Yield Curve Dynamics and Fiscal Policy Shocks

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Abstract

We show that government spending does play a role in shaping the yield curve which has important consequences for the cost of private and government financing. We combine government spending shock identification strategies from the fiscal macro literature with recent advancements in no-arbitrage affine term structure modeling, where we account for time-varying macroeconomic trends in inflation and the equilibrium real interest rate. We stress in our empirical macro-finance framework the importance of timing in the response of yields to government spending. We find that the yield curve responds positively but mildly to a surprise in government spending shocks where the rise in risk-neutral yields is compensated by a drop in nominal term premia. The news shock in expectations about future expenditures decreases yields across all maturities. Complementarily, we also analyze the effect of fiscal policy uncertainty where higher fiscal uncertainty lowers yields.

Keywords: Government Expenditures, Fiscal policy, U.S. Treasury Yield Curve, Affine Term Structure Model

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1 Introduction

Vast theoretical (e.g. Baxter and King (1993), Christiano *et al.* (2011))and empirical (e.g. Blanchard and Perotti (2002), Ramey (2011), Aschauer (1985)) evidence has documented that changes in government spending explain a large fraction of business cycle fluctuations. The importance of government spending for economic activity has further increased with the fiscal response to the great financial and lockdown crises[1]. However, in contrast to monetary policy the transmission of fiscal policy to asset markets received very little attention. In this paper we provide an empirical investigation showing how shocks in government spending impact the term structure of interest rates (yield curve). Estimating the relationship between government spending and the yield curve is essential for understanding how fiscal policy affects the cost of financing (through the yield curve), both for the government and private entities in the economy. Since the price of government bonds consequently impacts the real economy through the quantity of credit, we also point to one of the channels through which government spending affects changes in aggregate output[2].

The impact of government debt on bond prices across the maturity spectrum has been long identified in the literature (Evans and Marshall 2007). Dai and Philippon (2005) point to the fact that government deficits are also a significant determinant of long term interest rates. Conversely, the impact of government spending on yields has received much less attention. It has been believed that government spending exhibits marginal a impact on the yield curve (see, for instance, Evans and Marshall 2007). This is a surprising result, as textbook economic theory predicts that an exogenous increase in public spending should lead to a rise in aggregate demand (see (Baxter and King 1993)), driving interest rates up (Fisher and Turnovsky 1992). In addition, if the rise in government expenditures triggers a rise in the number of outstanding bonds, the bond supply literature documents the positive relationship between the supply of outstanding government bonds and interest rates (see Krishnamurthy and Vissing-Jorgensen 2007 for a literature review).

Empirical research directly studying the link between fiscal policy and bond yields relies mainly on the least-squares estimates reduced to single bond maturity (see Evans and Marshall 2007, Laubach 2009 or Gale and Orszag 2003). We use more general framework based on vector autoregression (VAR) models where we link together the literature on fiscal policy shock identification and literature on term structure modeling. To model yield curve we start with the simple framework where the yield curve enters our macrofinance model as a single yield together with the Federal Reserve Board (Fed) funds rate. Next, we move to the Nelson and Siegel (1987) framework where yields are represented by the level, slope and curvature of the yield curve. Finally, we specify an affine term structure model that allows us to decompose the yield curve into the term premia and expectations of short-term rates.

[1]Both the American Recovery and Reinvestment Act of 2009 and Biden administration $1.9 trillion stimulus plan were the biggest stimulus packages of the time.

[2]The impact of fiscal policy on the real economy has been extensively covered in the literature on fiscal multipliers (see Christiano *et al.* 2011 for a survey)

More specifically, we build on the Bauer and Rudebusch (2020) framework and estimate the dynamic term structure model (DTSM) with shifting endpoints for interest rates to capture the long-run trends in inflation (π_t^*) and equilibrium real interest rate (r_t^*). We use this wide variety of models not only for robustness but also to help us to identify the economic mechanism driving the transmission of government spending to yields.

To identify the shock in government spending we build on the identification methods discussed in Ramey (2016). Namely we use the (i) Blanchard and Perotti (2002) identification strategy, (ii) forward-looking approach to shock identification and (iii) government spending estimated from a dynamic stochastic general equilibrium (DSGE) model. In addition, we also estimate the effect of changes in government spending uncertainty on the yield curve that we measure by the fiscal policy uncertainty (FPU) index. This is done because macroeconomic uncertainty has been shown to be an important driver of business cycle dynamics (Fernndez-Villaverde and Guerrn-Quintana (2020) and specifically fiscal uncertainty as shown by Giacoletti *et al.* (2021) who argues that fiscal uncertainty has substantial predictive power for yields. Using this distinct identification approach allows us to distinguish between the timing attitude of economic agents responding to government spending shocks. We use the Blanchard and Perotti (2002) method to pin down the response of the yield curve to contemporaneous (surprise) changes in government spending. Forward-looking identification is based on obtaining spending shocks from the changes in projections of government spending by the Congressional Budget Office (CBO 2020). By using the updates in fiscal projections we can identify the anticipated component of the economic response to government spending which is stressed by the fiscal foresight literature. In an empirical study, Ramey (2011) is among the first to forcefully document the importance of fiscal foresight in how the economy responds to an increase in public expenditures.[3] The fiscal foresight literature (see Leeper *et al.* 2012) closely relates to news literature (Beaudry and Portier 2006 and Barsky and Sims 2011) which posits that business cycles arise on the basis of expectations of future fundamentals rather than on the impact of shock. The importance of news shocks for the yield curve has been established in Kurmann and Otrok (2013); they show that it is news about future total factor productivity that explains more than 50% of the unpredictable movements in the slope of the yield curve. However, the effect of news about government spending on the yield curve has not been studied in the literature. However, intuitively, many fiscal policy measures are known well in advance. The lags in decision and implementation

[3] Gale and Orszag (2003) provide an extensive literature review on how the timing of fiscal policy in case of deficit and debt matters for the response of the yields. For instance, Barth *et al.* (1991) surveys 42 studies and finds that of 19 studies with projected deficits 13 have positive effects, 5 mixed effects, 1 no effect. Gale and Orszag (2003) redo Barth *et al.* (1991) and find that 18 studies have a positive effect, 6 mixed effects and 19 neither significant nor negative. A similar conclusion was found by Mankiw (2000). Often cited papers by Evans (1987) or Plosser (1982) find no effect. Ardagna *et al.* (2007) use both a simple static estimation and a vector autoregression model for a panel of countries and show that an increase in the primary government deficit increases the long-term yields. However, in the case of an increase in government debt, the yields are affected only for the above-averagely indebted countries. Laubach (2009) shows the upward effect of fiscal expansion on the long-term yields by comparing the budget deficit forecasts with the long-horizon forward rates.

can be demonstrated by many examples. Trump's fiscal package to boost infrastructure spending has been debated since he won the election. Obamacare[4] was discussed for more than a year before coming into force and the implementation was only gradual. Ramey (2011) lists other examples related to defense spending, such as the aftermath of 9/11 or the Soviet invasion to Afghanistan, where the rise in defense spending was anticipated in advance.

We find that the canonical shocks, identified using the Blanchard and Perotti (2002) method from the realized government spending data, increase the yield curve. The rise is driven by the increase in future expected short rates. Risk associated with this increase in spending is represented by the nominal term premia (NTP). NTP decreases after a government spending shock, thus partly compensating for the rise in expected short rates and making the overall increase in the yield curve milder. The anticipated changes deliver the opposite initial response of the yields than the Blanchard and Perotti (2002) method, i.e., yields drop temporarily after an expansionary fiscal policy shock. We attribute this drop to a precautionary saving effect that increases the demand for savings in government bonds. We provide complementing view on the importance of fiscal foresight by focusing on fiscal policy uncertainty (FPU). Decomposing government spending shocks based on timing allows us to describe the complete dynamics of propagation of the government spending shocks to the Treasury yield curve.

The rest of the paper is organized as follows. section 2 further describes our empirical framework, the motivation to use a set of models and the channels that are expected to be crucial for shock transmission. section 3 introduces the Treasury yield curve and the way it is incorporated into the modelling framework, with special attention given to the description of the model by Bauer and Rudebusch (2020) along with its results. Sections 4–6 present the results of VAR models in the form of impulse-responses, while each of these sections uses a single approach to fiscal policy shock identification. Finally, section section 7 concludes.

2 Empirical Approach

We use multiple model specifications to evaluate linkages between the U.S. government spending shocks and the U.S. Treasury yield curve. Our identification strategy consists of three mainstream approaches that we utilize in three distinct techniques applied to model yield curves. This means that we evaluate nine model variants in total to provide insights into multiple channels through which government spending shocks might affect Treasury yields (Table 1).

To connect our yield curve model with the identification of government spending we build a macrofinance model using the VAR modeling framework. The framework comprises three groups of variables. The **first group** includes the Fed funds rate together with yields or yield curve factors (depending on the specific model version). Various yield specifications allow us

[4]Patient Protection and Affordable Care Act.

Table 1: Model Versions

Fiscal shock specification	Yield curve representation Individual yields (YLD)	Level, slope and curvature (LSC)	Affine Term Structure Model Factors (AFF)
Identification within structural VAR model (SVAR)	SVAR-YLD (see 4.1)	SVAR-LSC (see 4.2)	SVAR-AFF (see 4.3)
Identification using narrative apprach (NARR)	NARR-YLD (see 5.1)	NARR-LSC (see 5.2)	NARR-AFF (see 5.3)
Structural shocks from DSGE model (DSGE)	DSGE-YLD (see 6.1)	DSGE-LSC (see 6.2)	DSGE-AFF (see 6.3)

to interpret the channels driving the response of the yield curve to the government spending shock and control for changes in monetary policy. We use several levels of complexity in the yield curve modeling: we include either an individual yield time series into a VAR model (YLD specification), the yield factors representing the level, the slope and the curvature of the yield curve (LSC specification) or yield latent factors obtained from a no-arbitrage affine term structure model by Bauer and Rudebusch (2020) (AFF specification). The following section 3 details the yield curve models we use and explains the each model motivation and its properties.

The **second group** of variables consists of fiscal policy variables. Using multiple approaches to government spending shock identification allows us to capture the distinct timings of the shock which has been heavily stressed in the literature on government expenditures. The identification approaches include, (i) a baseline fiscal policy shock identification using a structural VAR as in Blanchard and Perotti (2002) (SVAR specification); (ii) forward looking approach that identifies the news about future government spending measured by observing changes in projections by Congressional Budget Office (NARR specification); and (ii) an estimation of structural shocks using a DSGE model (DSGE specification). Each of Sections 4–6 in this paper describes in detail each of these approaches and shows the results.

The **third group** includes business cycle variables represented by real GDP growth and the annual rate of inflation. These control variables were shown to be important in explaining the dynamics of yield curve movements (Ang and Piazzesi 2003) and the identification of government spending shocks.

In our empirical approach, we make some implicit assumptions. In the affine term structure application with shifting endpoints we take a “two-step” estimation approach. This means that we first estimate the term structure model separately and use its outputs in a VAR framework to measure the linkages between the yield curve and the government spending shocks. It would also be possible to follow a “one-step” approach and incorporate the fiscal policy variables into the affine model directly as in Dai and Philippon (2005). We prefer however the "two-step" estimation to "one-step" as it improves comparability of the affine model, and it improves robustness of our estimates given our affine term structure model with unobserved stochastic trend (see Bauer and Rudebusch (2020)). Additionally, the "two-step" approach avoids the complications related to the spanning hypotheses (see Joslin *et al.* (2014)). De Pooter *et al.* (2010) and Joslin *et al.* (2011) provide evidence that the "two-step" approach does not provide significantly different results than a "one-step" process.

