6) and (7), our identification imposes the following zero restrictions on H:

$$\begin{bmatrix} \eta_t^{Level} \\ \eta_t^{Slope} \\ \eta_{3:rt} \end{bmatrix} = \begin{bmatrix} H_{11} & 0 & 0 \\ H_{21} & H_{22} & 0 \\ H_{\bullet 1} & H_{\bullet 2} & H_{\bullet\bullet} \end{bmatrix} \begin{bmatrix} \nu_t^{Level} \\ \nu_t^{Slope} \\ \nu_{3:rt} \end{bmatrix}, \tag{9}$$

where H_{11}, H_{21} and H_{22} are scalars. These restrictions deliver a recursive identification scheme which has also been used by other authors to identify shocks to the yield curve factors, see for example Diebold, Rudebusch and Aruoba (2006) and Bianchi, Mumtaz and Surico (2009). We combine such a recursive identification with the forecast error variance maximization approach of Uhlig (2003) to identify a yield news shock, which is the main object of interest in our analysis.

3.2. Data

Our data are monthly and cover the sample period from July 1962 to June 2019. We summarize the Treasury yield curve using 109 yields on zero-coupon Treasuries with maturities from 12 to 120 months. We obtain these as end-of-month observations from Gurkaynak, Sack and Wright (2007). We further include the expected average future short rate and term premium components for the yields with maturities 24, 60 and 120 months based on the model by ACM.

In the macro-yields specification, we augment these yields and yield components with a large set of macroeconomic and financial time series covering the most important categories of economic activity in the U.S. We obtain these from the FRED-MD database compiled by McCracken and Ng (2016). We further include average weekly hours of production and non-supervisory employees, the Philadelphia Fed leading indicator for the U.S. economy, the Bank of America Merrill Lynch MOVE bond volatility index, the measure of financial uncertainty from Ludvigson, Ma and Ng (2021, henceforth LMN), the excess bond premium from Gilchrist and Zakrajšek (2012, henceforth GZ), the measure of realized stock market volatility from BDG extended to the end of our sample period, and the 3-Month Treasury bill forecast from the Consensus Economics Survey of Professional Forecasters. Of the 135 series, 125 are available from July 1962 to June 2019. A complete list of macroeconomic and financial variables is provided in the Data Appendix.

3.3. Estimation and Standard Errors

We estimate the model using a two-step approach. First, we estimate the yield curve factors F_t^Y as the principal components extracted from the set of 109 Treasury yields. For the macro-yields model, we augment the estimates of F_t^Y with macroeconomic factors that we normalize to be unconditionally orthogonal to the yield curve factors by regressing the macroeconomic variables on the estimate of F_t^Y, and then computing principal components of the residuals. This estimation procedure resembles that of FAVARs as described by Stock and Watson (2016, footnote 27), where the estimates of F_t^Y are treated as observed. It ensures that the factor loadings Λ_{YY} are identical in both models and that the first two yields principal components have the interpretation as the yield curve level and slope. As a second step, given the estimated set of factors, we estimate factor VARs with the lag order selected by BIC with $1 \leq p \leq 12$.

To compute standard errors for the impulse response functions and forecast error variance decompositions, we use a parametric bootstrap following Stock and Watson (2016), which proceeds with the following steps: (1) Estimate Λ, F_t, $\Phi(L)$, Σ_η and the idiosyncratic vector of residuals $\hat{e}_t = X_t - \hat{\Lambda}\hat{F}_t$; (2) Estimate univariate ARs for idiosyncratic residuals, $\hat{e}_{it} = \alpha_i(L)\hat{e}_{it-1} + u_{it}$; (3) Generate random draws $\tilde{\eta}_t \overset{iid}{\sim} N(0, \hat{\Sigma}_\eta)$ and $\tilde{u}_{it} \overset{iid}{\sim} N(0, \hat{\sigma}_i^2)$ and use them to generate bootstrap data as $\tilde{X}_t = \hat{\Lambda}\tilde{F}_t + \tilde{e}_t$ with $\hat{\Phi}(L)\tilde{F}_t = \tilde{\eta}_t$ and $\tilde{e}_{it} = \hat{\alpha}_i(L)\tilde{e}_{it} + \tilde{u}_{it}$; (4) Estimate the model parameters, impulse response functions and forecast error variance decompositions; (5) Repeat steps 3-4 for 500 bootstrap replications and compute the standard errors.

3.4. Model Selection

Stock and Watson (2002a) show that the space spanned by the factors can be constructed by principal components analysis when N and T are large and the number of principal components is equal to or greater than the number of factors r. The number of factors can be consistently estimated when N and T are large using the penalized least squares criteria from Bai and Ng (2002). These balance the benefit of adding an additional factor against the cost of increased sampling variability.

Crump and Gospodinov (2019) note that estimation of the true number of yield curve factors may be empirically problematic for two reasons. First, since yields are highly persistent time series, estimates of the number of factors could be overstated. Second, the fact that yields represent cross-sectional averages of one-period forward rates could lead to a spuriously small estimated number of factors. We estimate the number of factors driving yields ($N = 109$) and the remaining macroeconomic data ($N = 135$) using Bai-Ng (2002) IC2, and in light of the analysis in Crump and Gospodinov (2019) consider the predictive ability for future yields as an additional criterion.

Table 1 provides the Bai-Ng (2002) IC2 criterion for yields and macroeconomic variables for a given number of factors i, along with the trace R^2 that measures the fraction of total variance explained by the factors 1 to i, and the marginal trace R^2 of factor i. For the macroeconomic dataset, the trace R^2 of the first factor is much smaller (about 0.15) and the contributions of higher-order factors decline slowly compared to the yield dataset. The Bai-Ng (2002) IC2 selects eight factors which capture more than 48 percent of the variation of all FRED-MD series. This estimate is consistent with McCracken and Ng (2016), who also estimate eight factors for essentially the same set of variables and a slightly shorter sample. For the yield dataset, the trace R^2 shows that the first factor explains around 99 percent of the overall variance of yields in our sample, in line with previous evidence. Despite this large share of variance explained by the first principal component, the Bai-Ng (2002) IC2 criterion selects five yield factors (the maximum number of factors we consider). While the higher-order yield curve factors have tiny marginal explanatory power for yield variances, they have significant marginal predictive power for future individual yields, as we show next. Specifically, we run the following regressions of one-year yield changes on factor estimates, $\hat{F}_t$:

$$y_{t+12}^{(n)} - y_t^{(n)} = \beta_0 + \beta_1' \hat{F}_t + e_{t+12}, \tag{10}$$

where e_{t+12} is the error term due to innovations orthogonal to $\hat{F}_t$. Table 2 reports the estimates of β_1, and the $\bar{R}^2$ for the two, five, and ten-year Treasury, assuming different numbers of yield curve factors. We compute Newey-West HAC standard errors with 18 lags, following Cochrane and Piazzesi (2005), who use 18 lags in similar predictive regressions for bond returns. For all three maturities the fifth yield curve principal component, $\hat{F}_{5t}$, has strongly significant marginal predictive power for future yield changes over and above the first three principal components of yields. Including the fourth and fifth yield curve principal components (columns 2, 5, and 8) markedly increases predictability with respect to the first three principal components (columns 1, 4, 7), with the $\bar{R}^2$ increasing from 5 to 9 percent for the two-year maturity, from 8 to 13 percent for the five-year maturity, and from 14 to 19 percent for the ten-year maturity. Adding the eight additional macro factors (columns 3, 6, 9) further raises predictability, with $\bar{R}^2$ values increasing to 22-25 percent. This is consistent with e.g. Moench (2008) and Ludvigson and Ng (2009) and suggests that information embedded in these macro factors helps to capture future yield variation.

Informed by these results, we set the number of yield factors to five in both specifications. This choice is consistent with ACM, who use the same underlying Treasury yield data but a different sample and test for the number of factors using a rank test of the factor loading matrix. Another reason to include additional yield factors beyond the first three principal components is the "excess volatility" of asset prices relative to affine models. As Giglio and Kelly (2018) document, the volatility of very long-term Treasury yields exceeds that implied by a standard affine model with three factors. In unreported results, we find that a five-factor model for Treasuries does not exhibit excess volatility in our sample. Based on the BIC with $1 \leq p \leq 12$, we further set the lag order in the factor VARs to $p = 2$.[3]

4. Results

This section summarizes our results. We start by providing impulse responses and forecast error variance decompositions for the three identified shocks to the yield curve in Section 4.1. We show that the yield news shock is associated with strong contemporaneous responses of financial market volatility and leading business cycle indicators. In Section 4.2, we then explicitly identify innovations to realized and implied stock market volatility and document that these are positively correlated with the yield news shock. Section 4.3 isolates shocks to contemporaneous volatility from those to expectations of future volatility, and shows that the contractionary effects of innovations to volatility on yields derive from the former. To shed further light on the link between yield news and leading economic indicators, we explicitly identify a business cycle news shock in Section 4.4. We show that this shock also leads to a persistent compression of expected future short rates and thus has a long-lasting effect on yields while being largely hidden in the contemporaneous yield curve. About three quarters of the yield news shock are captured by the realized volatility and business cycle news shocks. Section 4.5 documents that the residual component of the yield news shock is associated with persistent responses of international sovereign bond yields. Finally, Section 4.6 performs several robustness analyses. They show that the similarity between the yield news, realized volatility and business cycle news shocks i) is not driven by our use of principal components to summarize yield curve variation; ii) prevails when we include the volatility and leading business cycle indicators as observed factors; and iii) that the yield news

[3]The estimated lag order greater than one in the only-yields model is consistent with recent evidence that yield dynamics may not be fully Markovian; see e.g. Cochrane and Piazzesi (2005) and Hanson, Lucca and Wright (2017).

shock is different from the yield curve slope shock studied by Kurmann and Otrok (2013).

4.1. *Yield Curve Shocks*

We start by documenting that the three yield curve shocks combined explain all yield curve variation. Figure 1 (panel a) provides forecast error variance decompositions for the two-year (top row), five-year (middle row), and ten-year Treasury yields (bottom row). The first three columns provide the shares of FEV explained by the level, slope and yield news shocks, and the fourth column provides the sum of the shares explained by the three shocks. The blue dashed lines show the estimates from the only-yields model, the black solid lines from the macro-yields model. In both models, the level shock explains at least 90 percent of the contemporaneous response of Treasury yields. The contribution of this shock to the FEV declines to about 70 percent at the three-year horizon in the only-yields model, and to about 50 percent in the macro-yields model. A shock to the slope factor explains considerably smaller shares of variance; it is highest at about 15 percent of the variance on impact for the two-year maturity, and slowly declines towards zero for longer forecast horizons. The variance shares explained by the slope shock are similarly low in both the only-yields and the macro-yields specifications.

The FEV contributions of the yield news shock, shown in the third column, are strikingly different. As imposed through its orthogonality with level and slope, the news shock explains essentially none of the contemporaneous variation of yields. However, the longer the horizon the more prominent the role of the news shock. At the three-year horizon, the yield news shocks explains about 30 percent of the yield curve variation in the only-yields and a staggering 50 percent in the macro-yields model.[4] Hence, a large share of the medium to longer-term variation in Treasury yields is driven by a shock that does not move yields contemporaneously. This finding strongly supports previous evidence for unspanned or hidden factors in the term structure of interest rates. The fact that the FEV contributions of the news shock are substantially larger in the macro-yields model suggests that macroeconomic information that is not captured by yields contemporaneously explains future yield curve variation.

Strikingly, the three shocks combined explain essentially all of the variation in Treasury

[4]Note that these estimates are from two structural DFMs with a different number of factors (5 in the only-yields and 13 in the macro-yields model), and therefore one may view them as not being fully comparable. As an alternative, we have applied the Gorodnichenko and Lee (2020) R^2 method for consistent comparison of the contributions of the identified shocks from different model specifications. This proceeds in several steps. First, estimate Equation (10) using the lagged values of 13 macro-yields factor estimates as predictors, and obtain the h-step ahead forecast errors as the residual from these regressions. Then, the FEVD estimator is R^2 of the regression of the forecast error on the current and future v_t^{Level}, v_t^{Slope} and v_t^{News} that are identified from the only-yields and the macro-yields specification of the structural DFM. This obtains the combined share explained by these three shocks. To further decompose this into the contributions from each shock, we can use the Frisch-Waugh-Lovell theorem by first regressing the forecast errors on current and future v_t^{Level}, then on current and future v_t^{Slope} after removing the variation associated with current and future v_t^{Level}, and lastly on current and future v_t^{News} after removing the variation associated with current and future v_t^{Level} and v_t^{Slope}. We find that these local projection estimates (not shown here) are essentially identical to those in Figure 1, and therefore support the comparison of estimates across our two different structural DFM specifications.

yields for horizons as far as three years out. Hence, studying these three shocks we can disentangle the different driving forces of Treasury yields. The bottom panel of Figure 1 shows that the level and slope shocks identified in the two model specifications are almost perfectly correlated, while the correlation between the yield news shocks across the two model specifications is 0.59. This reinforces the notion that macroeconomic information is important for future yield curve variation, over and above the information contained in yields themselves. In the following, we therefore focus on the shocks identified in the richer macro-yields model.[5]

Yield Response to Yield Curve Shocks: Our identification of shocks driving Treasury yields follows statistical criteria. We thus provide an economic interpretation of the shocks via impulse response analysis. We show the impulse responses of the two- and ten-year Treasury yields to the shocks in the first column of Figure 2. We scale all three shocks so that they each lead to the same peak decline of the two-year yield as implied by a one-standard-deviation impulse of the yield news shock. This corresponds to a roughly negative 25 basis points peak decline of the two-year yield in the point estimates.

The level shock, shown in the top row, reduces both yields by about 23 and 17 basis points on impact. The responses are quite persistent, slowly returning to zero over the subsequent years, with a half-life of about two years. The slope shock (middle row) implies initial responses of opposite sign for the two-year and the ten-year Treasury. While the two-year Treasury falls by about 20 bps, the ten-year yield increases by a similar amount, thus resulting in a steepening of the yield curve by almost 50 bps. Slope shocks are less persistent than level shocks, and die out after about 18 months. In contrast, the yield news shock (bottom row) does not move yields on impact, as per construction. However, yields drop sharply during the first few months after the shock hits, with the two-year yield declining by 25 bps and the ten-year yield by about 15 bps after one year. The responses are even more persistent than those of the level shock, and remain substantially negative in the first three years.

How can a shock that does not move yields contemporaneously have such a strong effect on future yields? A common explanation in the literature on unspanned factors in the term structure is that such factors have an offsetting initial impact on the term premium and expected short rate components of yields, but differential impacts at longer horizons. We can see if this is also the case fo the yield news shock by studying the impulse responses of both yield components to this shock. As discussed above, we do so by augmenting our panel of macroeconomic variables and Treasury yields with estimated risk-neutral yield and term premium components from ACM.[6]

[5]Note that we use final revised macroeconomic data in our analysis. Ghysels, Horan and Moench (2017) show that the predictive content of macro variables for future bond returns is considerably higher when final revised instead of real-time data are considered. Moreover, macroeconomic data revisions are correlated with future bond yields. Some of the additional predictive content of news shocks in the macro-yields model might thus be attributed to embedded data revision components.

[6]Daily updates of these decompositions can be found on Bloomberg and Haver, and also here: https://www.newyorkfed.org/medialibrary/media/research/data_indicators/ACMTermPremium.xls.

The former measures the average expected future short rate over the life of the bond while the latter represents an estimate of the compensation investors demand for holding longer-term Treasuries instead of rolling over short-term bills. As we use the same underlying yields as ACM in our analysis and as the ACM model fits these yields close to perfectly, the impulse responses of the risk-neutral yield and term premium sum to the responses for the corresponding yield itself.

The top panel of Figure 2 provides the impulse responses. The first column shows the response of yields, the middle that of expected short rates and the last column that of term premiums. Focusing on the level shock first (top row), we see that the bulk of the yield response to that shock is driven by a sharp and persistent drop of expected future short rates, accompanied by a quantitatively smaller but also persistent decline in term premiums. The slope shock (middle row) elicits an initial reduction of expected future short rates of about 40 bps at the two-year maturity and 20 bps at the ten-year maturity. The decline in expected short rates is relatively persistent, taking two years to converge back to zero. Interestingly, the slope shock is also followed by a persistent increase in term premiums, which partly offsets the initial decline in expected short rates. The responses to the yield news shock (bottom row) show that expected future short rates drop by only a few basis points initially, but then continue to decline sharply over the next year or so, largely mimicking the shape and magnitude of the yield responses. Term premiums initially rise by the same amount as risk-neutral yields fall. As a result, the on-impact response of yields – which equals the sum of the two components – is essentially zero, thus "hiding" the news shock in contemporaneous yields. Notably, while the yield news shock initially drives up term premiums by a few basis points, that response turns negative after about two to three years, thus contributing to the strong and persistent response of yields to the news shock at longer horizons.

The bottom panel of Figure 2 shows the FEV decompositions for the yields and their two components. The charts highlight that yield variation at shorter horizons in response to the level shock (top row) is almost entirely driven by the response of expected future short rates and only to a small extent by term premiums. The opposite picture emerges for the slope shock (middle row). It explains about 20-30 percent of the variation of expected short rates on impact, and this fraction slowly declines with the forecast horizon. In contrast, the slope shock explains about 80 percent of the variation of the ten-year term premium on impact, which declines to a sizable 50 percent after three years. The fraction of variance explained for the two-year term premium ranges between 20 percent on impact to 50 percent after one year and 40 percent after three years. It is worth noting that since the expected short rate and term premium responses to the slope shock are of opposite signs, the sizable term premium variance shares explained by the slope shock do not translate into substantial yield variation. Turning to the bottom row, we see that essentially all of the yield variation induced by the news shock is driven by its highly persistent impact on expected future short rates. Only small fractions of term premiums variation are explained by the news shock. At longer horizons, yield variation is accounted for by level and news shocks in similar magnitudes, and is mainly driven by the expected short rate component. To better understand the economics behind the three shocks driving Treasury yields, we next study their impact on key financial and macroeconomic variables.

Financial Market Response to Yield Curve Shocks: Figure 3 (panel a) provides impulse responses of the S&P500 index; the MOVE index, which captures implied volatility from a basket of Treasury options; the VXO index, which measures volatility implied in S&P100 options and is the precursor to the VIX index; realized stock market volatility (RVol), and the GZ excess bond premium (EBP). For comparison, we again show the responses of the two-year Treasury yield. Focusing first on the response of the S&P 500 index, we see that stock prices rise by about 70 bps and remain elevated in response to a level shock (blue line), and drop by about 40 bps before they revert back to zero in response to a slope shock (black line). The S&P 500 drops much more strongly, by about 2 percent, in reaction to a yield news shock (red line), and this response is very long-lasting. Notice that the sharp decline of stock prices on impact is in stark contrast to the zero contemporaneous response of Treasury yields to a news shock.

Looking at the responses of VXO, RVol, MOVE and EBP, the following picture emerges. Level shocks have essentially no impact on any of the financial market indicators. Slope shocks elicit a sizable response of Treasury option implied volatility, but only moderate responses of the other financial indicators. Again in sharp contrast, the yield news shock is associated with sharp and persistent increases of bond and stock market volatility. The VXO jumps by about 2.5 percent on impact, and only reverts back to its initial level after more than one year. This pattern is paralleled by realized stock market volatility which also jumps on impact and then reverts back over a period of more than one year. The MOVE and the EBP all show similar responses. Hence, despite the fact that it is not apparent in Treasury yields initially, the yield news shock is associated with large spikes in financial market indicators that are consistent with heightened volatility and risk premiums. The sharp response of stock prices and volatility indices to yield news shocks is also reflected in the FEV decompositions provided in the bottom panel of Figure 3. The yield news shock explains around 20-30 percent of the forecast error variance of stock prices, financial volatility indices and the credit risk premium across forecast horizons. In contrast, the level and slope shocks explain little if any of the variation of these key financial market indicators.

Macroeconomic Response to Yield Curve Shocks: The previous set of results document that a yield news shock is associated with a sharp increase in financial market volatility and risk premiums. A vast literature pioneered by Bloom (2009) has shown that shocks to implied and realized financial market volatility are important drivers of macroeconomic dynamics. Given that our identified yield news shock is associated with a sharp contemporaneous increase in realized and implied volatility, we investigate whether it induces similarly strong effects on macroeconomic aggregates.

The top panel of Figure 4 provides impulse responses for key macro indicators to the three yield curve shocks. They show that shocks to the yield curve level have essentially no discernible effect on real macroeconomic aggregates. That said, they are associated with a small but persistent drop of CPI inflation and a persistent but shallow decline in the federal funds rate and in expected future three-month Treasury bill forecasts from the Consensus Survey. The responses to the slope shock are economically more sizable. Industrial production, nonfarm payroll and personal consumption expenditures all start to rise after a few months but then increase persistently, with the growth rate of industrial production being about one percent higher after three years. This economic expansion is mirrored by a hump-shaped increase in the Philadelphia Fed Leading Indicator and housing starts, as well as a persistent decline of initial claims for unemployment insurance. Slope shocks also appear to be related to monetary policy as they are followed by a lower federal funds rate and a lower expected path of policy rates.

The impulse responses to the yield news shock paint a different picture. All measures of real economic activity fall persistently. IP growth declines by a little less than one percent after one year, nonfarm payrolls fall by about half a percent, and personal consumption expenditures by about 0.2 percent. While the initial response of these measures of real activity is only small, a yield news shock is associated with a sharp response of several leading business cycle indicators, as shown in the second row of Figure 4. The Philadelphia Fed Leading Economic Indicator, housing starts, and initial claims all show a strong and persistent reaction when the yield news shock hits. Hence, in addition to hightened financial market volatility the yield news shock is associated with negative news about the state of the business cycle. The strong negative response of leading indicators is accompanied by a small but persistent drop in inflation. The Federal Reserve accommodates the decline of inflation and real activity by lowering the federal funds rate persistently. Professional forecasters understand this and also persistently lower their expectations of the three-month Treasury bill rate.

The forecast error variance decompositions in the bottom panel of Figure 4 underscore these findings. The contributions of level and slope shocks to the variation in key macroeconomic variables are small. The level shock only meaningfully contributes to the variation in the federal funds rate itself and expected future TBill yields. The slope shock explains some variation of real economic growth, especially at longer forecast horizons, consistent with a prior literature documenting predictive power of the term spread for economic conditions several quarters out. In sharp contrast, the yield news shock explains large fractions of the forecast error variance of macroeconomic aggregates at all but the shortest horizons. At the one-year horizon, the shock explains more than 40 percent of the variation of IP growth and a staggering 60 percent of the variation in nonfarm payroll growth.

The top panel of Figure 5 provides a time series plot of the identified yield news shock series. Positive realizations of the shock seem to cluster before and during recessions, whereas negative observations tend to occur more often just after recessions. That said, while the shock series is somewhat heavy-tailed, it does not feature much skewness. To better visualize its cyclical properties, the bottom panel of the figure shows the shock series run through an AR(1) filter with autoregressive coefficient of 0.9. This chart clearly indicates that recessions are associated with strings of positive yield news, while negative realizations tend to cluster right after recessions.

The filtered series is strongly negatively correlated with 12-month IP growth, confirming the counter-cyclical behavior of the yield news shock series.

Combined with the impulse responses discussed above, this countercyclical pattern suggests that a yield news shock, which affects Treasury yields not contemporaneously but in the future, has properties akin to those documented for uncertainty shocks (e.g., Bloom, 2009; Basu and Bundick, 2017) and, more recently, shocks to realized stock market volatility as in BDG. In the next section, we explicitly contrast the impulse responses to the yield news shock with those to identified shocks to implied and realized stock market volatility.

4.2. Shocks to Implied and Realized Stock Market Volatility

For implied volatility, our identification closely follows Caldara, Fuentes-Albero, Gilchrist and Zakrajšek (2016), who use a structural VAR to identify an uncertainty shock as an innovation that leads to the largest positive response in a measure of uncertainty over the first six months after the shock hits. We deviate from their approach in two ways. First, we achieve identification by maximizing the forecast error variance share of an uncertainty measure, in the same way as we identify the yield news shock.[7] In contrast, Caldara, Fuentes-Albero, Gilchrist and Zakrajšek (2016) use a penalty function approach which maximizes the impulse responses as opposed to the forecast error variance of the target variable. Second, we identify the shock within our structural macro-yields DFM as opposed to a structural VAR. This allows us to estimate responses for the same variables in an internally consistent way and enables comparison of the responses to the yield news and uncertainty shocks. As our baseline measure, we use the VXO to identify an implied volatility shock. For comparison, we also show the responses for two more shocks targeting the MOVE and the LMN indices in Figures A.1 to A.3 in the Appendix.

Measures of implied volatility from stock options are highly correlated with measures of realized stock market volatility. In recent work, BDG document that it is realizations of contemporaneous volatility rather than anticipations of future volatility that are associated with sharp and protracted declines of real economic activity. In light of this finding, we contrast the impulse responses for the yield news shock with those of shocks to implied and realized stock market volatility. Specifically, we identify a shock to realized volatility as the innovation which maximizes the FEV share of realized volatility over the next month. We choose the horizon of one

[7]To be precise, the goal is to identify a single shock that explains a maximum share of forecast error variation in a volatility measure over h periods. Let the volatility shock be indexed by 1, and let the volatility measure in X_t be indexed by j. Because the lag matrices in $\Lambda\Phi(L)^{-1}$ and the variance-covariance matrix of the factor innovations Σ_η in (5) are identified, $C(L)$ is identified, and in turn we only need to identify the first column of the matrix Q. This is achieved by solving $\underset{Q_1}{\operatorname{argmax}} \frac{\Sigma_{k=0}^{h-1}\left(C_{k,j}Q_1\right)^2}{\operatorname{var}\left(X_{jt+h}|X_t,X_{t-1},\ldots\right)}$, subject to $Q_1'Q_1 = 1$, where $C_{k,j}$ is the jth row of the kth lag matrix in $C(L)$, and the constraint ensures that Q_1 is an orthonormal vector. Similarly to the argument in Section 2, the solution of this latter problem obtains as the eigenvector associated with the first eigenvalue of the $r \times r$ matrix $\frac{\Sigma_{k=0}^{h-1}\left(C_{k,j}'C_{k,j}\right)}{\operatorname{var}\left(X_{jt+h}|X_t,X_{t-1},\ldots\right)}$.

month to focus on contemporaneous innovations to volatility and not to confound these with anticipations of future volatility.

Financial Market Response to Realized and Implied Volatility Shocks: We first show the impulse responses of financial market variables to the two volatility shocks. The top panel of Figure 6 provides the responses of the two-year Treasury yield, the S&P500 index, the volatility measures and the EBP to shocks to the implied volatility (purple solid line) and the realized volatility (blue dashed line). For comparison, we superimpose the responses for a yield news shock studied in the previous section.[8] The impulse responses to all three innovations are strikingly similar. They are essentially indistinguishable for the two-year Treasury yield. The MOVE, VXO and RVol indices also respond almost identically. The responses of the S&P500 are also similar, the most important difference being that the implied and realized volatility shocks elicit a somewhat stronger stock market reaction than the yield news shock. The corresponding FEVDs shown in the bottom panel of Figure 6 confirm these findings: yield news and shocks to implied and realized stock market volatility explain similarly large proportions of the variation in key financial variables.

Yield Response to Realized and Implied Volatility Shocks: We next compare the responses of Treasury yields and their components to the three shocks. The top panel of Figure 7 shows that while Treasury yields only show a muted response to the shocks on impact, they drop sharply in subsequent months, and persistently remain below their initial level thereafter. The impulse responses to the implied and realized volatility shocks essentially mimic those of the yield news shock which are again superimposed. As for the yield news shock, the strong delayed response of yields is primarily driven by their expected short rate component. In contrast, the term premium component of yields rises somewhat initially, and then slowly declines over subsequent years. That said, the stock market volatility shocks are associated with a somewhat stronger response of term premiums. Since term premiums and expected short rate components induce impulse responses of opposite signs, the share of yield variance explained by the volatility shocks is slightly lower than for the yield news shock, as shown in the bottom panel of Figure 7.

