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Fiscal policy driven bond risk premia

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Abstract

Fiscal policy matters for bond risk premia. Empirically, government spending level and uncertainty predict bond excess returns, as well as term structure level and slope movements. Shocks to government spending level and uncertainty are also priced in the cross-section of bond and stock portfolios. Theoretically, government spending level shocks raise inflation when marginal utility is high, thus generating positive inflation risk premia (term structure level effect). Uncertainty shocks steepen the yield curve (slope effect), producing positive term premia. These effects are consistent with evidence from a structural vector autoregression. Asset pricing tests using model simulated data corroborate our empirical findings.

JEL classification: E43, E62, G12.

Keywords: Term structure, Bond risk premia, Fiscal policy, Uncertainty.

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1. Introduction

Fiscal policy has first-order effects on economic activity. Government spending and taxation affect corporate investment-borrowing choices, household consumption-saving behavior, and economic aggregates, such as output and inflation. There is a burgeoning literature in finance on the interaction between fiscal policy and equity pricing. Croce, Kung, Nguyen, and Schmid (2012) study the effects of fiscal policy in a production-based general equilibrium model in which taxation affects corporate decisions. They find that tax distortions have negative effects on the cost of equity and investment. Pastor and Veronesi (2012, 2013) examine the stock market's reaction to the announcement of the government's policy decisions and the response of the equity risk premium to government-induced (political) uncertainty. Belo, Gala, and Li (2013) and Belo and Yu (2013) examine the impact of government spending and investment on the cross-section of equity risk premia and document the connection between public sector spending and private sector returns. Diercks and Waller (2017) investigate the role of the Federal Reserve Bank in influencing the reaction of equity returns to tax cuts. They conclude that discount rate news dominates cash flow news in the post-1980 era so that tax cuts result in lower stock returns. Finally, Croce, Nguyen, Raymond, and Schmid (2019) find that high research and development (R&D) firms have greater exposure to government debt relative to low R&D firms. This makes high R&D firms riskier and causes them to generate higher expected returns.

On the other hand, the link between fiscal policy and the term structure of interest rates is not as established. Dai and Philippon (2005) provide empirical evidence of fiscal deficits driving nominal yield curve dynamics in a no-arbitrage affine macro-finance model. However, their model does not accommodate endogenous inflation, which Piazzesi and Schneider (2007) document to be the main risk factor in generating bond risk premia. More recently, Corhay, Kind, Kung, and Morales (2018) use a New Keynesian model to explore the effect of government debt maturity on yield dynamics. Studying the impact of fiscal policy on bond risk premia is important given the recent debt level increase in the United States and the need for monetary-fiscal policy coordination. High political uncertainty leads to further concerns on how the government will finance itself going forward. In this paper, we investigate the effects of U.S. fiscal policy on the term structure of interest rates and bond risk premia.

Empirically, we examine the link between fiscal policy and the term structure of U.S. Treasury yields both in the time series and in the cross-section. We find that higher government spending level and uncertainty predict higher bond excess returns after controlling for yield curve level, slope, and curvature factors, as well as maturity-weighted debt from Greenwood and Vayanos (2014). Furthermore, an increase in government spending level cor-responds to a negative change in the level, as well as a positive change in the slope of the yield curve over the next year. Government spending uncertainty increases are associated with positive changes in the slope of the term structure. In the cross-section, we find that government spending level and uncertainty shocks explain a large fraction of the cross-sectional variation in the average returns of stock portfolios formed on size and book-to-market and bond portfolios sorted by maturity.

We develop a New-Keynesian[1] stochastic growth model with fiscal policy to study the mechanism underlying bond risk premia. In particular, we introduce fiscal policy to the model via a government budget constraint that links government revenue, spending, and debt. Government revenue consists of lump-sum transfers and taxes levied on the return of capital (capital income). Both government spending and taxes on capital income follow an exogenous process with stochastic volatility. Finally, Ricardian equivalence in the model is disrupted by the inclusion of distortionary taxation.

In our model, a positive level shock to government spending increases output demand and crowds out consumption and investment. At the same time, the negative wealth effect of lower consumption increases the supply of labor and depresses real wages. Moreover, marginal utility rises because consumption growth is low. Higher output leads to an increase in the return on capital, which causes inflation to spike immediately after a positive spending level shock is realized. This results in a level shift in the term structure. The combination of high inflation while marginal utility is high translates to positive inflation risk premia. On the other hand, a positive government spending uncertainty shock has a differential impact on short- and long-term bonds. Higher uncertainty leads to a transitory decline in real wages, return on capital, and investment together with an increase in government debt. The transitory nature of the uncertainty shock renders short-term bonds more valuable as a consumption hedge than long-term bonds. As a result, short-term bonds become expensive relative to long-term bonds in high marginal utility states. Ultimately, an increase in government spending uncertainty leads to a steepening of the yield curve and positive term premia.

We validate the theoretical mechanism implied by our model along several dimensions. First, our model reproduces dynamic responses of macroeconomic and financial variables from an empirical vector autoregression (VAR). Second, we confirm the importance of government spending level and uncertainty for bond risk premia via predictive regressions on

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[1] In this class of models, intermediate-good firms adjust prices according to the Calvo (1983) process. That is, only a fraction of the firms are allowed to maximize the present value of their expected profits by choosing the optimal price in a given period. This mechanism induces monetary policy non-neutrality with respect to the real economy, allowing us to make comparisons between fiscal policy impacts and monetary policy impacts.

model simulated data. Finally, our model captures the relation between fiscal variables and future changes in the level and slope of the yield curve.

This paper contributes to a growing literature on the relation between government policies, economic activity, and asset prices. The joint modeling of the yield curve and macroeconomic variables has received much attention since Ang and Piazzesi (2003), who connect latent term structure factors with inflation and the output gap. More recently, many term structure studies include monetary policy elements in their models based on the fact that the nominal short-term interest rate is the monetary policy instrument. However, these models are generally silent on how fiscal policy affects the term structure. Our primary contribution is to establish the link between fiscal policy and the risk premia on nominal bonds. Our model implies that loose fiscal policy and high government spending cause investors to demand higher returns in exchange for holding Treasury securities.

Our paper is also related to the literature on term structure and bond risk premia in macro-finance. Campbell (1986) presents an endowment economy in which utility-maximizing agents trade bonds that have different maturities. When the exogenous consumption growth process is negatively autocorrelated, the term premia on long-term bonds are positive, generating upward-sloping yield curves. Wachter (2006) uses habit formation to generate upward-sloping nominal and real yield curves. More recently, Campbell, Pflueger, and Viceira (2018) find that an intensified monetary policy focus on inflation increases bond risk premia, while a focus on stabilizing output has the opposite effect.

Our work also adds to the literature on term structure in production economy models. Rudebusch and Swanson (2008, 2012) examine bond risk premia in general equilibrium using habit and Epstein and Zin (1989) utilities, respectively. Palomino (2012) shows that, depending on the credibility of the monetary authority and the representative agent's preferences, welfare-maximizing monetary policy affects inflation risk premia. Kung (2015) builds an equilibrium model with stochastic endogenous growth to explain the impact of monetary policy shocks on bond risk premia. Hsu, Li, and Palomino (2019) employ an endogenous growth model with habit formation nested inside Epstein-Zin recursive preferences to produce nominal and real yield curves as in the data. Nguyen (2019) studies the impact of debt-to-GDP ratio on the slope of the term structure in a model with endogenous growth. The author finds that high government debt forecasts low growth and deflation. As a result, long-dated bonds are ideal hedging assets. In contrast, in order to explore the impact of fiscal policy on the term structure, we employ a model without endogenous growth but with stochastic volatility in fiscal rules. Moreover, we focus on government spending and capital income taxation as fiscal instruments, rather than the debt level.

Finally, this paper relates to an extensive literature on fiscal policy in economics. See, among many others, Barro (1974), Aschauer (1985), Aiyagari, Christiano, and Eichenbaum (1992), Baxter and King (1993), Ramey and Shapiro (1998), Gali, Valles, and Lopez-Salido (2007), Christiano, Eichenbaum, and Rebelo (2011). The majority of the papers focus on optimal taxation and fiscal multipliers. Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2015) show that an unexpected increase in capital tax uncertainty has a strong negative impact on output. In contrast, we analyze the impact of fiscal policy shocks on the term structure of interest rates. To the best of our knowledge, our paper is the first attempt to evaluate how bond risk premium responds to unexpected changes in fiscal uncertainty.[2]

The rest of the paper is structured as follows. In Section 2, we document the estimation of the fiscal policy processes in the data and show how fiscal policy affects bond risk premia. We introduce the model in Section 3. In Section 4, we present our solution method and estimation approach of the theoreical model. In Section 5, we analyze the model performance and associated term structure. We conclude in Section 6.