Motivation for our identification strategy of government spending shocks comes from the need to understand various channels of the shock propagation into the real economy, financial markets and, finally, the Treasury yields. We find evidence for four transmission channels of government expenditures to yield curve: (i) the *real channel*; the impact of government spending shock on aggregate demand received substantial attention in the literature (Blanchard and Perotti 2002 or Ramey 2011, among others), and this change in the aggregate demand further propagates through the investment versus savings re-balancing to bond prices; (ii) the *fight to quality channel* that is well documented driver of bond yields in the literature (i.e., Bauer (2017)): U.S Treasury bonds serve the purpose of safe saving instrument which keeps its value in times of big risks and uncertainties and carry the so called convenience yield (i.e., Horvath *et al.* 2017); (iii) the *Treasury supply channel*, documented in Gale and Orszag (2003), Dai and Philippon (2005), Ardagna *et al.* (2007) and Laubach (2009), among others [5], capturing the effect of changes in government budget that needs to be financed on the financial market, i.e., increased government indebtedness, moving the Treasury supply and hence affecting the yields; and (iv) *the debt sustainability channel* which represents the credit risk of U.S. government debt.

We use quarterly data between 1985/Q2 and 2020/Q1. The use of quarterly data provides a sufficient number of observed periods and, simultaneously, facilitates modeling of longer-term transitions.[6] The beginning of the sample is constrained by the availability of the data (especially fiscal projection data and uncertainty indices; see section 4. Beginning the sample in the mid-1980s also ensures that the sample starts after the Fed monetary policy using monetary aggregate targeting was mostly abandoned.[7] The end of the sample in 2020/Q1 prevents data contamination due to the COVID pandemic and its detrimental economic and financial impacts.

[5]See Spencer and Yohe (1970) for an important contribution and Moretti *et al.* 2019 for a recent reference.

[6]The latter would require VAR models with large number lags and therefore might result in less robust results when monthly data were used instead.

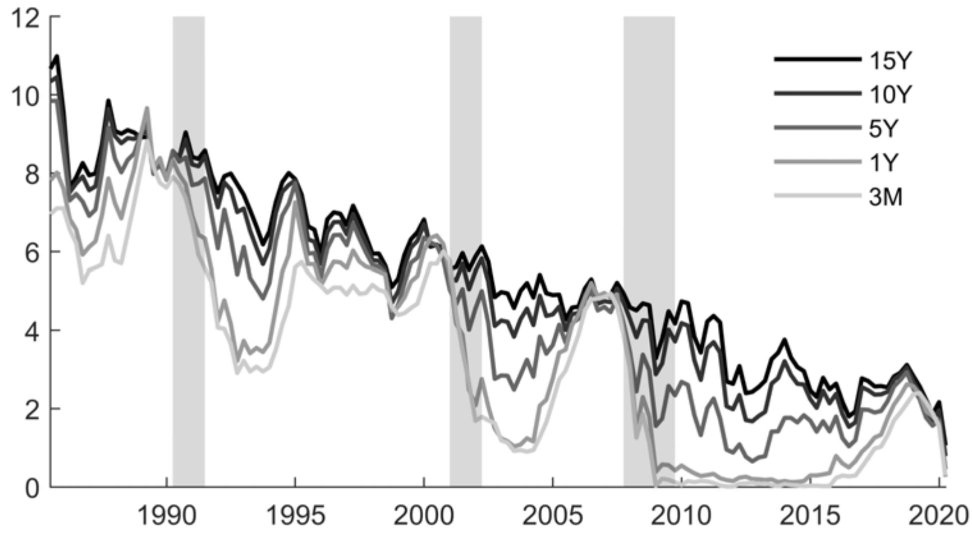
[7]Including the monetary aggregate targeting period might deliver biased results. The models do not assume time-varying volatility of yields; however, the period of increased inflation and monetary aggregate targeting could imply structurally different yield volatilities therefore resulting in bias if not controlled for. Since 1985, we consider inflation to be at sufficiently low levels and monetary targeting policy to be largely deemphasized (Mishkin 2001).

3 Yield Curve Data and Modeling

We use zero-coupon Treasury yields from Gurkaynak and Wright (2007). In our sample, we include maturities in the range of 1–15 years, which we further extend by 3-month and 6-month Treasury bill yields from Fed (2020). Since we use fiscal and control macroeconomic variables observed at a quarterly frequency, we gather the end-of-quarter yields. We present the evolution of U.S. government bond yields over the selected period in Figure 1. In this period, the yield curve was mostly upward-sloping, with few exceptions prior to the 1990, 2001 and 2008 crises. Since the end of 2008, the lower bound proximity has apparently been effective, as the short end of the yield curve fluctuated around the zero level with limited volatility. At the end of 2015, the lift-off of the short yields began to take place, whereas the long end of the yield curve gradually decreased over the whole period.

Lower bound proximity poses a threat of biased results of the affine term structure model, which we use below. However, the model of Bauer and Rudebusch (2020) allows us to treat the yields close to the lower bound in certain periods as missing: therefore, the zero lower bound has only a limited impact on the validity of the term structure model, compared to the case of the Gaussian stationary models (see Krippner 2015 for discussion).

Figure 1: Treasury Yields (in %)



Note: The shaded areas show the NBER-defined crises.

We demonstrate the linkages of fiscal policy shocks to yields using multiple representations of the yields. As a starting point, we include the five-year Treasury yield together with the Fed funds rate in the models. This approach provides the first view on the implications of various approaches to fiscal policy shock identification for their linkages with yields.

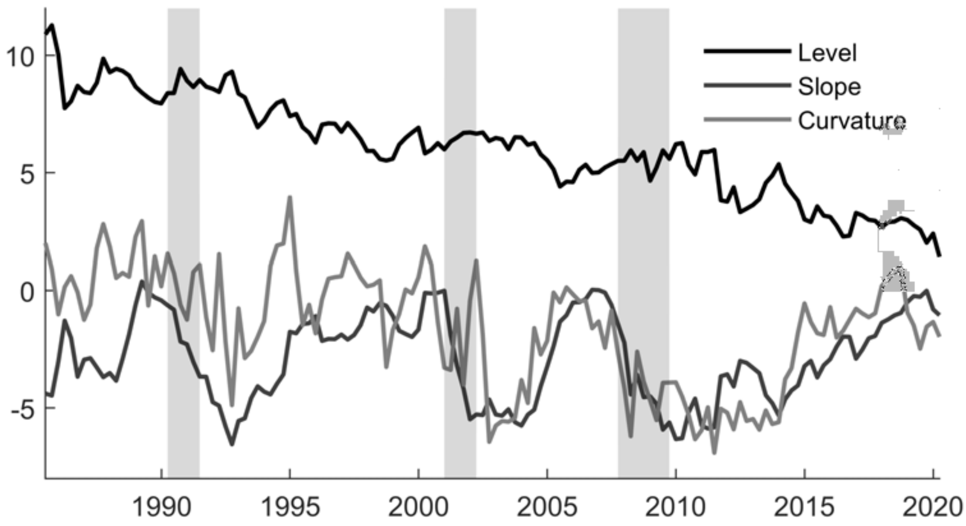
To generalizethe results for the whole yield curve, we replace the single yield by the level, slope and curvature of the yield curve, obtained from from Nelson and Siegel (1987) functional representation of the yield curve:

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

where $y_t(\tau)$ is a yield with a time to maturity τ at time t, L_t, S_t and C_t are the level, slope and curvature of the yield curve, respectively and λ is a scalar parameter. L_t, S_t and C_t can be obtained individually for each period t by considering them as unknown parameters and fitting the functional form to the given term structure of interest rates $y_t(\tau)$ via OLS.[8] In the case of this approach, we omit the Fed funds rate from the model to simplify the model and avoid multicollinearity. The slope factor reflects the fluctuations on the short end of the yield curve, and, therefore, provides sufficient information about the short rate movements.

Figure 2 presents the estimated L_t, S_t and C_t of yields. The level of the yield curve declines gradually with longer yields. The slope of the yield curve mirrors the way the short rate fluctuated around the level. Finally, the curvature of the yield curve is more volatile than the level and the slope, and loosely follows combined developments of both the level and the slope, allowing for improved fit in the middle of the yield curve.

Figure 2: Yield level, slope and curvature



Note: The shaded areas show the NBER-defined crises.

As the most complex representation of the yield curve, we estimate an affine no-arbitrage term structure model and use obtained yield factors to represent the yield curve. The added value of using the term structure model is its ability to decompose yields, and yield

[8]The λ parameter is considered to be fixed for the whole sample. We set its value by numerically finding the optimal values minimizing the difference between the observed and fitted yields. The optimal value of 0.0409 is lower than the value of 0.0609 applied in Diebold and Li (2006), meaning that our yield curves have the maximum loading curvature related to a lower maturity.

responses to the risk-neutral expectations and risk premiums. Such decomposition provides further insight into the nature of the model-implied response of yields to shocks.

We use the affine term structure model of Bauer and Rudebusch (2020). The model incorporates time-varying trends in longer yields, which is suitable for modeling the downward trend in U.S. Treasury yields over the last four decades and allows us to decompose the yields into risk-neutral expectations and risk premium without bias. The core element of the model is the process by which the three yield curve factors F_t follow under the data-generating (real-world) $\mathcal{P}$-measure process. The use of three factors is common in the term structure literature, given the importance of the first three principal components of yields as documented by Litterman and Scheinkman (1991). The term structure literature usually considers the $\mathcal{P}$-measure process to be a stationary VAR(1) process. The model by Bauer and Rudebusch (2020) differs by assuming the process for F_t is given, apart from the three stationary factors $\widetilde{F}_t$, also by a single stochastic trend τ_t following a random walk process (Bauer and Rudebusch 2020):

$$F_t = \bar{F} + \gamma\tau_t + \widetilde{F}_t, \quad \tau_t = \tau_{t-1} + u_{\tau,t} \quad \widetilde{F}_t = \Phi\widetilde{F}_{t-1} + u_{F,t}, \tag{2}$$

where γ is a 3-vector determining how the stochastic trend affects single yield factors, $u_{\tau,t} \sim N\left(0, \sigma_\tau^2\right)$ and $u_{F,t} \sim N\left(0, \Omega\right)$ are assumed to be i.i.d. and mutually orthogonal and Φ is a VAR(1) loading matrix assumed to ensure stationarity of the $\widetilde{F}_t$ process, i.e., with eigenvalues less than ones.

The model can be written in state-space form, with the transition equation defined by (2). To obtain the measurement equation, the factor process needs to be first specified under the risk-neutral $\mathcal{Q}$-measure. Following Bauer and Rudebusch (2020), the $\mathcal{Q}$-process is assumed to be stationary, which ensures that the yields do not explode with increasing bond maturity:

$$F_t = \bar{F}^Q + \Phi^Q F_{t-1} + u_{F^Q,t}, \tag{3}$$

where Φ^Q is a VAR(1) loading matrix assumed to ensure stationarity of F_t process under the $\mathcal{Q}$-measure and $u_{F^Q,t} \sim N\left(0, \Omega\right)$ is assumed to be i.i.d.

The affine class of the no-arbitrage term structure model is defined under the assumption of an affine mapping of the short rate on the yield factors, i.e., $i_t = \delta_0 + \delta_1' F_t$. This, together with (3), determines the $\mathcal{Q}$-path for i_t, which under the risk-neutral measure directly determines the observed yields, which are affine functions of the yield factors with parameter matrices A and B:

$$Y_t = A + BF_t + u_{y,t}, \tag{4}$$

where $u_{y,t} \sim N(0, R)$ is assumed to be i.i.d. measurement noise. (4) represents the measurement equation of the model.[9]

To obtain unique values of the yield factors, several restrictions are imposed (see Bauer and Rudebusch 2020 for detailed discussion and further reference). First, to ensure that the observed yields imply unique F_t, restrictions on the parameters in (3) are imposed.[10] The model by Bauer and Rudebusch (2020) uses the restrictions of Joslin *et al.* (2011), which is one of the most popular approaches in the literature, given its parsimony: (3) is defined by a single scalar and three eigenvalues of Φ^Q, only. Second, as the three factors F_t are driven by four underlying factors (three $\widetilde{F}_t$ and one τ_t), restrictions are needed to identify unique processes for τ_t. Bauer and Rudebusch (2020) use restrictions in both $\bar{F}$ and γ vectors and also set $\tau_t = i_t^* = \delta_0 + \delta_1' F_t^*$, where $F_t^* = \bar{F} + \gamma\tau_t$ are the expected long-run mean values of the factors and the stochastic trend τ_t is viewed as the long-run mean short rate.[11]

To summarize, the state-space form of the model is defined by (4) and (2) with restrictions imposed as described above. Bauer and Rudebusch (2020) discuss two approaches to estimate the model. First, when τ_t is considered as observed by using relevant proxy, the model can be estimated separately for measurement and transition equations, using maximum likelihood estimation and ordinary least squares, respectively, following the common approach by Joslin *et al.* (2011). Alternatively, a Bayesian estimation using the Metropolis Hastings procedure can be used when τ_t is required to be kept unobserved and estimated within the model. In this case, a set of priors on the dynamics of τ_t is required instead.