Macroeconomic Response to Realized and Implied Volatility Shocks: We next study the responses of our set of key macroeconomic variables to the two stock market volatility shocks. These are provided in the top panel of Figure 8. Not surprisingly, the responses are again very similar and mimic closely those obtained for the yield news shock. Industrial production, nonfarm payroll employment, and personal consumption expenditures all decline significantly with some delay. Leading indicators respond sharply on impact and remain elevated for one to two years. Inflation drops only slightly but persistently. The Federal Reserve responds by persistently lowering the federal funds rate. After a few months, professional forecasters incorporate this pol-

[8]Similarly to the level and slope shocks studied in the previous section, we rescale the responses to the realized and implied volatility shocks so that they each generate the same peak decline of the two-year yield as a one-standard-deviation yield news shock.

icy response into their projections for short-term rates. The quantitative importance of the shocks for macroeconomic dynamics is highlighted in the forecast error variance decompositions in the bottom panel of Figure 8. Similar to the yield news shock, the shocks to implied and realized stock market volatility explain about 50 percent of the variation in nonfarm payrolls at horizons from about one to three years. Around 30 percent of the federal funds rate variation at the three-year horizon is explained by the two volatility shocks, a highly significant but somewhat smaller share than that explained by the yield news shock.

The previous results have highlighted the close similarity in impulse responses of yields, their components, and macroeconomic aggregates to the shocks to realized and implied stock market volatility and the yield news shock. In the next section, we disentangle between innovations to contemporaneous and expected volatility and contrast them to the yield news shock.

4.3. Uncertainty About the Future or Realization of Current Volatility?

So far, we have shown that the responses to the yield news shock and shocks to implied and realized stock market volatility are similar. As discussed above, BDG show that it is the shocks to realized volatility rather than those driving expected future volatility that strongly affect macroeconomic aggregates. In light of their finding, we next seek to tease out the incremental contributions of innovations to realized and implied stock market volatility to the observed responses of financial and macroeconomic variables. We do so by separately identifying the two shocks in the macro-yields DFM: a realized volatility shock as before; and an uncertainty shock identified as a shock that explains the highest share of the forecast error variance in the VXO over the next six months, but is orthogonal to the realized volatility shock. Hence, the uncertainty shock is purged from having any impact on the realization of current volatility.[9]

Figure 9 provides the results. The dashed blue and purple lines show the impulse responses for the independently identified shocks to realized and implied stock market volatility as already shown in the previous figures, respectively. The brown solid lines and associated bands show the response of the identified uncertainty shock, i.e. the component in implied stock market volatility that is orthogonal to contemporaneous movement in realized volatility.[10] Looking first at the responses of the two-year yield and other financial market indicators in the top panel, we see a much more muted and somewhat short-lived response of the uncertainty component of implied volatility compared to the realized volatility component. This is also reflected in the sizably smaller variance shares explained by the uncertainty shock for all financial market indicators, as shown in the bottom panel. Hence, it is the realization of stock market volatility

[9]We achieve identification of the two shocks sequentially. The realized volatility shock (Q_1) is identified by maximizing the share of the forecast error variance of RVol over the next month. Then, given Q_1, we identify the uncertainty shock (Q_2) by maximizing the share of forecast error variance of the VXO over the next six months, subject to $Q_2'Q_1 = 0$. We solve the latter problem by using a numerical procedure.

[10]As before, the responses for realized and implied volatility shocks are scaled so that they each produce the same peak decline in the two-year yield as a one-standard-deviation yield news shock. The uncertainty shock is scaled so that it has the same cumulative effect on the VXO over the next 2-60 months as the implied volatility shock.

rather than anticipation of future uncertainty that mainly drives these responses.

Figure 10 provides the corresponding impulse responses of yields and their components in the top panel and FEV decompositions in the bottom panel. While the shocks to realized and implied stock market volatility both lead to the previously discussed persistent and delayed decline of yields which is primarily driven by their expected short rate component, the uncertainty component of implied volatility induces very different responses. Short rate expectations show a relatively mild and short-lived increase followed by a subsequent decline while term premiums persistently rise. These impulse responses are mirrored by FEV decompositions which underscore that it is the realized component of stock market volatility rather than uncertainty about future that primarily drives the observed yield curve response to increased stock market volatility.

In sum, the results in this section show that the striking similarity of yield news shocks and innovations to stock market volatility shocks documented in the previous section is primarily driven by contemporaneous responses to realized volatility, and not by expectations of future volatility, i.e. uncertainty. In particular, heightened realized stock market volatility is associated with a short-lived increase in term premiums and a persistent decrease in short rate expectations which leads to a protracted compression of yields.

4.4. News about the Business Cycle

We have seen in Section 4.1 that the yield news shock is also associated with a sharp contemporaneous response of leading indicators of the business cycle, which peaks within one year. This suggests that in addition to realized volatility, the effects of the yield news shock could also reflect responses to broader news about the business cycle. To shed light on this potential interpretation, we identify a business cycle news shock as a shock that jointly maximizes the FEV shares of a set of standard leading business cycle indicators: the Philadelphia Fed's leading index for the US economy, initial claims for unemployment insurance, and housing starts. We set the horizon to one year ahead, a choice consistent with Angeletos, Collard and Dellas (2020) who argue that a shock identified this way dominates the variation of target variables (leading indicators in our case) over business cycle frequencies. As before, we scale the business cycle news shock so that it leads to the same peak decline of the two-year yield as a one-standard-deviation yield news shock.

Figures 11 to 13 provide the results. The impulse responses and FEV decompositions of the business cycle news shock with associated error bands are shown in green, the corresponding objects for the yield news shock are superimposed as red dotted lines. Focusing first on the yields and their components in the top panel of Figure 11, we observe a similarity between the two news shocks. Both lead to persistently lower yields, primarily driven by a compression of expected short rates. Moreover, both news shocks are contemporaneously hidden in yields as expected rates and term premiums feature offsetting initial responses. However, while the yield news shock leads to an initial compression of expected short rates and an increase in term premiums, the opposite is true for the business cycle news shock. Although the impulse responses for the two shocks share similar features, the bottom panel of Figure 11 indicates that business cycle news explain only about half of the variation of yields compared to the yield news shock. That said, Figure 12 shows that with the exception of Treasury yields, the responses of the other financial variables to the two news shocks are quite similar. Finally, Figure 13 provides the results for the set of macroeconomic aggregates and leading indicators. The impulse responses show qualitatively similar but quantitatively more pronounced responses of these variables to the business cycle news shock as compared to the yield news shock. With the exception of the fed funds rate and survey forecasts of the TBill rate, the contribution of the business cycle news shock to variation in these variables is also more pronounced, especially at longer horizons.

These results highlight that the yield news shock is also associated with macroeconomic and financial market responses that are similar to those implied by a business cycle news shock. In light of this finding and the observation that shocks to realized volatility also feature similar responses, a natural question is to what extent the three shocks – yield news, realized volatility, and business cycle news – are correlated. Table 3 provides the in-sample correlation coefficients between the different shocks identified in the previous sections. We focus our attention on the correlations between the yield news shock, the realized volatility and the business cycle news shocks. As shown in the third column of the table, the yield news shock is similarly strongly correlated with the realized volatility and business cycle news shocks. Both correlation coefficients are around 75 percent. Figure 14 provides plots of the realized volatility and business cycle news shocks, run through an AR(1) filter with autocorrelation coefficient of 0.9. In both charts, we superimpose the filtered yield news shock. The charts visualize the similarities between the three shock series, but they also show that they behave quite differently in certain periods. For example, in the period around the double-dip recession in the early 1980s, the yield news shock featured a sequence of negative realizations, indicating a sharp rise of expected future short rates that was not associated with by heightened stock market volatility or particularly negative news about the US economy at the time. Instead, these yield news likely reflected expectations of a series of rate hikes by the newly appointed Federal Reserve chairman Volcker which were hidden in yields as term premiums increased concurrently.

The charts also document that the realized volatility and business cycle news shocks share similar time series dynamics. Table 3 confirms that they are about 60 percent correlated. In unreported results, we find that the shock to realized volatility and the business cycle news shock generate very different responses of the financial market and macroeconomic variables once they have been orthogonalized to one another. A realized volatility shock purged of business cycle news explains only a small fraction (if any) of the variation in leading indicators and real activity variables. A business cycle news shock purged of realized volatility, in turn, explains only a small share of the variation in stock and bond market volatility measures. This suggests that while the two shocks capture partially overlapping information, they also represent different sources of variability of economic and financial indicators. A regression of the yield news shock on the realized volatility and business cycle news shocks combined delivers an adjusted R-squared of 70 percent. Hence, about three quarters of the variation of the yield news shock are captured by these two innovations. This begs the question what captures the residual variation of the yield news shock.

4.5. Residual Variation in Yield News

To answer this question, we identify a yield news shock that is by construction orthogonal to the realized volatility and business cycle news shocks. Specifically, we include two additional orthogonality constraints in the optimization problem in Equation (8). The resulting shock is thus the shock which maximizes future yield variation and is orthogonal to shocks to level, slope, realized stock market volatility and business cycle news. Figures 15 and 16 compare the impulse responses and FEV decompositions of the original with those of the orthogonalized yield news shock. The picture emerging is that much of the financial market and macroeconomic response to the yield news shock is indeed subsumed by the other two shocks. The orthogonalized shock is associated with few significant responses and explains little to no variation in most of the considered variables. A crucial exception are Treasury yields, however, of which a significant share is captured by the orthogonalized yield news shock, especially at longer maturities and horizons.

Previous work has documented a strong comovement of global sovereign bond yields (Diebold, Li and Yue 2008; Dahlquist and Hasseltoft 2013; Adrian, Crump, Durham and Moench 2018, henceforth ACDM). Hence, innovations driving joint variation in international bond markets represent a candidate source of residual Treasury yield variation embedded in the yield news shock that is not captured by realized stock market volatility and U.S. business cycle news. To verify this conjecture, we study the impulse responses of yields and their components to the orthogonalized yield news shock for three major economies: Japan, Germany, and the U.K. We obtain the yield curve decompositions into expected short rate paths and term premiums from ACDM who apply a four-factor version of the model in Adrian, Crump and Moench (2013) to the zero coupon yield curves denominated in the respective home currency.

The impulse responses for the ten-year yield and its components are provided in the top panel of Figure 17. The red solid line and associated bands again capture the responses to the yield news shock, the dashed yellow lines those of the orthogonalized yield news shock. The first column shows the ten-year U.S. Treasury yield for reference. The second to fourth columns display the impulse responses for Germany, the U.K. and Japan, respectively. They document that international bond yields respond very similarly to the U.S. yield news shock. The initial response is muted, but yields in all four economies sharply decline after a few months. While this decline is primarily driven by a compression of expected short rates in the U.S., in the other three countries term premiums also account for some of the yield compression. Importantly, the orthogonalized yield news shock is associated with economically and statistically significant variation of yields and their components in all countries. The bottom panel of the figure provides the associated forecast error variance decompositions. These show that the yield news shock purged from realized volatility and U.S. business cycle news explains about as much of the variation of international sovereign yields and their components as the unorthogonalized yield news shock. These results suggest that news related to international bond markets account for the residual variation of Treasury yields embedded in the yield news shock.

To summarize, the evidence presented in the previous sections and here suggests that three distinct sources of variation account for U.S. Treasury yield variation associated with the identified yield news shock. First, a surprise increase in realized stock market volatility leads to a delayed but persistent decline of federal funds rate expectations and Treasury yields. Second, surprisingly negative news about the U.S. business cycle as captured by standard leading indicators have a similar effect: they lead bond market investors to correctly anticipate the Federal Reserve to cut policy rates. As a result, yields get compressed with a few months delay. Third, while essentially all of the predictive information about macroeconomic conditions embedded in the yield news shock is captured by these two sources of variation, there is a sizable forward-looking component in Treasury yields that is not subsumed by the realized volatility and business cycle news shocks. This component appears to be related to news which drive comovement in international bond markets.

4.6. Robustness

In this section, we document that our results are robust along several dimensions. First, in light of the difficulty in identifying the true factor space in bond yields documented by Crump and Gospodinov (2019), we show that the yield curve shocks that we identify from yield factors are essentially identical to a similar set of shocks identified from a VAR in individual yields. Second, we expand this VAR to also include a small number of macroeconomic and financial market volatility variables. We further estimate a macro-yields FAVAR using the VXO and realized stock market volatility as observed factors. We show that the impulse responses for yield news, realized volatility and business cycle news shocks are highly similar when identified in either of these two alternative models or the baseline macro-yields DFM. Finally, we show that our yield news shock implies very different responses of macroeconomic and financial variables and explains a substantially larger fraction of Treasury yield variation than the shock to the yield curve slope identified in Kurmann and Otrok (2013).

4.6.1. Comparison with an Only-Yields Structural VAR

Our identification relies on the assumption that the yield news shock can be expressed as a linear combination of the innovations to a small number of factors, estimated by principal components. This identification thus requires that principal components accurately capture the true factor structure of yields. As discussed by Crump and Gospodinov (2019), this may be problematic for two reasons. First, estimates of the number of factors could be overstated because the yields are highly persistent time series. Second, the fact that yields represent cross-sectional averages of one-period forward rates could lead to a spuriously small estimated number of factors. In this section, we address these concerns by identifying the yield news shock in a structural VAR of Treasury yields. We then show that the resulting news shock is essentially identical to the one obtained in the only-yields specification of the structural DFM.

Specifically, we consider a monthly structural VAR estimated over the full sample from 1962-2019 which includes five variables: four Treasury yields with maturities 2, 5, 7 and 10 years, and the spread between the 10 and 1-year yields. Because the benchmark only-yields DFM includes two lags, we estimate this VAR with two lags.

As a first step, we follow Stock and Watson (2016) and analyze whether the reduced-form innovations from the VAR and the only-yields DFM span the same space by computing the canonical correlations between the reduced-form VAR innovations and the innovations of the DFM. All five canonical correlations exceed 0.98, showing that essentially no information embedded in yields is lost in the factor innovations.

Next, we identify three shocks in the VAR. The first shock is obtained as a shock explaining a maximum share of one-step-ahead forecast error variation in the four Treasury yields and the 10y-1y spread. The second shock is identified as a shock explaining a maximum share of one-step-ahead forecast error variation in the 10y-1y spread, while being orthogonal to the first shock. Finally, the third shock is identified as a shock explaining a maximum share of the forecast error variation in the five variables over a period of one year, while being orthogonal to the first and second shocks.[11]

We compute the canonical correlations between the level, slope and yield news shocks identified from the only-yields model with the three shocks from the structural VAR. All are above 0.97, again suggesting that our use of yield principal components does not result in a loss of information relative to a model where yields are used directly. Figure 18 shows the impulse responses of the two- and ten-year Treasury yields for the three shocks. The charts confirm that the yield responses obtained from the structural VAR with five variables strongly mimic those for

[11] To be precise, we use a structural VAR: $A(L)Y_t = \eta_t$ with $\eta_t = H\nu_t$ where $A(L)$ is a lag polynomial, η_t denotes the innovations with variance-covariance matrix Σ_η, and ν_t denotes the shocks with diagonal covariance Σ_ν. Similarly to Section 2, we adopt a unit standard deviation normalization and then write $Y_t = B(L)Q\nu_t$ where $B(L) = A(L)^{-1}Chol(\Sigma_\eta)$ and Q is an orthonormal matrix. The goal is to identify the first three columns Q_1, Q_2 and Q_3, which we achieve by solving three optimization problems. The first problem is to maximize the sum of one-step-ahead FEVDs of the five variables: $\underset{Q_1}{\operatorname{argmax}} \sum_{j=1}^{5} \frac{\left(B_{0,j}Q_1\right)^2}{\operatorname{var}\left(Y_{jt+1}|Y_t,Y_{t-1},\ldots\right)}$, subject to a single constraint $Q_1'Q_1 = 1$. The second problem is to maximize the one-step-ahead FEVD for the 10y-1y spread that is indexed by 1: $\underset{Q_2}{\operatorname{argmax}} \frac{\left(B_{0,1}Q_2\right)^2}{\operatorname{var}\left(Y_{1t+1}|Y_t,Y_{t-1},\ldots\right)}$, subject to two constraints $Q_2'Q_2 = 1$ and $Q_2'Q_1 = 0$. The third problem is to maximize the sum of FEVDs of the five variables over h periods: $\underset{Q_3}{\operatorname{argmax}} \sum_{j=1}^{5} \frac{\sum_{k=0}^{h-1}\left(B_{k,j}Q_3\right)^2}{\operatorname{var}\left(Y_{jt+h}|Y_t,Y_{t-1},\ldots\right)}$, subject to three constraints $Q_3'Q_3 = 1$, $Q_3'Q_2 = 0$ and $Q_3'Q_1 = 0$. Similarly, the solution to the first problem is the eigenvector associated with the first eigenvalue of the 5×5 matrix $B_0'S_{5\times5}B_0$ where $S_{5\times5}$ is a diagonal matrix with entries $\frac{1}{\operatorname{var}\left(Y_{jt+1}|Y_t,Y_{t-1},\ldots\right)}$ for $j = 1,\ldots,5$. Given the solution for Q_1, we numerically obtain a solution for the second problem, and at last, given the solutions for Q_1 and Q_2, we numerically obtain a solution for the third problem.

the level, slope and yield news shocks identified from the only-yields DFM. Hence, the difficulties in identifying the true factor structure of bond yields documented in Crump and Gospodinov (2019) do not impinge on the identification of structural shocks from yield curve factors instead of individual yields.

4.6.2. Comparison with an Alternative Structural VAR and FAVAR

In our baseline macro-yields DFM, the different shocks are identified as the linear combinations of factor innovations that maximize the forecast error variations of the target variables. Hence, these shocks are identified by maximizing the future variation of the component of the target variables that is spanned by all model factors. According to Table 4, yields are fully spanned by the five yield principal components, but only about half of the variation of RVol, four-fifths of that of the Philadelphia Fed leading indicator, and one-third of the variation of initial claims are explained by their common components, respectively. As the different identification approaches maximize the forecast error variation of only the common component in our baseline DFM, one may therefore be concerned that not considering idiosyncratic variation in these target variables biases our results.

In this section, we identify realized volatility, business cycle news and yield news shocks in two alternative model specifications that target these variables directly. The first expands the 5-yield structural VAR of Section 4.6.1 to include eight additional financial and macroeconomic variables. These are the two stock market volatility indexes VXO and RVol, the three standard leading indicators (Philadelphia Fed leading indicator, initial claims, and housing starts), as well as IP, nonfarm payroll, and CPI inflation. The second alternative model is a FAVAR in which the VXO and RVol are treated as observed factors. In this specification, we also include the five Treasury yield factors and six additional macro factors, where the latter are estimated by computing the principal components of the residuals obtained from regressing all FRED-MD series on the five yield curve factors, the VXO and RVol. Because the macro-yields DFM contains 13 factors, we also specify the two alternative models to have 13 variables. We then compare the IRFs of our baseline DFM with their counterparts obtained from the two alternative model specifications. All models are estimated for the period 1962M7 to 2019M6.[12] All the approaches used for shock identification are described as in the previous sections.

Figure 19 provides the IRFs for the yield news, realized volatility and business cycle news shocks from the DFM in comparison to the structural VAR and FAVAR specifications, where again the responses are scaled so that they each produce the same peak decline in the two-year yield. The main result of the figure is that the IRFs are robust to the two alternative model

[12] As the Philadelphia Fed leading indicator is not available before 1982, the missing observations are calculated using the expectation–maximization (EM) algorithm given in Stock and Watson (2002b). The algorithm iteratively computes the principal components from a large number of series (the FRED-MD dataset in our case) and updates missing observations using these factors. Over the post-1982 sample the Philadelphia Fed leading indicator has an R^2 of 0.84 as reported in Table 4, and this changes to 0.91 for the full period.

specifications. Hence, targeting the volatility and leading indicator variables directly rather than their common component does not alter the results.

4.6.3. Comparison to a Kurmann and Otrok (2013) Type Slope Shock

Thus far, we have shown that a yield news shock which explains a maximum share of future yield variation while being orthogonal to level and slope contemporaneously is highly correlated with identified shocks to financial market volatility and business cycle news. All three shocks are associated with a persistent decline of real activity and lower expected short rates. These results provide a new angle on the dynamic interactions between the yield curve and macroeconomic activity. While the previous literature has mostly focused on summarizing bond yields by a few factors and studying their interaction with macroeconomic aggregates, little effort has been devoted to understanding the sources of yield curve variation. A notable exception is Kurmann and Otrok (2013, henceforth KO), who identify a shock which maximizes the forecast error variance of the yield curve slope in a small-scale structural VAR. Contrasting with a news shock about future TFP, KO show that the identified TFP news and slope shocks are strongly correlated, and that the responses of different macroeconomic aggregates to both shocks are very similar.

While the yield news shock we identify maximizes the forecast error variance of level *and* slope instead of only slope, a natural question is whether our yield news shock partly captures the information embedded in the Kurmann-Otrok slope shock. To compare the two shocks, we use a macro-yields DFM estimated at the quarterly frequency. All macroeconomic series are from the FRED-QD series, compiled by McCracken and Ng (2020) and designed to emulate the dataset used in Stock and Watson (2012). We add TFP growth adjusted for variations in factor utilization as updated by Fernald (2014), which is also used by KO. The model is estimated for the sample period 1962Q3-2019Q2. The quarterly dataset is described in detail in the Appendix.

To make the quarterly DFM comparable to the monthly model used in the previous sections, we use the same number of five yield and eight macroeconomic factors. We identify the level, slope and yield news shocks exactly as before. We follow KO and identify a slope shock as a shock that explains a maximum share of forecast error variance of the spread between the five-year Treasury yield and the federal funds rate over a period of four quarters, the same horizon we used to identify a yield news shock.[13] Both identification schemes are implemented in this quarterly model based on a factor VAR with one lag, selected by BIC with $1 \leq p \leq 12$.

The upper panel of Figure 20 provides the impulse responses for the Kurman-Otrok type slope shock in comparison to the level, slope and yield news shocks. They show that the KO slope shock implies impulse responses that are quantitatively and qualitatively similar to the contemporaneous slope shock we identify. The only exception is the response of TFP growth, which is considerably larger and more persistent for the KO slope shock. Notably, while the yield

[13]Note that KO maximize the FEV of the yield spread over a period of ten years instead. The results are almost unchanged with respect to the identification using a horizon of four quarters.

news shock features very different impulse responses for almost all macro variables compared to the KO slope shock, the responses of TFP to both shocks are similar for about six months but deviate thereafter. It is also worth noting that the KO slope shock essentially leaves financial market volatility unaffected, in sharp contrast to the yield news shock.

We can gauge the relative importance of both shocks for the different variables by looking at the FEV decompositions shown in the lower panel of Figure 20. They document that both the yield news and the KO slope shock explain only about 10 percent of the variation of TFP growth. The variance shares explained for the other real activity indicators are somewhat larger in magnitude, ranging between 20 and 40 percent. Interestingly, the yield news shock tends to explain larger fractions of variance at shorter forecast horizons, while the KO shock is more relevant at longer horizons. It is important to note that while the two shocks explain similar magnitudes of macro variation, the yield news and the level shocks are substantially more important for yield variation. The Kurman-Otrok slope shock explains only slightly more than 20 percent of the variation in the two-year Treasury at shorter horizons while the level and yield news shocks both explain about 50 percent and thus, combined, essentially all of the variation of yields at longer horizons. That said, by construction the KO shock explains sizable fractions of the FEV of the term spread across horizons.

To summarize, these results show that our shock identification is very different from the one in Kurmann and Otrok (2013) and provides complementary insights into which shocks move Treasury yields and what economic interpretation these shocks have.

5. Conclusion

In this paper, we jointly characterize the dynamics of a large number of macroeconomic variables and Treasury yields in a dynamic factor model. We find that three shocks explain essentially all of the variation of yields at forecast horizons from one month to several years out: two shocks that contemporaneously move the level and the slope of the yield curve and, importantly, a yield news shock that does not move yields initially, but explains about half of their variation at forecast horizons several years out. The impact of the news shock remains hidden in contemporaneous yields since it initially shifts their expected future short rate and term premium components in opposite directions. At the same time, the shock is associated with sharp and persistent increases in realized and implied stock and bond market volatility, a drop of stock prices, and sharp reactions of leading business cycle indicators that are followed by a protracted decline of real activity. These responses trigger an easing of monetary policy that is well understood by market participants who significantly lower their future short rate expectations, which in turn compresses yields.

We show that the yield news shock embeds several macroeconomic driving forces. First, innovations to realized stock market volatility similarly lead to briefly higher term premiums and persistently lower expected short rates. Second, negative news about the U.S. business cycle also lead to a protracted decline of short rate expectations and have a sizable impact on yields in the medium run. Our findings thus highlight the important role of monetary policy accommodating demand shocks for Treasury yield dynamics. Finally, news about international bond yields also explain significant shares of Treasury yield variation, but do not carry predictive information about U.S. macroeconomic dynamics beyond that contained in realized volatility and U.S. business cycle news.

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Table 1: Statistics for estimating number of static factors

(a) Yield dataset ($N = 109$)

Number of static factors	Trace R^2	Marginal trace R^2	Bai-Ng (2002) IC2
1	0.99	0.99	-4.50
2	1.00	0.01	-7.60
3	1.00	0.00	-10.47
4	1.00	0.00	-13.00
5	1.00	0.00	-15.52

(b) Macroeconomic dataset ($N = 135$)

Number of static factors	Trace R^2	Marginal trace R^2	Bai-Ng (2002) IC2
1	0.15	0.15	-0.12
2	0.22	0.07	-0.16
3	0.29	0.07	-0.21
4	0.35	0.06	-0.25
5	0.39	0.04	-0.27
6	0.43	0.04	-0.28
7	0.46	0.03	-0.29
8	0.48	0.02	-0.29
9	0.50	0.02	-0.29
10	0.52	0.02	-0.28

Note: The trace R^2 values capture the fraction of total variation explained in the data by the row number of factors. The Bai-Ng (2002) IC2 criterion balances the benefit of adding an additional factor against the cost of increased sampling variability in static factor models.