2. Empirical analysis

We present our empirical analysis in this section. In the first part, we estimate fiscal policy rules for government spending and capital tax rates, both of which contain stochastic volatility. We then use the estimated level and uncertainty series in bond excess return predictive regressions to verify that these fiscal policy instruments are significantly related to Treasury bond risk premia. In the last part of the empirical exercise, we examine the pricing capabilities of government spending level and uncertainty in the cross-section of stock and bond portfolios. We develop a three-factor fiscal asset pricing model to show that government spending level and volatility are priced risk factors for asset returns.

2.1. Fiscal rules with stochastic volatility

In this subsection, we estimate fiscal rules with stochastic volatility using data on taxes, government spending, debt, and output. Our sample period spans 1970Q1 to 2016Q4. Online Appendix A provides information about the data sources and variable construction. Our two

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[2] We follow Fernández-Villaverde et al. (2015) and interpret the unexpected changes in the time-varying volatility of the fiscal instrument (e.g., government spending) as unexpected variations in uncertainty about fiscal policy. We also use the term "uncertainty" for what might more precisely be referred to as "risk." See also Bachmann, Bai, Lee, and Zhang (2018), who quantify the welfare costs of fiscal uncertainty in a neo classical stochastic growth model.

policy instruments, government spending and capital tax rate, evolve as follows:

$$x_{t+1} = (1-\phi_x)\theta_x + \phi_x x_t + \phi_{x,y}\tilde{y}_t + \phi_{x,d}\left(\frac{d_t}{y_t} - \frac{d}{y}\right) + e^{\sigma_{x,t+1}}\epsilon_{x,t+1} \tag{1}$$

$$\sigma_{x,t+1} = (1-\phi_{\sigma_x})\theta_{\sigma_x} + \phi_{\sigma_x}\sigma_{x,t} + \sigma_{\sigma_x}\epsilon_{\sigma_x,t+1} \tag{2}$$

for $x \in \{g, \tau^k\}$, where g denotes government spending as a share of output, and τ^k denotes the tax rate on capital income. Each policy instrument features stochastic volatility, since the log of the standard deviation of the innovation, $\sigma_{x,t}$, is random. The parameter θ_{σ_x} determines the average standard deviation of a fiscal shock, $\frac{\sigma_{\sigma_x}}{\sqrt{(1-(\phi_{\sigma_x})^2)}}$ is the unconditional standard deviation of the fiscal volatility shock to instrument x, and ϕ_{σ_x} controls the shock's persistence. Finally, we allow for two feedbacks in the law of motion of the fiscal instrument: one from the state of the business cycle as proxied by detrended log output, $\tilde{y}_t$, and another from the debt-to-output ratio, $\frac{d_t}{y_t}$.

Following Fernández-Villaverde et al. (2015), we estimate Eq. (1) and (2) for each fiscal instrument separately, and we set the means in Eq. (1) to each instrument's sample mean. We estimate the rest of the parameters following a Bayesian approach by combining the likelihood function with uninformative priors and sampling from the posterior using a Markov Chain Monte Carlo.[3] Table 1 reports the posterior median of the parameters, along with 95% probability intervals. Both tax rates and government spending as a share of output are persistent; for example, the half-life of government spending is around $-\log(2)/\log(0.98) = 34$ quarters. Deviations from average volatility also persist for some time. The $\epsilon_{x,t}$s have an average standard deviation of $100 \times \exp(-5.93) = 0.27$ and $100 \times \exp(-4.84) = 0.79$ percentage points for government spending and capital tax rates, respectively. Our results are in line with Fernández-Villaverde et al. (2015) (see, in particular, their Table 1).

[Insert Table 1 about here.]

Panels 1(a) and 1(b) of Fig. 1 display the 95% posterior probability intervals of the smoothed fiscal uncertainty of government spending and capital tax rates over the sample period. Government spending uncertainty was high in 1974–1975 and in the early 1980s (during the Reagan administration). We then observe a "moderation" in both of our fiscal uncertainty series until the second quarter of 2001. Thereafter, uncertainty increases again due to the potentially vast fiscal implications of the September 11, 2001 terrorist attacks

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[3] For government spending, we adopt a beta distribution for ϕ_{σ_g} and ϕ_g with mean 0.8 and 0.85, respectively; a uniform distribution between -11 and -3 for θ_{σ_g}; and an inverse gamma for σ_{σ_g} with mean 0.1. Correspondingly, for capital tax, we use a beta distribution for $\phi_{\sigma_{\tau^k}}$ and ϕ_{τ^k} with mean 0.85 and 0.8, respectively; a uniform distribution between -8 and -3 for $\theta_{\sigma_{\tau^k}}$; and an inverse gamma for $\sigma_{\sigma_{\tau^k}}$ with mean 0.2.

and the 2001–2002 recession. Finally, uncertainty substantially increases toward the end of our sample period, which is mainly due to the historically high level of the government's debt-to-output ratio.

[Insert Figure 1 about here.]

2.2. Predicting bond excess returns

In this subsection, we provide evidence that government spending level and uncertainty predict excess bond returns. We start with predictive regressions of the form:

$$xr^{(n)}_{t+4} = \beta_0 + \beta_1' x_t + u_{t+4}, \tag{3}$$

where $xr^{(n)}_{t+4} = p^{(n-4)}_{t+4} - p^{(n)}_t - y^{(4)}_t$ is the excess 4-quarter holding period return of a bond with maturity of n-quarters. The set of predictors x_t contains fiscal and control variables.

Table 2 reports the results for the quarterly sample from 1970Q1 to 2016Q4. Throughout, we focus on excess returns with maturities of $n = 8$ (Panel A) and $n = 20$ (Panel B) quarters (2 and 5 years, respectively). We use the *filtered* series of volatilities to mitigate any look-ahead bias present in the smoothed estimates. Since the persistence of the predictors and the presence of overlapping observations plague these forecasting regressions with small sample biases, we rely on conservative standard errors from reverse regressions (RR) proposed by Hodrick (1992) and extended by Wei and Wright (2013). This approach removes the overlap in the error term by exploiting the covariance of one-period returns with an h-period sum of the predictor ($h = 4$ in our case).[4]

[Insert Table 2 about here.]

Specifications (1) and (2) in Panels A and B of Table 2 show that coefficient loadings on government spending level and uncertainty are positive and significant. Specifications (3) and (4) document that this is also the case when we control for the government debt supply - an important state variable in our model and a key determinant of the slope of the term structure (Nguyen, 2019). Jointly, government spending level and uncertainty explain a substantial fraction of the variation in future excess returns on short- and long-maturity bonds with an R^2 of up to 20% in Specification (5).

In the next specification, we run the following regression to establish a benchmark for return predictability:

$$xr^{(n)}_{t+4} = \beta_0 + \beta_1 \mathcal{P}_t + u_{t+4}, \tag{4}$$

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[4] Also, we employ a one-sided filter to remove a decadal trend from the level of government spending and capital tax rates. This procedure not only allows us to focus on business cycle fluctuations, but it also reduces the persistence of the series and thus alleviates some of the econometric concerns listed above.

where the predictors $\mathcal{P}_t$ capture the information in the yield curve as summarized by the first three principal components (PCs) of observed yields (i.e., level, slope, and curvature). The results in Specification (6) in Panels A and B of Table 2 show that the ability of the PCs alone to predict excess returns is modest and only the slope (PC2) is a significant predictor. This is consistent with the results of Campbell and Shiller (1991) and Duffee (2013).

In addition, the results for Specification (7) in Table 2 show that government spending level is a significant predictor for short- and long-maturity bond excess returns even after controlling for the first three PCs. Also, government spending uncertainty continues to be a significant predictor of short-maturity bond excess returns. Importantly, the estimated coefficient on the second principal component (PC2) becomes insignificant once the spending series are added. This is due to the correlation between the slope factor (PC2) and government spending uncertainty, which makes it hard for the ordinary least squares (OLS) regression to discern between the two predictors.

Moreover, the statistical significance of government spending level and uncertainty continues to hold when we control for the tax rate level and uncertainty. We also find that tax rate level and uncertainty are not statistically significant predictors of excess bond returns.[5] Hence, we only focus on government spending in the remainder of our discussion.

A natural concern is that our fiscal variables are correlated with macroeconomic quantities which also predict bond returns. Online Appendix Table E.1 provides evidence that government spending level and uncertainty are statistically robust predictors of bond returns, even after controlling for a host of macroeconomic drivers of the term structure.