We follow the latter method, because it avoids the use of a proxy that could strongly influence our results. The Bayesian approach also allows us to handle the period of the lower bound proximity by treating part of the sample (the shorter end of the yield curve for the given periods) as missing observations. The priors and the design of Metropolis Hastings procedure were taken directly from Bauer and Rudebusch (2020). The estimated model parameters are summarized in section 7. The resulting factors (τ_t and $\widetilde{F}_t$) are displayed in Figure 3, and the three yield factors F_t would be obtained through (2). The factor dynamics confirm that they were estimated in line with the aim of the model. τ_t factor is responsible for overall decrease in yields over the last decades, whereas the cyclical factors $\widetilde{F}_t$ define in which the yields of various maturities fluctuate around the trend.

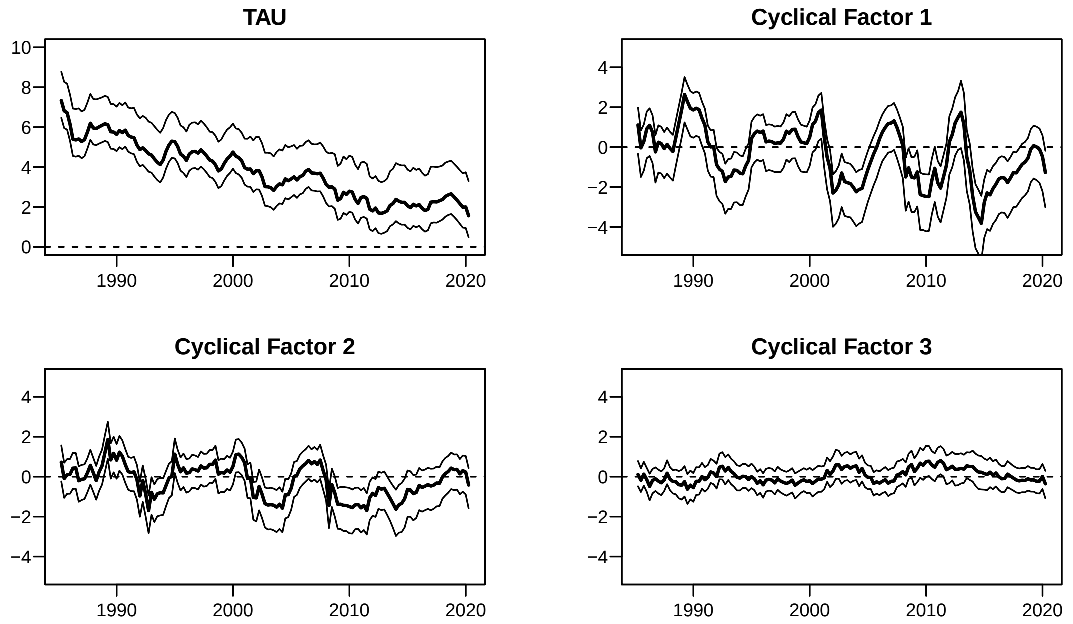
Further, the resulting loadings matrix B shows that the difference between short and long yields (which also includes the term premium) is mostly reflected by the third yield factor $F_{3,t}$, whose cyclicality is driven by $\widetilde{F}_{3,t}$. As Figure 3 shows (bottom-right panel), this factor grew in value during the early 1990s, in approximately 2001 and between 2007 and 2010. This clearly shows countercyclicality of the term premia implied by the model.

[9]See Ang and Piazzesi (2003), Joslin *et al.* (2011) and the online appendix of Bauer and Rudebusch (2020) for derivation of the matrices A and B. The derivation is nontrivial and the matrices themselves are defined iteratively for increasing maturities and therefore are not further described in this paper. Referring to Ang and Piazzesi (2003) for providing more detail on the matrices is common in the term structure literature.

[10]Without the restrictions, a "rotation" would be possible, given the affine nature of the model. This means, that given the observed yields, an infinite number of yield factors could be inferred.

[11]Note that the long-run means are time-varying, which is the key advantage of this model.

Figure 3: Yield Factors τ_t and $\widetilde{F}_t$



Note: The narrow lines display the 90% credible intervals. The values of factors are multiplied by 100 to better illustrate their relation to yields in percentage terms.

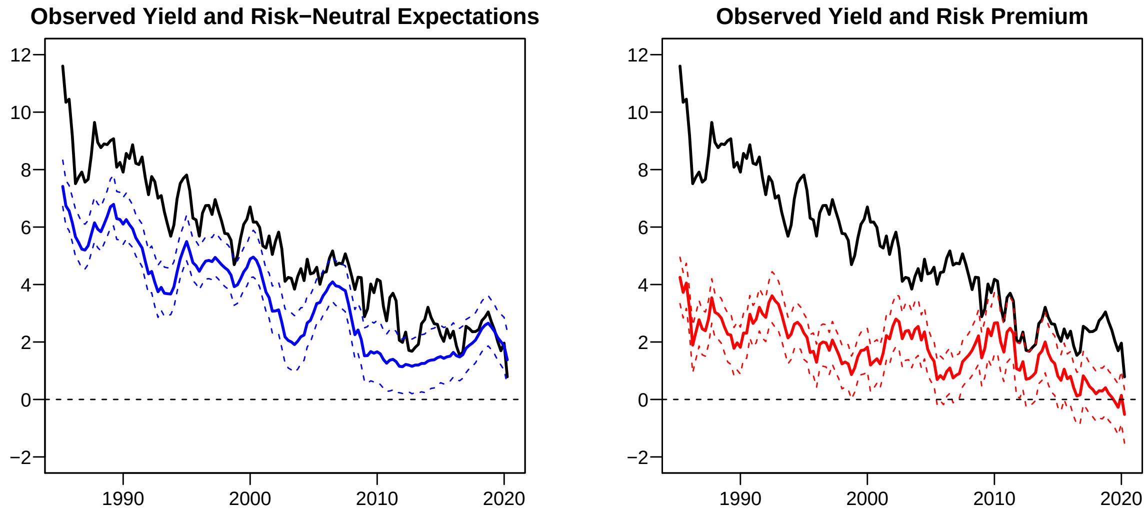
The countercyclicality is an important property of the term premia (Bauer *et al.* 2014) and confirms that the model is correctly specified and estimated. This is also evaluated explicitly by decomposing the yields into the risk-neutral expectations and the term premia[12] (see Figure 4). The longer-term decline in yields is attributed mostly to a drop in risk-neutral yields, which is in line with the literature (Bauer *et al.* 2014). The overall behavior of term premia estimated in our model is in line with the results of Bauer and Rudebusch (2020) and similar studies that control for small sample bias and use affine term structure models (Christensen and Rudebusch 2016, for example).

4 Fiscal Policy Shock Identification Using Structural VAR

The first approach to identify the U.S. fiscal policy shocks follows the work of Blanchard and Perotti (2002). The fiscal policy shocks are identified based on data on government net taxes and spending within a VAR model, using restrictions on the contemporary relations among the fiscal policy variables and real GDP. The model of Blanchard and Perotti (2002)

[12]With certain simplification, the risk-neutral expectations component is calculated as a mean expected future short rate, which is obtained from the expected path of the yield factors under the $\mathcal{P}$-measure via (2). The term premium is the difference between the yield and its risk-neutral expectations.

Figure 4: Ten-Year Yield Components (in %)



Note: The dashed lines display the 90% credible intervals.

can be written as

$$Y_t = A(L)Y_{t-1} + U_t \ , \tag{5}$$

where Y_t consists of real U.S. GDP, net taxes (taxes less transfers) and government spending, all expressed in per capita terms and using quarterly frequency. $A(L)$ denotes a lag polynomial. U_t gathers cross-correlated reduced-form residuals. Blanchard and Perotti (2002) impose restrictions on the relations among the reduced-form residuals and the structural shocks so that the model is identified in line with observed evidence. The model is estimated using quarterly dependence, i.e., four separate models are estimated for single quarters.

We extend the model to also include the yields or the yield factors and to provide some further adjustments to obtain interpretations useful for our purposes. We use GDP, quarterly net taxes and government spending all in year-over-year growth rates adjusted for inflation. Such dynamic transformation aligns our results with similar results from the term structure literature that predominantly uses macrovariables in their growth rates (see De Pooter *et al.* 2010 for overview). Additionally, in our case, using quarterly dependence and estimating four separate VAR models would provide weak results in terms of their robustness, as the extended model includes more parameters to be estimated against only a limited number of observations. The use of year-over-year growth rates solves this issue by incorporating seasonality instead of using quarterly dependence. Our extended model includes additional variables: annual inflation rate and variables representing the yields. The inclusion of inflation is crucial to control for a significant part of the variation in yields.

We identify the model similarly to Blanchard and Perotti (2002), with adjustments reflecting our additional variables and the need to link them to the original ones. The reduced-form residuals are written in the form of their combinations and the structural shocks:

$$\begin{aligned}
\text{net taxes:} \quad & t_t = a_1 x_t + e_t^t \ , \\
\text{government spending:} \quad & g_t = b_1 x_t + e_t^g \ , \\
\text{GDP growth:} \quad & x_t = c_1 t_t + c_2 g_t + e_t^x \ , \\
\text{price inflation:} \quad & p_t = d_1 t_t + d_2 x_t + e_t^p \ , \\
\text{yields and rates:} \quad & \text{depending on the approach to include yields,}
\end{aligned}$$

where e_t^* denotes the structural shocks. In the first three equations we differ from Blanchard and Perotti (2002) in several ways. First, we do not consider contemporary dependency of reduced-form residuals for taxes on structural shocks to spending and vice versa, given the claim by Blanchard and Perotti (2002) that their correlation is sufficiently small.[13] Second, we relax the assumption that $b_1 = 0$, given the experience on the swift supportive reaction of fiscal policy to economic negative developments during the Great Recession.[14] Instead, we impose the restriction that $c_2 = 1$, which is close to the Blanchard and Perotti (2002) result and is plausible because spending is part of the aggregate demand identity. It allows us to adjust the GDP growth identification equation to a private product growth: $x_t - g_t = c_1 t_t + e_t^x$, i.e., an innovation in GDP is contemporarily linked only to the private product. To finalize the identification, we use the calibrated value for $a_1 = 2.08$ similar to Blanchard and Perotti (2002).

The data on government spending used within this approach for the identification of shocks are shown in Figure 5, the top-left panel. The data were obtained from Government Current Receipts and Expenditures tables from BEA (2020). The contemporary government spending for each quarter is calculated as a sum of government consumption expenditures, net interest payments and net investment expenditures.[15] As noted above, we specify the variable as the year-over-year growth rate in quarterly spending, where the annual growth rate helps to ensure that the seasonality pattern of government figures does not affect the results significantly. The data show an increase in government spending during 2008–2009 in particular, in relation to the global financial crisis breakout.