Table 2: OLS regressions of one-year change in Treasury yields on lagged factors

Model: $y^{(n)}_{t+12} - y^{(n)}_t = \beta_0 + \beta_1' \hat{F}_t + e_{t+12}$									
	$y^{(2)}_{t+12} - y^{(2)}_t$			$y^{(5)}_{t+12} - y^{(5)}_t$			$y^{(10)}_{t+12} - y^{(10)}_t$		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\hat{F}^{Level}_t$	**-0.32**	**-0.32**	**-0.31**	-0.22	-0.22	-0.21	-0.14	-0.14	-0.14
	(0.19)	(0.18)	(0.16)	(0.16)	(0.15)	(0.13)	(0.14)	(0.14)	(0.12)
$\hat{F}^{Slope}_t$	-0.07	-0.06	-0.06	**-0.25**	**-0.25**	**-0.24**	**-0.36**	**-0.36**	**-0.35**
	(0.14)	(0.14)	(0.14)	(0.12)	(0.12)	(0.12)	(0.10)	(0.10)	(0.10)
$\hat{F}^{Curv.}_t$	0.00	0.00	0.01	0.14	0.14	0.14	0.12	0.13	0.13
	(0.15)	(0.14)	(0.13)	(0.12)	(0.12)	(0.11)	(0.10)	(0.10)	(0.10)
$\hat{F}^{Y}_{4t}$		-0.04	-0.04		-0.05	-0.06		-0.09	-0.09
		(0.10)	(0.08)		(0.08)	(0.07)		(0.07)	(0.06)
$\hat{F}^{Y}_{5t}$		**0.32**	**0.32**		**0.26**	**0.27**		**0.22**	**0.22**
		(0.11)	(0.12)		(0.08)	(0.09)		(0.07)	(0.08)
$\hat{F}^{M}_{1t}$			**-0.34**			**-0.18**			-0.09
			0.12			0.09			0.08
$\hat{F}^{M}_{2t}$			**0.05**			**0.04**			**0.04**
			0.03			0.02			0.02
$\hat{F}^{M}_{3t}$			**0.27**			**0.19**			**0.14**
			0.09			0.07			0.05
$\hat{F}^{M}_{4t}$			**-0.25**			**-0.17**			-0.11
			0.09			0.07			0.07
$\hat{F}^{M}_{5t}$			0.03			-0.03			-0.08
			0.10			0.08			0.06
$\hat{F}^{M}_{6t}$			**0.13**			**0.13**			**0.13**
			0.06			0.05			0.04
$\hat{F}^{M}_{7t}$			-0.03			-0.02			-0.03
			0.04			0.04			0.03
$\hat{F}^{M}_{8t}$			-0.10			-0.08			**-0.07**
			0.06			0.05			0.04
$\bar{R}^2$	0.05	0.09	0.22	0.08	0.13	0.22	0.14	0.19	0.25

Note: $\hat{F}^{Level}_1$, $\hat{F}^{Slope}_2$, $\hat{F}^{Curv.}_3$, $\hat{F}^{Y}_4$ and $\hat{F}^{Y}_5$ denote the yield curve level, slope, curvature and 4th and 5th yield factors, all estimated by principal components using yields with maturities from 12 to 120 months. $\hat{F}^{M}_1$, $\hat{F}^{M}_2$, ..., $\hat{F}^{M}_8$ denote eight macroeconomic factors estimated by first regressing 135 FRED-MD series on the five yield curve factors and then estimating factors by computing principal components from the residuals. The numbers in parentheses are standard errors computed by Newey-West HAC with 18 lags. The factor estimates are normalized to have unit standard deviation. Coefficients that are statistically significant at the 10% level are highlighted in bold. A constant is always included in the regression even though its estimate is not reported in the table.

Table 3: Correlations among estimated shocks

	L	S	Y	VXO	RVol	BC	U	YP
Level Shock (L)	1.00							
Slope Shock (S)	0.00	1.00						
Yield News Shock (Y)	0.00	0.00	1.00					
Implied Volatility Shock (VXO)	0.03	0.10	0.74	1.00				
Realized Volatility Shock (RVol)	0.11	0.11	0.71	0.92	1.00			
Business Cycle News Shock (BC)	-0.08	-0.22	0.76	0.72	0.57	1.00		
Uncertainty Shock (U)	-0.23	-0.04	0.24	0.38	0.00	0.57	1.00	
Yield News Shock Purged of Realized Volatility & BC News (YP)	0.00	0.00	0.54	-0.09	0.00	0.00	-0.20	1.00

Note: Entries are correlations between individually identified shocks, which are computed over the full sample 1962M7–2019M6.

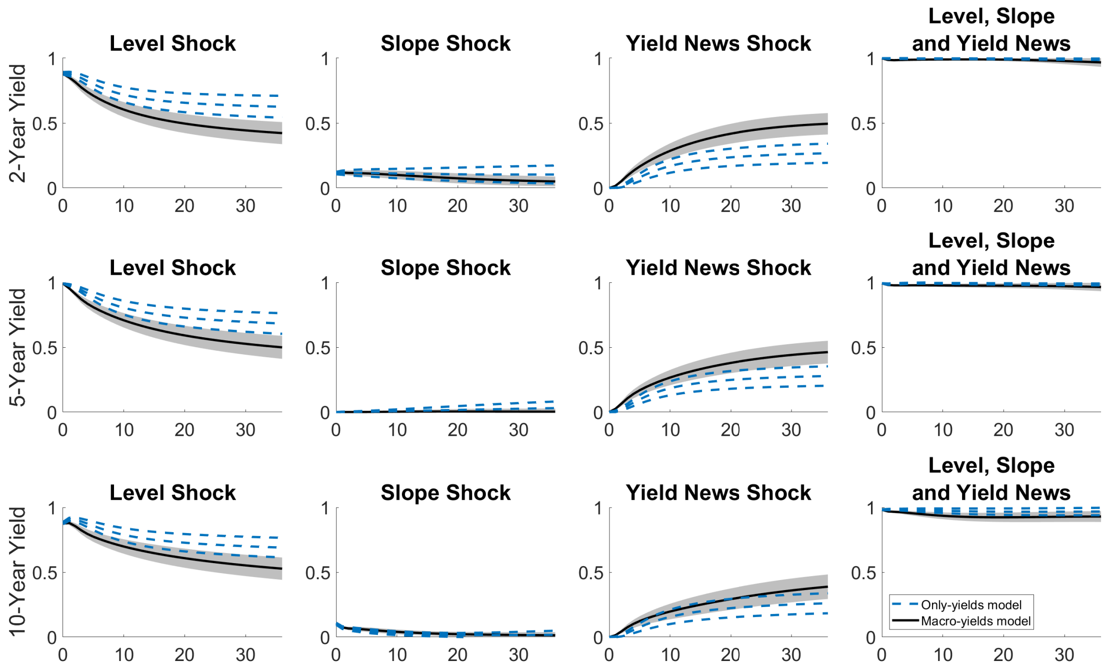
Table 4: Importance of factors for selected series

Series	R^2
1-Year Treasury Bond Yield	1.00
2-Year Treasury Bond Yield	1.00
5-Year Treasury Bond Yield	1.00
7-Year Treasury Bond Yield	1.00
10-Year Treasury Bond Yield	1.00
ACM Risk-Neutral 2-Year Yield	1.00
ACM Risk-Neutral 10-Year Yield	1.00
ACM 2-Year Yield Term Premium	0.99
ACM 10-Year Yield Term Premium	1.00
MOVE Bond Volatility	0.59
VXO	0.58
Realized Volatility	0.57
LMN - financial uncertainty	0.49
GZ - excess bond premium	0.49
S&P 500	0.81
Industrial Production	0.92
Total Nonfarm Payroll	0.87
Average Weekly Hours: Total Private Industry	0.20
Real Personal Consumption Expenditures	0.31
Philadelphia Leading Indicator	0.84
Housing Starts	0.98
Initial Claims	0.29
New Orders for Durable Goods	0.20
Trade Weighted U.S. Dollar Index	0.37
CPI	0.81
Federal Funds Rate	0.51
3-Month T-Bill Rate Survey Forecast: Average of 3 and 12-Month Horizons	0.99

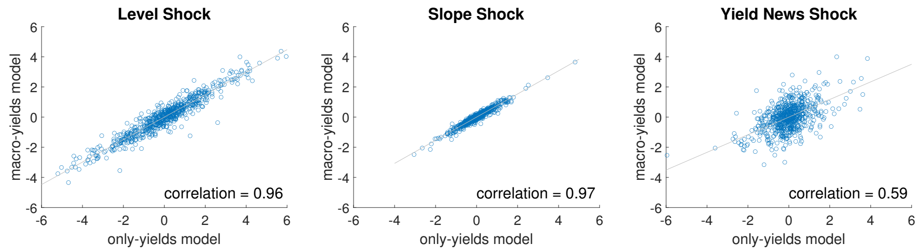
Note: This table shows the R^2 obtained from regressions of selected series on the 13 factors in the baseline macro-yields DFM.

Figure 1: FEVDs from only-yields and macro-yields DFMs

(a) FEVDs



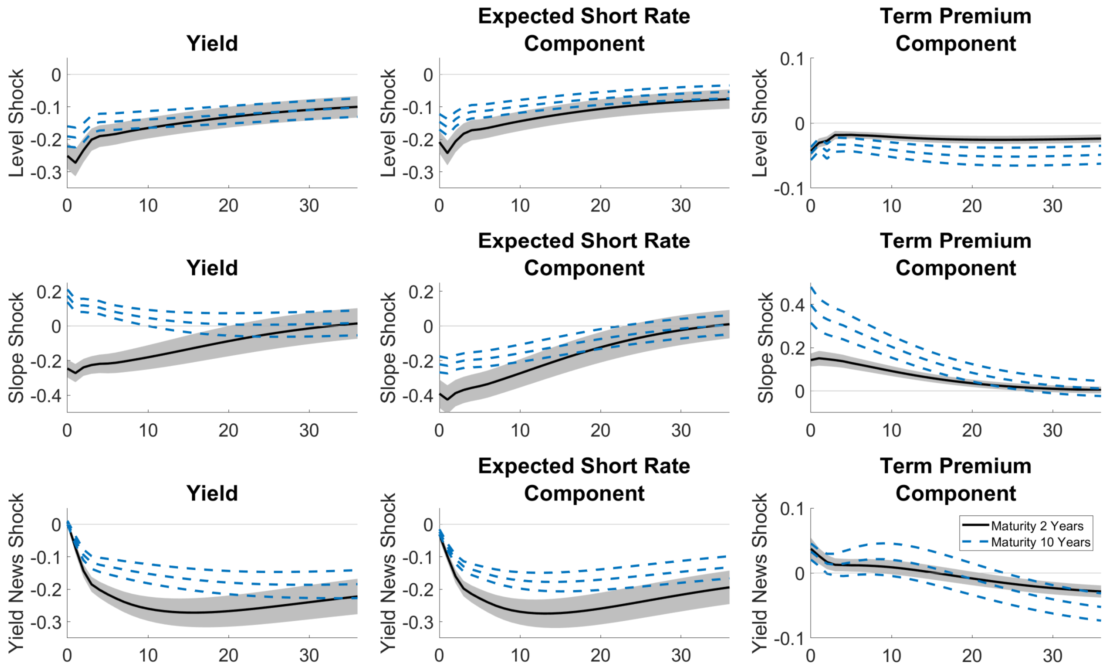
(b) Correlations among estimated shocks across model specifications



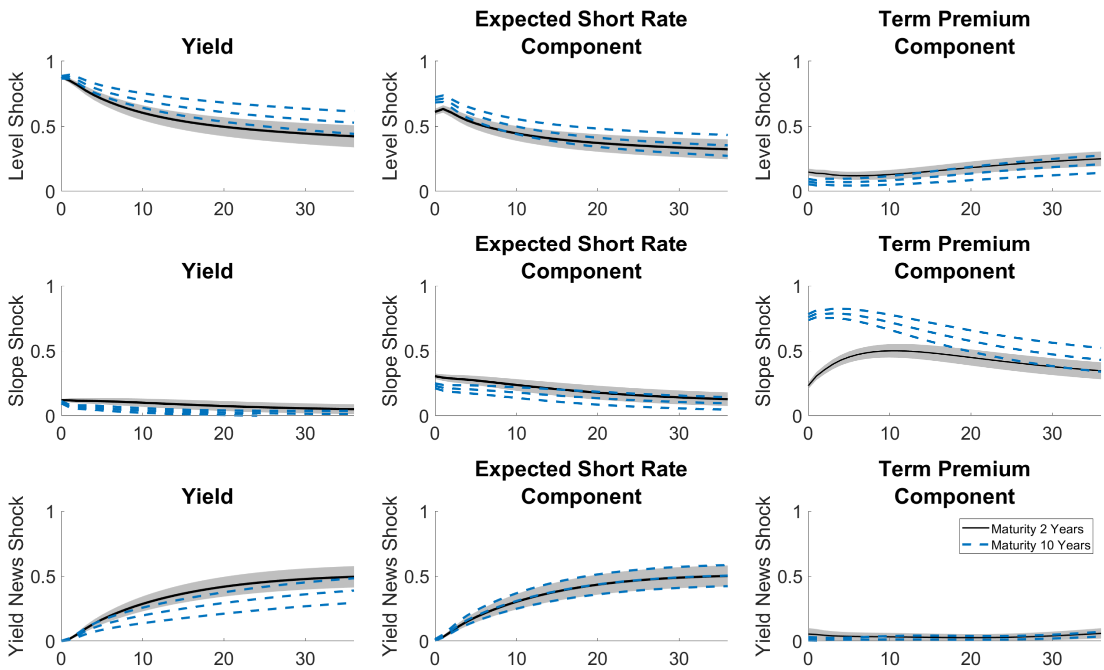
Note: The top panel of this figure shows the FEVDs from the only-yields model (blue dashed ± 1 standard error bands), and the macro-yields model (black solid ± 1 standard error bands) for the level, slope and yield news shocks, as well as the three shocks combined. The bottom panel provides scatterplots of each shock estimated in the two model specifications.

Figure 2: IRFs and FEVDs of yields and their components to yield shocks

(a) IRFs



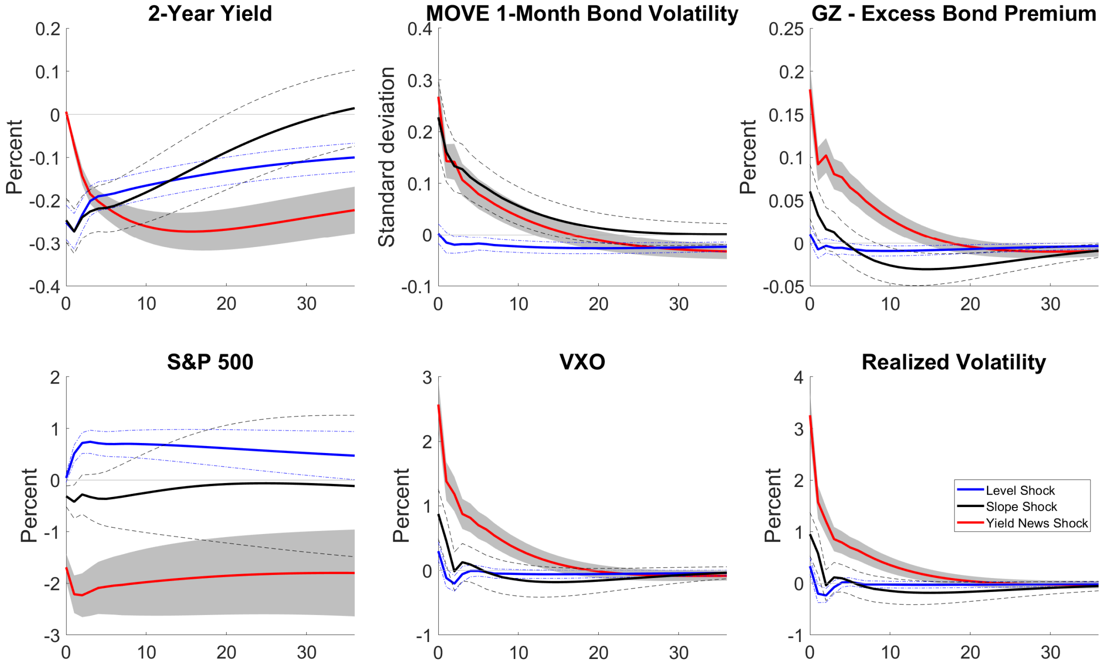
(b) FEVDs



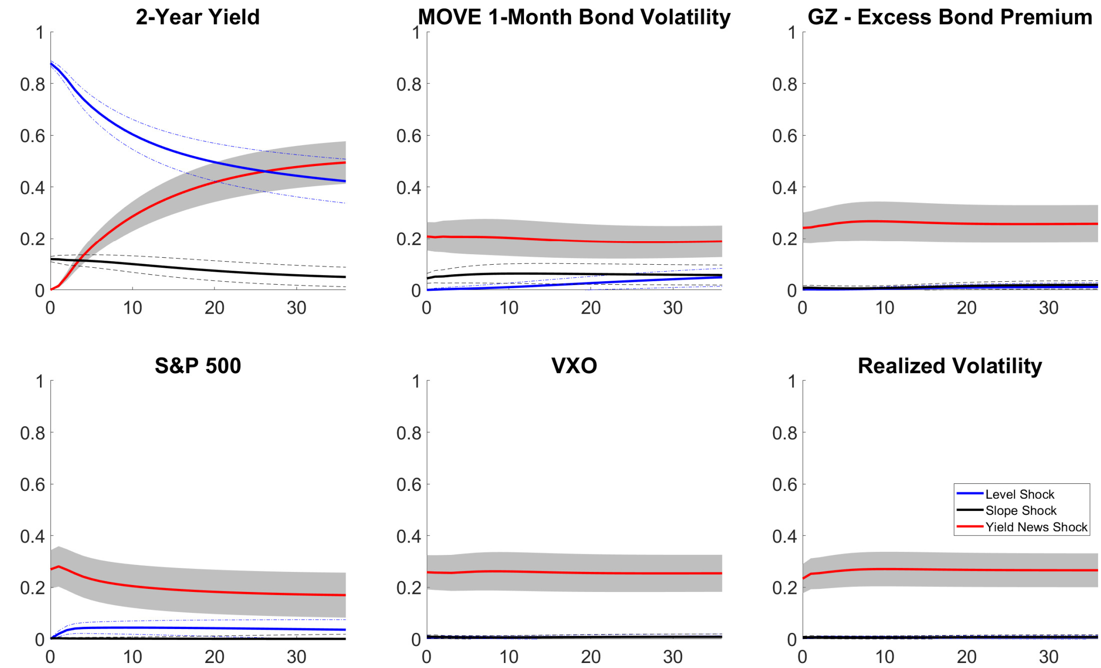
Note: The top panel of this figure shows the IRFs for the level, slope and yield news shocks for yields and their expected short rate and term premium components for the two-year (black solid ± 1 standard error bands) and the ten-year (blue dashed ± 1 standard error bands) maturity from the macro-yields model. The yield news shock is reported as a one-standard deviation impulse, and the responses for level and slope shocks are scaled so that they each produce the same peak decline in the two-year yield as the yield news shock. The bottom panel displays the corresponding FEVDS.

Figure 3: IRFs and FEVDs of financial market indicators to yield shocks

(a) IRFs



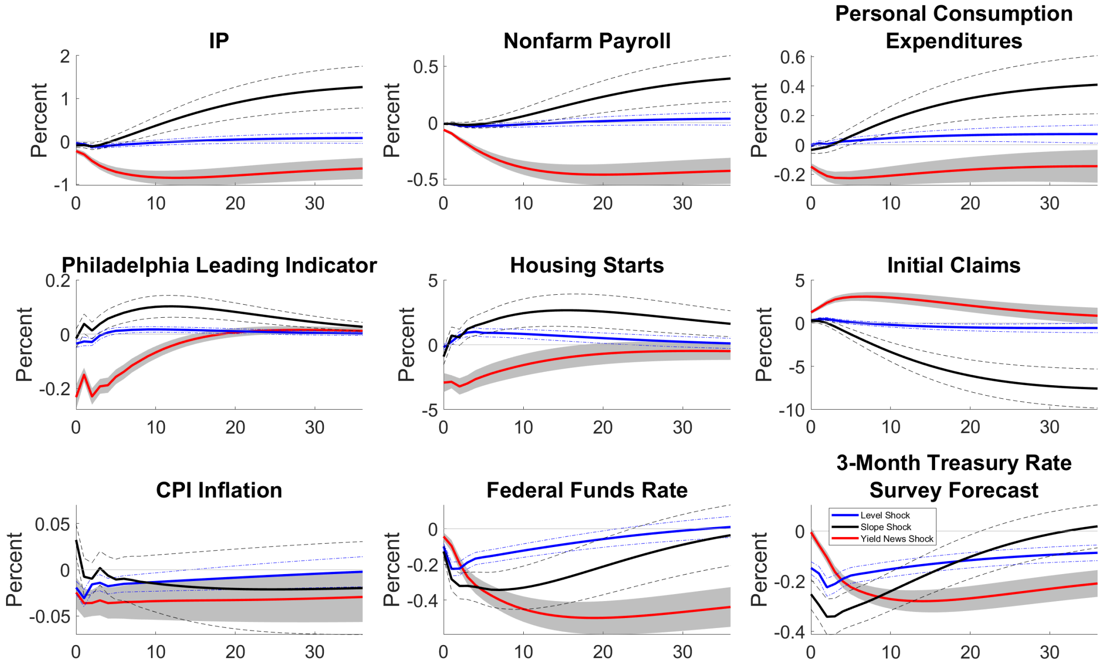
(b) FEVDs



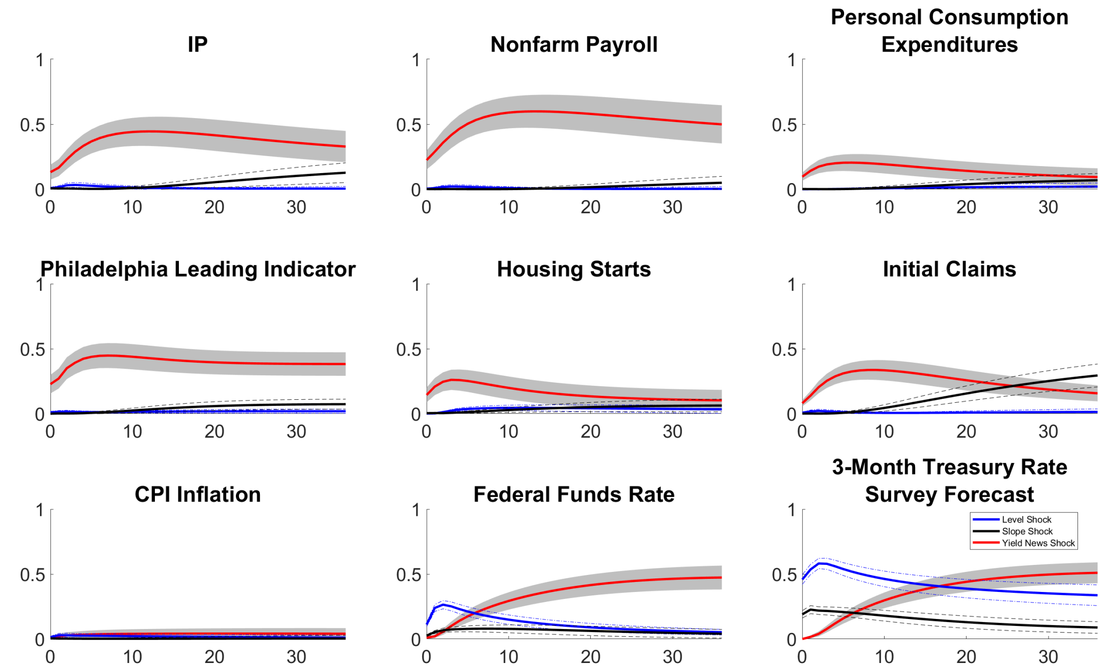
Note: The top panel of this figure shows the IRFs for the level shock (blue solid ± 1 standard error bands), the slope shock (black solid ± 1 standard error bands), and the yield news shock (red solid ± 1 standard error bands) from the macro-yields model. The yield news shock is reported as a one-standard-deviation impulse, and the responses for the level and slope shocks are scaled so that they each produce the same peak decline in the two-year yield as the yield news shock. The bottom panel displays the corresponding FEVDs.

Figure 4: IRFs and FEVDs of macroeconomic variables to yield shocks

(a) IRFs



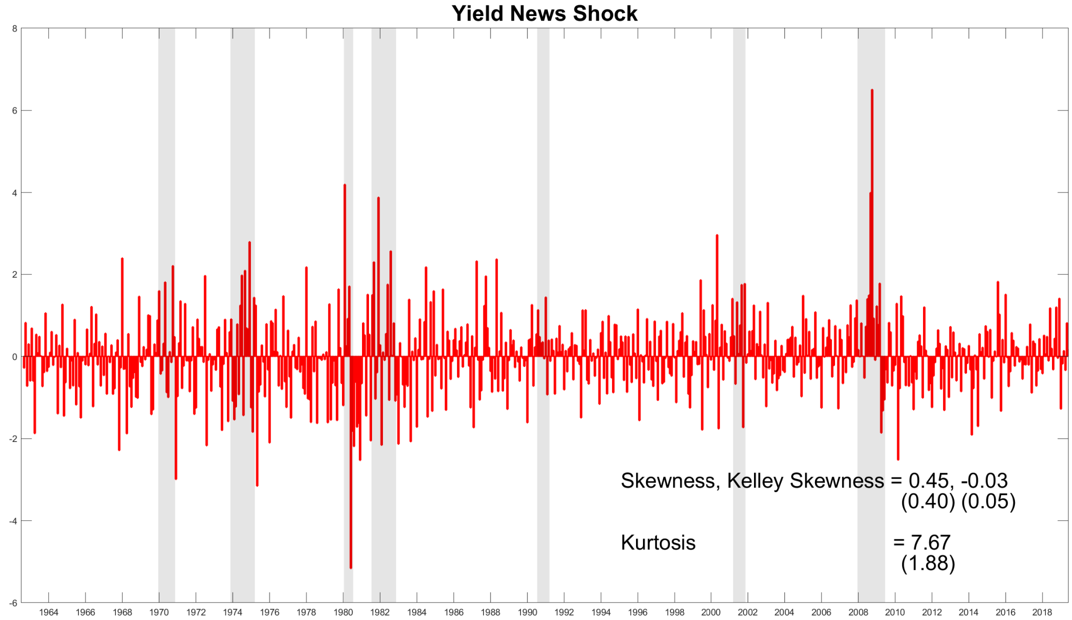
(b) FEVDs



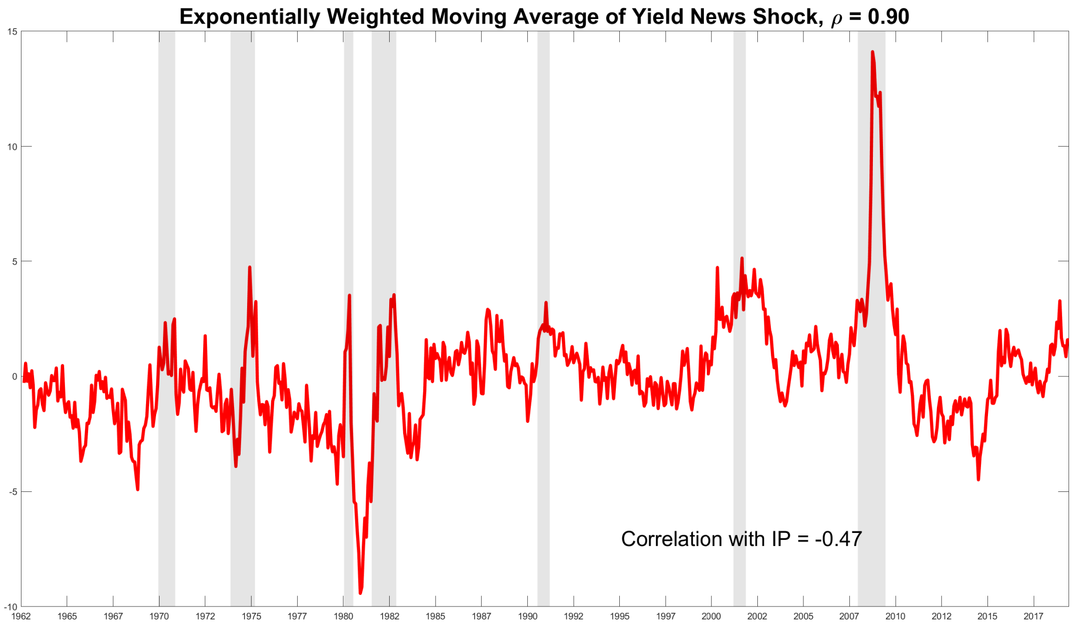
Note: The top panel of this figure shows the IRFs for the level shock (blue solid ± 1 standard error bands), the slope shock (black solid ± 1 standard error bands), and the yield news shock (red solid ± 1 standard error bands) from the macro-yields model. The yield news shock is reported as a one-standard-deviation impulse, and the responses for the level and slope shocks are scaled so that they each produce the same peak decline in the two-year yield as the yield news shock. The bottom panel displays the corresponding FEVDs.