To further understand the predictability induced by government spending, we exploit the fact that the forecasts of expected bond returns are also forecasts of future yields (see Campbell and Shiller, 1991). Therefore, in the regressions we replace bond excess returns with annual changes in the first three principal components of yields as the dependent variable. We find in Specification (1) in Panel A of Table 3 that the term structure factors (PC1, PC2, and PC3) do not predict future changes in the level of the term structure. Changes in the slope (Panel B) and curvature (Panel C), on the other hand, are predictable. These results are in line with Duffee (2013). Interestingly, government spending level predicts future changes in the level of the yield curve in Specifications (2) and (4) in Panel A. Higher government spending causes bond yields to drop and bond prices to rise over the next period. This implies higher expected returns, consistent with the evidence from predictive regressions. The results in Specifications (2) to (4) in Panel B show that government spending level and uncertainty both predict future changes in the slope of the yield curve. Finally, Specifications (2) to (4) in Panel C show that fiscal variables have no incremental explanatory power

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[5] Corresponding results are available upon request.

for changes in the curvature of the yield curve.

[Insert Table 3 about here.]

To summarize, we document that government spending level and uncertainty predict bond excess returns and subsume information about the level and the slope factors of the yield curve. Furthermore, government spending level is able to predict changes in the level and the slope of the yield curve. Government spending uncertainty is able to predict only changes in the slope of the yield curve.

2.3. Cross-sectional tests

In a next step, we examine the performance of fiscal variables in cross-sectional asset pricing tests. To this end, we study a cross-section of test assets formed by the 25 Fama-French equity portfolios sorted on book-to-market and size, the market portfolio, and maturity-sorted government bond portfolios.[6]

Panel A of Table 4 reports the regression betas of bond returns on innovations in the government spending level and uncertainty series. We find that excess Treasury bond returns comove negatively with government spending level and positively with government spending uncertainty. We return to the sign of the covariances in Section 5.4, where we discuss excess returns through the lens of our model.[7]

[Insert Table 4 about here.]

We further investigate whether the various pricing models provide a good fit for the cross-section of expected returns. Lewellen, Nagel, and Shanken (2010) point out several pitfalls of using a high cross-sectional R^2 to evaluate model success. To address this issue, we report both the cross-sectional R^2 and the asymptotic standard error of the sample R^2 (see Kan, Robotti, and Shanken, 2013). In Table 5, we summarize the performance of asset pricing models based on fiscal variables. To provide a baseline, we start by only using the market factor and present the results in Panel A. Comparing Panel B to Panel

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[6] Since our test assets include both bonds and stocks, we follow Shanken (1987) and proxy for the true market portfolio using a combination of the value-weighted stock index and a long-term government bond index. We thank an anonymous referee for this suggestion.

[7] We are aware that spurious factors (Kan and Zhang, 1999), i.e., factors that are only weakly related to the asset returns, constitute a severe problem that makes standard estimation and inference techniques unreliable (e.g., Kleibergen (2009); Gospodinov, Kan, and Robotti (2014; 2017), Giglio and Xiu (2017)). However, in Section 5.4, we revisit our findings using simulated data from the theoretical model. We validate the sign and the magnitude of the time-series and cross-sectional coefficients, and we test additional restrictions (e.g., variance ratios) to provide further *economic* support for fiscal factors and to complement the *statistical* evidence of this section.

A, the inclusion of government spending level in the regression leads to a higher and less volatile R^2. Panel C shows that government spending uncertainty also explains substantial cross-sectional variation in expected returns, as evidenced by the high R^2.

Next, we examine the risk premium estimates of the beta pricing models. For each model in Table 5, we report $\widehat{\lambda}$s and the associated Fama and MacBeth (1973) t-ratios, followed by the generalized method of moments (GMM)-corrected t-ratio, which accounts for estimation error in the betas (see Shanken, 1992; Jagannathan and Wang, 1998). Panel B shows that the government spending level factor is negatively priced. In addition, removing the constant does neither materially affect the mean absolute pricing errors nor reduce the R^2. In Panel C, we document that the risk premium on government spending uncertainty is positive and significant. Finally, including both $\beta_{i,g}$ and β_{i,σ_t} as regressors leads to statistically significant estimates of the market price of risk for both government spending level and uncertainty factors.

[Insert Table 5 about here.]

The high explanatory power of our fiscal asset pricing model is not due to a few outliers but rather to an overall improvement in fit across both asset classes (bonds and stocks) and, within stocks, across both size and book-to-market quintiles. Fig. 2 provides a graphical illustration of this result. While neither the variation in book-to-market nor bond portfolios can be successfully explained by the market factor alone, adding government spending variables to the market factor reduces the pricing errors in bond portfolios and almost eliminates the value spread. Online Appendix Table E.2 reports individual pricing errors of each of our test assets. Further tests show that our cross-sectional results are robust to the inclusion of industry portfolios (see Online Appendix Table E.3).

[Insert Figure 2 about here.]

Our empirical evidence provides support that government spending level and uncertainty are significantly priced in financial assets. A model with three factors (the market factor together with government spending level and uncertainty) accounts for the bulk of the cross-sectional variation in stock and bond returns.

3. The benchmark model

In this section, we develop a New-Keynesian dynamic stochastic general equilibrium (DSGE) model with government spending and distortionary taxes on capital income that allows us to study the links between fiscal policy, bond yields, and risk premia. The model consists out of five building blocks: a representative household with Epstein-Zin preferences, capital accumulation with investment adjustment costs, staggered price setting with monopolistic producers, a monetary authority, and fiscal policy conducted via a government budget constraint.

3.1. The household's problem

The model features a continuum of identical households that can be summarized by a representative household. This household has Epstein and Zin (1989) preferences and can purchase government bonds to smooth future consumption. Hence, the household maximizes lifetime utility by solving the following optimization problem:

$$\begin{aligned}
\max \quad & V(C_t, N_t) = \left\{(1-\beta)\left(\frac{C_t^{1-\psi}}{1-\psi} - \varphi_t^{1-\psi}\frac{N_t^{s\,1+\omega}}{1+\omega}\right) + \beta E_t\left[V_{t+1}^{1-\gamma}\right]^{\frac{1-\psi}{1-\gamma}}\right\}^{\frac{1}{1-\psi}}, \\
\text{s.t.} \quad & P_tC_t + P_tInv_t + Q_t^{(1)}B_t(t+1) + P_t\tau_t \\
& = P_tW_tN_t^s + (1-\tau_t^k)P_tR_t^kK_{t-1} + B_{t-1}(t) + P_t\Psi_t,
\end{aligned}$$

where β denotes the time discount factor, ψ is the inverse of the intertemporal elasticity of substitution (IES), the parameter γ is related to the coefficient of relative risk aversion, and ω is the inverse of the Frisch elasticity of labor supply. The variable φ_t is a time-varying function that is cointegrated with the labor productivity (A_t) to achieve a balanced path in wage growth, which is smoothed such that the permanent shock does not drive labor disutility.[8]

The variables C_t and N_t^s represent real consumption and labor supply, respectively; Inv_t denotes investment in real terms; P_t denotes the price level in the economy; $B_t(t+1)$ denotes the amount of nominal bonds outstanding at the end of period t and due in period $t+1$ with a price equal to $Q_t^{(1)}$; W_t refers to real labor income, which is identical across households; τ_t denotes real lump-sum tax collected by the fiscal authority to keep the real debt process from exploding; Ψ_t denotes firm dividends; K_t denotes capital; and R_t^k denotes the return on capital. τ_t^k denotes the distortionary tax on the return on capital, which we define when

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[8] The equation relating φ_t and A_t is:

$$\log\left(\frac{\varphi_t}{A_t}\right) = \phi_\varphi \log\varphi + (1-\phi_\varphi)g_a - (1-\phi_\varphi)\left[\Delta a_t - \log\left(\frac{\varphi_{t-1}}{A_{t-1}}\right)\right].$$

Δa_t is equal to $\log\left(\frac{A_t}{A_{t-1}}\right)$, and g_a is the unconditional mean of Δa_t. See Colacito, Croce, Ho, and Howard (2018) for details.

we describe fiscal policy in the model.

The variable V_t is the value function of the dynamic programming problem for the representative household, and V_{t+1} is the "continuation utility" of the value function.[9] The budget constraint states that the household receives periodic after-tax income from labor, capital, and dividends, as well as bonds that mature at time t. The household then decides how much to consume after taxes, how much to invest, and how much to pay for newly issued bonds at time t at price $Q_t^{(1)}$. The nominal pricing kernel equals:

$$M_{t,t+1}^{\$} \quad = \quad \beta \left(\frac{C_{t+1}}{C_t}\right)^{-\psi} \left(\frac{P_{t+1}}{P_t}\right)^{-1} \left[\frac{V_{t+1}}{E_t[V_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}}\right]^{\psi-\gamma} .$$

The equilibrium wage demand equation is:

$$W_t = \varphi_t^{(1-\psi)} C_t^{\psi} N_t^{s\omega},$$

where the wage equals the marginal productivity of labor supply.

3.2. Capital accumulation

Households rent out capital to firms in exchange for earning a return on capital, R_t^k. The capital accumulation equation is standard with convex quadratic adjustment cost, Φ:

$$K_t = (1-\delta)K_{t-1} + \Phi\left(\frac{Inv_t}{K_{t-1}}\right) K_{t-1},$$

where δ is the rate of capital depreciation.