The remaining data are obtained as follows. The net taxes are obtained from BEA (2020) and current taxes minus transfers. Inflation, real GDP and the Fed funds rate were obtained

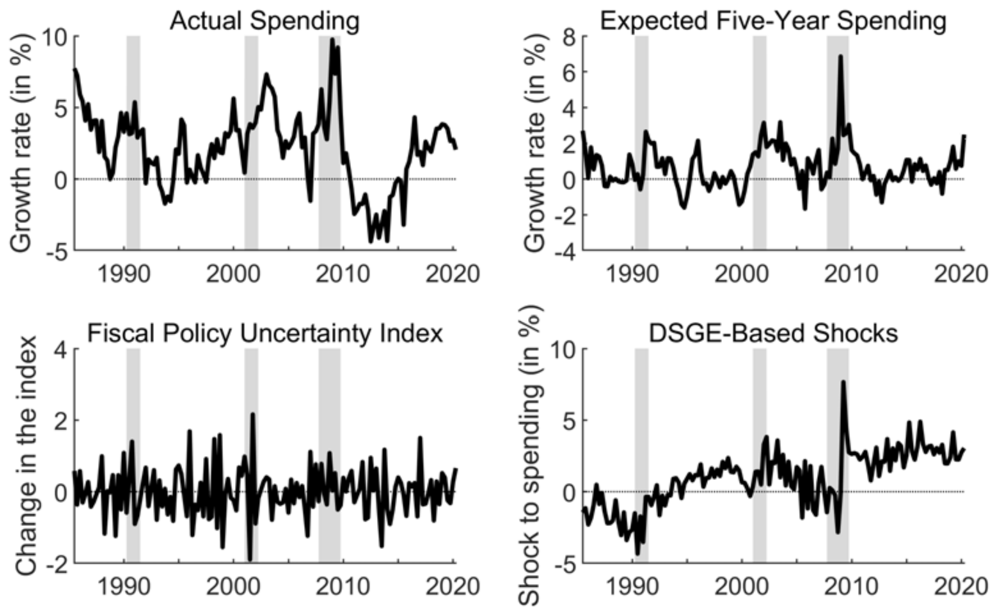
[13] More precisely, Blanchard and Perotti (2002) document that models with dependency of t_t on e_t^g and with dependency of g_t on e_t^t provide similar results.

[14] Economic Stimulus Act (2008); American Recovery and Reinvestment Act (2009).

[15] Using net investment expenditures means that we consider government spending in the wide context, i.e., not only current expenditures. The expenditures related to net investments were added to the series so that our subsequent discussion on the possible effect of the risk premia and the Treasury supply side channel accounts for the whole amount of funds needed to be financed through the Treasuries. However, the expenditures related to net investments represented only 4.9% of the total expenditures over the period under analysis. Therefore, we consider minor adjustment to complete the picture while not changing the interpretation of the variable.

from FRED (2020), all being transformed again into quarterly year-over-year growth rates (the fourth log-differences). The yield used in the model is as described in section 3.

Figure 5: Government Spending Variables for Various Models



Note: The shaded areas show the NBER-defined crises.

4.1 Single-Yield Model (SVAR-YLD)

The first model version involves the Fed funds rate and a five-year Treasury yield as the representatives of the yields. We consider monetary policy to react contemporaneously to innovations in GDP growth and inflation. The yield, which is a financial market variable, reacts contemporaneously to all other variables, whereas we put its reaction to fiscal policy as a reaction to innovation in the contemporary budget $(t_t - g_t)$. Therefore, the model identification is spefified by two equations:

$$\text{Fed funds rate:} \quad f_t = e_1 x_t + e_2 p_t + e_t^f \ ,$$
$$\text{five-year yield:} \quad y_t = f_1(t_t - g_t) + f_2 x_t + f_3 p_t + f_4 f_t + e_t^y \ .$$

We estimate the VAR model using OLS to obtain the reduced form shocks and series of regressions to obtain the shock identification parameters. Similar to Blanchard and Perotti (2002), we use instruments by replacing t_t with e_t^t in the GDP growth residual regression to obtain an unbiased estimate of c_1, and then by replacing x_t with e_t^x in the spending residual regression to obtain b_1.

The lag of four quarters was chosen for the model. This lag seems to be close to the optimal, from the information criteria perspective, and yet does not imply too large model that would bring a risk of overparametrization. We consider the Hannan-Quinn Information Criterion and Schwarz Information Criterion to be the most accurate, given the size of the sample and following the discussion in Ivanov and Kilian (2005); in section 7 we present visualization of the information criteria for various lags. Both information criteria suggest a range from 4 to 8 lags as the preferred choice. Hence, to keep the model parsimonious and to avoid overparametrization, we use four lags.[16] For the other models in this paper, the information criteria provided roughly similar values for the above range of lags. Therefore, to make the results comparable and simplify the calculations, we use four lags throughout the paper.

The results of the model are displayed in the form of selected impulse-responses in Figure 6.[17]. The impulses are set as an increase in a growth rate, the Fed funds rate or a yield by one percentage point; responses are also measured in percentage points. The dashed lines around the responses display 68% confidence bands obtained by bootstrapping.[18] The x-axis denotes years, i.e., the responses are calculated on a 32-quarter horizon.

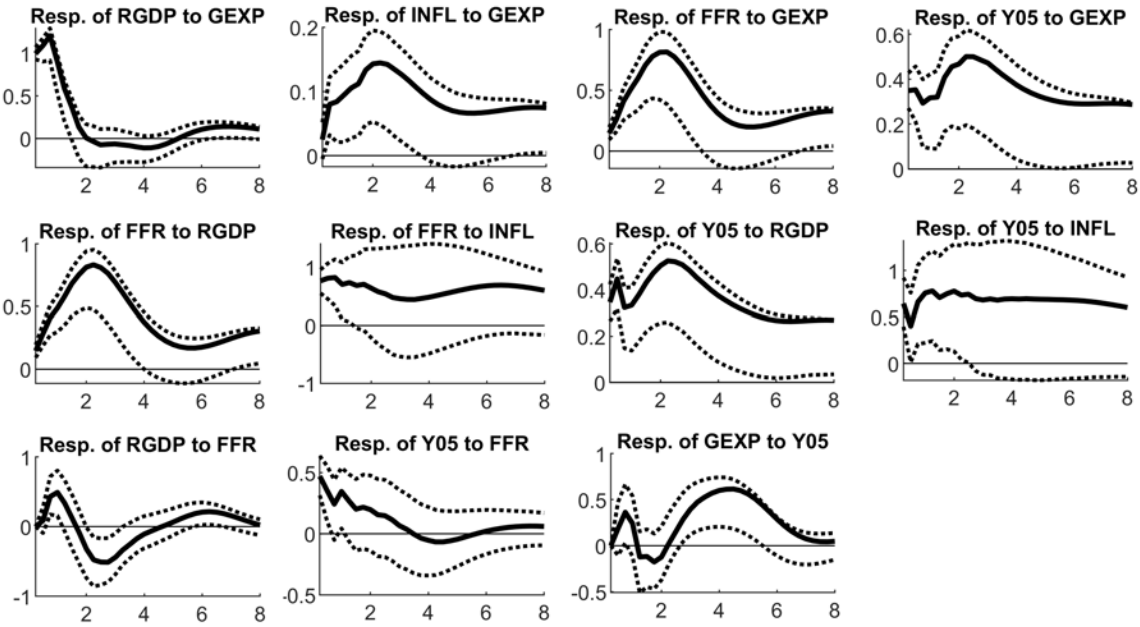
The results demonstrate a strong positive effect of a positive shock in government spending transferred to both macroeconomic variables (GDP and inflation) as well as to the short rate and the yield (see the first row of Figure 6). The latter effect is directly shown by the impact of economic growth on the yield curve (see the second row of Figure 6), i.e., the transmission from government spending into the yields can be largely attributed to the positive effect of the spending shock to GDP and inflation, pointing at the *real channel* of the transmission (see section 2). Apart from these observations, the model provides plausible results in general terms: GDP decreases with some delay after a positive shock to the Fed funds rate, and the pass-through from the Fed funds rate shock to the five-year yield is less than proportionate and government expenditures (including interest payment on government debt) increase after a positive shock to yields. Naturally, the results of this model provide neither full information about the varying impact on specific parts of the yield curve nor insight into the behavior of the yield risk premia. Such questions are answered via two other methods including the yield curve in the VAR model.Overall, after some generalization, it can be concluded that an exogenous increase in government spending, if identified using structural VAR, results in an increase in yields largely due to the positive effect of spending shock on the real economy (the *real channel*).

[16] Information criteria exhibit minimum value for six lags. The results based on six lags are not materially different from those based on four lags that allow for parsimonious model specification.

[17] Given the number of models in the paper (and the need to generate two sets of impulse-responses for some models, both for the yield factors and for the yield), we do not display the full map of impulse-responses in the paper. They are, however, available with the authors upon request. For this reason, we also do not further discuss the effects of a shock to government income, which is used in the SVAR model specification only the identification purposes and is not present in the other model specifications

[18] Using asymptotic normality, the 68% level roughly represents a single standard deviation confidence band, which is common in the literature to measure the effects of fiscal policy; see, for example, Ramey (2011).

Figure 6: Impulse-responses in SVAR-YLD model (selected)



Note: The impulses are set as an increase in a growth rate or a yield by one percentage point, responses are also measured in percentage points. The x-axis denotes years. The dashed lines display the 68% confidence bands. RGDP=real GDP growth rate, GEXP=growth rate in government expenditures, INFL=annual rate of inflation, FFR=Fed funds rate, Y05=five-year Treasury yield.

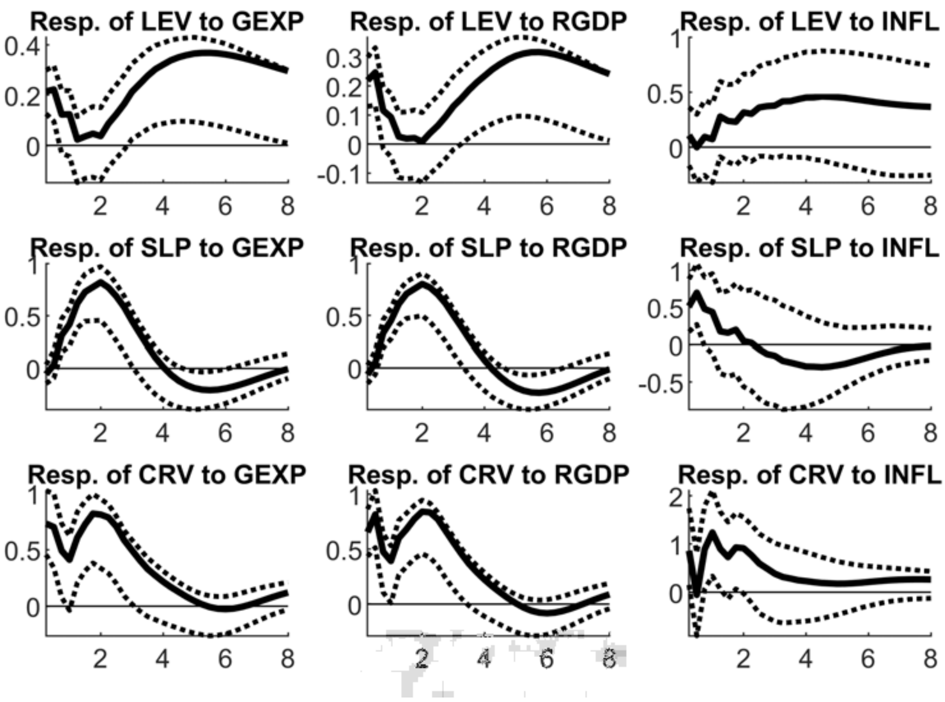
4.2 Level, Slope and Curvature Model (SVAR-LSC)

A similar model (as the one presented in the previous section) is obtained by including the level, slope and curvature yield curve factors instead of the Fed funds rate and the five-year yield. Regarding model identification, we keep the original four equations and add identifying restrictions on the three yield curve factors. We assume that the level reduced-form residuals depend contemporaneously on the shocks to budget (similar to the five-year yield in the previous model), GDP and inflation. The slope reduced-form residuals are linked to GDP, inflation and the level; the level dependence is motivated by the definition of level and slope.[19] Finally, the curvature, which may be difficult to interpret, is set to be dependent on all other variables.

$$\text{the level:} \quad l_t = e_1 (t_t - g_t) + e_2 x_t + e_3 p_t + e_t^l \ ,$$
$$\text{the slope:} \quad s_t = f_1 x_t + f_2 p_t + f_2 l_t + e_t^s \ ,$$
$$\text{the curvature:} \quad ct = g_1 t_t + g_2 g_t + g_3 x_t + g_4 p_t + g_5 l_t + g_6 s_t \ .$$

[19] For example, in case the long end of the yield curve decreases, but the short yields remain the same, the level of the yield curve drops whereas the slope increases (note that the level variable is common to all maturities). The dependence of slope shocks on the level shocks allows for correctly measuring the responses with respect to such events. The slope is viewed as providing an "extra" information about the short yields beyond the level.