Figure 5: Time series of estimated yield news shock

(a)



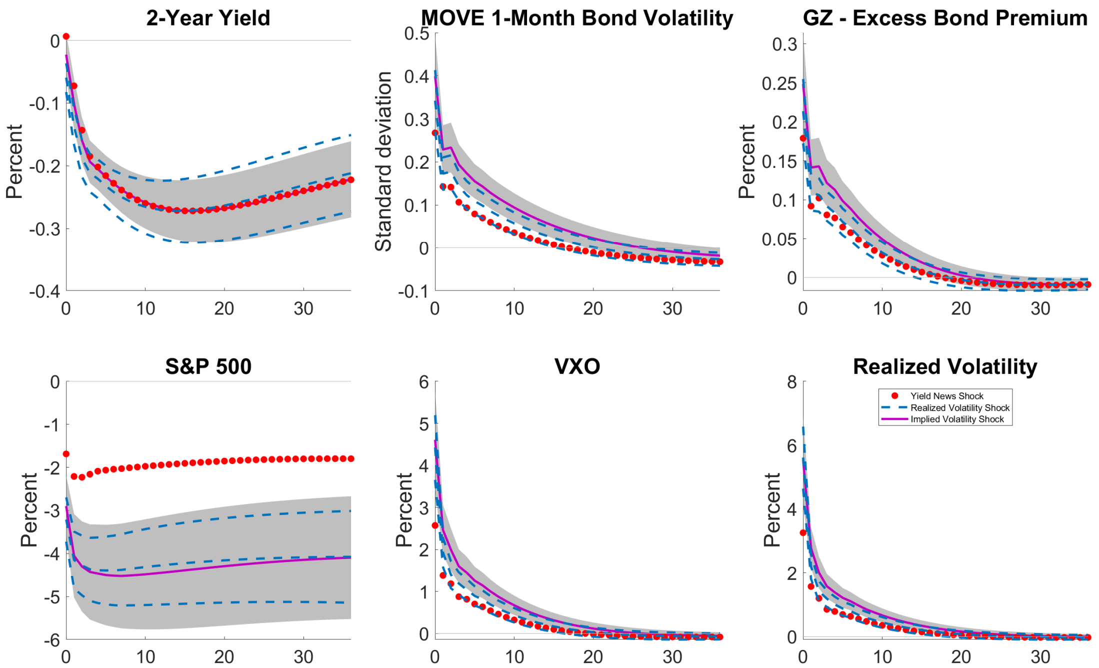
(b)



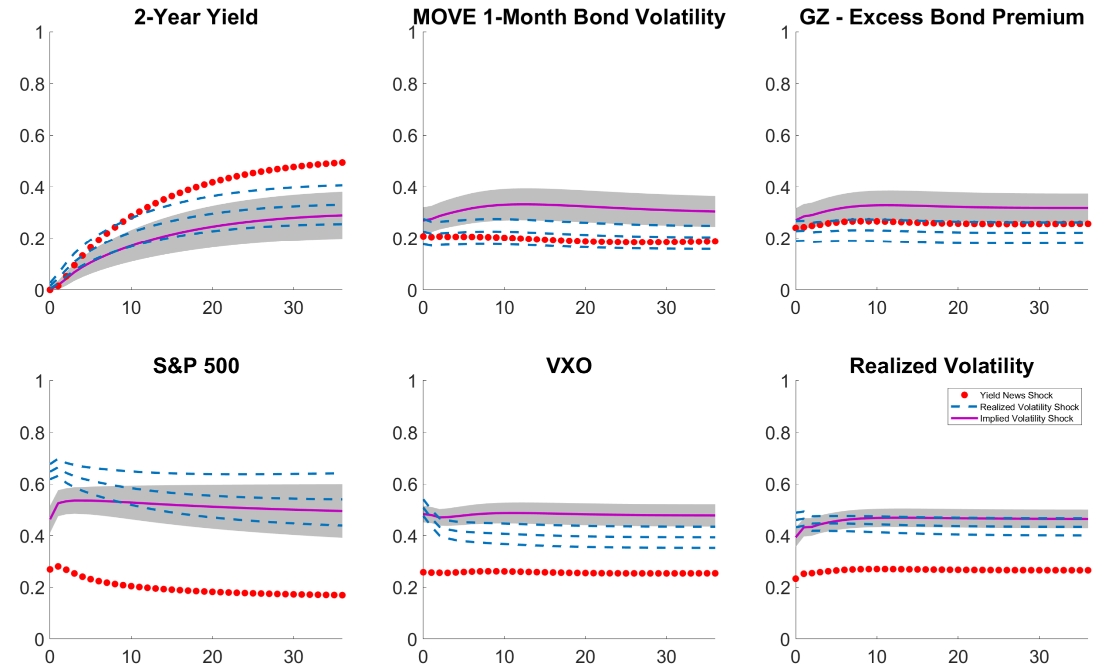
Note: The top panel of this figure shows the estimated yield news shock, along with the skewness and kurtosis. The Kelley skewness is computed as the difference between the 90th-to-50th percentiles differential and the 50th-to-10th percentiles differential divided by the 90th-to-10th percentiles differential. The bottom panel displays the exponentially weighted moving average of the estimated yield news shock based on AR(1) coefficient $\rho = 0.9$. Correlation is computed with 12-month IP growth. Standard errors are constructed by bootstrap resampling with 500 replications.

Figure 6: IRFs and FEVDs of financial market indicators to realized and implied volatility shocks

(a) IRFs



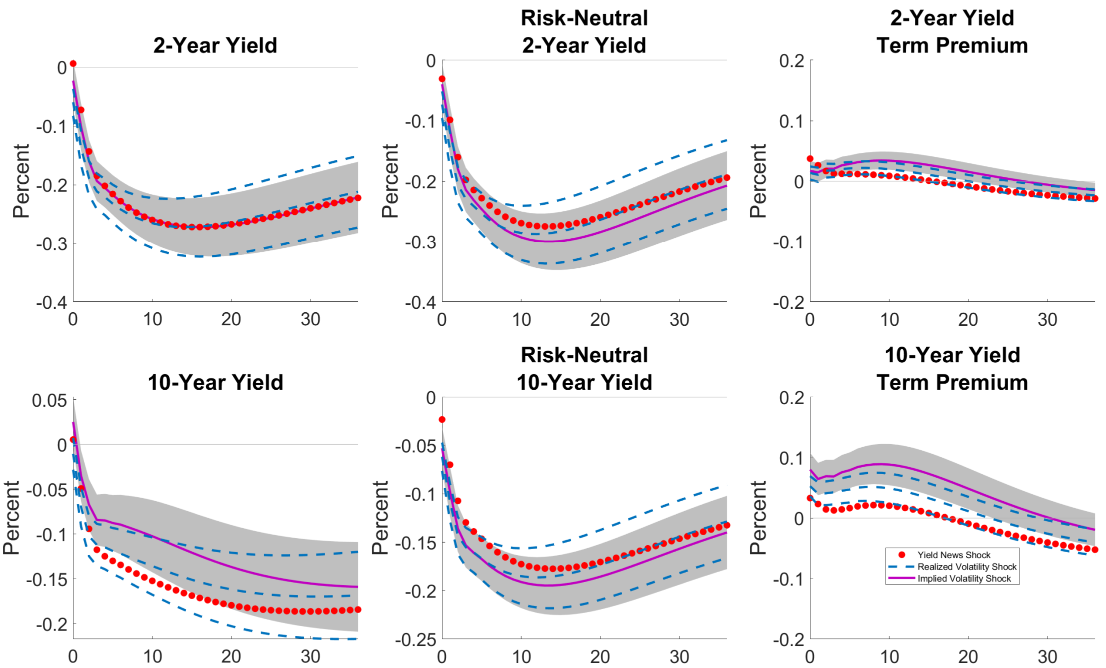
(b) FEVDs



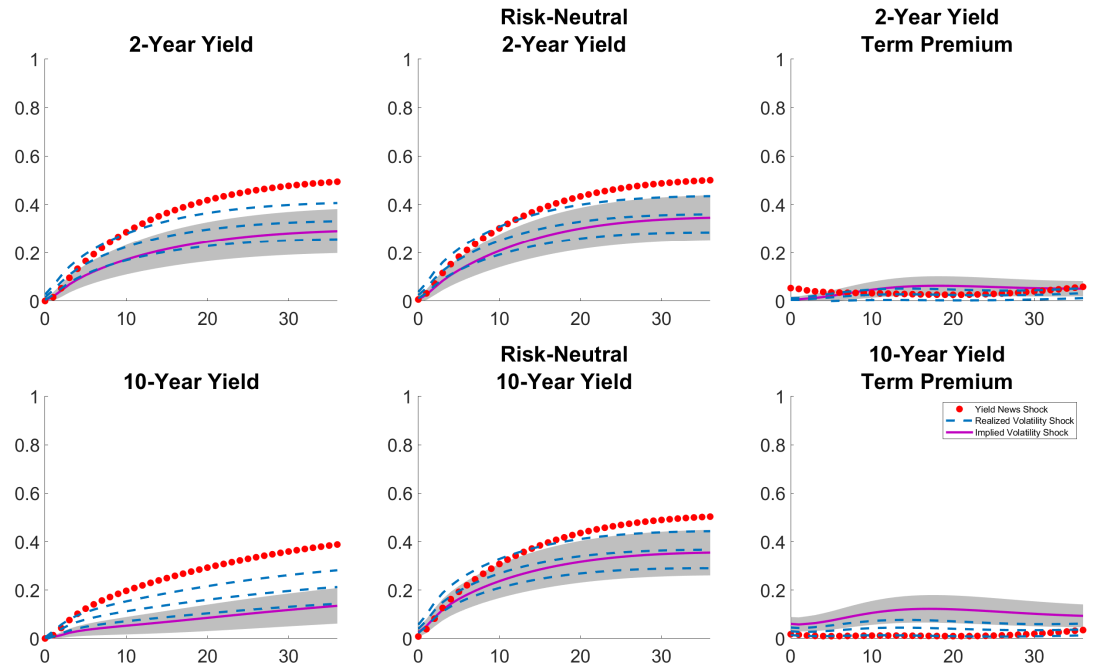
Note: The top panel shows the IRFs for the yield news shock (red dotted), the shock to realized volatility (blue dashed ± 1 stand error bands), and the shock to implied volatility (purple solid ± 1 stand error bands) from the macro-yields model. The yield news shock is reported as a one-standard-deviation impulse, and the responses for the realized and implied volatility shocks are scaled so that they each produce the same peak decline in the two-year yield as the yield news shock. The bottom panel displays the corresponding FEVDs.

Figure 7: IRFs and FEVDs of yields and their components to realized and implied volatility shocks

(a) IRFs



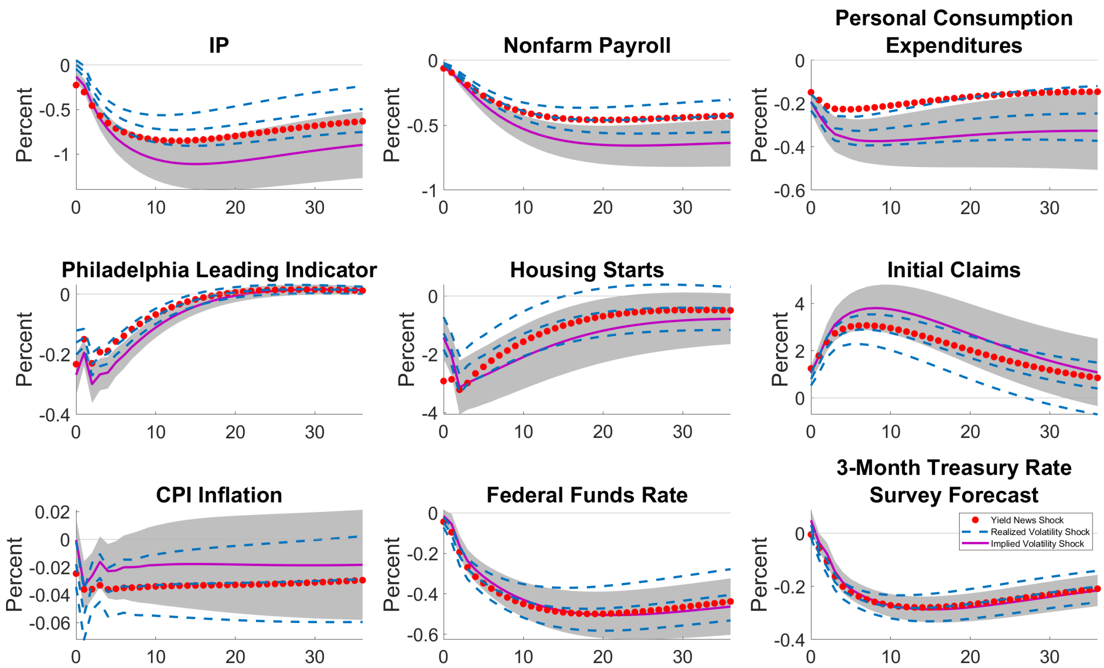
(b) FEVDs



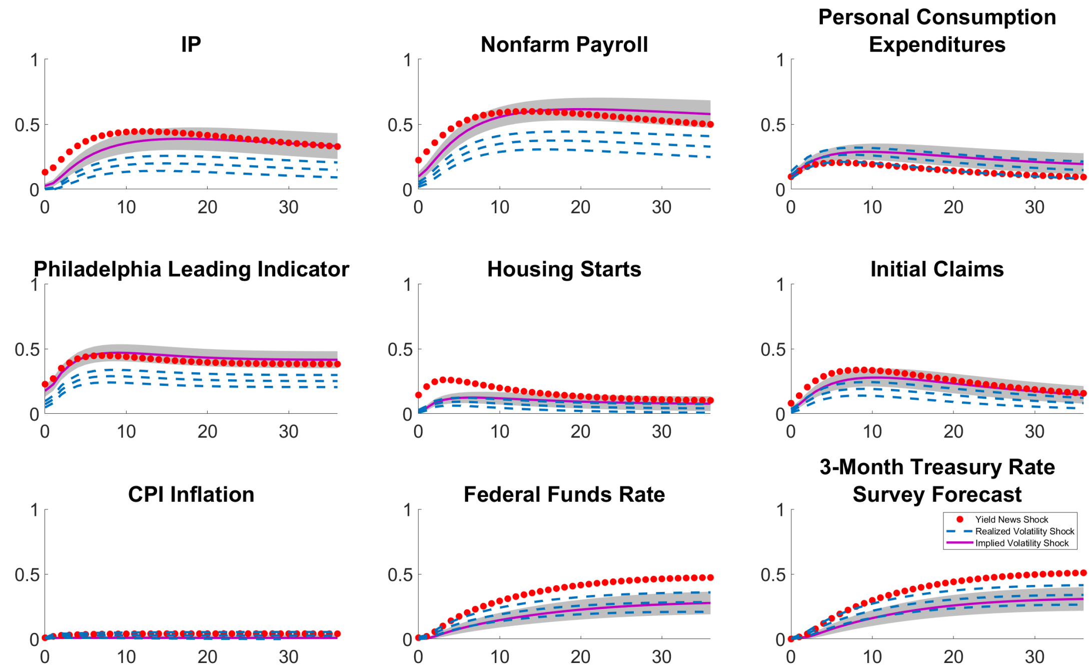
Note: The top panel shows the IRFs for the yield news shock (red dotted), the shock to realized volatility (blue dashed ±1 stand error bands), and the shock to implied volatility (purple solid ±1 stand error bands) from the macro-yields model. The yield news shock is reported as a one-standard-deviation impulse, and the responses for the realized and implied volatility shocks are scaled so that they each produce the same peak decline in the two-year yield as the yield news shock. The bottom panel displays the corresponding FEVDs.

Figure 8: IRFs and FEVDs of macroeconomic variables to realized and implied volatility shocks

(a) IRFs



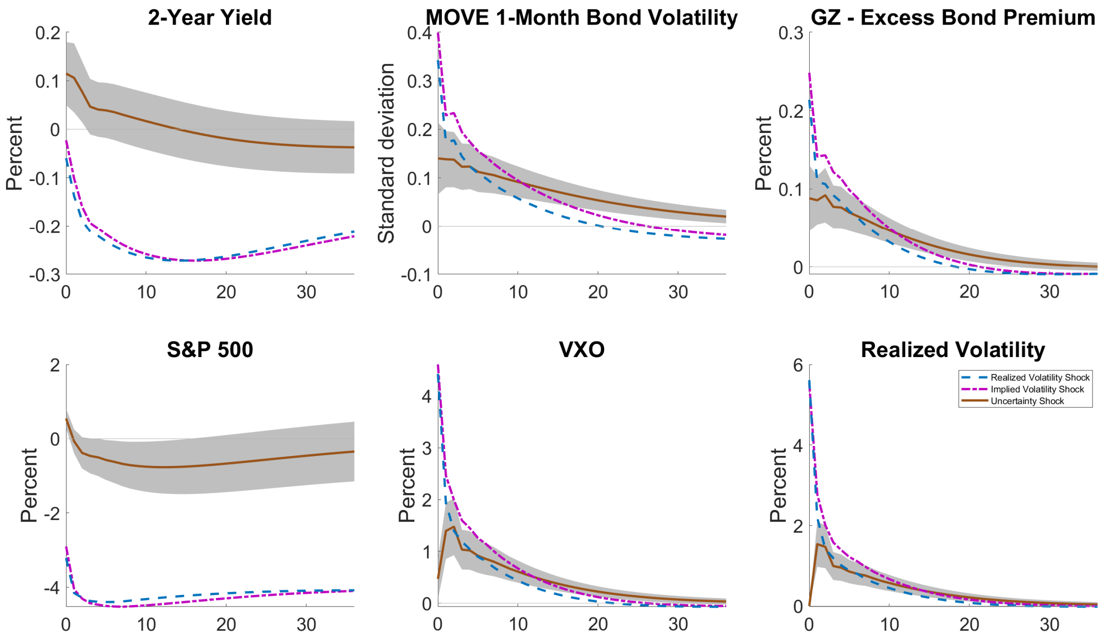
(b) FEVDs



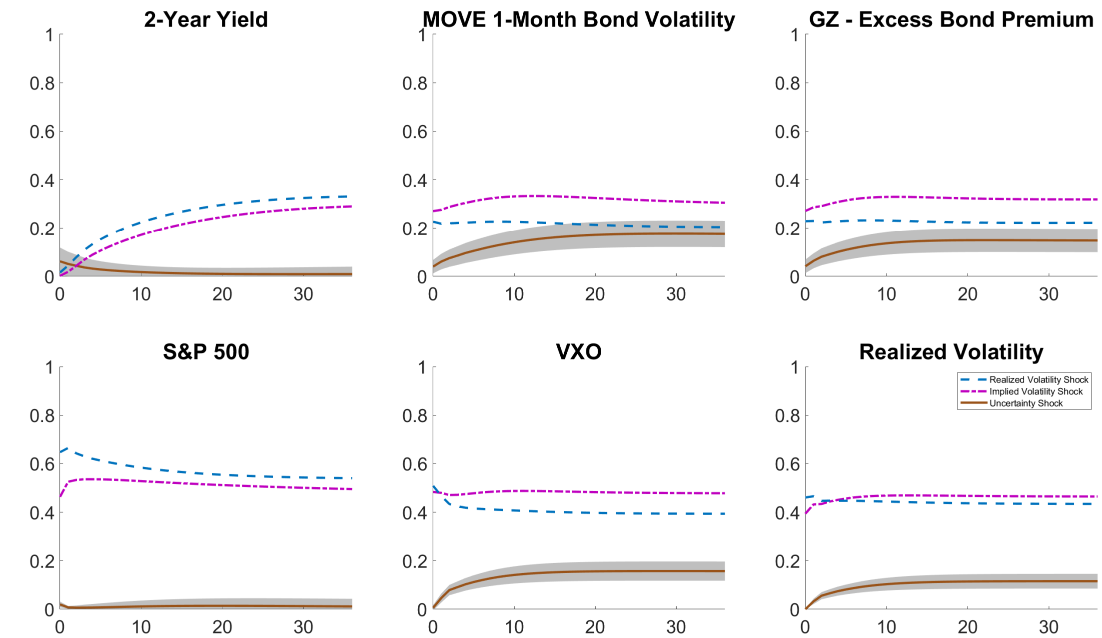
Note: The top panel shows the IRFs for the yield news shock (red dotted), the shock to realized volatility (blue dashed ± 1 stand error bands), and the shock to implied volatility (purple solid ± 1 stand error bands) from the macro-yields model. The yield news shock is reported as a one-standard-deviation impulse, and the responses for the realized and implied volatility shocks are scaled so that they each produce the same peak decline in the two-year yield as the yield news shock. The bottom panel displays the corresponding FEVDs.

Figure 9: IRFs and FEVDs of financial market indicators to volatility and uncertainty shocks

(a) IRFs



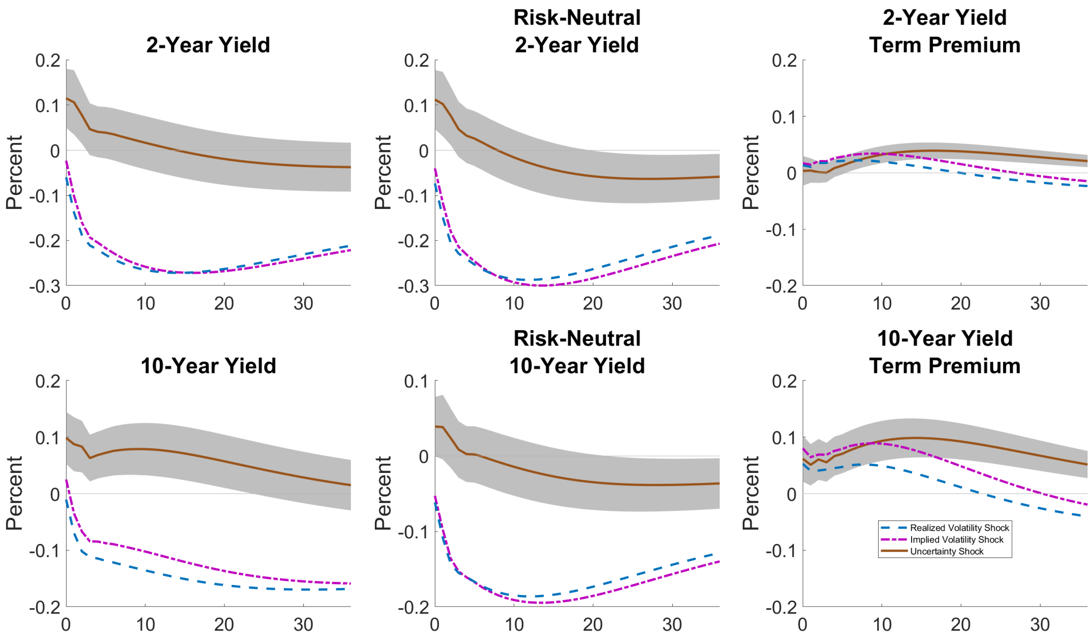
(b) FEVDs



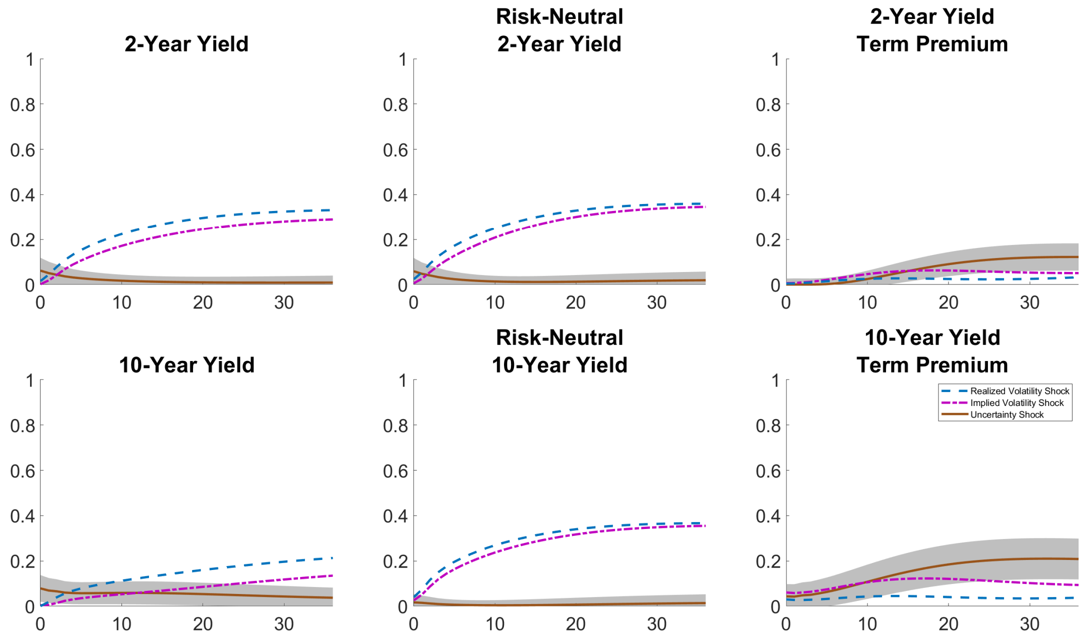
Note: The top panel of this figure shows the IRFs for the shock to realized volatility (blue dashed), the shock to implied volatility (purple dash-dot), and the uncertainty shock *i.e.* implied volatility shock orthogonal to realized volatility shock (yellow solid ± 1 stand error bands) from the macro-yields model. The responses for the realized and implied volatility shocks are scaled so that they each produce the same peak decline in the two-year yield as the yield news shock, and the uncertainty shock is scaled so that it has the same cumulative effect on the VXO over the next 2-60 months as the implied volatility shock. The bottom panel displays the corresponding FEVDs.