Further, households' optimal investment decisions satisfy the following equation:

$$\begin{aligned} q_t^{inv} \quad = \quad & \mathbb{E}_t \Bigg[M_{t,t+1} \Bigg[(1-\tau_t^k) R_{t+1}^k + q_{t+1}^{inv} \Bigg\{ (1-\delta) + \Phi\left(\frac{Inv_{t+1}}{K_t}\right) \\ & -\Phi'\left(\frac{Inv_{t+1}}{K_t}\right) \frac{Inv_{t+1}}{K_t} \Bigg\} \Bigg] \Bigg] , \end{aligned}$$

where q_t^{inv} is the shadow price of investment, and Φ' is the first derivative of the quadratic adjustment cost function.

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[9] As pointed out by Rudebusch and Swanson (2012), V_t can be positive or negative depending on the sign of the within-period utility $\left(\frac{C_t{}^{1-\psi}}{1-\psi} - \varphi_t^{1-\psi} \frac{N_t^{s\,1+\omega}}{1+\omega}\right)$. In our case, because the estimated value of ψ is less than but close to one, the consumption utility term is always greater than the labor dis-utility term. We thank an anonymous referee for suggesting this clarification.

3.3. Staggered price setting with monopolistic producers

There is a continuum of monopolistically competitive intermediate good firms, denoted by j, each endowed with an identical production technology. Moreover, staggered nominal price setting prevents firms from setting prices optimally in each period. Each firm faces the following optimization problem:

$$\begin{aligned}
&\max_{P_t^*(j)} \quad E_t\left[\sum_{s=0}^{\infty}\alpha^s M_{t,t+s}^{\$}\left\{P_t^*(j)Y_{t+s}(j)-P_{t+s}\left[W_{t+s}N_{t+s}^d(j)+R_{t+s}^k K_{t+s}(j)\right]\right\}\right] \\
&\text{s.t.} \quad Y_{t+s}(j)=Z_{t+s}K_{t+s-1}(j)^{\kappa}(A_t N_{t+s}^d(j))^{1-\kappa} && (5)\\
&\qquad\quad Y_{t+s}(j)=\left(\frac{P_t^*(j)}{P_{t+s}}\right)^{-\eta}Y_{t+s}^{aggr} && (6)\\
&\qquad\quad P_t=\left[\int_0^1 P_t(j)^{1-\eta}dj\right]^{\frac{1}{1-\eta}}=\left[(1-\alpha)P_t^{*1-\eta}+\alpha P_{t-1}^{1-\eta}\right]^{\frac{1}{1-\eta}}, && (7)
\end{aligned}$$

where η denotes the markup charged by the firm when it sets $P_t^*(j)$ due to monopolistic competition.

The objective function of the firm is simply to maximize profits, that is, revenues minus labor costs and rental costs on capital. $P_t^*(j)Y_{t+s}(j)$ is total revenues for firm j at time $t+s$, where $P_t^*(j)$ denotes the optimal price firm j charges for one unit of the consumption good at time t. $W_{t+s}N_{t+s}^d(j)$ and $R_{t+s}^k K_{t+s}(j)$ are real labor costs and the real rental costs of capital, respectively. Real wage and real return on capital are determined in equilibrium and are common across all firms. Finally, future cash-flows are discounted by the nominal stochastic discount factor (SDF) between times t and $t+s$, $M_{t,t+s}^{\$}$, and by the probability that the firm cannot reset its price up to period $t+s$, α^s.

Each firm's profit maximization problem is subject to three constraints. First, Eq. (5) is the production function of firm j, where Z_t is transitory productivity, A_t is permanent labor productivity that drives growth in the economy, $Y_{t+s}(j)$ denotes the output of firm j at time $t+s$ given that the last time firm j was able to reset its price was at time t, and the parameter κ determines the capital share in the Cobb-Douglas production function. Second, Eq. (6) describes the demand equation for firm j's output relative to aggregate output expressed as a function of its optimal price at time t. Third, Eq. (7) defines the aggregate price index as a weighted average of the optimal price at time t and the price at time $t-1$.

The log of transitory productivity follows an exogenous AR(1) process with stochastic volatility:

$$\begin{aligned} z_{t+1} &= \log(Z_t) = \phi_z z_t + e^{\sigma_{z,t+1}} \epsilon_{z,t+1} \\ \sigma_{z,t+1} &= (1-\phi_{\sigma_z})\theta_{\sigma_z} + \phi_{\sigma_z}\sigma_{z,t} + \sigma_{\sigma_z}\epsilon^{z}_{\sigma,t+1} \ , \end{aligned}$$

with $\epsilon_{z,t} \sim$ i.i.d. $\mathcal{N}(0,1)$. The log growth rate of the permanent labor productivity ($\Delta a_t = \log\left(\frac{A_t}{A_{t-1}}\right)$) evolves according to an AR(1) process with mean growth rate g_a:

$$\Delta a_t = (1-\phi_a) g_a + \phi_a \Delta a_{t-1} + \sigma_a \epsilon_{a,t} \ ,$$

with $\epsilon_{a,t} \sim$ i.i.d. $\mathcal{N}(0,1)$. Note that we allow for stochastic volatility in technology since uncertainty in transitory productivity has been shown to have a sizable impact on bond prices (e.g., Andreasen, 2012; Kung, 2015), and we want our analysis of the fiscal policy implications for term premia to be robust to this alternative channel.[10]

With staggered price setting, only a $1-\alpha$ share of firms can reset their prices each period. Hence, the firm's optimal price setting behavior has to satisfy the following equation:

$$\left[\frac{1}{1-\alpha}\left(1-\alpha\left(\frac{1}{\Pi_t}\right)^{(1-\eta)}\right)\right]^{\frac{1}{(1-\eta)}} F_t = \frac{\nu\kappa^{-\kappa}(1-\kappa)^{-(1-\kappa)} R_t^{k^{\kappa}} W_t^{(1-\kappa)} J_t}{Z_t A_t^{1-\kappa}}, \tag{8}$$

where $\nu = \frac{\eta}{\eta-1}$ is the frictionless markup and $\Pi_t = \left(\frac{P_t}{P_{t-1}}\right)$ is inflation. F_t and J_t are recursively defined as:

$$F_t = 1 + \alpha \mathbb{E}_t \left[M^{nom}_{t,t+1} \left(\frac{Y^{aggr}_{t+1}}{Y^{aggr}_t}\right) \Pi^{\eta}_{t+1} F_{t+1} \right] \ , \tag{9}$$

$$J_t = 1 + \alpha \mathbb{E}_t \left[M^{nom}_{t,t+1} \left(\frac{Z_t}{Z_{t+1}}\right) \left(\frac{A_t}{A_{t+1}}\right)^{1-\kappa} \left(\frac{R^K_{t+1}}{R^K_t}\right)^{\kappa} \left(\frac{W_{t+1}}{W_t}\right)^{(1-\kappa)} \left(\frac{Y^{aggr}_{t+1}}{Y^{aggr}_t}\right) \Pi^{(1+\eta)}_{t+1} J_{t+1} \right] \ . \tag{10}$$

3.4. The monetary authority

Monetary policy has real effects in the model due to nominal price rigidities. We assess the implications of fiscal policy on bond risk premia where there is an effective monetary authority. The monetary authority sets the nominal short rate, $R^{(1)}_t$, according to the following

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[10] Justiniano and Primiceri (2008) show that time-varying volatility in permanent productivity accounts for about 20% of the variance of GDP growth and real wages, although they did not explore its implications for asset prices.

Taylor rule:[11]

$$\frac{R_t^{(1)}}{R} = \left(\frac{R_{t-1}^{(1)}}{R}\right)^{\rho_r} \left(\frac{\Pi_t}{\Pi^*}\right)^{(1-\rho_r)\rho_\pi} \left(\frac{Y_t^{aggr}/A_t}{Y_{t-1}^{aggr}/A_{t-1}}\right)^{(1-\rho_r)\rho_x} e^{u_t},$$

where R denotes the steady-state nominal rate, Π_t is inflation, Π^* is the long-run inflation target, Y_t^{aggr} is aggregate output, and u_t is the monetary policy shock. The parameter ρ_r is the autoregressive coefficient used for interest rate smoothing, and ρ_π and ρ_x are the central bank's responses to inflation and output growth,[12] respectively. The monetary rule is said to satisfy the Taylor principle when $\rho_\pi > 1$. Finally, the short-term interest rate is affected by a monetary policy shock,

$$u_t = \sigma_u \epsilon_t^u,$$

with $\epsilon_t^u \sim$ iid $\mathcal{N}(0,1)$.