Figure 7: Impulse-responses in SVAR-LSC model (selected, yield factors)



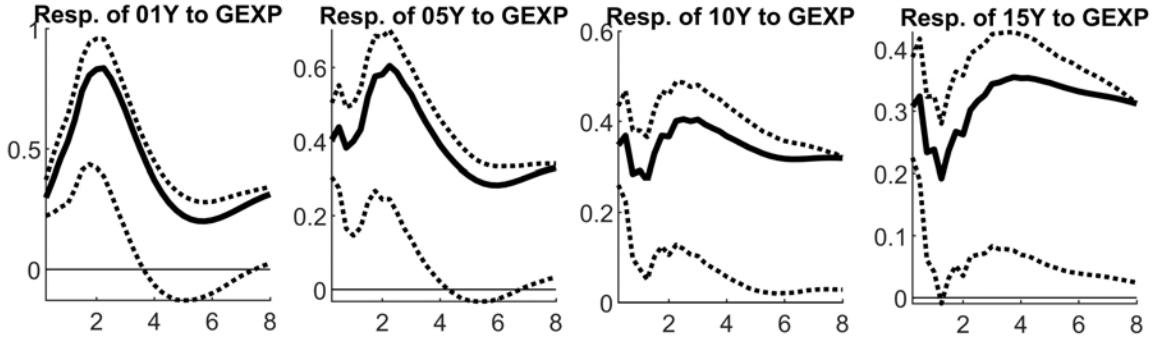
Note: The impulses are set as an increase in a growth rate by one percentage point, responses are measured in factor units. The x-axis denotes years. The dashed lines display the 68% confidence bands. RGDP=real GDP growth rate, GEXP=growth rate in government expenditures, INFL=annual rate of inflation, LEV=the level, SLP=the slope, CRV=the curvature.

The results of the model are roughly similar to the previous case. GDP and inflation react positively to an increase in government spending, implying that government spending presents an expansionary shock. The shock propagates further into the level, slope and curvature of the yield curve (Figure 7), which also determines the responses of yields (Figure 8). Propagation is gradual over the response horizon. First, the level of the yield curve increases, whereas the slope and the curvature partially compensate for this increase at short and medium maturities. Finally, further in the propagation, the level increases once again and relatively persistently, whereas the short end of the yield curve is partially suppressed. This means that the longer yields do not drop back in the case of an expansionary shock, unlike the short yields that do. We argue that a plausible interpretation of this movement is the effect of an increase in the bond risk premia due to increased indebtedness (the *debt sustainability channel*). This hypothesis is further evaluated below using the affine term structure model.

4.3 Affine Term Structure Model (SVAR-AFF)

In our AFF model specification, which follows Bauer and Rudebusch (2020), the yield curve is represented by the affine model stochastic trends in the vector τ_t and the three stochastic factors $\widetilde{F}_t$. We first calculate the impulse-response functions for $\widetilde{F}_t$. In the next step we use

Figure 8: Impulse-responses in SVAR-LSC model (selected, yields)



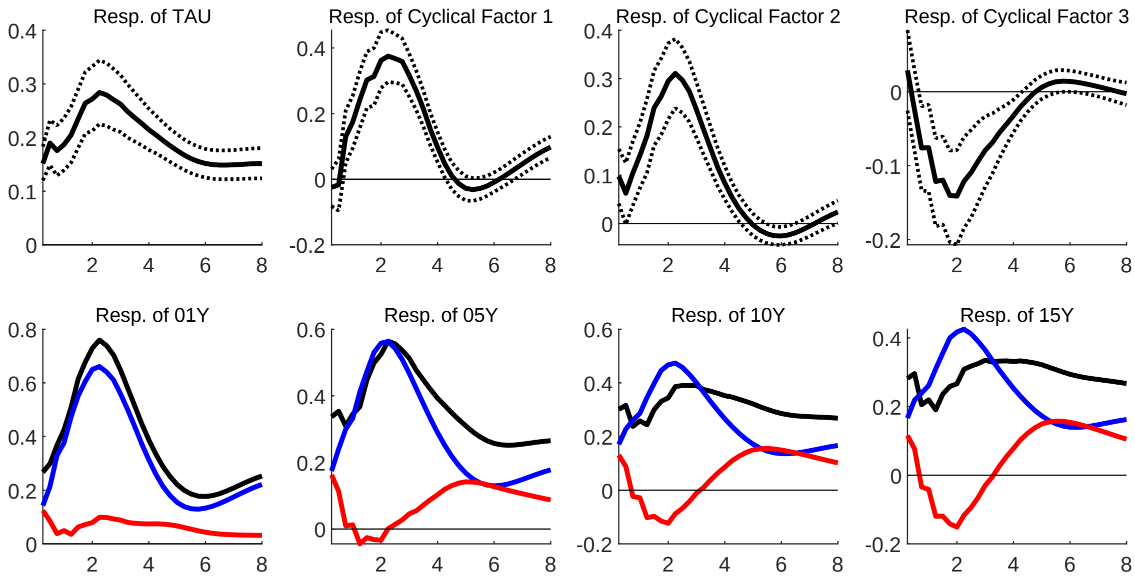
Note: The impulses are set as an increase in a growth rate or a yield by one percentage point, and responses are also measured in percentage points. The x-axis denotes years. The dashed lines display the 68% confidence bands. GEXP=growth rate in government expenditures, xxY=xx-year Treasury yield.

equation (2) to map responses in $\widetilde{F}_t$ to yield factors F_t which we can use in equation (4) to derive the impulse response function for the entire yield curve. To account for the affine model parameter uncertainty, we use results from individual simulations (obtained from the Metropolis Hasting algorithm in the estimation of the affine model) in the VAR analysis (both for the yield factors and parameter estimates). This implies that the resulting impulse responses display credible intervals rather than confidence bands.

Further, we use our affine model to decompose the yield impulse-responses to the risk-neutral expectations and the term premium. Figure 9 shows that the response of yields to government spending shocks is similar to the responses in SVAR-LSC model (see Figure 8 for comparison). Therefore, we focus our discussion only on the components of yields. The increase in yields after the initial spending shock is driven by an increase in risk-neutral expectations. This suggests that the *real channel* of shock propagation is the main driver: a positive government spending shock increases aggregate demand which changes expectations of future monetary policy as FED responds to changes in output and inflation. The risk-neutral expectations can also increase due to the *Treasury supply channel* that would increase the interest rates due to a shift in the bond supply.

We argued in the SVAR-LSC model that the persistence of the response of longer yields was driven by the increase in the term premium. The decomposition confirms this view: the term premium is characterized by long persistence compared to risk-neutral yields which are short lived (this holds especially for yields with longer maturity). While our modeling approach lacks the possibility of explicitly attributing term premium volatility to various investor behavior, we present several intuitive interpretations. First, the initial temporary increase in the term premium can be linked to flight-from-quality behavior since the positive spending shock is viewed as an expansionary impulse and investors are willing to take more risk. Second, the following drop in the term premium represents further gradual shifts through the *flight-to-quality channel* due to a gradually diminishing initially positive effects of the government spending shock. Three, the final longer-term increase in the term premium may be explained by an actual perceived riskiness of the Treasuries due to fiscal policy uncertainty and increased government indebtedness (*debt sustainability channel*).

Figure 9: Responses in SVAR-AFF model to government spending impulse (selected)



Note: The yield response (black) is decomposed to the response of the risk-neutral yield (blue) and the response of the term premium (red) at the bottom panels. The impulses are set as an increase in a growth rate, and responses are measured in factor units or yield percentage points. The x-axis denotes years. The dashed lines in the upper panel display the 68% credible intervals. xxY=xx-year Treasury yield.

5 Narrative Approach

The second approach to the identification of fiscal policy shocks is largely motivated by the results of Ramey (2011), who show that the economy responds strongly already to announcements of government expenditures. The Blanchard and Perotti (2002) method identifies only actual changes in government expenditure. Ramey (2011) argues that the identification of shocks in time of their announcement from newspaper articles can better capture the actual effect of government expenditure on the economy.

Motivated by these findings, we use the regularly published projections of government outlays by the Congressional Budget Office (CBO)[20]. These projections have been published since 1983 on at-least a bi-annual basis. We gather projections five years ahead from each

[20] Ramey (2011) argues that defense spending is better suited than overall government expenditure to study the impact of government expenditure on business cycle variables. This is because defense spending are likely to be orthogonal to the business cycle. The identification approach of Ramey (2011) would provide too small sample of narrative-based defense spending shocks and the results would not be robust. Therefore, we use the aggregate spending data instead. We ensure that the changes in government spending induced by business cycle shocks are correctly controlled for by ordering the spending variable behind the macroeconomic variables in the VAR model.

published report (cbo2018). In the first step, we calculate for every forecasted period the present value of future government expenditure. As a discount rate, we use the contemporary nominal yield curve from the spot market. More specifically, the projection for k periods forward at time t is discounted by the yield of maturity k, $\frac{OUTL_{t,k}}{(1+y_k)^k}$). In the second step, to smooth the anticipated (forecasted) outlays and to eliminate the seasonal effects we calculate the four-quarter moving average of each time series of discounted anticipated outlays. Finally, we calculate the average of the present value of the expenditure to obtain our proxy for the anticipated government expenditure. Formally,

$$GSexp_t = \sum_{k=1}^{5} \frac{1}{4} \sum_{j=0}^{3} \frac{OUTL_{Y+k,t-j}}{(1 + y_{t-j}(k))^k}$$

where $GSexp_t$ is the present value of five-year-forward U.S. government spending expected at time t; k-sum aggregates the projected annual outlays for five fiscal years forward with respect to fiscal year Y related to time t; j-sum averages the values for the past four quarters; $OUTL_{Y+k,tt}$ is the value of nominal projected outlays for fiscal year $Y + k$ from the most up-to-date projection available at time $t - j$; $y_{t-j}(k)$ is the k-year U.S. Treasury yield in time $t - j$ used for discounting.

These series represent our narrative-based forward-looking government spending variable. The fiscal projections from the Congressional Budget Office were similarly used by Laubach and Williams (2003), who focused on measuring the relationship between the change in projected deficit and long-horizon forecasts of government yields. The obtained time series of the expected government spending are shown in Figure 5, the top-right panel. The peak in 2008–2009 is also present in the case of the forward-looking series; however, the dynamics of the series are otherwise quite different to the actual government spending series (compare with the top-left panel).

We employ the year-over-year growth rate of this expected five-year spending, adjusted for inflation, within a VAR model. The other data series are identical to those used by the previous SVAR model specifications, depending on the specific model version (YLD, LSC or AFF). We use Choleski decomposition of the covariance matrix to identify the model. To obtain fiscal policy shocks, we order the expected spending behind GDP growth and inflation to control for the changes in the fiscal outlooks that were induced by changes in macroeconomic conditions (Kilian and Lütkepohl 2017). Therefore, we interpret the structural shocks to the expected spending variable as the macro-unrelated fiscal policy shocks. We order the variables representing the yield curve at the end of the VAR vector, in order for these variables to be contemporaneously affected by shocks to macroeconomic and fiscal variables, similarly to the SVAR identification approach above.