Figure 10: IRFs and FEVDs of yields and their components to volatility and uncertainty shocks

(a) IRFs



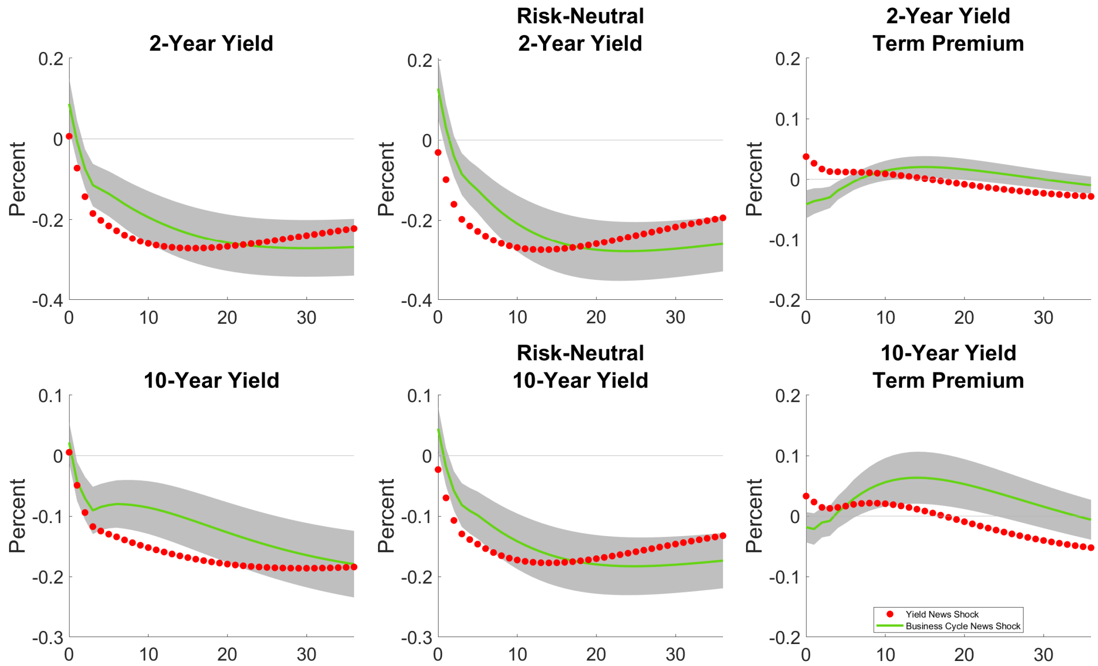
(b) FEVDs



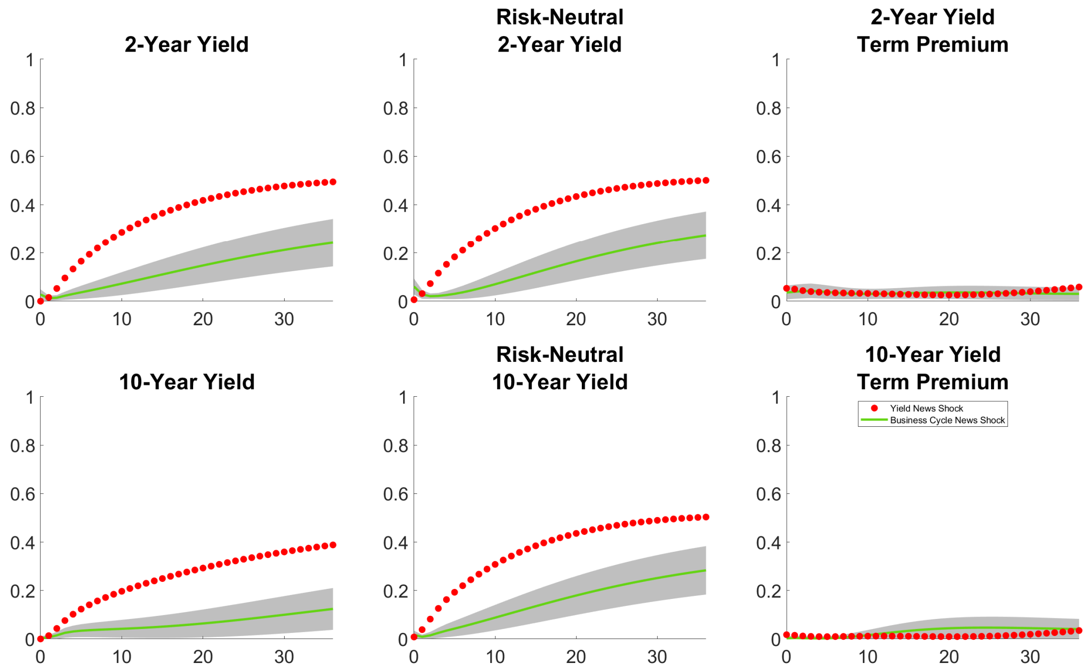
Note: The top panel of this figure shows the IRFs for the shock to realized volatility (blue dashed), the shock to implied volatility (purple dash-dot), and the uncertainty shock *i.e.* implied volatility shock orthogonal to realized volatility shock (yellow solid ± 1 stand error bands) from the macro-yields model. The responses for the realized and implied volatility shocks are scaled so that they each produce the same peak decline in the two-year yield as the yield news shock, and the uncertainty shock is scaled so that it has the same cumulative effect on the VXO over the next 2-60 months as the implied volatility shock. The bottom panel displays the corresponding FEVDs.

Figure 11: IRFs and FEVDs of yields and their components to business cycle news shock

(a) IRFs



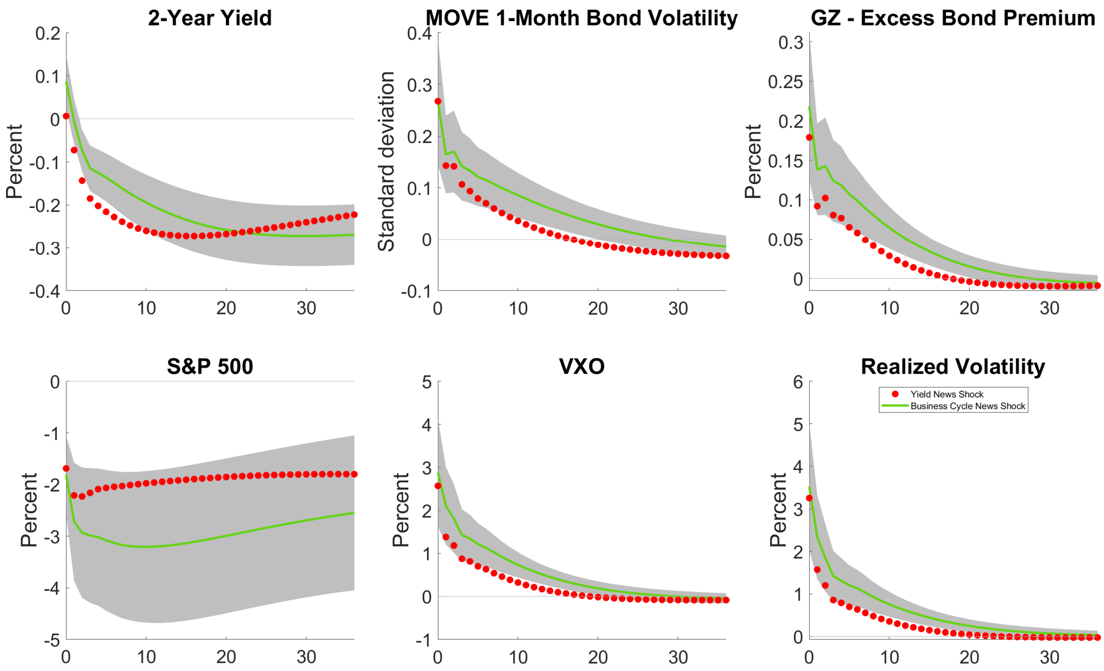
(b) FEVDs



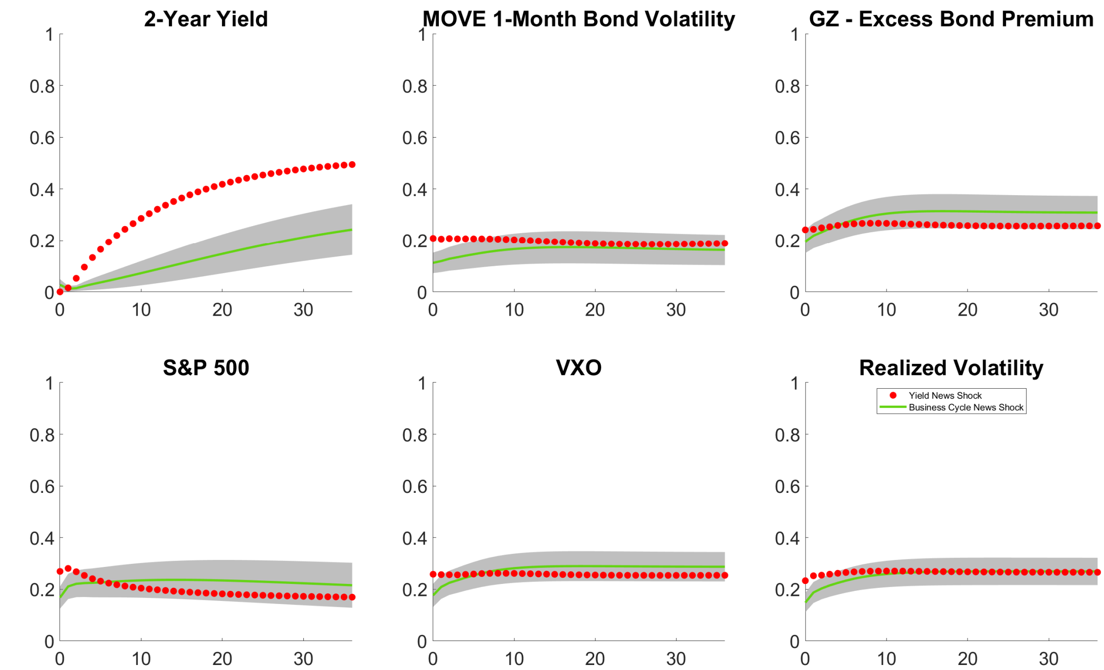
Note: The top panel of this figure shows the IRFs for the yield news shock (red dotted), and the business cycle news shock (green solid ± 1 stand error bands) from the macro-yields model. The yield news shock is reported as a one-standard-deviation impulse, and the responses for the business cycle news shock are scaled so that the shock produces the same peak decline in the two-year yield as the yield news shock. The bottom panel displays the corresponding FEVDs.

Figure 12: IRFs and FEVDs of financial market indicators to business cycle news shock

(a) IRFs



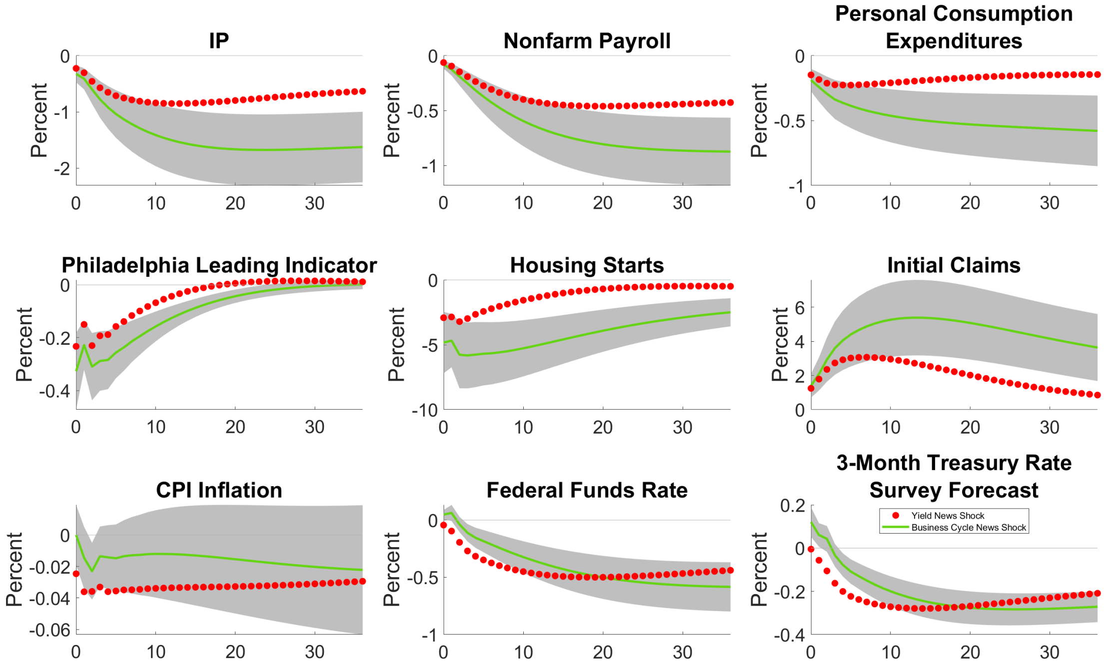
(b) FEVDs



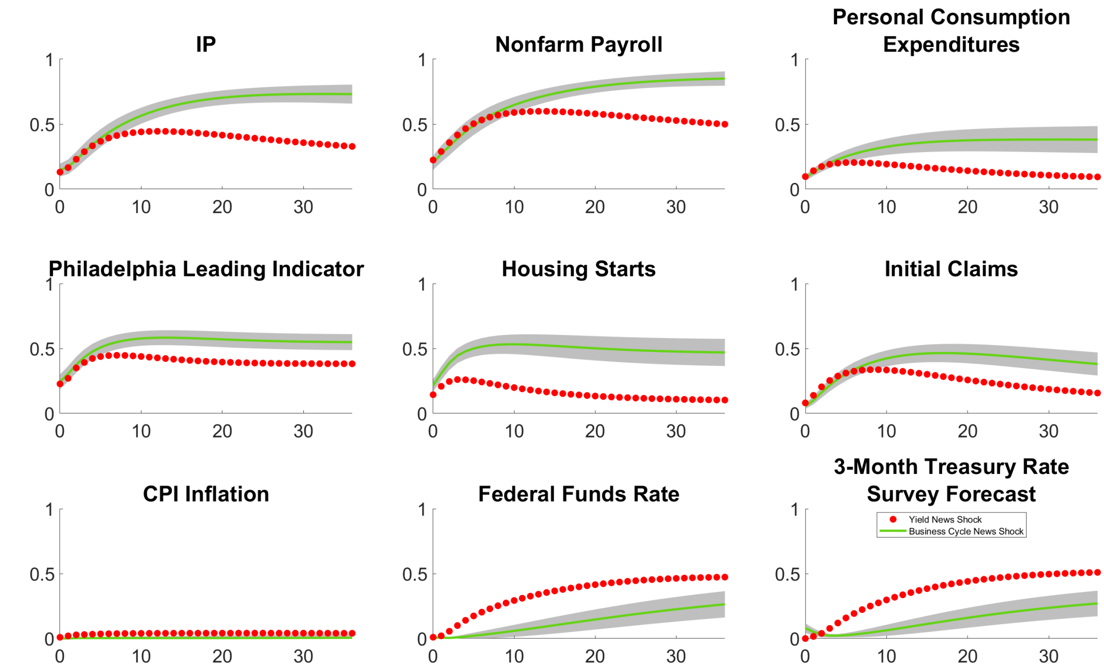
Note: The top panel of this figure shows the IRFs for the yield news shock (red dotted), and the business cycle news shock (green solid ± 1 stand error bands) from the macro-yields model. The yield news shock is reported as a one-standard-deviation impulse, and the responses for the business cycle news shock are scaled so the shock produces the same peak decline in the two-year yield as the yield news shock. The bottom panel displays the corresponding FEVDs.

Figure 13: IRFs and FEVDs of macroeconomic variables to business cycle news shock

(a) IRFs



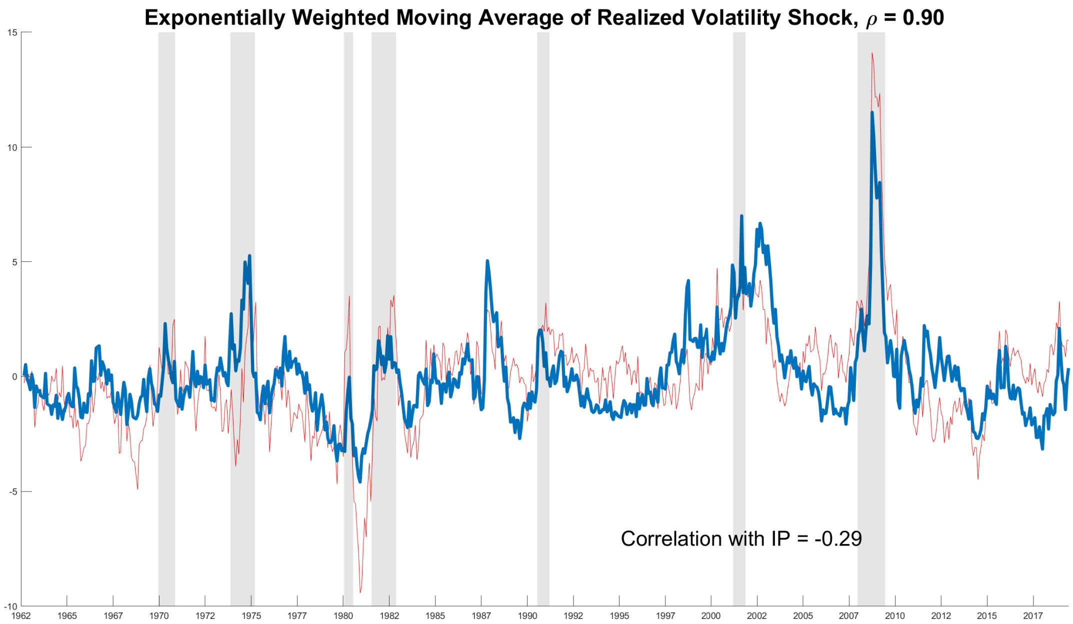
(b) FEVDs



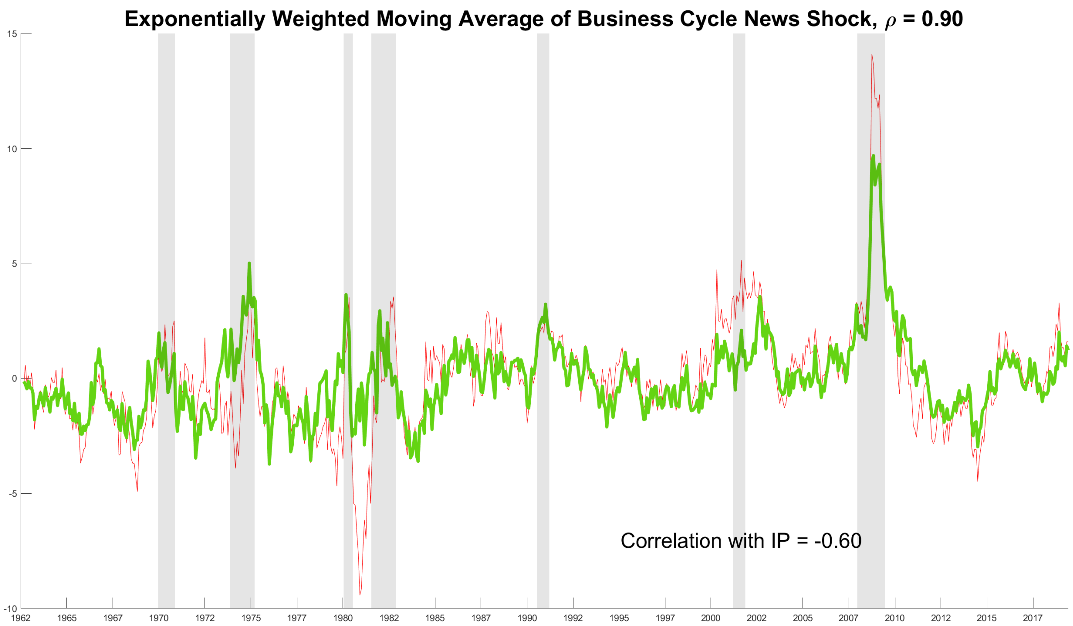
Note: The top panel of this figure shows the IRFs for the yield news shock (red dotted), and the business cycle news shock (green solid ± 1 stand error bands) from the macro-yields model. The yield news shock is reported as a one-standard-deviation impulse, and the responses for the business cycle news shock are scaled so the shock produces the same peak decline in the two-year yield as the yield news shock. The bottom panel displays the corresponding FEVDs.

Figure 14: Exponentially weighted moving average of estimated realized volatility and business cycle news shocks

(a)



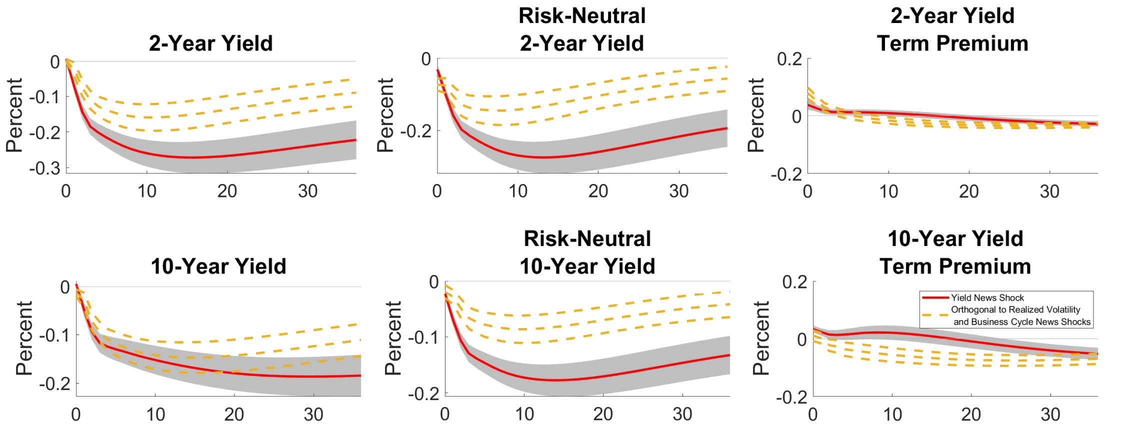
(b)



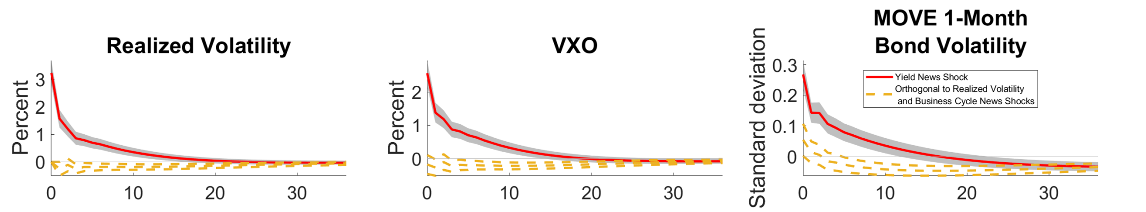
Note: The top panel of this figure shows the exponentially weighted moving average of the estimated yield news shock based on AR(1) coefficient $\rho = 0.9$. The bottom panel displays that of the estimated business cycle news shock. Correlations are computed with 12-month IP growth.

Figure 15: IRFs to yield news shock purged of realized volatility and business cycle news shocks

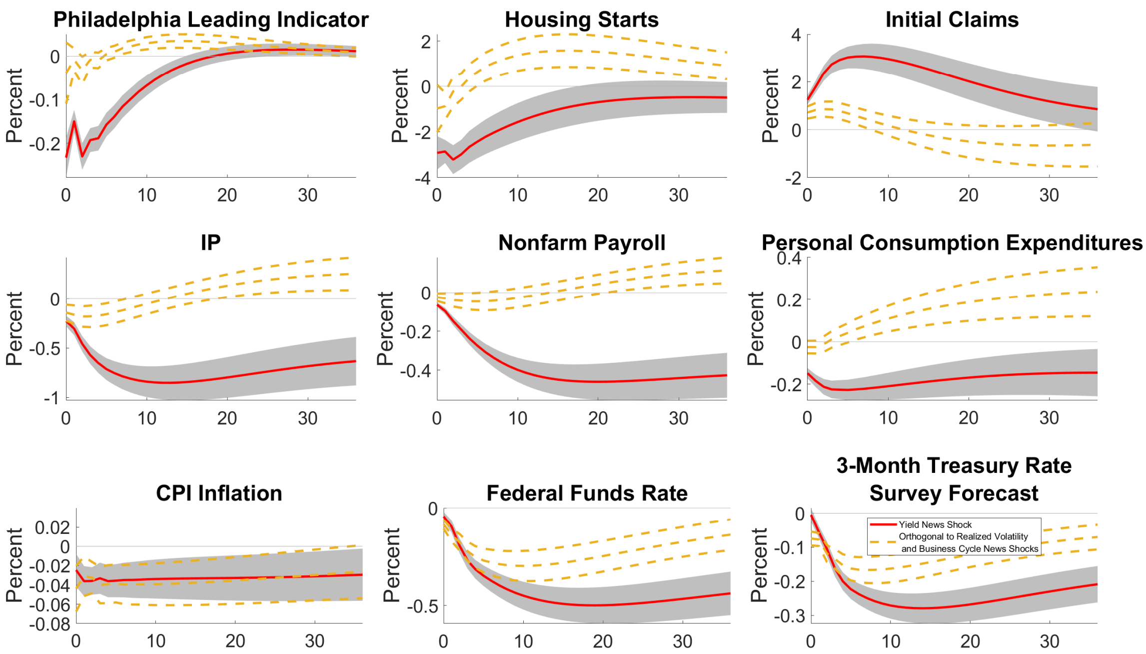
(a) IRFs of Yields, and Their Components



(b) IRFs of Volatility Measures



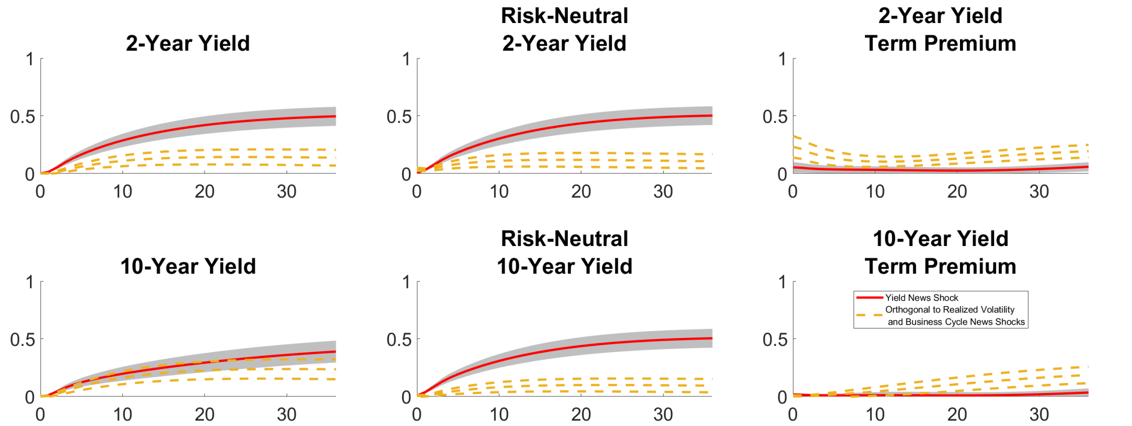
(c) IRFs of Macroeconomic Variables



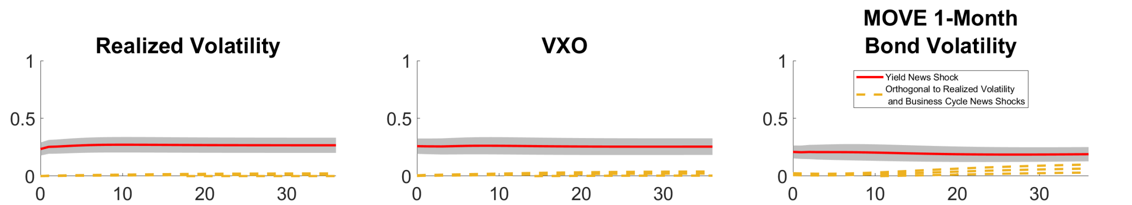
Note: This figure shows the IRFs for the yield news shock (red solid ± 1 stand error bands), and the yield news shock that is made orthogonal to the realized volatility and business cycle news shocks (blue dashed ± 1 stand error bands) from the macro-yields model. Each shock is reported as a one-standard-deviation impulse.