3.5. Fiscal policy and the government's budget constraint

The government's flow budget constraint acts to balance resources with their uses as follows:

$$P_t Tax_t + Q_t^{(1)} B_t(t+1) = B_{t-1}(t) + P_t Gov_t,$$

where Gov_t is government spending, which is non-productive. Furthermore,

$$Tax_t \quad = \quad \tau_t + \tau_t^k R_t^k K_{t-1},$$

such that τ_t is the lump-sum tax described below. Government spending as a fraction of output, $g_t = \frac{Gov_t}{Y_t}$, evolves as follows:

$$\begin{aligned} g_{t+1} &= (1-\phi_g)\theta_g + \phi_g g_t + \phi_{g,d}\left(\frac{D_t(t+1)}{Y_t^{aggr}} - \frac{D}{Y^{aggr}}\right) + \phi_{g,y}\log\left(\frac{Y_t^{aggr}}{Y^{aggr}}\right) + e^{\sigma_{g,t+1}}\epsilon_{g,t+1} \\ \sigma_{g,t+1} &= (1-\phi_{\sigma_g})\theta_{\sigma_g} + \phi_{\sigma_g}\sigma_{g,t} + \sigma_{\sigma_g}\epsilon_{\sigma_g,t+1}, \end{aligned}$$

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[11] Diercks (2015) shows that monetary policy under welfare maximization in the presence of long-run productivity risk, à la Croce (2014), can produce interesting inflation dynamics not captured by a rule-based policy. We leave this as a promising direction for future research.

[12] Following Basu and Bundick (2017), the monetary authority reacts to output growth rather than output gap. We employ this specification because output growth is directly observed and can be measured easily. Output gap, on the other hand, needs to be filtered in the data. Importantly, employing a Taylor rule with output gap in place of output growth does not affect the impulse response functions (IRFs) in Fig. 3, leaving the mechanism of the model intact.

where $\sigma_{g,t}$ is stochastic volatility specific to the government spending shock, $\epsilon_{g,t}$, with mean θ_{σ_g}. The variable σ_{σ_g} is the time-invariant volatility-of-volatility, and $D_t(t+1)$ is the amount of real debt ($D_t(t+1) = \frac{B_t(t+1)}{P_t}$) issued at time t and maturing at time $t+1$. Variables without time subscripts denote steady-state values. The variable $\phi_{g,d}$ is the government spending response to the deviation of real debt from its steady-state value, and $\phi_{g,y}$ is the automatic stabilizer to allow government spending to react to the state of the business cycle.

Similarly, the capital tax rate is an exogenous process with stochastic volatility:

$$\begin{aligned}
\tau^k_{t+1} &= (1-\phi_{\tau^k})\theta_{\tau^k} + \phi_{\tau^k}\tau^k_t + \phi_{\tau^k,d}\left(\frac{D_t(t+1)}{Y^{aggr}_t} - \frac{D}{Y^{aggr}}\right) + \phi_{\tau^k,y}\log\left(\frac{Y^{aggr}_t}{Y^{aggr}}\right) + e^{\sigma_{\tau^k,t+1}}\epsilon_{\tau^k,t+1} \\
\sigma_{\tau^k,t+1} &= (1-\phi_{\sigma_{\tau^k}})\theta_{\sigma_{\tau^k}} + \phi_{\sigma_{\tau^k}}\sigma_{\tau^k,t} + \sigma_{\sigma_{\tau^k}}\epsilon_{\sigma_{\tau^k},t+1}.
\end{aligned}$$

The lump-sum tax is collected to prevent the debt path of the government from exploding. Following standard procedure in the literature (see Gali et al., 2007; Fernández-Villaverde et al., 2015, for two recent examples), we specify the lump-sum tax as a function of real debt and government spending:

$$\tau_t = \rho_d D_{t-1}(t) + \rho_g Gov_t,$$

where ρ_d and ρ_g are parameters of the lump-sum tax rule. Alternatively, one could model long-term bonds using a geometrically declining series to proxy for the maturity structure of government debt, similar to Cochrane (2001). We find that modeling long-term bonds this way does not alter the term structure implications in our model economy. For simplicity, we abstract from that setup to obtain a simpler government budget constraint.

3.6. Equilibrium

The competitive equilibrium is characterized by the following market clearing conditions: composite labor, capital stock, bonds, and final goods. Furthermore, given the prices and wages of other households, each optimizing household chooses the optimal allocation to solve its utility maximization problem. Finally, given the wages and prices of other firms, each firm chooses the optimal production input to solve its profit maximization problem. In equilibrium, $N^s_t = N^d_t$, that is, total labor supply equals total labor demand. In the economy, aggregate demand must equal total private consumption and private investment plus total government spending:

$$Y^{aggr}_t = C_t + Inv_t + Gov_t \ . \tag{11}$$

Aggregate demand is related to firm output through $Y_t = L_{p,t} Y_t^{aggr}$, where $L_{p,t}$ is the distortion term from price dispersion. Finally, because markets are complete, there exists a unique pricing kernel that allows us to price all assets in the economy, including short- and long-term bonds.

4. Model solution

In this section we describe the key steps to bring the model to the data. We start by describing the solution methodology. We then describe those parameters that are calibrated to conventional values. Finally we describe the approach used to estimate the remaining parameters.

4.1. Solution methodology

We use perturbation methods to solve our model. In particular, we employ a third-order Taylor approximation of the policy functions that characterize the equilibrium dynamics. In Online Appendix B, we provide a detailed discussion of the model solution.

In a next step, we follow Andreasen, Fernández-Villaverde, and Rubio-Ramírez (2017) and obtain closed-form expressions for the first and second unconditional moments of the nonlinear pruned state-space of the model.[13] These closed-form expressions allow us to estimate a subset of model parameters via generalized method of moments (GMM). In our estimation, we use the first and second unconditional moments of the following quarterly macroeconomic and financial time series: (i) log output growth, Δy_t (henceforth, Δ denotes the temporal difference operator); (ii) log investment growth, Δinv_t; (iii) log consumption growth, Δc_t; (iv) inflation, π_t; (v) the one-quarter nominal interest rate, r_t; (vi) the ten-year nominal interest rate, $y_t^{(40)}$; and (vii) the slope of the term structure, $y_t^{(40)} - r_t$. The sample spans 1970Q1 to 2016Q4.[14] Online Appendix A provides a detailed description of all variable definitions and sources.

4.2. Model parameters

We calibrate a number of parameters to values commonly used in the literature, as reported in Table 6. In particular, as in Kaltenbrunner and Lochstoer (2010), the rate of

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[13] Pruning helps ensure stability of the model solution, a requirement for the calculation of model moments in closed-form; see Online Appendix B for additional details.

[14] The starting date follows Fernández-Villaverde et al. (2015) and it is dictated by the start of our fiscal series. We have also repeated our estimation exercise with moments computed from a sample period (1970Q1 to 2007Q4) that excludes the financial crisis, and we find that the results remain qualitatively the same.

depreciation on capital is 0.02. This value implies a steady-state investment-output ratio of 10%. The capital share of intermediate output, κ, is 0.3. The price rigidity parameter, α, equals 0.65. That is, every period, approximately one-third of the firms in the economy can adjust their prices to the optimal level. Further, the price markup parameter for monopolistically competitive firms, η, is set to 6, which implies a steady-state price markup of 20%.

Finally, we calibrate the parameters for transitory productivity to values commonly adopted in the literature, such as in Andreasen (2012) and Kung (2015).[15]

[Insert Table 6 about here.]

As discussed in Section 2.1, we estimate the processes for capital income taxes and government spending outside the model (see Table 1). This procedure ensures that the latent fiscal uncertainty factors maintain their intended economic interpretation.[16] In order to align our theoretical and empirical analysis, we impose the same dynamics of fiscal variables in the model as in the data.

Finally, we estimate a subset of parameters via GMM, as reported in Table 6. The estimation results in β and γ values of 0.984 and 181, respectively. These values are needed to match the unconditional means of the one-period nominal interest rate and the slope of the nominal yield curve. Further, the estimation procedure leads to an intertemporal elasticity of substitution slightly above one. While this value is in line with the large literature on long-run risks, our model does not feature a persistent component in the mean growth rate, as in Bansal and Yaron (2004). Our estimates imply a Frisch elasticity that is in line with the macroeconomics literature, as well as a substantial degree of adjustment costs for investment, consistent with previous studies such as Del Negro, Schorfheide, Smets, and Wouters (2007) and Smets and Wouters (2007). Further, our estimates of the loadings of lump-sum taxes on debt, ρ_d, and government spending, ρ_g, are 0.6 and 0.05, respectively. The responses of the monetary policy authority to inflation, ρ_π, and output growth, ρ_x, are similar to that used in Judd and Rudebusch (1998), Taylor (1999), and Clarida, Galí, and Gertler (2000). Finally, the shock persistence and variance for permanent productivity, ϕ_a and σ_a, are broadly in line with the estimates in Justiniano, Primiceri, and Tambalotti (2011).