5.1 Single-Yield Model (NARR-YLD)

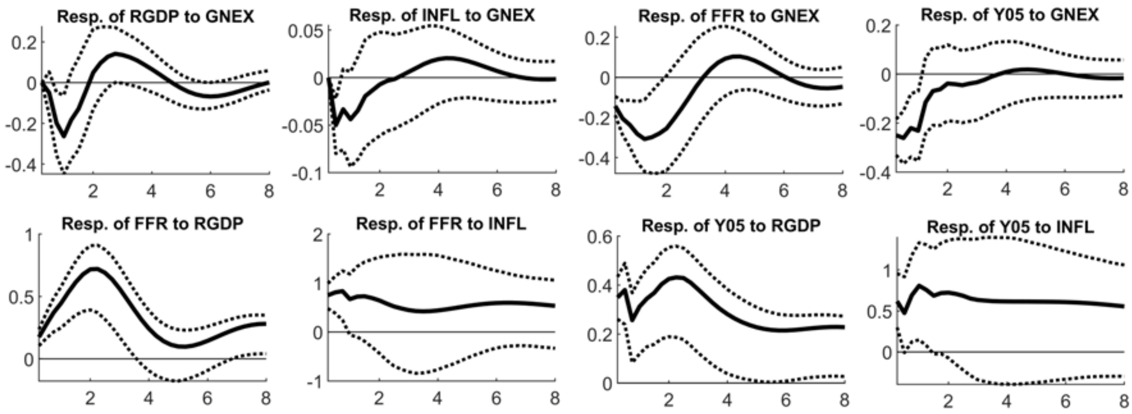
Analogous to the case of previous fiscal shock identification, the yield curve is included in the VAR with narrative fiscal shocks either as a single yield (NARR-YLD model), as the level, the slope the curvature (NARR-LSC model) or as latent factors from the no-arbitrage affine term structure model (NARR-AFF model). Starting with the NARR-YLD model, its identification proceeds as described above, i.e., the VAR variables are ordered as follows: GDP growth, inflation rate, narrative government spending. The VAR vector is completed by the Fed funds rate and the five-year yield ordered at the end.

The results of the NARR-YLD model are displayed in Figure 10. The Fed funds rate and the yield respond positively to an increase in GDP growth and inflation similar to the case of previous results (Figure 10, second row). The shock to anticipated government spending pushes for several periods the GDP growth and inflation rate down (Figure 10, top-left chart). This result supports our view that the response of the yield curve to shocks in anticipated government expenditures is driven by precautionary saving effects. First, lower inflation increases the real return on bond holdings and the price of government bonds increases (yields drop). In addition, lower GDP increases demand for additional savings (Ramey (2011)) and therefore rises demand for government bonds. Second, a positive correlation of inflation and GDP means that the value of bonds increases in its real value because of the drop in inflation exactly at the time when the economy is in recession and savings in the form of government bonds are needed to smooth consumption. This is precisely the mechanism explaining the existence of term premia in the theoretical literature (for instanceAndreasen *et al.* (2018) and Rudebusch and Swanson (2012)). This makes government bonds less risky because they hedge investors against business cycle inflation risks and, therefore, explain why we observe a drop in nominal term premia in response to anticipated government expenditure.

Our interpretation is very close to the intuition offered by Ramey (2011), who demonstrates a drop in consumption after a positive spending shock (opposite to the evidence by Blanchard and Perotti 2002). We find the same results in our model with yields. Both our results and the findings of Ramey (2011) are in line with Ricardian equivalence (Barro 1974), which suggests that economic agents will increase savings after an expansionary fiscal policy shock driving both consumption and yields downward.

We, however, admit that the transmission of shock in anticipated government expenditure is more complex and also includes the expected monetary policy response, bond market investors' response to the expectations about future new emissions of Treasuries (the *Treasury supply channel*), and the behavioral aspects of investor reaction. Depending on which of these channels prevails at various maturities and response horizons, yields may increase or decrease. In particular, once an announcement of future government spending improves the expectations of agents about future economic prospects, the effect might be opposite, i.e., growth in both consumption and yields. For example, Bauer (2017) finds that after the

Figure 10: Impulse-responses in NARR-YLD model (selected)



Note: The impulses are set as an increase in a growth rate by one percentage point, an responses are also measured in percentage points. The x-axis denotes years. The dashed lines display the 68% confidence bands. RGDP=real GDP growth rate, GNEX=growth rate in the five-year projected government expenditures, INFL=annual rate of inflation, FFR=Fed funds rate, Y05=five-year Treasury yield.

2016 presidential election an anticipated fiscal stimulus improved agents' expectations about future economic situations and, therefore, drove yields upwards.

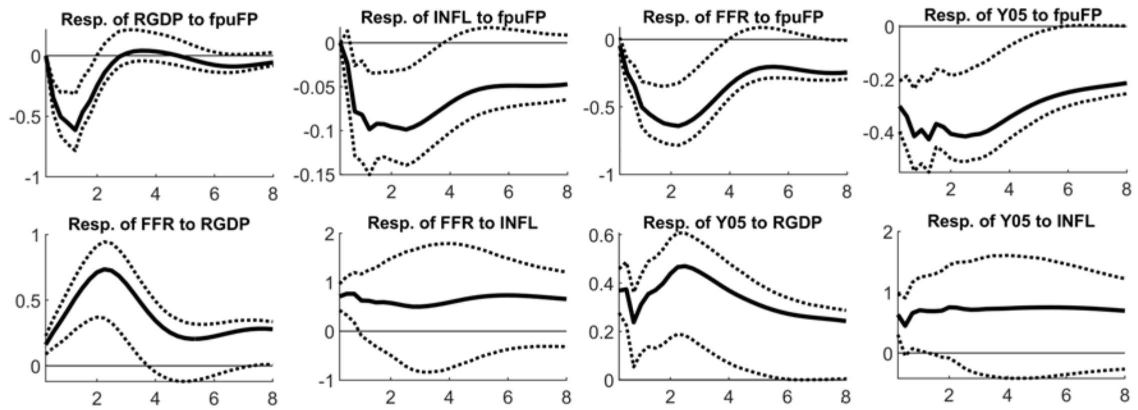
The reason for a drop in yields after the positive shock to anticipated government spending is related to the change in fiscal uncertainty after the shock. To support this hypothesis, we estimate a model identical to NARR-YLD, only with the expected government spending variable replaced by the change in FPU index obtained from Baker *et al.* (2016) (see Figure 5, the bottom-left panel). The results are surprisingly close to the results of the NARR-YLD model (see Figure 11). The drops in GDP growth, inflation and yields are even more significant and persistent in the case of a positive shock to FPU, than in the case of a positive news in anticipated spending shock. We consider this to be evidence that the drop following a positive shock in anticipated spending is attributed partly to the uncertainty related to the shock and, therefore, the cautious response of economic agents.

5.2 Level, Slope and Curvature Model (NARR-LSC)

We adjust the NARR-YLD model by replacing the Fed funds rate and the yield by the level, slope and curvature of the yield curve, ordered at the end of the VAR vector. This allows us to study the implications of anticipated government spending shocks for the whole yield curve.

The results of the estimation are presented in Figure 12. After the shock to anticipated government spending the level, slope and curvature of the yield curve drop down. The response to the government spending variable (Figure 12, top panels) differs from the SVAR-LSC model confirming our result that the response of the yield curve depends on the timing

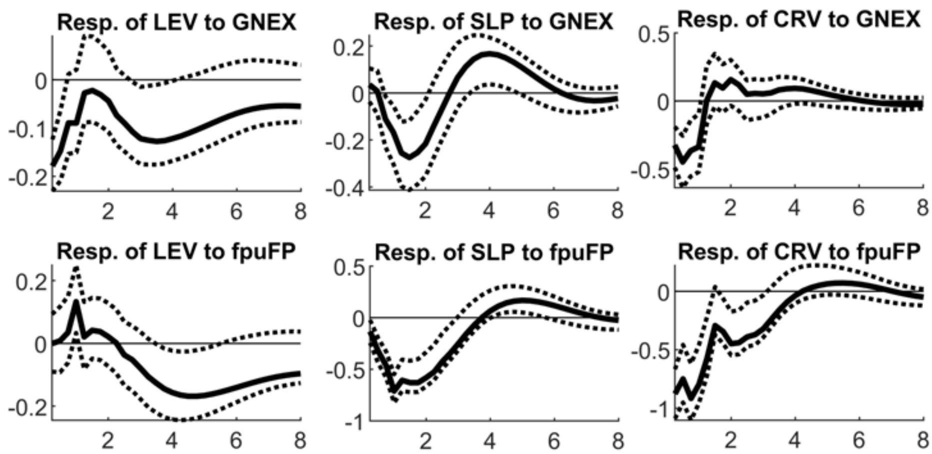
Figure 11: Impulse-responses in NARR-YLD model with FPU (selected)



Note: The impulses are set as an increase in a growth rate one percentage point, responses are also measured in percentage points. The x-axis denotes years. The dashed lines display the 68% confidence bands. RGDP=real GDP growth rate, fpuFP=growth rate in the FPU index, INFL=annual rate of inflation, FFR=Fed funds rate, Y05=five-year Treasury yield.

of the government spending shock. We attribute the drop in level and the temporary drop in slope (exchanged for growth after some time) to being driven by precautionary saving motives, as in the case of the NARR-YLD model.

Figure 12: Impulse-responses in NARR-LSC model (selected, yield factors)



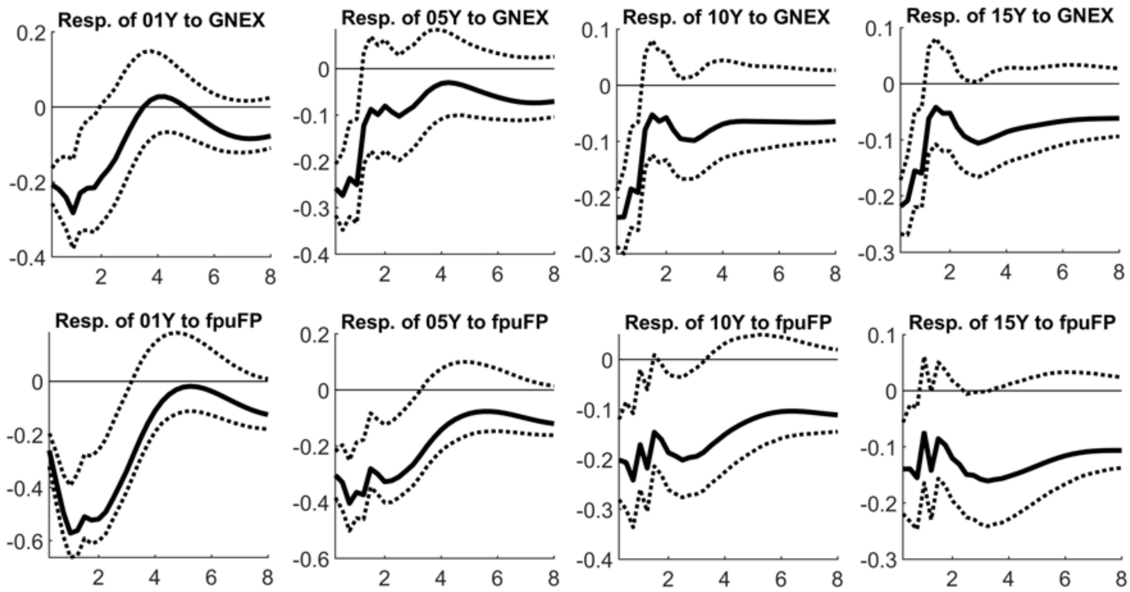
Note: The impulses are set as an increase in a growth rate, and responses are measured in factor values. The x-axis denotes years. The dashed lines display the 68% confidence bands. GNEX=growth rate in the five-year projected government expenditures, fpuFP=growth rate in the FPU index, LEV=the level, SLP=the slope, CRV=the curvature.

The response of yields is displayed in Figure 13. The initial drop in the level following a positive expected spending shock implies a decrease in yields across all maturities. The immediate adjustment in yields may be interpreted in light of the *flight to quality channel* and the *real channel*.