Figure 16: FEV shares explained by yield news shock purged of realized volatility and business cycle news shocks

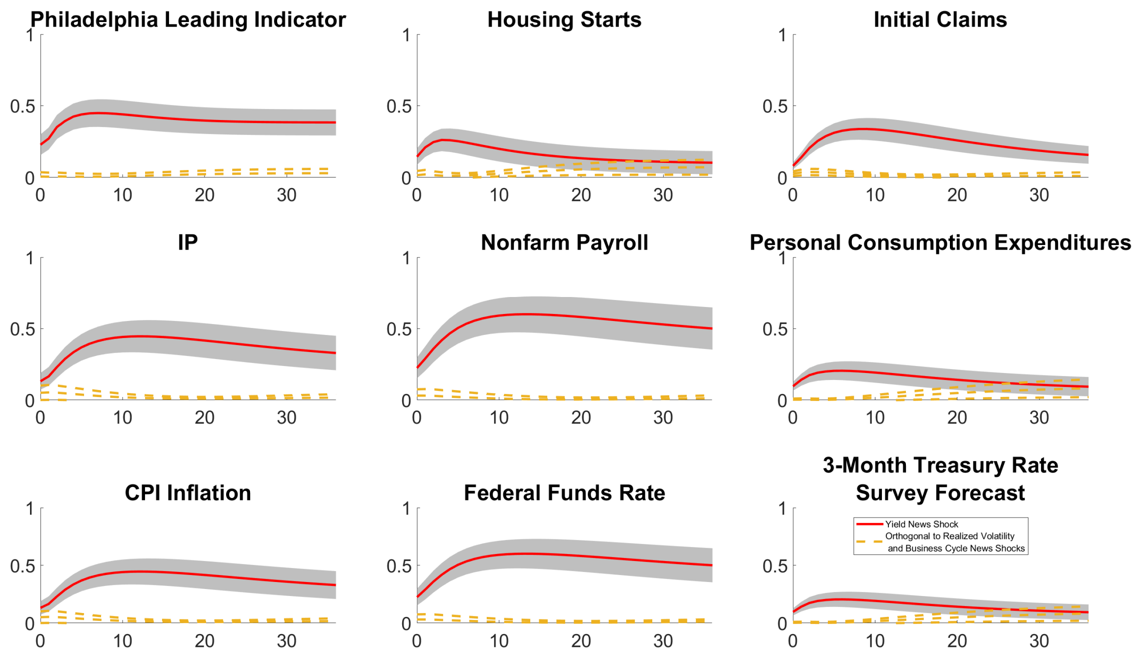
(a) FEVDs for Yields, and Their Components



(b) FEVDs for Volatility Measures



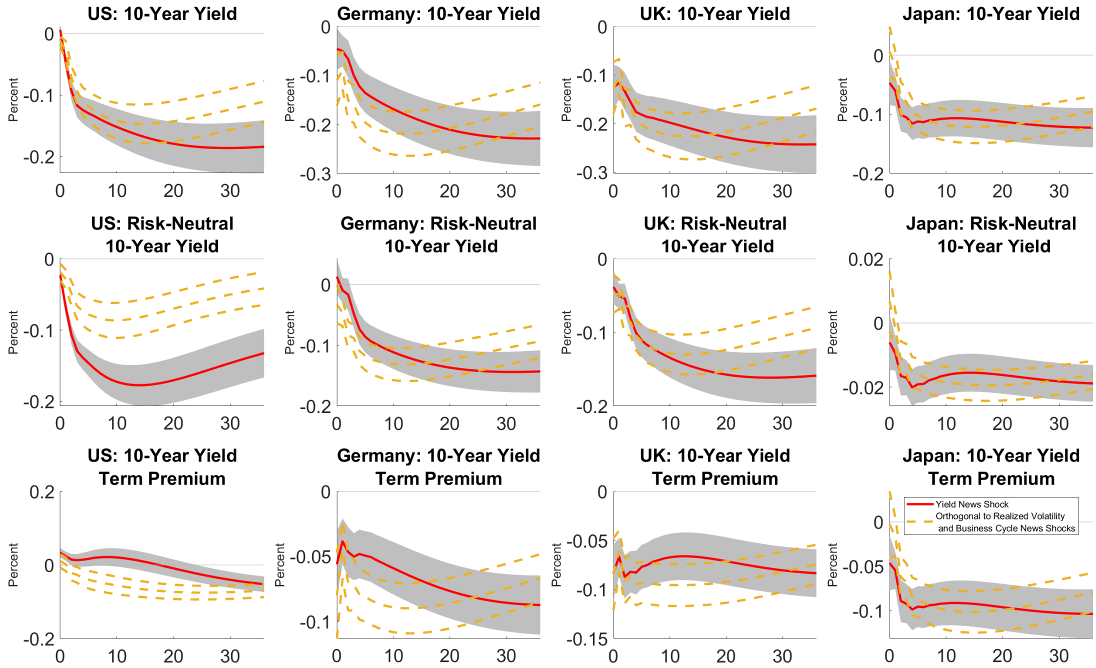
(c) FEVDs for Macroeconomic Variables



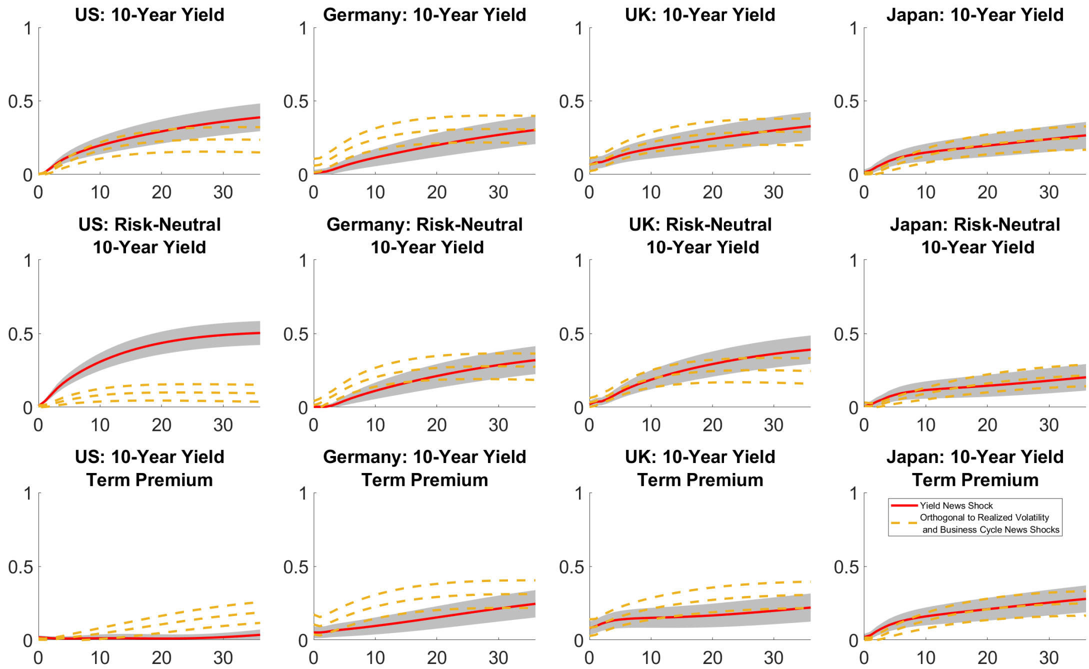
Note: This figure shows the FEVDs for the yield news shock (red solid ± 1 stand error bands), and the yield news shock that is made orthogonal to the realized volatility and business cycle news shocks (yellow dashed ± 1 stand error bands) from the macro-yields model.

Figure 17: IRFs and FEVDs of 10-year yields and components for the US, Germany, the UK and Japan to purged yield news shock

(a) IRFs



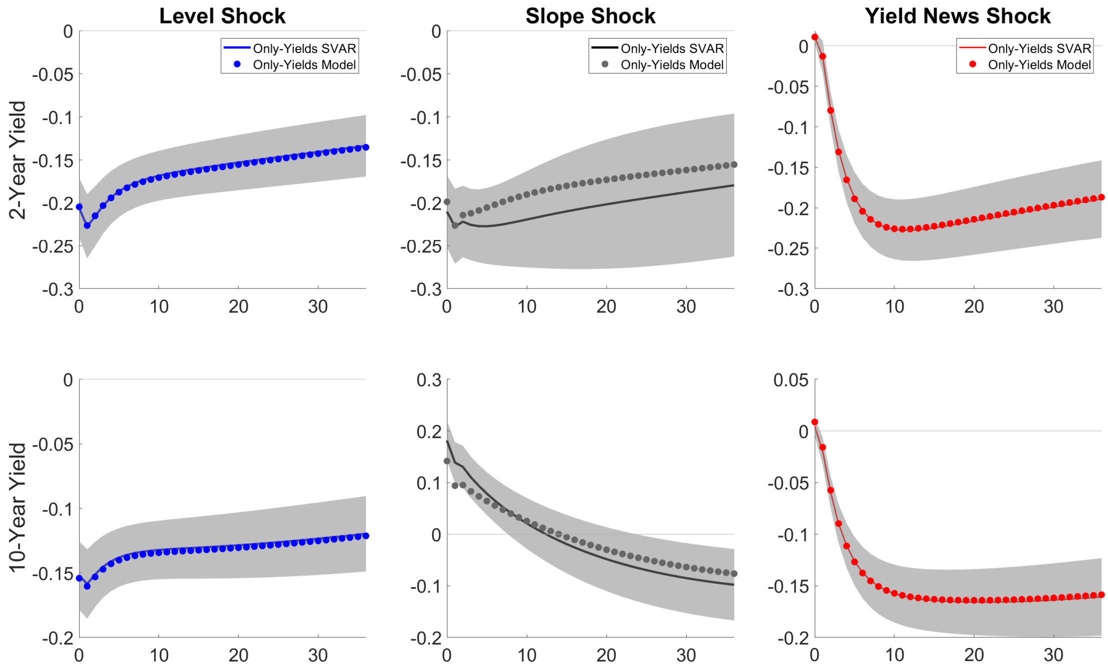
(b) FEVDs



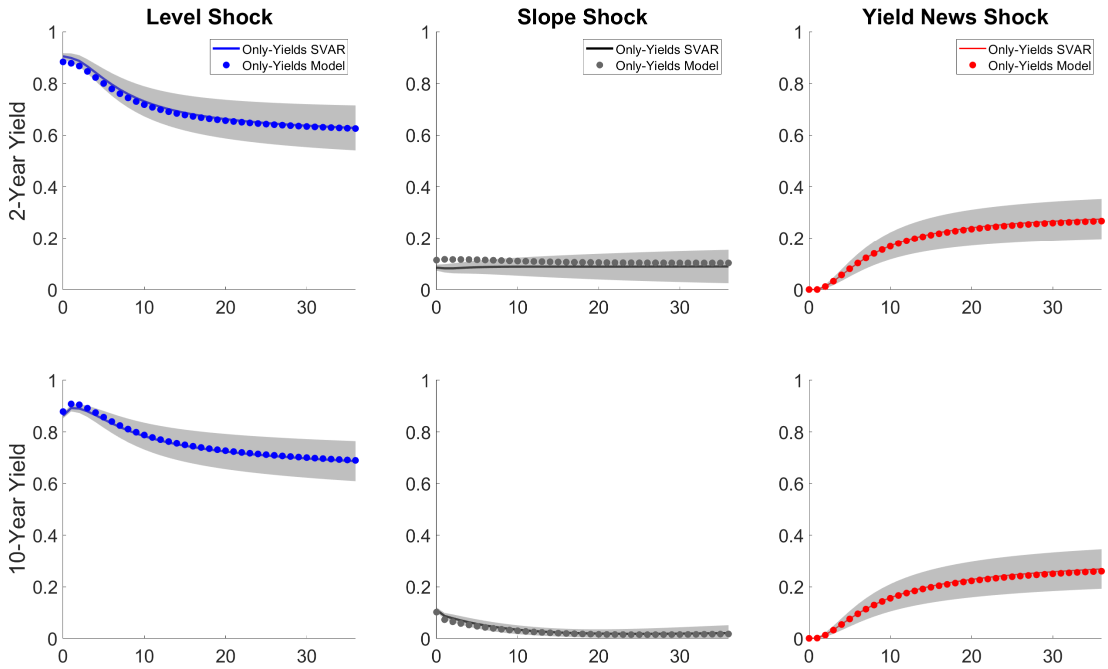
Note: The top panel of this figure shows the IRFs for the yield news shock (red solid ± 1 stand error bands), and the yield news shock that is made orthogonal to the realized volatility and BC news shocks (blue dashed ± 1 stand error bands) from the macro-yields model. Each shock is reported as a one-standard-deviation impulse.

Figure 18: IRFs and FEVDs from only-yields DFM and structural VAR

(a) IRFs

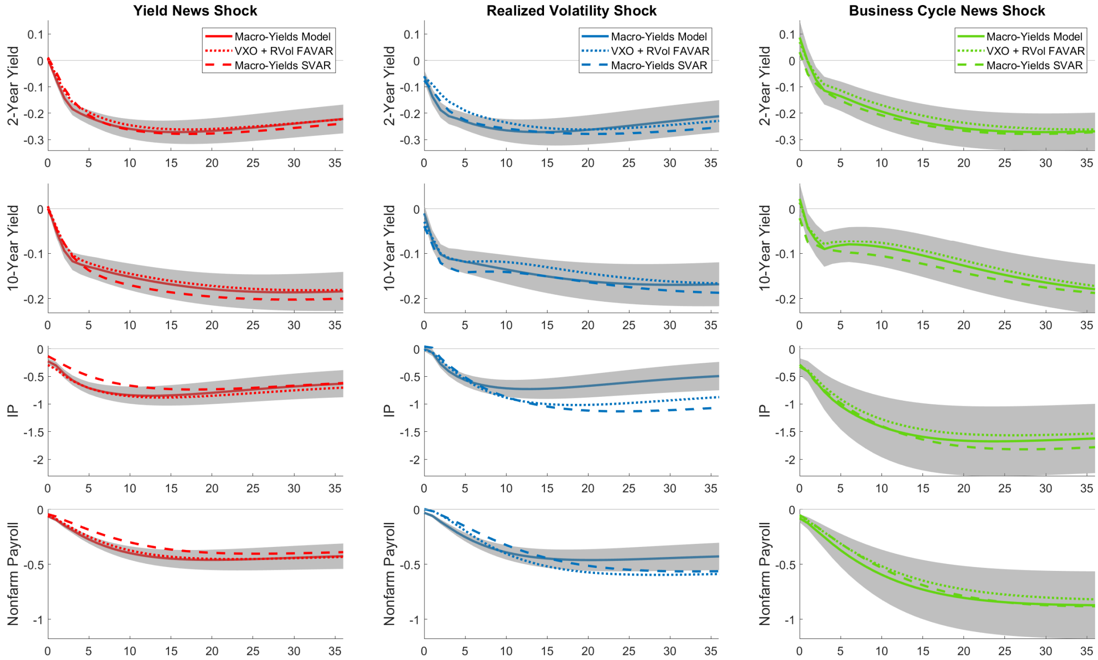


(b) FEVDs



Note: In the top panel of this figure, the solid lines show the IRFs of yields for the level, slope and yield news shocks from the structural VAR with 4 yields and 10y-1y spread with one-standard error bands. The dotted lines show the results from the only-yields model. The bottom panel displays the corresponding FEVDs.

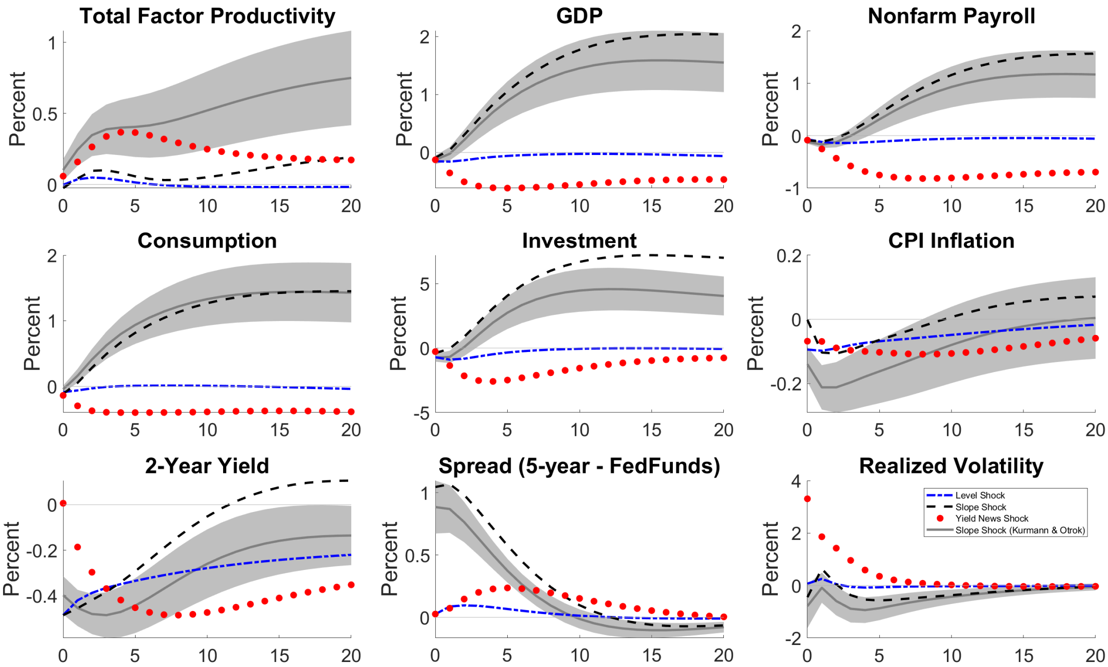
Figure 19: IRFs from macro-yields DFM, FAVAR, and structural VAR



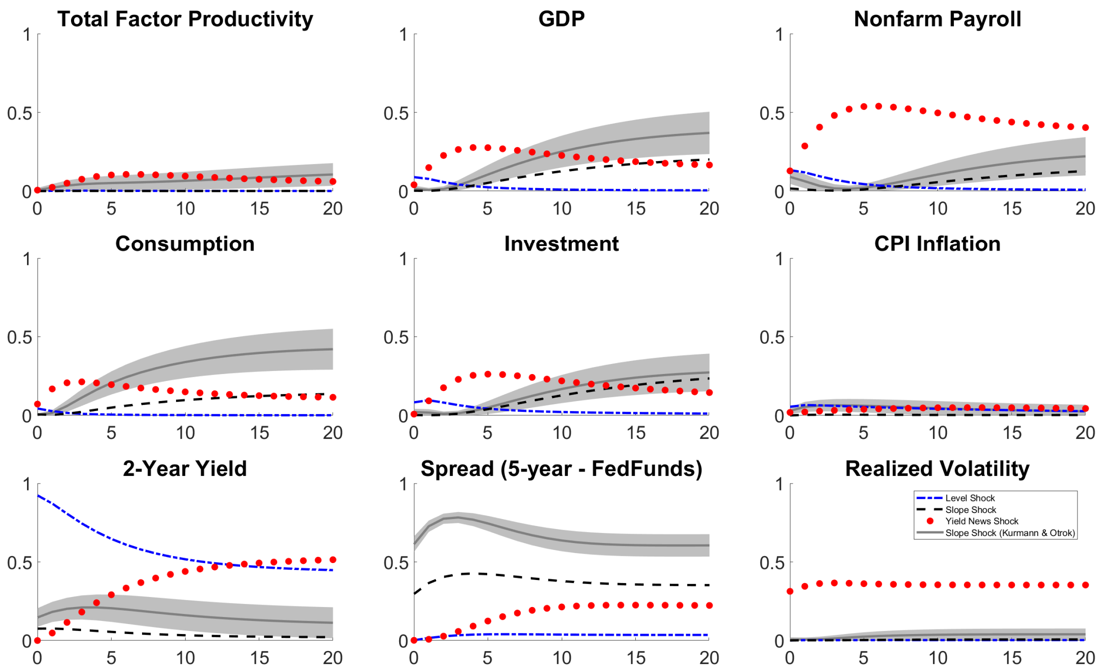
Note: This figure shows the IRFs for selected variables for the yield news, realized volatility and business cycle news shocks from the macro-yields model (solid ±1 stand error bands), 13-factor FAVAR with the VXO and RVol treated as observed (dotted), and 13-variable structural VAR including four yields, the 10y-1y spread, the VXO and RVol, the Philadelphia Fed Leading Indicator, initial claims, housing starts, IP, nonfarm payrol and CPI inflation (dashed).

Figure 20: IRFs and FEVDs from quarterly macro-yields DFM

(a) IRFs



(b) FEVDs



Note: The top panel of this figure shows the IRFs for the level, slope and yield news shocks, and for the Kurmann-Otrok slope shock that maximizes the FEV share of the 5y-FedFunds spread over the next year from the quarterly macro-yields DFM. The yield news shock is reported as a one-standard-deviation impulse, and the responses for the other shocks are scaled so that they each produce the same peak decline in the two-year yield as the yield news shock. The bottom panel displays the corresponding FEVDs.

Appendix A. Data Descriptions

Appendix A.1. Monthly Macroeconomic Dataset

Most of series were taken from the FRED monthly macroeconomic database. The series were converted to first differences, growth rates, and etc. using the transformation codes listed in the column labeled "T". Letting x_t denote a series, the transformations are: (1) no transformation; (2) Δx_t; (3) $\Delta^2 x_t$; (4) $ln(x_t)$; (5) $\Delta ln(x_t)$; (6) $\Delta^2 ln(x_t)$; (7) $\Delta(x_t/x_{t-1} - 1)$.

No.	Series	Description	T	Data Span
		Output and Income		
1	RPI	Real Personal Income	5	1962:7-2019:6
2	W875RX1	Real personal income ex transfer receipts	5	1962:7-2019:6
3	INDPRO	IP Index	5	1962:7-2019:6
4	IPFPNSS	IP: Final Products and Nonindustrial Supplies	5	1962:7-2019:6
5	IPFINAL	IP: Final Products (Market Group)	5	1962:7-2019:6
6	IPCONGD	IP: Consumer Goods	5	1962:7-2019:6
7	IPDCONGD	IP: Durable Consumer Goods	5	1962:7-2019:6
8	IPNCONGD	IP: Nondurable Consumer Goods	5	1962:7-2019:6
9	IPBUSEQ	IP: Business Equipment	5	1962:7-2019:6
10	IPMAT	IP: Materials	5	1962:7-2019:6
11	IPDMAT	IP: Durable Materials	5	1962:7-2019:6
12	IPNMAT	IP: Nondurable Materials	5	1962:7-2019:6
13	IPMANSICS	IP: Manufacturing (SIC)	5	1962:7-2019:6
14	IPB51222S	IP: Residential Utilities	5	1962:7-2019:6
15	IPFUELS	IP: Fuels	5	1962:7-2019:6
16	CUMFNS	Capacity Utilization: Manufacturing	2	1962:7-2019:6
		Labor Market		
17	HWI	Help-Wanted Index for United States	2	1962:7-2019:6
18	HWIURATIO	Ratio of Help Wanted/No. Unemployed	2	1962:7-2019:6
19	CLF16OV	Civilian Labor Force	5	1962:7-2019:6
20	CE16OV	Civilian Employment	5	1962:7-2019:6
21	UNRATE	Civilian Unemployment Rate	2	1962:7-2019:6
22	UEMPMEAN	Average Duration of Unemployment (Weeks)	2	1962:7-2019:6
23	UEMPLT5	Civilians Unemployed - Less Than 5 Weeks	5	1962:7-2019:6
24	UEMP5TO14	Civilians Unemployed for 5-14 Weeks	5	1962:7-2019:6
25	UEMP15OV	Civilians Unemployed - 15 Weeks & Over	5	1962:7-2019:6
26	UEMP15T26	Civilians Unemployed for 15-26 Weeks	5	1962:7-2019:6
27	UEMP27OV	Civilians Unemployed for 27 Weeks and Over	5	1962:7-2019:6
28	CLAIMSx	Initial Claims	5	1962:7-2019:6
29	PAYEMS	All Employees: Total nonfarm	5	1962:7-2019:6
30	USGOOD	All Employees: Goods-Producing Industries	5	1962:7-2019:6
31	CES1021000001	All Employees: Mining and Logging: Mining	5	1962:7-2019:6
32	USCONS	All Employees: Construction	5	1962:7-2019:6
33	MANEMP	All Employees: Manufacturing	5	1962:7-2019:6
34	DMANEMP	All Employees: Durable goods	5	1962:7-2019:6
35	NDMANEMP	All Employees: Nondurable goods	5	1962:7-2019:6
36	SRVPRD	All Employees: Service-Providing Industries	5	1962:7-2019:6
37	USTPU	All Employees: Trade, Transportation & Utilities	5	1962:7-2019:6
38	USWTRADE	All Employees: Wholesale Trade	5	1962:7-2019:6
39	USTRADE	All Employees: Retail Trade	5	1962:7-2019:6
40	USFIRE	All Employees: Financial Activities	5	1962:7-2019:6
41	USGOVT	All Employees: Government	5	1962:7-2019:6
42	CES0600000007	Avg Weekly Hours : Goods-Producing	1	1962:7-2019:6
43	AWOTMAN	Avg Weekly Overtime Hours : Manufacturing	2	1962:7-2019:6
44	AWHMAN	Avg Weekly Hours : Manufacturing	1	1962:7-2019:6
45	CES0600000008	Avg Hourly Earnings : Goods-Producing	6	1962:7-2019:6
46	CES2000000008	Avg Hourly Earnings : Construction	6	1962:7-2019:6
47	CES3000000008	Avg Hourly Earnings : Manufacturing	6	1962:7-2019:6
48	AWHNONAG	Average Weekly Hours of Production and Non-supervisory Employees: Total Private	5	1964:1-2019:6
		Housing		
49	HOUST	Housing Starts: Total New Privately Owned	4	1962:7-2019:6

50	HOUSTNE	Housing Starts, Northeast	4	1962:7-2019:6
51	HOUSTMW	Housing Starts, Midwest	4	1962:7-2019:6
52	HOUSTS	Housing Starts, South	4	1962:7-2019:6
53	HOUSTW	Housing Starts, West	4	1962:7-2019:6
54	PERMIT	New Private Housing Permits (SAAR)	4	1962:7-2019:6
55	PERMITNE	New Private Housing Permits, Northeast (SAAR)	4	1962:7-2019:6
56	PERMITMW	New Private Housing Permits, Midwest (SAAR)	4	1962:7-2019:6
57	PERMITS	New Private Housing Permits, South (SAAR)	4	1962:7-2019:6
58	PERMITW	New Private Housing Permits, West (SAAR)	4	1962:7-2019:6
		Consumption, Orders and Inventories		
59	DPCERA3M086SBEA	Real personal consumption expenditures	5	1962:7-2019:6
60	CMRMTSPLx	Real Manu. and Trade Industries Sales	5	1962:7-2019:6
61	RETAILx	Retail and Food Services Sales	5	1962:7-2019:6
62	ACOGNO	New Orders for Consumer Goods	5	1992:3-2019:6
63	AMDMNOx	New Orders for Durable Goods	5	1962:7-2019:6
64	ANDENOx	New Orders for Nondefense Capital Goods	5	1968:3-2019:6
65	AMDMUOx	Unfilled Orders for Durable Goods	5	1962:7-2019:6
66	BUSINVx	Total Business Inventories	5	1962:7-2019:6
67	ISRATIOx	Total Business: Inventories to Sales Ratio	2	1962:7-2019:6
68	UMCSENTx	Consumer Sentiment Index	1	1978:2-2019:6
		Money and Credit		
69	M1SL	M1 Money Stock	6	1962:7-2019:6
70	M2SL	M2 Money Stock	6	1962:7-2019:6
71	M2REAL	Real M2 Money Stock	5	1962:7-2019:6
72	AMBSL	St. Louis Adjusted Monetary Base	6	1962:7-2019:6
73	TOTRESNS	Total Reserves of Depository Institutions	6	1962:7-2019:6
74	NONBORRES	Reserves Of Depository Institutions	7	1962:7-2019:6
75	BUSLOANS	Commercial and Industrial Loans	6	1962:7-2019:6
76	REALLN	Real Estate Loans at All Commercial Banks	6	1962:7-2019:6
77	NONREVSL	Total Nonrevolving Credit	6	1962:7-2019:6
78	CONSPI	Nonrevolving Consumer Credit to Personal Income	2	1962:7-2019:6
79	MZMSL	MZM Money Stock	6	1962:7-2019:6
80	DTCOLNVHFNM	Consumer Motor Vehicle Loans Outstanding	6	1962:7-2019:6
81	DTCTHFNM	Total Consumer Loans and Leases Outstanding	6	1962:7-2019:6
82	INVEST	Securities in Bank Credit at All Commercial Banks	6	1962:7-2019:6
		Interest and Exchange Rates		
83	FEDFUNDS	Effective Federal Funds Rate	2	1962:7-2019:6
84	CP3Mx	3-Month AA Financial Commercial Paper Rate	2	1962:7-2019:6
85	TB3MS	3-Month Treasury Bill	2	1962:7-2019:6
86	TB6MS	6-Month Treasury Bill	2	1962:7-2019:6
87	GS1	1-Year Treasury Rate	2	1962:7-2019:6
88	GS5	5-Year Treasury Rate	2	1962:7-2019:6
89	GS10	10-Year Treasury Rate	2	1962:7-2019:6
90	AAA	Moody's Seasoned Aaa Corporate Bond Yield	2	1962:7-2019:6
91	BAA	Moody's Seasoned Baa Corporate Bond Yield	2	1962:7-2019:6
92	COMPAPFFx	3-Month Commercial Paper Minus FEDFUNDS	1	1962:7-2019:6
93	TB3SMFFM	3-Month Treasury C Minus FEDFUNDS	1	1962:7-2019:6
94	TB6SMFFM	6-Month Treasury C Minus FEDFUNDS	1	1962:7-2019:6
95	T1YFFM	1-Year Treasury C Minus FEDFUNDS	1	1962:7-2019:6
96	T5YFFM	5-Year Treasury C Minus FEDFUNDS	1	1962:7-2019:6
97	T10YFFM	10-Year Treasury C Minus FEDFUNDS	1	1962:7-2019:6
98	AAAFFM	Moody's Aaa Corporate Bond Minus FEDFUNDS	1	1962:7-2019:6
99	BAAFFM	Moody's Baa Corporate Bond Minus FEDFUNDS	1	1962:7-2019:6
100	TWEXMMTH	Trade Weighted U.S. Dollar Index: Major Currencies	5	1973:2-2019:6
101	EXSZUSx	Switzerland / U.S. Foreign Exchange Rate	5	1962:7-2019:6
102	EXJPUSx	Japan / U.S. Foreign Exchange Rate	5	1962:7-2019:6
103	EXUSUKx	U.S. / U.K. Foreign Exchange Rate	5	1962:7-2019:6
104	EXCAUSx	Canada / U.S. Foreign Exchange Rate	5	1962:7-2019:6
		Prices		
105	WPSFD49207	PPI: Finished Goods	6	1962:7-2019:6
106	WPSFD49502	PPI: Finished Consumer Goods	6	1962:7-2019:6
107	WPSID61	PPI: Intermediate Materials	6	1962:7-2019:6
108	WPSID62	PPI: Crude Materials	6	1962:7-2019:6
109	OILPRICEx	Crude Oil, spliced WTI and Cushing	6	1962:7-2019:6