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[15] We set the volatility of volatility, σ_{σ_z}, to 0.027, in line with Andreasen (2012). Our value for the vol-of-vol parameter lies on the upper end of those used in the literature, which makes our results for fiscal policy conservative. Indeed, lower values for σ_{σ_z} would only increase the relative contribution of fiscal uncertainty shocks relative to productivity uncertainty.

[16] Alternatively, we could have used macro and financial variables (bond yields) to estimate the full-fledged model with stochastic volatility in fiscal rules. However, bond yields may compromise the interpretation of uncertainty in government spending and capital tax rate. Instead, our approach constrains the stochastic volatility to fit the observed government spending and capital tax rate data only.

5. Structural model analysis

We present the analysis of our theoretical model here. We first examine the performance of the model relative to the data in terms of macroeconomic aggregates. We then investigate the mechanism through which government spending level and volatility shocks drive bond risk premia. Further, we replicate the empirical forecasting regressions and asset pricing tests via simulated data. Finally, we study the drivers of nominal yields in the model using a news-type decomposition à la Campbell and Ammer (1993).

5.1. Model fit

Table 7 reports the empirical and model-implied moments for macroeconomic variables (Panel A), nominal asset prices (Panel B), and real asset prices (Panel C). We further categorize the variables into those that were *targeted* and *non-targeted* in the estimation. For each variable, we report the standard deviation, autocorrelation, and contemporaneous correlation with output. We also report the 90% probability intervals in brackets.[17]

[Insert Table 7 about here.]

From Panel A, we see that the model matches the variability of output, consumption, investment, and inflation in the data fairly well. Even though not targeted in the estimation, the variability of wages and hours is close to their data counterparts. Further, the model matches the average growth rates in output, consumption, and investment (not reported).

In Panel B of Table 7, we report the means and standard deviations of yields across different maturities, as well as the slope for the nominal term structure. We note that the model produces a slope of 1.23% and generates a volatile 10-year nominal interest rate. Notably, a substantial part of the variation in the nominal short-term interest rate and slope is generated by the stochastic volatility of the fiscal instruments.[18] Moreover, government spending level (G level) and uncertainty (G uncertainty) shocks separately contribute to the overall positive average slope of the term structure in the model,[19] suggesting these shocks

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[17] We draw the structural parameters from a normal distribution with a variance-covariance matrix obtained in the second step of the GMM estimation. The parameters governing the fiscal variables are obtained from the posterior distribution reported in Table 1. For each parameter draw, we simulate the model for 3,000 quarters while discarding the 1,000 initial quarters. Hence, we account for parameter uncertainty but not for small sample uncertainty.

[18] In Online Appendix Table E.4, we quantify the importance of the structural shocks in the model. Apart from the uncertainty in the transitory productivity, government spending uncertainty is the most effective shock that contributes to the overall variability of macroeconomic quantities and asset prices in the model.

[19] In Online Appendix Table E.5, we document the unconditional means of the term structure when we shut down structural shocks one-by-one. The average nominal slope drops from 1.23% to 1.17% with G level turned off. When G uncertainty is turned off, the average slope falls to 1.13%. The real term structure in the bottom panel of the same table exhibits similar findings.

induce positive bond risk premia. The model performs well in matching the autocovariances in the data, which constitute an out-of-sample test of the model's fit. This can be seen either from the first-order autocorrelation coefficients in Table 7 or, more directly, from Online Appendix Fig. E.1, in which we plot autocovariance functions in the model against the data.

In addition, we investigate the model implications for the real term structure. In Panel C of Table 7, we report statistics of real bond yields across different maturities and the real slope (10-year minus 2-year yield spread). We compare these statistics with real term structure data obtained from splicing together real yields from Chernov and Mueller (2012) and Gurkaynak, Sack, and Wright (2010). The volatility of the model-implied real yields is in line with the data, but the average level of the real yield curve in our model is slightly too high. Importantly, however, the average real slope and its standard deviation are close to their data counterparts. Consistent with Campbell, Shiller, and Viceira (2009) and Hsu et al. (2019), the real term structure is upward sloping (see also the discussion in Beeler and Campbell, 2012). This implies that when expected consumption growth is low, real long-term bonds have lower payoffs than real short-term bonds. We return to this implication in our discussion of government spending uncertainty shocks and the term premia in Section 5.2.

We conclude this section by highlighting another quantitative aspect of the model. Our model can match the empirical average correlation of consumption growth and inflation. In the data, the two series are negatively correlated at -0.14 over 1970Q1–2016Q4. Consistent with the data, our model implies a negative correlation of -0.07.[20]

5.2. Impulse response functions

Bond risk premia are substantial and vary significantly over time (e.g., Campbell and Shiller, 1991; Cochrane and Piazzesi, 2005). However, the economic forces behind such large and variable premia are less clear. In order to provide insight on this issue, we compare impulse response functions (IRFs) in the model with the results of an empirical VAR.

In the VAR, we combine our two fiscal policy instruments and their uncertainties (g_t, $\sigma_{g,t}$, τ^k, and $\sigma_{\tau^k,t}$; in this order) with macroeconomic and term structure variables. We use real per capita GDP and a measure of the nominal price level, the GDP deflator, as macroeconomic variables. For the term structure, we use two time series of yields: the nominal short-term

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[20] Although mostly negative, the magnitude of this correlation varies in the literature depending on the sample period. For example, Kung (2015) finds an even stronger negative correlation between inflation and consumption growth of -0.56. David and Veronesi (2013) reconcile these facts in a regime-switching model with learning in which the correlation between earnings and inflation changes stochastically over time, both in magnitude and direction.

and the 5-year interest rates. In Online Appendix D, we provide a detailed description of the identification scheme, the estimation procedure, and additional robustness checks.

In Panels (a) and (b) of Fig. 3, we plot the impulse responses of output, price level, the nominal short-term interest rate, and the nominal 5-year interest rate following a positive one standard deviation shock to government spending level and uncertainty, respectively. The figures show the model-implied responses (solid lines), empirical responses (dashed lines), and corresponding 95% confidence bands.[21]

[Insert Figure 3 about here.]

Panels (a) and (b) show that our model performs well in matching the dynamics of the macroeconomy as well as the term structure induced by government spending shocks. Output, price level, the nominal short- and long-term interest rates all rise after a positive spending level shock, in line with the data. Government spending is a demand shock, which causes output to increase. At the same time, government spending crowds out consumption and investment, leading to higher marginal cost and inflation. High inflation puts downward pressure on nominal bond prices, causing interest rates to rise. After a positive spending uncertainty shock, on the other hand, all four variables highlighted in the figure decline, consistent with the empirical VAR results. Uncertainty shocks operate through expectations. Higher government spending uncertainty today raises expected spending tomorrow. This drives the precautionary savings motive of households and leads them to consume less and save more. Lower demand decreases output and inflation today. At the same time, bond prices are higher due to greater savings demand, causing interest rates to fall. The government spending uncertainty shock is a slope shock to the yield curve as the short-term interest rate drops more than the long-term interest rate.

Further, Panels (c) and (d) of Fig. 3 report the results for the capital tax rate shocks. Output, and the short- and the long-term interest rates all decline, both in the model and in the data, after a positive tax level shock. The price level falls slightly in the model but stays basically unchanged in the data. The downward shift in the term structure is intuitive. Higher capital taxes decrease consumption and the return on capital, rendering capital investment unattractive. Lower consumption demand prompts aggregate output to fall. At the same time, higher taxes reduce the government's need for debt issuance. These two effects combined lead to a drop in interest rates.

With regard to capital tax uncertainty shocks, the model generates a fall in output, as well as nominal short- and long-term interest rates similar to the data. While the price level

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[21] The confidence bands of the model-implied responses only account for parameter uncertainty; they neglect small sample uncertainty. For this reason, the bands shrink at longer horizons.

remains essentially unchanged in the data, it falls slightly on impact in the model. Overall, both in the data and in the model, positive tax shocks slow aggregate economic activity and cause the yield curve to shift downwards. At the same time, the price level is not particularly responsive to these shocks.

Overall, Fig. 3 shows that our model reproduces the empirical dynamics well. To further study how bond risk premia interact with fiscal policy, we examine the model-implied responses of investment, debt, the stochastic discount factor (SDF), and the real wage to fiscal shocks. Panels (a) through (d) in Fig. 4 display the IRFs to a positive one standard deviation shock to our fiscal variables.

[Insert Figure 4 about here.]