The response of the economy to the shock in anticipated spending is reflected by the drop in the slope of the yield curve after several periods. This implies that the return of the one-year bond yield to its long run mean is slower than in the case of bonds with long maturity yields (Figure 13). Afterwards, the slope turns positive; however, the level still remains below the initial value. The yields therefore do not exceed their initial values over the whole response horizon.

This shows that when correctly identifying the the initial negative effect of government uncertainty on the yields, the possible delayed positive effect of yields is not sufficient to rise the yields, unlike the case of shock identification using the structural VAR model. The NARR-LSC model, compared to the NARR-YLD model, emphasizes the interaction among the initial drop across all yields and the delayed volatility in the short yields. In the case where the FPU variable is used instead, the drop in longer yields is even longer-term (Figure 13, bottom panels).

Figure 13: Impulse-responses in NARR-LSC model (selected, yields)

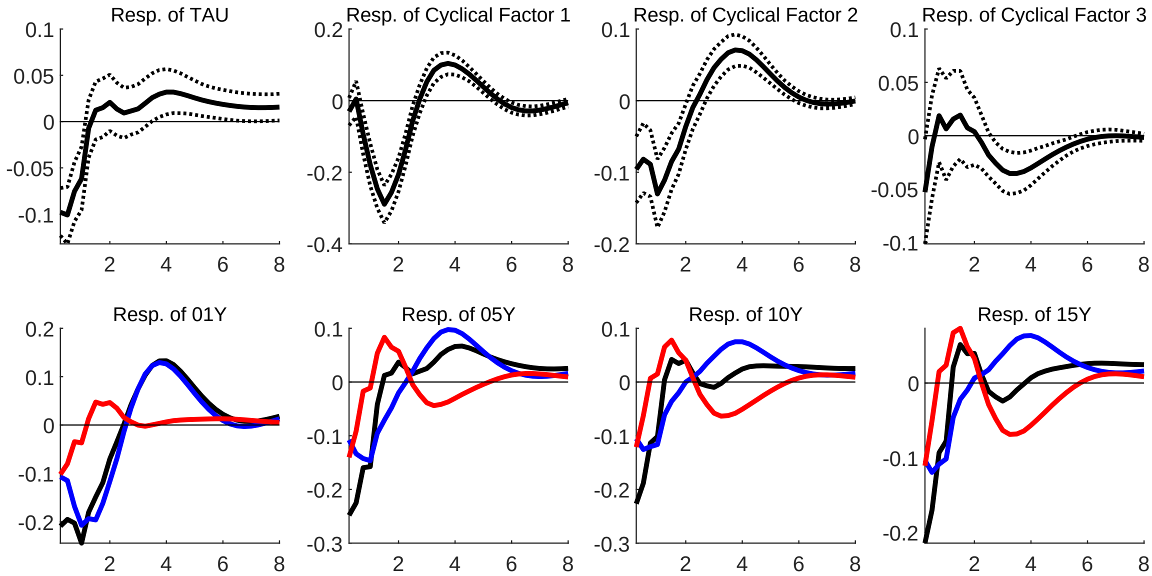


Note: The impulses are set as an increase in a growth rate by one percentage point, responses are also measured in percentage points. The x-axis denotes years. The dashed lines display the 68% confidence bands. GEXP=growth rate in government expenditures, xxY=xx-year Treasury yield.

5.3 Affine Term Structure Model (NARR-AFF)

The third NARR model specification again confirms the previous results while providing an additional view of the actual transmission channels. Stochastic trend τ_t temporarily decreases after a positive spending shock, which pushes yields down across all bond maturities (Figure 14), mostly due to a drop in the risk-neutral yields. While the responses of the first and the second cyclical factors $\widetilde{F}_t$ drive certain additional volatility mostly in the risk-neutral yields, the third cyclical factor volatility (the initial and the secondary delayed drop) is the source of volatility in the term premium (see section 3 and section 7 for yield factor loadings).

Figure 14: Responses in the NARR-AFF model to government spending impulse (selected)



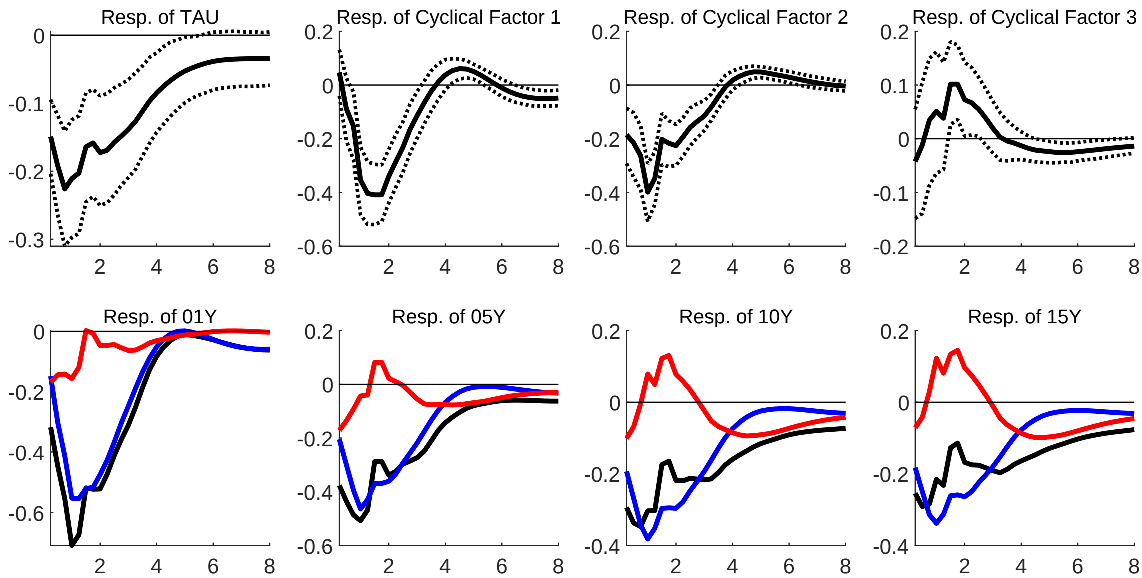
Note: The yield response (black) is decomposed to the response of the risk-neutral yield (blue) and the response of the term premium (red) at the bottom panels. The impulses are set as an increase in a growth rate, and responses are measured in factor values or yield percentage points. The x-axis denotes years. The dashed lines in the upper panel display the 68% credible intervals. xxY=xx-year Treasury yield.

These observations support the previous discussion on spending shock transmission, given that the shock is identified in a narrative way. The shock causes an initial cautious response of economic agents, which transmits through the *real channel* to the lower yields across all maturities. Additionally, the NARR-AFF model shows that the initial drop in yields is partially caused by the drop in the term premium. This supports the importance of the *financial market sentiment channel*, as uncertainty causes demand for Treasuries, representing a safe haven and a certain tool to hedge against uncertainty.

Importantly, the NARR-AFF model specification differs from NARR-YLD and NARR-LSC in the way that the shorter yields switch to a growth instead of the initial drop after several quarters, in case of a positive spending shock. These dynamics are mostly governed by the factors driving the risk-neutral yields, whose switch to positive is statistically significant (Figure 14). In the longer yields, the delayed positive response is muted by opposite behavior of the term premium. Such delayed behavior is very close to the results displayed in the SVAR-AFF model. The risk-neutral yields and the short yields increase thanks to the positive effects of government spending on the real economy (the *real channel*) and possibly also due to a need to finance the additional spending (the *Treasury supply channel*). The longer-term yields are, in turn, affected by simultaneously growing uncertainty and the need for a certain hedging via safe haven assets (*financial market sentiment channel*), which pushes the yields down and, thus, compensates the increase in the risk-neutral yield. Unlike the SVAR-AFF model, the evidence on the presence of the *debt sustainability channel* is not strong in the NARR-AFF model results.

Finally, the NARR-AFF model version with the FPU index replacing the narrative spending shock again further supports the importance of uncertainty when explaining the yield response to the shock. In the case where a mere uncertainty increases, the risk-neutral yields drop and return more slowly, compared with the previous case (compare Figure 15 and Figure 14). The absence of the positive effect of delayed realized spending after FPU shocks implies that the cautious response of economic agents through the *real channel* is more persistent. In contrast, the pure FPU shock, which may have various possible causes beyond news about future government spending, causes a rise in the term premium. In this case, the importance of the *debt sustainability channel* is apparent, while the effect of the flight to quality behavior (the *financial market sentiment channel*) is diminished.

Figure 15: Responses in the NARR-AFF model with FPU to government spending impulse (selected)



Note: The yield response (black) is decomposed to the response of the risk-neutral yield (blue) and the response of the term premium (red) at the bottom panels. The impulses are set as an increase in a growth rate, and responses are measured in factor values or yield percentage points. The x-axis denotes years. The dashed lines in the upper panel display the 68% credible intervals. xxY=xx-year Treasury yield.

6 DSGE-Based Fiscal Policy Shocks

VARs have been shown to be very successful in capturing the dynamic properties of macroeconomic time-series data. However, interpreting these statistical relationships in the form of outcome of VAR estimations back to coherent economic stories can be ambiguous and it is subject to a vigorous debate in the literature. The difficulties interpreting the results from VAR analysis relate to the fact that the estimation depends crucially on the underlying assumptions (i.e. linearity and fundamentalness of the shocks) and that the various competing identification restrictions are often difficult to test against the data. Despite the fact that over time there has emerged a consensus on many specific questions about the identification strategy (i.e. Blanchard and Perotti (2002) in the case of identifying government spending), shock identification remains a highly controversial issue (see Ramey (2011) and Ramey (2016) for surveys on the issue). A type of model that is not susceptible to this problem is the dynamic stochastic general equilibrium (DSGE) model. In this case, economic theory is used to define all the linkages between variables. The economic structure implied by the model allows us to address the identification issue but at the cost of losing much of the flexibility provided by the VARs. The DSGE model imposes on data theory, which aims to explain the data exactly, and since the theoretical model is never a full representation of the complex reality, problems such as *i*) underidentification, *ii*) weak identification or partial identification, *iii*) observational equivalence, arise (see Canova and Ferroni (2011)). Nevertheless, despite its problems, we believe that the identification of government spending shocks within the theoretical macroeconomic model, which has been shown to match the underlying macro and finance data sufficiently well can provide further insights and robustness to our analysis. We therefore use the structural dynamic general equilibrium macroeconomic model as yet another approach to identify government spending shocks.

More specifically, we build on the New Keynesian model of Andreasen *et al.* (2018) which matches particularly well the mix of macro and asset pricing stylized facts related to the yield curve[21]. The model is solved nonlinearly up to the 3rd order of approximation to ensure time varying risk premia and consequently estimated by GMM. In the following step, we utilize the estimated model and use a Kalman filter to extract shock time series for government spending, total factor productivity and preferences. The time series of shocks when fed back in the model exactly replicates the observed time series of GDP, inflation and the 3-month nominal interest rate. In the next step, we use the shock series for government spending identified by this procedure in the DSGE model and feed it into our affine term structure model.

[21]Short description of the model: Prices are rigid in the model economy because firms face Calvo contracts. Households are specified by the preference of early resolution of uncertainty introduced by Epstein and Zin preferences and in addition the period utility function features consumption habits. To model the interactions between financial markets, monetary policy, and the real economy, which has been shown to be an important driver of yields in the last two decades, the model relies on two key features. First, households in the model deposit their savings in a financial intermediary in which the financial intermediary invests in short- and long-term bonds and creates a wedge between the policy rate set by the monetary authority and the interest rate on deposits. Second, the Taylor rule of the monetary authority contains the excess return on a longer-term bond and because of the direct mapping between the excess return and term premia the model endogenizes the term structure of interest rates. In other words, as the central bank responds to changes in nominal term premia by adjusting the policy rate, the yield curve has impact on the real economy through the policy rate.