110	PPICMM	PPI: Metals and metal products	6	1962:7-2019:6
111	CPIAUCSL	CPI : All Items	6	1962:7-2019:6
112	CPIAPPSL	CPI : Apparel	6	1962:7-2019:6
113	CPITRNSL	CPI : Transportation	6	1962:7-2019:6
114	CPIMEDSL	CPI : Medical Care	6	1962:7-2019:6
115	CUSR0000SAC	CPI : Commodities	6	1962:7-2019:6
116	CUSR0000SAD	CPI : Durables	6	1962:7-2019:6
117	CUSR0000SAS	CPI : Services	6	1962:7-2019:6
118	CPIULFSL	CPI : All Items Less Food	6	1962:7-2019:6
119	CUSR0000SA0L2	CPI : All items less shelter	6	1962:7-2019:6
120	CUSR0000SA0L5	CPI : All items less medical care	6	1962:7-2019:6
121	PCEPI	Personal Cons. Expend.: Chain Index	6	1962:7-2019:6
122	DDURRG3M086SBEA	Personal Cons. Exp: Durable goods	6	1962:7-2019:6
123	DNDGRG3M086SBEA	Personal Cons. Exp: Nondurable goods	6	1962:7-2019:6
124	DSERRG3M086SBEA	Personal Cons. Exp: Services	6	1962:7-2019:6
Stock Market				
125	S&P 500	S&P's Common Stock Price Index: Composite	5	1962:7-2019:6
126	S&P: indust	S&P's Common Stock Price Index: Industrials	5	1962:7-2019:6
127	S&P div yield	S&P's Composite Common Stock: Dividend Yield	2	1962:7-2019:6
128	S&P PE ratio	S&P's Composite Common Stock: Price-Earnings Ratio	5	1962:7-2019:4
129	VXOCLSx	VXO	1	1962:7-2019:6
Other				
130	MOVE	1-Month MOVE Volatility Index	1	1988:4-2019:6
131	LMN	Ludvigson-Ma-Ng Financial Uncertainty Index at 1-Month Forecast Horizon	1	1962:7-2019:6
132	EBP	Gilchrist-Zakrajšek Excess Bond Premium	1	1973:1-2016:8
133	RVol	Berger, Dew-Becker and Giglio Realized Volatility Series, Extended for the Full Period	1	1962:7-2019:6
134	TB3SAvg	Average of 3- and 12-Month Ahead Forecasts for 3-Month Treasury Bill	1	1999:1-2019:3
135	USSLIND	Philadelphia Fed's Leading Index for the U.S.	1	1982:1-2019:6

Appendix A.2. Quarterly Macroeconomic Dataset

Most of series were taken from the FRED quarterly macroeconomic database. The series were converted to first differences, growth rates, and etc. using the transformation codes listed in the column labeled "T". Letting x_t denote a series, the transformations are: (1) no transformation; (2) Δx_t; (3) $\Delta^2 x_t$; (4) $ln(x_t)$; (5) $\Delta ln(x_t)$; (6) $\Delta^2 ln(x_t)$; (7) $\Delta(x_t/x_{t-1} - 1)$. The column labeled "F" indicates whether the series was used to estimate the factors (1 = yes, 0 = no).

No.	Series	Description	T	F	Data Span
		NIPA			
1	GDPC1	Real Gross Domestic Product, 3 Decimal (Billions of Chained 2012 Dollars)	5	0	1962:3-2019:2
2	PCECC96	Real Personal Consumption Expenditures (Billions of Chained 2012 Dollars)	5	0	1962:3-2019:2
3	PCDGx	Real personal consumption expenditures: Durable goods (Billions of Chained 2012 Dollars), deflated using PCE	5	1	1962:3-2019:2
4	PCESVx	Real Personal Consumption Expenditures: Services (Billions of 2012 Dollars), deflated using PCE	5	1	1962:3-2019:2
5	PCNDx	Real Personal Consumption Expenditures: Nondurable Goods (Billions of 2012	5	1	1962:3-2019:2
6	GPDIC1	Real Gross Private Domestic Investment, 3 decimal (Billions of Chained 2012 Dollars)	5	0	1962:3-2019:2
7	FPIx	Real private fixed investment (Billions of Chained 2012 Dollars), deflated using PCE	5	0	1962:3-2019:2
8	Y033RC1Q027SBEAx	Real Gross Private Domestic Investment: Fixed Investment: Nonresidential: Equipment (Billions of Chained 2012 Dollars), deflated using PCE	5	1	1962:3-2019:2
9	PNFIx	Real private fixed investment: Nonresidential (Billions of Chained 2012 Dollars), deflated using PCE	5	1	1962:3-2019:2
10	PRFIx	Real private fixed investment: Residential (Billions of Chained 2012 Dollars), deflated using PCE	5	1	1962:3-2019:2
11	A014RE1Q156NBEA	Shares of gross domestic product: Gross private domestic investment: Change in private inventories (Percent)	1	1	1962:3-2019:2
12	GCEC1	Real Government Consumption Expenditures & Gross Investment (Billions of Chained 2012 Dollars)	5	0	1962:3-2019:2
13	A823RL1Q225SBEA	Real Government Consumption Expenditures and Gross Investment: Federal (Percent Change from Preceding Period)	1	1	1962:3-2019:2
14	FGRECPTx	Real Federal Government Current Receipts (Billions of Chained 2012 Dollars), deflated using PCE	5	1	1962:3-2019:2
15	SLCEx	Real government state and local consumption expenditures (Billions of Chained 2012 Dollars), deflated using PCE	5	1	1962:3-2019:2
16	EXPGSC1	Real Exports of Goods & Services, 3 Decimal (Billions of Chained 2012 Dollars)	5	1	1962:3-2019:2
17	IMPGSC1	Real Imports of Goods & Services, 3 Decimal (Billions of Chained 2012 Dollars)	5	1	1962:3-2019:2
18	DPIC96	Real Disposable Personal Income (Billions of Chained 2012 Dollars)	5	0	1962:3-2019:2
19	OUTNFB	Nonfarm Business Sector: Real Output (Index 2012=100)	5	0	1962:3-2019:2
20	OUTBS	Business Sector: Real Output (Index 2012=100)	5	0	1962:3-2019:2
21	OUTMS	Manufacturing Sector: Real Output (Index 2012=100)	5	0	1987:1-2019:2
22	B020RE1Q156NBEA	Shares of gross domestic product: Exports of goods and services (Percent)	2	0	1962:3-2019:2
23	B021RE1Q156NBEA	Shares of gross domestic product: Imports of goods and services (Percent)	2	0	1962:3-2019:2
		Industrial Production			
24	INDPRO	Industrial Production Index (Index 2012=100)	5	0	1962:3-2019:2
25	IPFINAL	Industrial Production: Final Products (Market Group) (Index 2012=100)	5	0	1962:3-2019:2
26	IPCONGD	Industrial Production: Consumer Goods (Index 2012=100)	5	0	1962:3-2019:2
27	IPMAT	Industrial Production: Materials (Index 2012=100)	5	0	1962:3-2019:2
28	IPDMAT	Industrial Production: Durable Materials (Index 2012=100)	5	1	1962:3-2019:2
29	IPNMAT	Industrial Production: Nondurable Materials (Index 2012=100)	5	1	1962:3-2019:2
30	IPDCONGD	Industrial Production: Durable Consumer Goods (Index 2012=100)	5	1	1962:3-2019:2
31	IPB51110SQ	Industrial Production: Durable Goods: Automotive products (Index 2012=100)	5	1	1962:3-2019:2
32	IPNCONGD	Industrial Production: Nondurable Consumer Goods (Index 2012=100)	5	1	1962:3-2019:2
33	IPBUSEQ	Industrial Production: Business Equipment (Index 2012=100)	5	1	1962:3-2019:2
34	IPB51220SQ	Industrial Production: Consumer energy products (Index 2012=100)	5	1	1962:3-2019:2
35	TCU	Capacity Utilization: Total Industry (Percent of Capacity)	1	1	1967:1-2019:2
36	CUMFNS	Capacity Utilization: Manufacturing (SIC) (Percent of Capacity)	1	1	1962:3-2019:2
37	IPMANSICS	Industrial Production: Manufacturing (SIC) (Index 2012=100)	5	0	1962:3-2019:2
38	IPB51222S	Industrial Production: Residential Utilities (Index 2012=100)	5	0	1962:3-2019:2
39	IPFUELS	Industrial Production: Fuels (Index 2012=100)	5	0	1962:3-2019:2
		Employment and Unemployment			
40	PAYEMS	All Employees: Total nonfarm (Thousands of Persons)	5	0	1962:3-2019:2

41	USPRIV	All Employees: Total Private Industries (Thousands of Persons)	5	0	1962:3-2019:2
42	MANEMP	All Employees: Manufacturing (Thousands of Persons)	5	0	1962:3-2019:2
43	SRVPRD	All Employees: Service-Providing Industries (Thousands of Persons)	5	0	1962:3-2019:2
44	USGOOD	All Employees: Goods-Producing Industries (Thousands of Persons)	5	0	1962:3-2019:2
45	DMANEMP	All Employees: Durable goods (Thousands of Persons)	5	1	1962:3-2019:2
46	NDMANEMP	All Employees: Nondurable goods (Thousands of Persons)	5	0	1962:3-2019:2
47	USCONS	All Employees: Construction (Thousands of Persons)	5	1	1962:3-2019:2
48	USEHS	All Employees: Education & Health Services (Thousands of Persons)	5	1	1962:3-2019:2
49	USFIRE	All Employees: Financial Activities (Thousands of Persons)	5	1	1962:3-2019:2
50	USINFO	All Employees: Information Services (Thousands of Persons)	5	1	1962:3-2019:2
51	USPBS	All Employees: Professional & Business Services (Thousands of Persons)	5	1	1962:3-2019:2
52	USLAH	All Employees: Leisure & Hospitality (Thousands of Persons)	5	1	1962:3-2019:2
53	USSERV	All Employees: Other Services (Thousands of Persons)	5	1	1962:3-2019:2
54	USMINE	All Employees: Mining and logging (Thousands of Persons)	5	1	1962:3-2019:2
55	USTPU	All Employees: Trade, Transportation & Utilities (Thousands of Persons)	5	1	1962:3-2019:2
56	USGOVT	All Employees: Government (Thousands of Persons)	5	0	1962:3-2019:2
57	USTRADE	All Employees: Retail Trade (Thousands of Persons)	5	1	1962:3-2019:2
58	USWTRADE	All Employees: Wholesale Trade (Thousands of Persons)	5	1	1962:3-2019:2
59	CES9091000001	All Employees: Government: Federal (Thousands of Persons)	5	1	1962:3-2019:2
60	CES9092000001	All Employees: Government: State Government (Thousands of Persons)	5	1	1962:3-2019:2
61	CES9093000001	All Employees: Government: Local Government (Thousands of Persons)	5	1	1962:3-2019:2
62	CE16OV	Civilian Employment (Thousands of Persons)	5	0	1962:3-2019:2
63	CIVPART	Civilian Labor Force Participation Rate (Percent)	2	0	1962:3-2019:2
64	UNRATE	Civilian Unemployment Rate (Percent)	2	0	1962:3-2019:2
65	UNRATESTx	Unemployment Rate less than 27 weeks (Percent)	2	0	1962:3-2019:2
66	UNRATELTx	Unemployment Rate for more than 27 weeks (Percent)	2	0	1962:3-2019:2
67	LNS14000012	Unemployment Rate - 16 to 19 years (Percent)	2	1	1962:3-2019:2
68	LNS14000025	Unemployment Rate - 20 years and over, Men (Percent)	2	1	1962:3-2019:2
69	LNS14000026	Unemployment Rate - 20 years and over, Women (Percent)	2	1	1962:3-2019:2
70	UEMPLT5	Number of Civilians Unemployed - Less Than 5 Weeks (Thousands of Persons)	5	1	1962:3-2019:2
71	UEMP5TO14	Number of Civilians Unemployed for 5 to 14 Weeks (Thousands of Persons)	5	1	1962:3-2019:2
72	UEMP15T26	Number of Civilians Unemployed for 15 to 26 Weeks (Thousands of Persons)	5	1	1962:3-2019:2
73	UEMP27OV	Number of Civilians Unemployed for 27 Weeks and Over (Thousands of Persons)	5	1	1962:3-2019:2
74	LNS13023621	Unemployment Level - Job Losers (Thousands of Persons)	5	1	1967:1-2019:2
75	LNS13023557	Unemployment Level - Reentrants to Labor Force (Thousands of Persons)	5	1	1967:1-2019:2
76	LNS13023705	Unemployment Level - Job Leavers (Thousands of Persons)	5	1	1967:1-2019:2
77	LNS13023569	Unemployment Level - New Entrants (Thousands of Persons)	5	1	1967:1-2019:2
78	LNS12032194	Employment Level - Part-Time for Economic Reasons, All Industries (Thousands of Persons)	5	1	1962:3-2019:2
79	HOABS	Business Sector: Hours of All Persons (Index 2012=100)	5	0	1962:3-2019:2
80	HOAMS	Manufacturing Sector: Hours of All Persons (Index 2012=100)	5	0	1987:1-2019:2
81	HOANBS	Nonfarm Business Sector: Hours of All Persons (Index 2012=100)	5	0	1962:3-2019:2
82	AWHMAN	Average Weekly Hours of Production and Nonsupervisory Employees: Manufacturing (Hours)	1	1	1962:3-2019:2
83	AWHNONAG	Average Weekly Hours Of Production And Nonsupervisory Employees: Total private (Hours)	5	1	1964:1-2019:2
84	AWOTMAN	Average Weekly Overtime Hours of Production and Nonsupervisory Employees: Manufacturing (Hours)	2	1	1962:3-2019:2
85	HWIx	Help-Wanted Index	1	0	1962:3-2019:2
86	UEMPMEAN	Average (Mean) Duration of Unemployment (Weeks)	2	0	1962:3-2019:2
87	CES0600000007	Average Weekly Hours of Production and Nonsupervisory Employees: Goods-Producing	2	0	1962:3-2019:2
88	HWIURATIOx	Ratio of Help Wanted/No. Unemployed	2	0	1962:3-2019:2
89	CLAIMSx	Initial Claims	5	0	1962:3-2019:2
		Housing			
90	HOUST	Housing Starts: Total: New Privately Owned Housing Units Started (Thousands of Units)	5	0	1962:3-2019:2
91	HOUST5F	Privately Owned Housing Starts: 5-Unit Structures or More (Thousands of Units)	5	0	1962:3-2019:2
92	PERMIT	New Private Housing Units Authorized by Building Permits (Thousands of Units)	5	1	1962:3-2019:2
93	HOUSTMW	Housing Starts in Midwest Census Region (Thousands of Units)	5	1	1962:3-2019:2
94	HOUSTNE	Housing Starts in Northeast Census Region (Thousands of Units)	5	1	1962:3-2019:2
95	HOUSTS	Housing Starts in South Census Region (Thousands of Units)	5	1	1962:3-2019:2
96	HOUSTW	Housing Starts in West Census Region (Thousands of Units)	5	1	1962:3-2019:2
97	USSTHPI	All-Transactions House Price Index for the United States (Index 1980 Q1=100)	5	1	1975:1-2019:2
98	SPCS10RSA	S&P/Case-Shiller 10-City Composite Home Price Index (Index January 2000 = 100)	5	1	1987:1-2019:2

99	SPCS20RSA	S&P/Case-Shiller 20-City Composite Home Price Index (Index January 2000 = 100)	5	1	2000:1-2019:2
100	PERMITNE	New Private Housing Units Authorized by Building Permits in the Northeast Census Region (Thousands, SAAR)	5	0	1962:3-2019:2
101	PERMITMW	New Private Housing Units Authorized by Building Permits in the Midwest Census Region (Thousands, SAAR)	5	0	1962:3-2019:2
102	PERMITS	New Private Housing Units Authorized by Building Permits in the South Census Region (Thousands, SAAR)	5	0	1962:3-2019:2
103	PERMITW	New Private Housing Units Authorized by Building Permits in the West Census Region (Thousands, SAAR)	5	0	1962:3-2019:2
		Inventories, Orders, and Sales			
104	CMRMTSPLx	Real Manufacturing and Trade Industries Sales (Millions of Chained 2012 Dollars)	5	0	1962:3-2019:2
105	RSAFSx	Real Retail and Food Services Sales (Millions of Chained 2012 Dollars), deflated by Core PCE	5	1	1962:3-2019:2
106	AMDMNOx	Real Manufacturers' New Orders: Durable Goods (Millions of 2012 Dollars), deflated by Core PCE	5	1	1962:3-2019:2
107	ACOGNOx	Real Value of Manufacturers' New Orders for Consumer Goods Industries (Millions of 2012 Dollars), deflated by Core PCE	5	1	1992:1-2019:2
108	AMDMUOx	Real Value of Manufacturers' Unfilled Orders for Durable Goods Industries (Millions of 2012 Dollars), deflated by Core PCE	5	1	1962:3-2019:2
109	ANDENOx	Real Value of Manufacturers' New Orders for Capital Goods: Nondefense Capital Goods Industries (Millions of 2012 Dollars), deflated by Core PCE	5	1	1968:1-2019:2
110	INVCQRMTSPL	Real Manufacturing and Trade Inventories (Millions of 2012 Dollars)	5	1	1967:1-2019:2
111	BUSINVx	Total Business Inventories (Millions of Dollars)	5	0	1962:3-2019:2
112	ISRATIOx	Total Business: Inventories to Sales Ratio	2	0	1962:3-2019:2
		Prices			
113	PCECTPI	Personal Consumption Expenditures: Chain-type Price Index (Index 2012=100)	6	0	1962:3-2019:2
114	PCEPILFE	Personal Consumption Expenditures Excluding Food and Energy (Chain-Type Price Index) (Index 2012=100)	6	0	1962:3-2019:2
115	GDPCTPI	Gross Domestic Product: Chain-type Price Index (Index 2012=100)	6	0	1962:3-2019:2
116	GPDICTPI	Gross Private Domestic Investment: Chain-type Price Index (Index 2012=100)	6	1	1962:3-2019:2
117	IPDBS	Business Sector: Implicit Price Deflator (Index 2012=100)	6	1	1962:3-2019:2
118	DGDSRG3Q086SBEA	Personal consumption expenditures: Goods (chain-type price index)	6	0	1962:3-2019:2
119	DDURRG3Q086SBEA	Personal consumption expenditures: Durable goods (chain-type price index)	6	0	1962:3-2019:2
120	DSERRG3Q086SBEA	Personal consumption expenditures: Services (chain-type price index)	6	0	1962:3-2019:2
121	DNDGRG3Q086SBEA	Personal consumption expenditures: Nondurable goods (chain-type price index)	6	0	1962:3-2019:2
122	DHCERG3Q086SBEA	Personal consumption expenditures: Services: Household consumption expenditures (chain-type price index)	6	0	1962:3-2019:2
123	DMOTRG3Q086SBEA	Personal consumption expenditures: Durable goods: Motor vehicles and parts (chain-type price index)	6	1	1962:3-2019:2
124	DFDHRG3Q086SBEA	Personal consumption expenditures: Durable goods: Furnishings and durable household equipment (chain-type price index)	6	1	1962:3-2019:2
125	DREQRG3Q086SBEA	Personal consumption expenditures: Durable goods: Recreational goods and vehicles (chain-type price index)	6	1	1962:3-2019:2
126	DODGRG3Q086SBEA	Personal consumption expenditures: Durable goods: Other durable goods (chain-type price index)	6	1	1962:3-2019:2
126	DFXARG3Q086SBEA	Personal consumption expenditures: Nondurable goods: Food and beverages purchased for off-premises consumption (chain-type price index)	6	1	1962:3-2019:2
127	DCLORG3Q086SBEA	Personal consumption expenditures: Nondurable goods: Clothing and footwear (chain-type price index)	6	1	1962:3-2019:2
128	DGOERG3Q086SBEA	Personal consumption expenditures: Nondurable goods: Gasoline and other energy goods (chain-type price index)	6	1	1962:3-2019:2
129	DONGRG3Q086SBEA	Personal consumption expenditures: Nondurable goods: Other nondurable goods (chain-type price index)	6	1	1962:3-2019:2
130	DHUTRG3Q086SBEA	Personal consumption expenditures: Services: Housing and utilities (chain-type price index)	6	1	1962:3-2019:2
131	DHLCRG3Q086SBEA	Personal consumption expenditures: Services: Health care (chain-type price index)	6	1	1962:3-2019:2
132	DTRSRG3Q086SBEA	Personal consumption expenditures: Transportation services (chain-type price index)	6	1	1962:3-2019:2
133	DRCARG3Q086SBEA	Personal consumption expenditures: Recreation services (chain-type price index)	6	1	1962:3-2019:2
134	DFSARG3Q086SBEA	Personal consumption expenditures: Services: Food services and accommodations (chain-type price index)	6	1	1962:3-2019:2
135	DIFSRG3Q086SBEA	Personal consumption expenditures: Financial services and insurance (chain-type price index)	6	1	1962:3-2019:2
136	DOTSRG3Q086SBEA	Personal consumption expenditures: Other services (chain-type price index)	6	1	1962:3-2019:2
137	CPIAUCSL	Consumer Price Index for All Urban Consumers: All Items (Index 1982-84=100)	6	0	1962:3-2019:2