The first column of Fig. 4 shows that investment declines after a positive realization of fiscal shocks. This is consistent with the notion that a higher government spending level crowds out investment, and higher taxes on return of capital make investment in capital less desirable. The second column documents that the debt level increases following positive government spending level and uncertainty shocks. According to the government budget constraint, more government spending requires more debt financing, ceteris paribus, which leads to greater Treasury issuance. On the other hand, higher capital taxes lead to less debt issuance. The third column demonstrates that all four positive fiscal shocks generate high marginal utility states, causing the SDF to spike immediately when the shocks materialize. Finally, the last column reports the impact of fiscal shocks on real wages. The top two subplots show that government spending shocks decrease real wages as high marginal utility causes labor supply to increase. In contrast, capital tax rate shocks slightly increase real wages in the short run but generate large falls in the long run, as shown in the bottom two subplots. A higher tax rate makes capital more expensive. Initially, the decline in capital leads to higher marginal labor productivity, but eventually, the complementarity of capital and labor kicks in as output declines, which results in lower wages.

Finally, we provide some intuition on how government spending shocks drive the term premium. The nominal term premium consists of the real term premium and the inflation risk premium. Both level and uncertainty shocks to government spending produce a positive nominal term premium. This is straightforward to rationalize for level shocks, since the combination of high inflation (Fig. 3) and high marginal utility (Fig. 4) generates positive inflation risk on nominal bonds. Uncertainty shocks command a positive nominal term premium despite having a negative inflation risk premium (i.e., negative covariance between inflation and the SDF, see Fig. 3 and 4); this suggests that long-term nominal bonds are riskier relative to short-term nominal bonds. In other words, when the marginal utility is high, the price of long-term bonds appreciates less than the price of short-term bonds. Overall, positive government spending uncertainty shocks have a negative level effect but a positive slope effect, and the slope effect dominates on average.

5.3. *Government spending and inflation risk premia*

Nominal bond yields consist of real yields, expected inflation, and inflation risk premia. That is,

$$y_t^{(n)} = r_t^{(n)} + \frac{1}{n}\left\{E_t\left[\pi_{t,t+n}\right] + cov_t(m_{t,t+n}, \pi_{t,t+n}) - \frac{1}{2}var_t(\pi_{t,t+n})\right\},$$

where the conditional covariance of the marginal rate of consumption substitution between times t and $t+n$ with inflation provides compensation for inflation risk to nominal bond holders. To form intuition on inflation risk premia in the model, we study this covariance term by examining the impact of fiscal shocks on $m_{t,t+1}$ and $\pi_{t,t+1}$.

Using lowercase letters to denote log-transformed variables, the real SDF can be written as,

$$m_{t-1,t} \;=\; \frac{1-\gamma}{1-\psi}\left[\log(\beta) - \psi\left(c_t - c_{t-1}\right)\right] + \frac{\psi-\gamma}{1-\psi}\log(R_t^{cl}),$$

where R_t^{cl} is the return on the wealth portfolio (consumption and labor income) of the representative household. Positive spending level shocks increase saving while crowding out consumption. This leads to an increase in $m_{t-1,t}$ due to low consumption growth.

To study the effect of government spending shocks on inflation, we loglinearize the Phillips curve in Eq. (8) as follows,

$$\frac{\alpha}{1-\alpha}\pi_t + f_t = \log(\nu\kappa^{-\kappa}(1-\kappa)^{-(1-\kappa)}) + \kappa r_t^K + (1-\kappa)\tilde{w}_t + j_t - z_t, \tag{12}$$

where $\tilde{w}_t = \log\left(\frac{W_t}{A_t}\right)$. f_t and j_t are log versions of F_t and J_t defined in Eq. (9) and (10), respectively. Recall F_t and J_t are expectations of future growth in productivity, return on capital, real wages, output, and inflation. In addition, we assume that the steady-state log inflation is zero. Hence, inflation is not only a function of the contemporaneous marginal costs (r_t^K and $\tilde{w}_t$) but also expected inflation and expected marginal costs.

Rearranging Eq. (12), we obtain: [22]

$$\frac{\alpha}{1-\alpha}\pi_t \;=\; \log(\nu\kappa^{-\kappa}(1-\kappa)^{-(1-\kappa)}) + \kappa r_t^K + (1-\kappa)\tilde{w}_t - z_t + j_t - f_t$$

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[22] Note that $const_f = const_j = const$, since steady-state $\Upsilon = \Phi$ by assuming $\pi = 0$. Moreover, for simplicity, we ignore the covariance terms in the decomposition of the variance terms within f_t and j_t.

$$
\begin{aligned}
&\approx \log(\nu\kappa^{-\kappa}(1-\kappa)^{-(1-\kappa)}) + \underbrace{\kappa r_t^K + (1-\kappa)\tilde{w}_t}_{\text{contemporaneous marginal cost}} - z_t \\
&+const \left\{ \mathbb{E}_t \left[\underbrace{\pi_{t+1}}_{\text{inflation expectation}} - \Delta z_{t+1} + \underbrace{\kappa \Delta r_{t+1}^K + (1-\kappa)\Delta\tilde{w}_{t+1}}_{\text{expected marginal cost}} \right. \right. \\
&\left. + j_{t+1} - f_{t+1} \right] + \frac{1}{2} \left[var_t(\Delta z_{t+1}) + \kappa^2 var_t(\Delta r_{t+1}^K) + (1-\kappa)^2 var_t(\Delta\tilde{w}_{t+1}) \right. \\
&\left. \left. + \underbrace{(1-2\eta)}_{-} var_t(\pi_{t+1}) + var_t(j_{t+1}) + var_t(f_{t+1}) \right] \right\},
\end{aligned}
$$

where the approximation relies on the log-normal assumption. There are a number of takeaways from this derivation. First, higher expected inflation raises current inflation. Second, higher expected marginal cost also raises current inflation. Third, uncertainty, which increases the conditional variance of endogenous inflation, decreases current inflation, since η is greater than one.

Panel (a) of Fig. 3 shows that output rises following a positive government spending level shock. That is, firms intend to produce more to meet demand by increasing labor and capital input. At the same time, the supply of labor is high, stemming from the negative wealth effect on households, while capital supply is low as households prefer relatively safe bonds over capital. The result is a drop in real wages but a strong increase in the return on capital, which raises the marginal costs for the firm. Hence, the increase in contemporaneous and expected marginal costs leads to an increase in inflation according to the loglinearized Phillips curve. In addition, positive government spending level shocks raise marginal utility by lowering consumption growth, thus the covariance between $m_{t,t+1}$ and π_{t+1} is positive, implying a positive inflation risk premium.

Similar to the level shock, a positive government spending uncertainty shock raises the marginal utility of consumption. Uncertainty about government spending affects the expectations of future government spending, which amplifies households' precautionary savings motive and decreases current consumption. At the same time, firms anticipate the increase in expected demand and partially postpone production from today to tomorrow. By decreasing labor and investment today, marginal costs decrease, which in turn lowers inflation, as seen in Panel (b) of Fig. 3. This decrease in inflation is reinforced by an increase in the conditional variance of inflation: as $(1-2\eta) < 0$, higher inflation uncertainty translates into lower current inflation according to the loglinearized Phillips curve. Overall, government spending uncertainty shocks generate low inflation in high marginal utility states, rendering $cov_t(m_{t,t+1}, \pi_{t+1})$ negative.

5.4. Model-implied asset pricing tests

In this subsection, we further validate our model by replicating the empirical asset pricing tests from Sections 2.2 and 2.3. To do so, we simulate the model 100 times for 188 periods. In particular, we initiate our simulations from the ergodic mean in absence of shocks, and we apply a burn-in period of 1,000 quarters.

Starting with the predictive regression results in Table 2, we regress 2-year and 5-year Treasury bond excess returns on lagged government spending level and uncertainty. The results are reported in Table 8. Overall, the model performs well in replicating the empirical predictive regression results. Across all specifications, the coefficient loading on government spending level (G) is positive and significant, even after controlling for the first three principal components (PCs) of the model-implied yield curve. Moreover, the regression R^2s are also on par with their empirical counterparts. Consistent with the empirical evidence in Table 2, the estimated coefficient on G vol is positive and significant. In fact, even after controlling for the first three PCs, government spending uncertainty remains a significant predictor of excess bond returns in the model.

[Insert Tables 8 and 9 about here.]

Further, Table 9 replicates the results presented in Table 3. Again, the regression results from model-simulated data closely mirror our empirical findings. Increases in government spending level predict a negative shift in the level of the yield curve (Panel A). This is consistent with the fact that G predicts bond excess returns as lower future yields imply higher future bond prices. Moreover, higher government spending level and uncertainty predict a steepening of the yield curve (Panel B). Again, this confirms our results in Table 2. Furthermore, the positive relation between uncertainty and changes in the slope can also be seen from the differential responses of the short-term and long-term interest rates to uncertainty shocks in Panel (b) of Fig. 3.