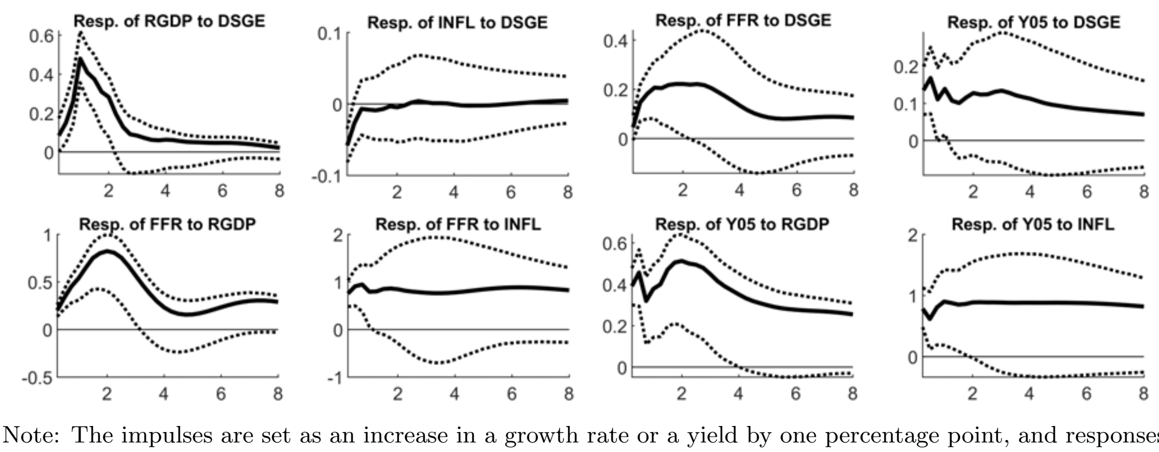
The resulting estimates of government spending structural shocks obtained from the DSGE model are displayed in Figure 5, in the bottom-right panel. As with the other identification methods, the peak in 2008-2009 is distinctive. We use the DSGE-based identification of shocks in our estimation framework, (i.e.,-YLD, -LSC and -AFF models). We enter the estimated time series for spending shocks into a VAR model.

The VAR model variables are consistent with the estimation in the previous sections, and the fiscal shocks are ordered as the first, using a Choleski identification, which helps to ensure that the assumptions imposed by the VAR model do not alter the relation between the fiscal shocks and the other variables significantly.

6.1 Single-Yield Model (DSGE-YLD)

The DSGE-YLD replaces the anticipated government expenditures in NARR-YLD by the DSGE-based spending shock and orders it as a first in the VAR variable vector. The DSGE-YLD based shock is identified as a contemporaneous surprise shock in realized government expenditures. It is, therefore, comparable in its timing to the identification based on the Blanchard and Perotti (2002) method. The response of both the Fed funds rate and the 5-year yield (representing the long-tail of the yield curve) to a positive spending shock is positive. The short rate rises however more than Y05 yield flattens the yield curve (slope of the yield curve decreases). The responses are statistically significant, although of a lesser magnitude than in the case of the SVAR-YLD model. We interpret this result as supporting evidence for the fact that shocks to realized government spending transmits to yields through what we call the real channel. This is because the impact of government spending shocks on yields in our DSGE model is implied by the shifts in the stochastic discount factor, which is represented by the economy macro variables.

Figure 16: Impulse-responses in the DSGE-YLD model (selected)

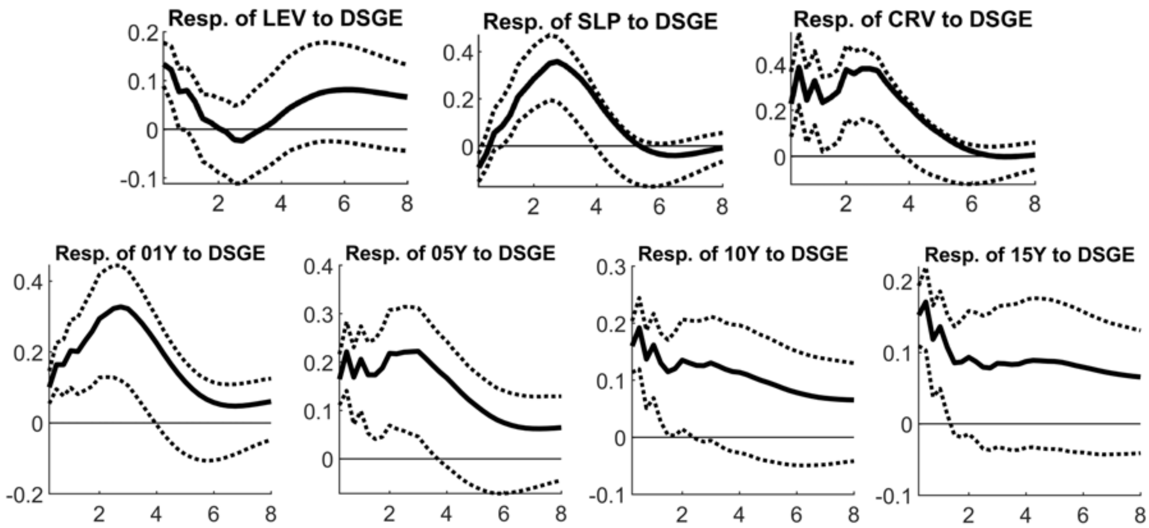


Note: The impulses are set as an increase in a growth rate or a yield by one percentage point, and responses are also measured in percentage points. The x-axis denotes years. The dashed lines display the 68% confidence bands. RGDP=real GDP growth rate, DSGE=the DSGE-based spending shock, INFL=annual rate of inflation, FFR=Fed funds rate, Y05=five-year Treasury yield.

6.2 Level, Slope and Curvature Model (DSGE-LSC)

The DSGE-LSC represents the modeling framework with the shock identified in a DSGE model and estimated VAR model. The Yield curve is represented in the VAR model by level, slope and curvature factors. The model therefore differs from SVAR-LSC only in the form of shock identification. The DSGE-LSC model impulse response functions are very similar to the results from SVAR-LSC model[22]. We interpret these results again as a supporting evidence that the yield factors are driven by what we call the *real channel*.

Figure 17: Impulse-responses in the DSGE-LSC model (selected)



Note: The impulses are set as an increase in a growth rate by one percentage point, and responses are measured in factor units. The x-axis denotes years. The dashed lines display the 68% confidence bands. DSGE=the DSGE-based spending shock, LEV=the level, SLP=the slope, CRV=the curvature, xxY=xx-year Treasury yield.

6.3 Affine Term Structure Model (DSGE-AFF)

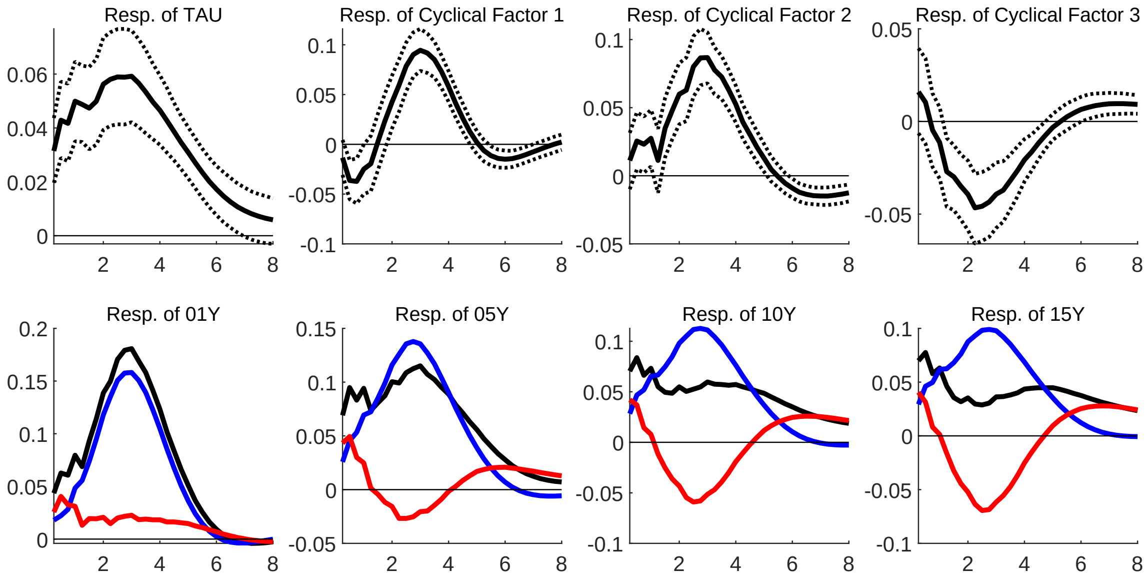
The DSGE-AFF specification uses yield curve factors from the affine term structure model. The responses of the stochastic trend τ and the three cyclical factors are similar to the results of SVAR-AFF, only with the difference in the τ response that converges back more quickly in the DSGE-based shock case (Figure 18). The consequence of such an outcome is smaller drop in the term premium compared to SVAR-AFF.

7 Concluding Remarks

The paper documents the effects of government expenditures on the yield curve in the US. Our approach takes advantage of multiple identification strategies to capture different re-

[22] Blanchard and Perotti (2002) shock identification and Nelson and Siegel (1987) term structure model in our macrofinance model

Figure 18: Responses in the DSGE-AFF model to government spending impulse (selected)



Note: The yield response (black) is decomposed to the response of the risk-neutral yield (blue) and the response of the term premium (red) at the bottom panels. The impulses are set as an increase in a growth rate, and responses are measured in factor values or yield percentage points. The x-axis denotes years. The dashed lines in the upper panel display the 68% credible intervals. xxY=xx-year Treasury yield.

sponses of yields to announcements and the realization of government spending. We find that the government spending shock identified at the moment when fiscal policy is realized leads to an increase in yields. The actual realization of government expenditure increases yields because of the real economic effects of expenditures and the need to finance the additional expenditure in the financial markets. On the other hand, we show that the shock to the anticipation of future government expenditures lowers yields through the precautionary saving channel. These two contradictory results provide a single whole picture of the transmission of fiscal policy into Treasury yields, which takes place from the time of announcement until the realization of the expenditure.

We further emphasize that the initial drop in yields is closely linked to uncertainty. When using the uncertainty shock based on FPU index by Baker *et al.* (2016) instead of the expected spending shocks, the drop in yields is larger and the term premium increases with some delay, compared to the response of the yields when the uncertainty is linked to a future fiscal expansion. By generalizing this observation, we claim that the degree of uncertainty perceived by financial markets and economic agents in relation to fiscal policy news is an important attribute of the response of bond investors to changes in government expenditures.

Given the specific position of Treasuries as a global safe haven instrument and the limited risk of default of the U.S. government, a possible next step would be to extend the analysis to a panel of countries. This would facilitate generalizing the results and could provide additional important contributions of the research for understanding fiscal policy, for example, in the case of developing countries that are more sensitive to geopolitical uncertainty shocks and capital flows than the U.S. We leave such an extension to future research.

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Appendices

Estimated Parameters

Table 2: Affine Model Parameters (selected)

Variable	mean	5% quantile	median	95% quantile
$\bar{F}$	0.000 -0.018 -0.018	0.000 -0.034 -0.052	0.000 -0.016 -0.015	0.000 -0.005 0.005
γ	1.000 1.557 1.813	1.000 1.321 1.462	1.000 1.554 1.820	1.000 1.786 2.117
σ_τ^2	0.0034	0030	0.0034	0.0038
Φ (the largest eigenvalue)	0.928	0.862	0.933	0.980
Φ^Q (the largest eigenvalue)	0.9984	0.9980	0.9984	0.9988
A (one-year yield)	0.0005	0.0004	0.0005	0.0006
A (ten-year yield)	0.0004	0.0004	0.0004	0.0004
B (one-year yield)	0.333 0.784 -0.118	0.325 0.772 -0.123	0.333 0.784 -0.118	0.340 0.796 -0.113
B (ten-year yield)	0.013 -0.064 1.049	0.012 -0.067 1.047	0.013 -0.064 1.049	0.014 -0.062 1.051

Information Criteria for SVAR-YLD Model

Figure 19: VAR Model Information Criteria for SVAR-YLD Model