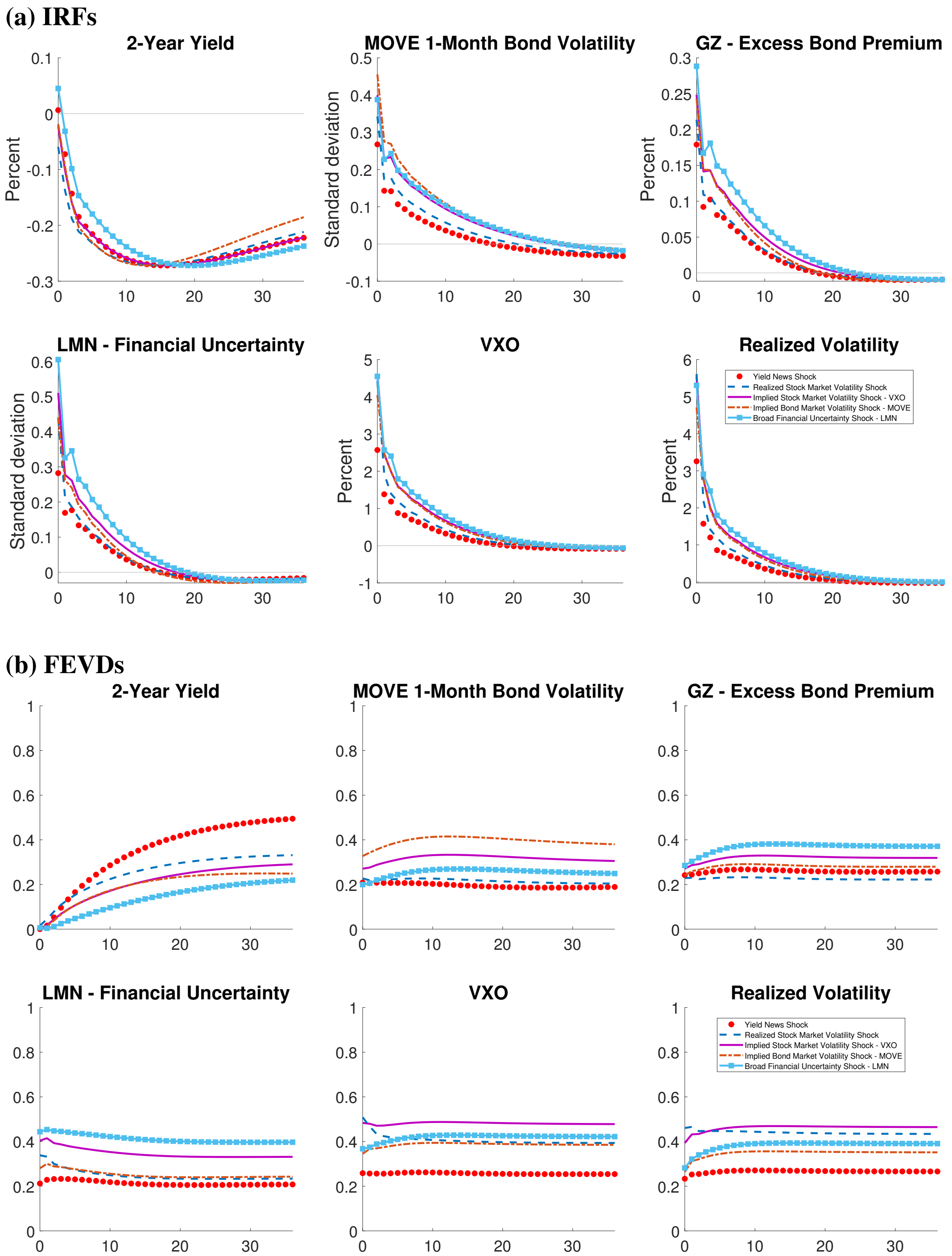
138	CPILFESL	Consumer Price Index for All Urban Consumers: All Items Less Food & Energy (Index 1982-84=100)	6	0	1962:3-2019:2
139	WPSFD49207	Producer Price Index by Commodity for Finished Goods (Index 1982=100)	6	0	1962:3-2019:2
140	PPIACO	Producer Price Index for All Commodities (Index 1982=100)	6	0	1962:3-2019:2
141	WPSFD49502	Producer Price Index by Commodity for Finished Consumer Goods (Index 1982=100)	6	1	1962:3-2019:2
142	WPSFD4111	Producer Price Index by Commodity for Finished Consumer Foods (Index 1982=100)	6	1	1962:3-2019:2
143	PPIIDC	Producer Price Index by Commodity Industrial Commodities (Index 1982=100)	6	1	1962:3-2019:2
144	WPSID61	Producer Price Index by Commodity Intermediate Materials: Supplies & Components (Index 1982=100)	6	1	1962:3-2019:2
145	WPU0531	Producer Price Index by Commodity for Fuels and Related Products and Power: Natural Gas (Index 1982=100)	5	1	1967:1-2019:2
146	WPU0561	Producer Price Index by Commodity for Fuels and Related Products and Power: Crude Petroleum (Domestic Production) (Index 1982=100)	5	1	1962:3-2019:2
147	OILPRICEx	Real Crude Oil Prices: West Texas Intermediate (WTI) - Cushing, Oklahoma (2012 Dollars per Barrel), deflated by Core PCE	5	0	1962:3-2019:2
148	WPSID62	Producer Price Index: Crude Materials for Further Processing (Index 1982=100)	6	0	1962:3-2019:2
149	PPICMM	Producer Price Index: Commodities: Metals and metal products: Primary nonferrous metals (Index 1982=100)	6	0	1962:3-2019:2
150	CPIAPPSL	Consumer Price Index for All Urban Consumers: Apparel (Index 1982-84=100)	6	0	1962:3-2019:2
151	CPITRNSL	Consumer Price Index for All Urban Consumers: Transportation (Index 1982-84=100)	6	0	1962:3-2019:2
152	CPIMEDSL	Consumer Price Index for All Urban Consumers: Medical Care (Index 1982-84=100)	6	0	1962:3-2019:2
153	CUSR0000SAC	Consumer Price Index for All Urban Consumers: Commodities (Index 1982-84=100)	6	0	1962:3-2019:2
154	CUSR0000SAD	Consumer Price Index for All Urban Consumers: Durables (Index 1982-84=100)	6	0	1962:3-2019:2
155	CUSR0000SAS	Consumer Price Index for All Urban Consumers: Services (Index 1982-84=100)	6	0	1962:3-2019:2
156	CPIULFSL	Consumer Price Index for All Urban Consumers: All Items Less Food (Index 1982-84=100)	6	0	1962:3-2019:2
157	CUSR0000SA0L2	Consumer Price Index for All Urban Consumers: All items less shelter (Index 1982-84=100)	6	0	1962:3-2019:2
158	CUSR0000SA0L5	Consumer Price Index for All Urban Consumers: All items less medical care (Index 1982-84=100)	6	0	1962:3-2019:2
159	CUSR0000SEHC	CPI for All Urban Consumers: Owners' equivalent rent of residences (Index Dec 1982=100)	6	0	1983:1-2019:2
		Earnings and Productivity			
160	TFP_UTIL	Fernald Utilization-Adjusted TFP	5	1	1962:3-2019:2
161	AHETPIx	Real Average Hourly Earnings of Production and Nonsupervisory Employees: Total	5	0	1964:1-2019:2
162	CES2000000008x	Real Average Hourly Earnings of Production and Nonsupervisory Employees: Construction (2012 Dollars per Hour), deflated by Core PCE	5	0	1962:3-2019:2
163	CES3000000008x	Real Average Hourly Earnings of Production and Nonsupervisory Employees: Manufacturing (2012 Dollars per Hour), deflated by Core PCE	5	0	1962:3-2019:2
164	COMPRMS	Manufacturing Sector: Real Compensation Per Hour (Index 2012=100)	5	1	1987:1-2019:2
165	COMPRNFB	Nonfarm Business Sector: Real Compensation Per Hour (Index 2012=100)	5	1	1962:3-2019:2
166	RCPHBS	Business Sector: Real Compensation Per Hour (Index 2012=100)	5	1	1962:3-2019:2
167	OPHMFG	Manufacturing Sector: Real Output Per Hour of All Persons (Index 2012=100)	5	1	1987:1-2019:2
168	OPHNFB	Nonfarm Business Sector: Real Output Per Hour of All Persons (Index 2012=100)	5	1	1962:3-2019:2
169	OPHPBS	Business Sector: Real Output Per Hour of All Persons (Index 2012=100)	5	0	1962:3-2019:2
170	ULCBS	Business Sector: Unit Labor Cost (Index 2012=100)	5	0	1962:3-2019:2
171	ULCMFG	Manufacturing Sector: Unit Labor Cost (Index 2012=100)	5	1	1987:1-2019:2
172	ULCNFB	Nonfarm Business Sector: Unit Labor Cost (Index 2012=100)	5	1	1962:3-2019:2
173	UNLPNBS	Nonfarm Business Sector: Unit Nonlabor Payments (Index 2012=100)	5	1	1962:3-2019:2
174	CES0600000008	Average Hourly Earnings of Production and Nonsupervisory Employees: Goods-Producing (Dollars per Hour)	6	0	1962:3-2019:2
		Interest Rates			
175	FEDFUNDS	Effective Federal Funds Rate (Percent)	2	1	1962:3-2019:2
176	TB3MS	3-Month Treasury Bill: Secondary Market Rate (Percent)	2	1	1962:3-2019:2
177	TB6MS	6-Month Treasury Bill: Secondary Market Rate (Percent)	2	0	1962:3-2019:2
178	GS1	1-Year Treasury Constant Maturity Rate (Percent)	2	0	1962:3-2019:2
179	GS10	10-Year Treasury Constant Maturity Rate (Percent)	2	0	1962:3-2019:2
180	MORTGAGE30US	30-Year Conventional Mortgage Rate© (Percent)	2	0	1971:2-2019:2
181	AAA	Moody's Seasoned Aaa Corporate Bond Yield© (Percent)	2	0	1962:3-2019:2
182	BAA	Moody's Seasoned Baa Corporate Bond Yield© (Percent)	2	0	1962:3-2019:2

183	BAA10YM	Moody's Seasoned Baa Corporate Bond Yield Relative to Yield on 10-Year Treasury Constant Maturity (Percent)	1	1	1962:3-2019:2
184	MORTG10YRx	30-Year Conventional Mortgage Rate Relative to 10-Year Treasury Constant Maturity (Percent)	1	1	1971:2-2019:2
185	TB6M3Mx	6-Month Treasury Bill Minus 3-Month Treasury Bill, secondary market (Percent)	1	1	1962:3-2019:2
186	GS1TB3Mx	1-Year Treasury Constant Maturity Minus 3-Month Treasury Bill, secondary market (Percent)	1	1	1962:3-2019:2
187	GS10TB3Mx	10-Year Treasury Constant Maturity Minus 3-Month Treasury Bill, secondary market (Percent)	1	1	1962:3-2019:2
188	CPF3MTB3Mx	3-Month Commercial Paper Minus 3-Month Treasury Bill, secondary market (Percent)	1	1	1962:3-2019:2
189	GS5	5-Year Treasury Constant Maturity Rate	2	0	1962:3-2019:2
190	TB3SMFFM	3-Month Treasury Constant Maturity Minus Federal Funds Rate	1	0	1962:3-2019:2
191	T5YFFM	5-Year Treasury Constant Maturity Minus Federal Funds Rate	1	0	1962:3-2019:2
192	AAAFFM	Moody's Seasoned Aaa Corporate Bond Minus Federal Funds Rate	1	0	1962:3-2019:2
193	CP3M	3-Month AA Financial Commercial Paper Rate	2	0	1962:3-2019:2
194	COMPAPFF	3-Month Commercial Paper Minus Federal Funds Rate	1	0	1962:3-2019:2
		Money and Credit			
195	AMBSLREAL	Real St. Louis Adjusted Monetary Base (Billions of 1982-84 Dollars), deflated by CPI	5	0	1962:3-2019:2
196	IMFSLx	Real Institutional Money Funds (Billions of 2012 Dollars), deflated by Core PCE	5	0	1980:1-2019:2
197	M1REAL	Real M1 Money Stock (Billions of 1982-84 Dollars), deflated by CPI	5	0	1962:3-2019:2
198	M2REAL	Real M2 Money Stock (Billions of 1982-84 Dollars), deflated by CPI	5	0	1962:3-2019:2
199	MZMREAL	Real MZM Money Stock (Billions of 1982-84 Dollars), deflated by CPI	5	0	1962:3-2019:2
200	BUSLOANSx	Real Commercial and Industrial Loans, All Commercial Banks (Billions of 2012 U.S. Dollars), deflated by Core PCE	5	1	1962:3-2019:2
201	CONSUMERx	Real Consumer Loans at All Commercial Banks (Billions of 2012 U.S. Dollars), deflated by Core PCE	5	1	1962:3-2019:2
202	NONREVSLx	Total Real Nonrevolving Credit Owned and Securitized, Outstanding (Billions of 2012 Dollars), deflated by Core PCE	5	1	1962:3-2019:2
203	REALLNx	Real Real Estate Loans, All Commercial Banks (Billions of 2012 U.S. Dollars), deflated by Core PCE	5	1	1962:3-2019:2
204	REVOLSLx	Total Real Revolving Credit Owned and Securitized, Outstanding (Billions of 2012 Dollars), deflated by Core PCE	5	1	1968:1-2019:2
205	TOTALSLx	Total Consumer Credit Outstanding (Billions of 2012 Dollars), deflated by Core PCE	5	0	1962:3-2019:2
206	DRIWCIL	FRB Senior Loans Officer Opions. Net Percentage of Domestic Respondents Reporting Increased Willingness to Make Consumer Installment Loans	1	1	1982:2-2019:2
207	TOTRESNS	Total Reserves of Depository Institutions (Billions of Dollars)	6	0	1962:3-2019:2
208	NONBORRES	Reserves Of Depository Institutions, Nonborrowed (Millions of Dollars)	7	0	1962:3-2019:2
209	DTCOLNVHFNM	Consumer Motor Vehicle Loans Outstanding Owned by Finance Companies (Millions of Dollars)	6	0	1962:3-2019:2
210	DTCTHFNM	Total Consumer Loans and Leases Outstanding Owned and Securitized by Finance Companies (Millions of Dollars)	6	0	1962:3-2019:2
211	INVEST	Securities in Bank Credit at All Commercial Banks (Billions of Dollars)	6	0	1962:3-2019:2
		Household Balance Sheets			
212	TABSHNOx	Real Total Assets of Households and Nonprofit Organizations (Billions of 2012 Dollars), deflated by Core PCE	5	0	1962:3-2019:2
213	TLBSHNOx	Real Total Liabilities of Households and Nonprofit Organizations (Billions of 2012 Dollars), deflated by Core PCE	5	1	1962:3-2019:2
214	LIABPIx	Liabilities of Households and Nonprofit Organizations Relative to Personal Disposable Income (Percent)	5	0	1962:3-2019:2
215	TNWBSHNOx	Real Net Worth of Households and Nonprofit Organizations (Billions of 2012 Dollars), deflated by Core PCE	5	1	1962:3-2019:2
216	NWPIx	Net Worth of Households and Nonprofit Organizations Relative to Disposable Personal Income (Percent)	1	0	1962:3-2019:2
217	TARESAx	Real Assets of Households and Nonprofit Organizations excluding Real Estate Assets (Billions of 2012 Dollars), deflated by Core PCE	5	1	1962:3-2019:2
218	HNOREMQ027Sx	Real Real Estate Assets of Households and Nonprofit Organizations (Billions of 2012 Dollars), deflated by Core PCE	5	1	1962:3-2019:2
219	TFAABSHNOx	Real Total Financial Assets of Households and Nonprofit Organizations (Billions of 2012 Dollars), deflated by Core PCE	5	1	1962:3-2019:2
220	CONSPIx	Nonrevolving consumer credit to Personal Income	2	0	1962:3-2019:2
		Exchange Rates			

221	TWEXMMTH	Trade Weighted U.S. Dollar Index: Advanced Foreign Currencies (Index Jan 2006=100)	5	1	1973:1-2019:2
222	EXUSEU	U.S. / Euro Foreign Exchange Rate (U.S. Dollars to One Euro)	5	1	1999:1-2019:2
223	EXSZUSx	Switzerland / U.S. Foreign Exchange Rate	5	1	1962:3-2019:2
224	EXJPUSx	Japan / U.S. Foreign Exchange Rate	5	1	1962:3-2019:2
225	EXUSUKx	U.S. / U.K. Foreign Exchange Rate	5	1	1962:3-2019:2
226	EXCAUSx	Canada / U.S. Foreign Exchange Rate	5	1	1962:3-2019:2
	Stock Markets				
227	VXOCLSx	CBOE S&P 100 Volatility Index: VXO	1	1	1962:3-2019:2
228	NIKKEI225	Nikkei Stock Average	5	0	1962:3-2019:2
229	NASDAQCOM	NASDAQ Composite (Index Feb 5, 1971=100)	5	0	1971:1-2019:2
230	S&P 500	S&P's Common Stock Price Index: Composite	5	1	1962:3-2019:2
231	S&P: indust	S&P's Common Stock Price Index: Industrials	5	0	1962:3-2019:2
232	S&P div yield	S&P's Composite Common Stock: Dividend Yield	2	0	1962:3-2019:2
233	S&P PE ratio	S&P's Composite Common Stock: Price-Earnings Ratio	5	0	1962:3-2019:2
	Non-Household Balance Sheets				
234	GFDEGDQ188S	Federal Debt: Total Public Debt as Percent of GDP (Percent)	2	0	1966:1-2019:2
235	GFDEBTNx	Real Federal Debt: Total Public Debt (Millions of 2012 Dollars), deflated by PCE	2	0	1966:1-2019:2
236	TLBSNNCBx	Real Nonfinancial Corporate Business Sector Liabilities (Billions of 2012 Dollars), Deflated by Implicit Price Deflator for Business Sector IPDBS	5	0	1962:3-2019:2
237	TLBSNNCBBDIx	Nonfinancial Corporate Business Sector Liabilities to Disposable Business Income (Percent)	1	0	1962:3-2019:2
238	TTAABSNNCBx	Real Nonfinancial Corporate Business Sector Assets (Billions of 2012 Dollars), Deflated by Implicit Price Deflator for Business Sector IPDBS	5	0	1962:3-2019:2
239	TNWMVBSNNCBx	Real Nonfinancial Corporate Business Sector Net Worth (Billions of 2012 Dollars), Deflated by Implicit Price Deflator for Business Sector IPDBS	5	0	1962:3-2019:2
240	TNWMVBSNNCBBDIx	Nonfinancial Corporate Business Sector Net Worth to Disposable Business Income (Percent)	2	0	1962:3-2019:2
241	TLBSNNBx	Real Nonfinancial Noncorporate Business Sector Liabilities (Billions of 2012 Dollars), Deflated by Implicit Price Deflator for Business Sector IPDBS	5	0	1962:3-2019:2
242	TLBSNNBBDIx	Nonfinancial Noncorporate Business Sector Liabilities to Disposable Business Income (Percent)	1	0	1962:3-2019:2
243	TABSNNBx	Real Nonfinancial Noncorporate Business Sector Assets (Billions of 2012 Dollars), Deflated by Implicit Price Deflator for Business Sector IPDBS	5	0	1962:3-2019:2
244	TNWBSNNBx	Real Nonfinancial Noncorporate Business Sector Net Worth (Billions of 2012 Dollars), Deflated by Implicit Price Deflator for Business Sector IPDBS	5	0	1962:3-2019:2
245	TNWBSNNBBDIx	Nonfinancial Noncorporate Business Sector Net Worth to Disposable Business Income (Percent)	2	0	1962:3-2019:2
246	CNCFx	Real Disposable Business Income, Billions of 2012 Dollars (Corporate cash flow with IVA minus taxes on corporate income, deflated by Implicit Price Deflator for Business Sector IPDBS)	5	0	1962:3-2019:2
	Other				
247	UMCSENTx	University of Michigan: Consumer Sentiment (Index 1st Quarter 1966=100)	1	1	1962:3-2019:2
248	USEPUINDXM	Economic Policy Uncertainty Index for United States	2	1	1985:1-2019:2
249	MOVE	1-Month MOVE Volatility Index	1	1	1988:4-2019:6
250	LMN	Ludvigson-Ma-Ng Financial Uncertainty Index at 1-Month Forecast Horizon	1	1	1962:7-2019:6
251	EBP	Gilchrist-Zakrajšek Excess Bond Premium	1	1	1973:1-2016:8
252	RVol	Berger, Dew-Becker and Giglio Realized Volatility Series, Extended for the Full Period	1	1	1962:7-2019:6
253	TB3SAvg	Average of 3- and 12-Month Ahead Forecasts for 3-Month Treasury Bill	1	1	1999:1-2019:3
254	USSLIND	Philadelphia Fed's Leading Index for the U.S.	1	1	1982:1-2019:6

Appendix B. Figures

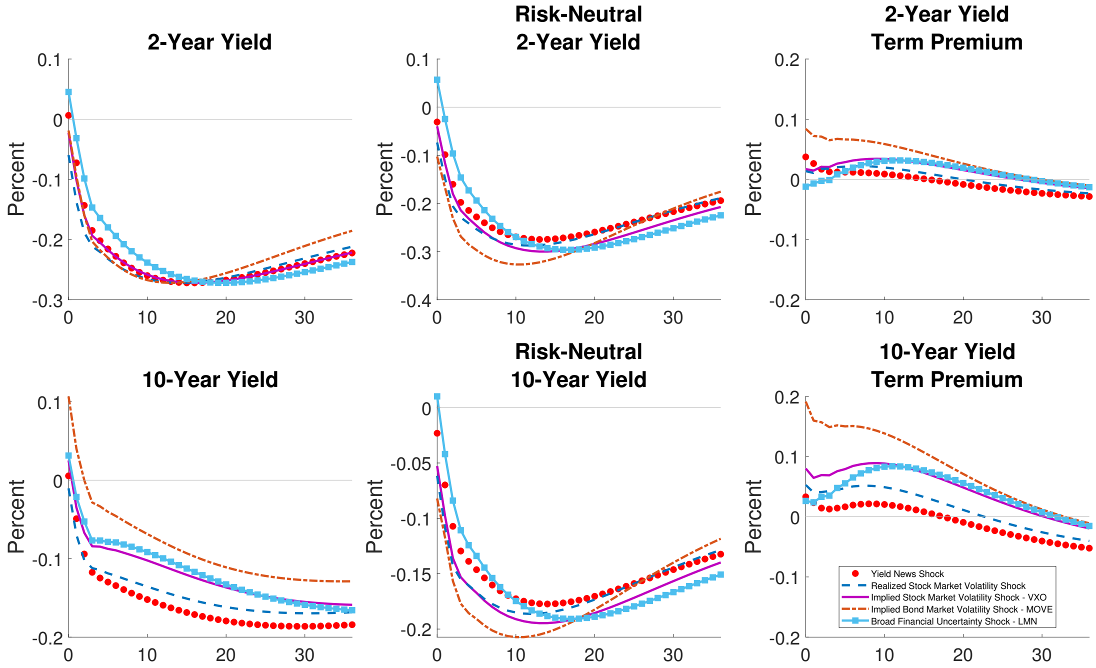
Figure A.1: IRFs and FEVDs of financial market indicators to shocks to volatility/uncertainty measures



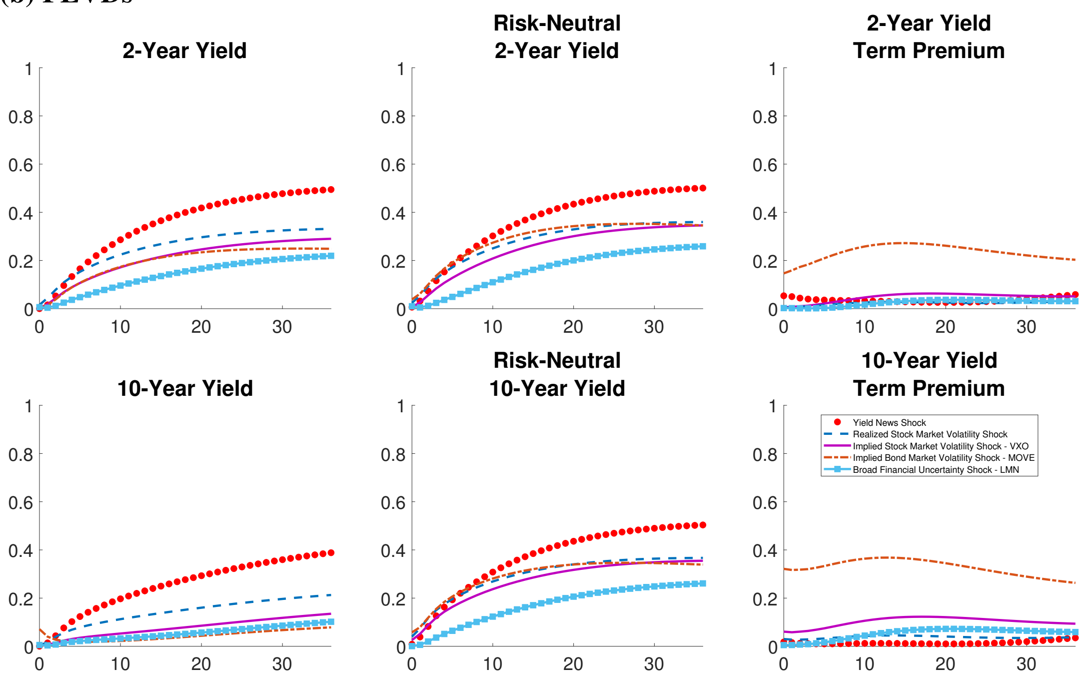
Note: This figure shows IRFs and FEVDs similar to Figure 6 in the main text, but here we add the results for the implied bond market volatility shock that maximizes the FEV share of the MOVE index over the next six months, as well as for the shock to broad financial uncertainty that maximizes the FEV share of the LMN financial uncertainty measure over the next six months from the macro-yields model. The yield news shock is reported as a one-standard-deviation impulse, and the responses for the other shocks are scaled so that they each produce the same peak decline in the two-year yield as the yield news shock.

Figure A.2: IRFs and FEVDs of yields and their components to shocks to volatility/uncertainty measures

(a) IRFs



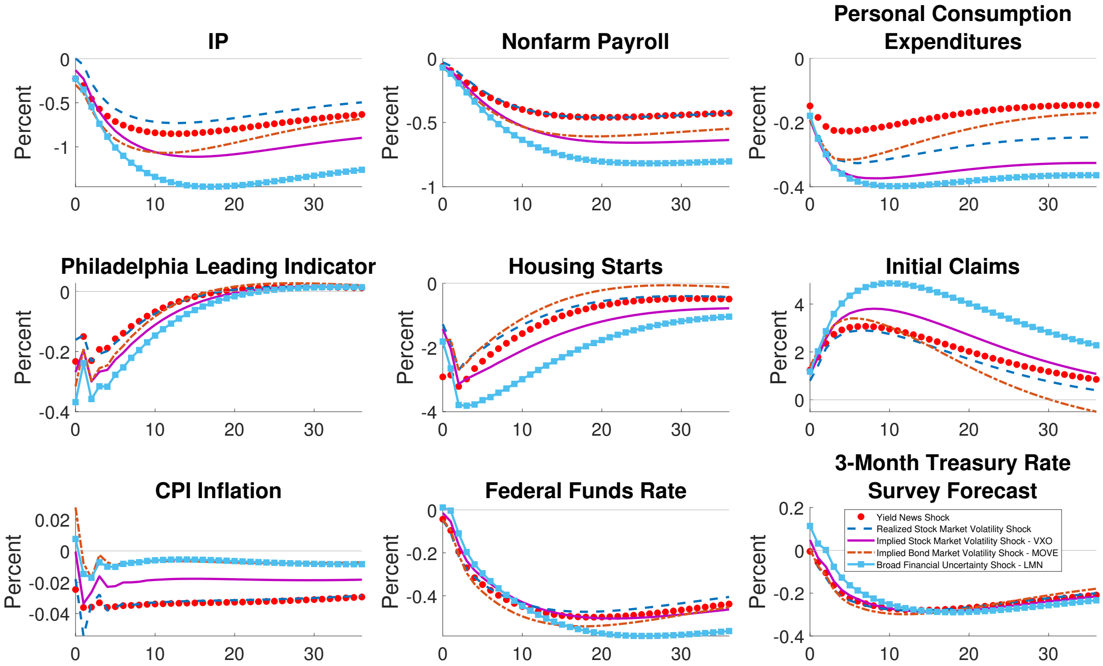
(b) FEVDs



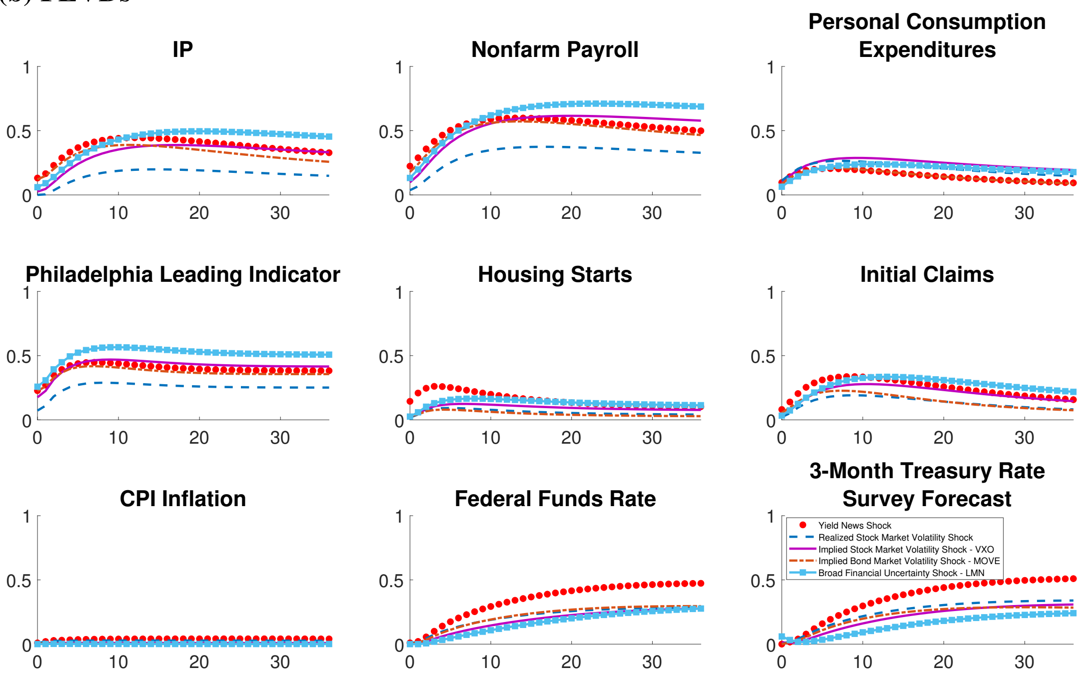
Note: This figure shows IRFs and FEVDs similar to Figure 7 in the main text, but here we add the results for the implied bond market volatility shock that maximizes the FEV share of the MOVE index over the next six months, as well as for the shock to broad financial uncertainty that maximizes the FEV share of the LMN financial uncertainty measure over the next six months from the macro-yields model. The yield news shock is reported as a one-standard-deviation impulse, and the responses for the other shocks are scaled so that they each produce the same peak decline in the two-year yield as the yield news shock.

Figure A.3: IRFs and FEVDs of macroeconomic variables to shocks to volatility/uncertainty measures

(a) IRFs



(b) FEVDs



Note: This figure shows IRFs and FEVDs similar to Figure 8 in the main text, but here we add the results for the implied bond market volatility shock that maximizes the FEV share of the MOVE index over the next six months, as well as for the shock to broad financial uncertainty that maximizes the FEV share of the LMN financial uncertainty measure over the next six months from the macro-yields model. The yield news shock is reported as a one-standard-deviation impulse, and the responses for the other shocks are scaled so that they each produce the same peak decline in the two-year yield as the yield news shock.