Finally, Panel B of Table 4 reports the cross-sectional regression results of realized bond returns on fiscal shocks. Across all maturity horizons, the βs are negative for level shocks and positive for uncertainty shocks in both the model and the data. The negative covariance between contemporaneous bond returns and government spending level shocks is explained by the level effect of the shock on the yield curve: Inflation and yields increase in Panel (a) of Fig. 3, causing bond prices to fall, which results in negative βs. Furthermore, the fact that realized bond returns are low when government spending and marginal utility are high suggests that the risk compensation should be positive, which is confirmed by the forecasting regression results in Table 8. On the other hand, the positive covariance between contemporaneous bond returns and government spending uncertainty shocks is explained by the decline of bond yields, as shown in Panel (b) of Fig. 3. Both the short- and long-term yields fall and, hence, corresponding prices increase.

In summary, our model successfully replicates the empirical asset pricing results documented in Sections 2.2 and 2.3. Specifically, government spending level and uncertainty are important drivers of nominal bond risk premia.

5.5. *Inflation as a determinant of treasury yields*

In this subsection, we explore the drivers of nominal bond yields within our model. Shocks to nominal yields are composed of news about expected future inflation, news about expected future real short-term interest rates, and news about expected excess returns. Duffee (2018) shows that, at a quarterly frequency, variance in news about expected inflation accounts for 10%–20% of the variance in yield shocks. This is at odds with many standard dynamic models, which tend to imply variance ratios that are much closer to one. Following Duffee (2018), we define innovations to the m maturity nominal yield from $t-1$ to t as $\tilde{y}_t^{(m)} \equiv y_t^{(m)} - E_{t-1} y_t^{(m)}$, which can be decomposed into news about expected average inflation, ex ante real rates, and excess returns, $\tilde{y}_t^{(m)} = \eta_{\pi,t}^{(m)} + \eta_{r,t}^{(m)} + \eta_{ex,t}^{(m)}$.[23] In Panels (a) and (b) of Fig. 5, we plot the empirical and model-implied unconditional standard deviations of yield innovations, $\mathrm{sd}(\tilde{y}_t^{(m)})$, and news about expected inflation, $\mathrm{sd}(\eta_{\pi,t}^{(m)})$, for different maturities m ($m = 4, 8, ..., 40$ quarters).[24] Consistent with the data, news about inflation is clearly less volatile compared to yield innovations in the model. Given the ability of our model to reproduce unconditional standard deviations, it is not surprising that it also performs well when reproducing the implied variance ratios, especially for short-term maturities. While the variability of news about inflation is in line with the data even at longer horizons, the standard deviations of yield innovations are slightly too low.

[Insert Fig. 5 about here.]

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[23] The news components are defined as follows:

$$\eta_{\pi,t}^{(m)} = E_t\left(\frac{1}{m}\sum_{i=1}^{m}\pi_{t+i}\right) - E_{t-1}\left(\frac{1}{m}\sum_{m}^{i=1}\pi_{t+i}\right), \tag{13}$$

$$\eta_{r,t}^{(m)} = E_t\left(\frac{1}{m}\sum_{i=1}^{m}r_{r+i-1}\right) - E_{t-1}\left(\frac{1}{m}\sum_{m}^{i=1}r_{r+i-1}\right), \tag{14}$$

$$\eta_{ex,t}^{(m)} = E_t\left(\frac{1}{m}\sum_{i=1}^{m}ex_{t+i}^{(m-i+1)}\right) - E_{t-1}\left(\frac{1}{m}\sum_{m}^{i=1}ex_{t+i}^{(m-i+1)}\right). \tag{15}$$

[24] In contrast to Duffee (2018), Panel (a) of Fig. 5 relies on inflation forecasts from our empirical VAR. Online Appendix D shows that model-implied inflation forecasts closely match survey-based forecasts from the Survey of Professional Forecasters.

The success of our model in matching variance ratios stems from two main sources: stochastic volatility and the high persistence of fiscal variables. As shown in Fig. E.3 in the Online Appendix, relaxing either of these two model features clearly worsens the model's ability to reproduce the empirical patterns.

6. Conclusion

In this paper, we document that fiscal policy is an important driver of the term structure of interest rates and Treasury bond risk premia. Empirically, higher government spending level and uncertainty predict higher future bond excess returns. Moreover, higher level of government spending leads to a positive shift and steepening of the yield curve, while higher uncertainty results in a steepening of the yield curve. Lastly, shocks to spending level and uncertainty are priced in the cross-section of stock and bond returns.

Motivated by this evidence, we develop a dynamic general equilibrium model that embeds fiscal policy. Our model successfully matches both macroeconomic and financial moments. Asset pricing tests via simulated data further verify our empirical results. In the model, government spending level shocks imply a positive correlation between marginal utility and inflation (term structure level effect), which leads to positive inflation risk premia. On the other hand, government spending uncertainty shocks imply a strong slope effect on the term structure. A positive spending uncertainty shock causes long-term bonds to be cheap relative to short-term bonds when marginal utility is high, thus generating positive term premia.

Our paper demonstrates that the linkage between fiscal policy and the cost of borrowing for the U.S. government is tight. Policymakers should not overlook this connection when considering spending and taxation legislations.

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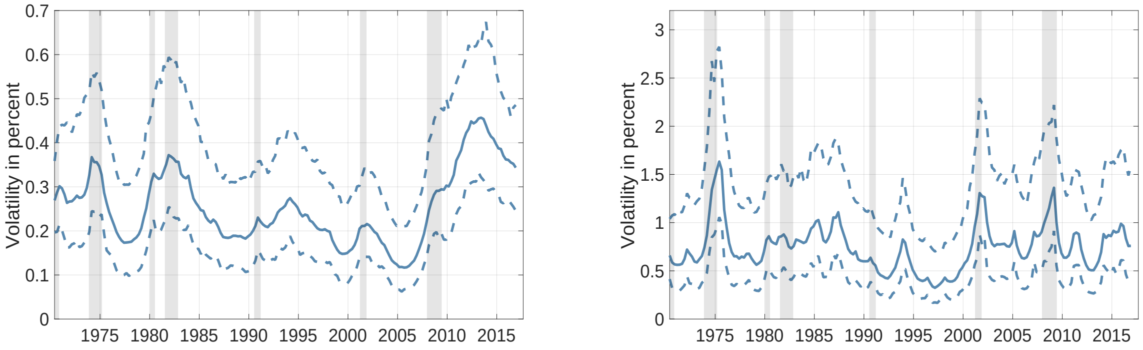
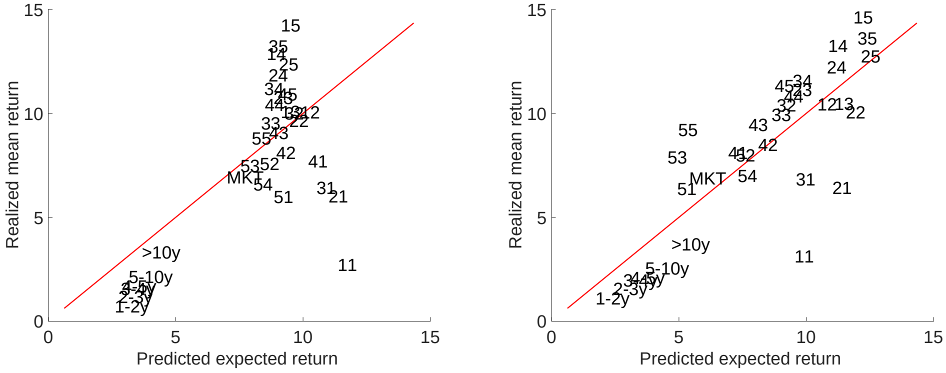
Figures



(a) Government spending uncertainty.

(b) Capital tax uncertainty.

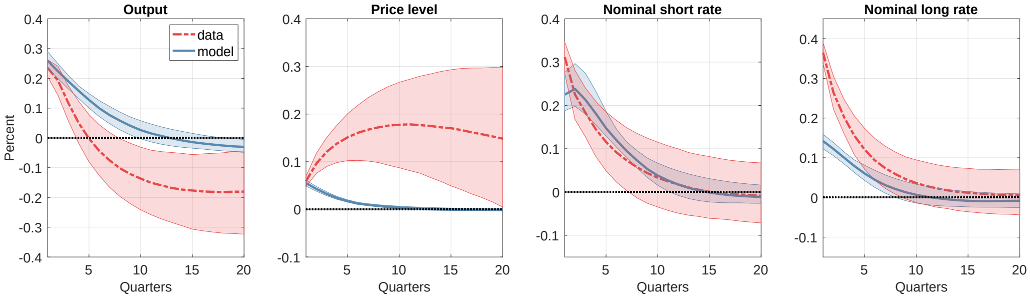
Fig. 1. Smoothed fiscal uncertainty. The figure displays the 95% posterior probability intervals of the smoothed uncertainty of government spending (left) and capital taxes (right), $100 \exp(\sigma_{x,t})$.



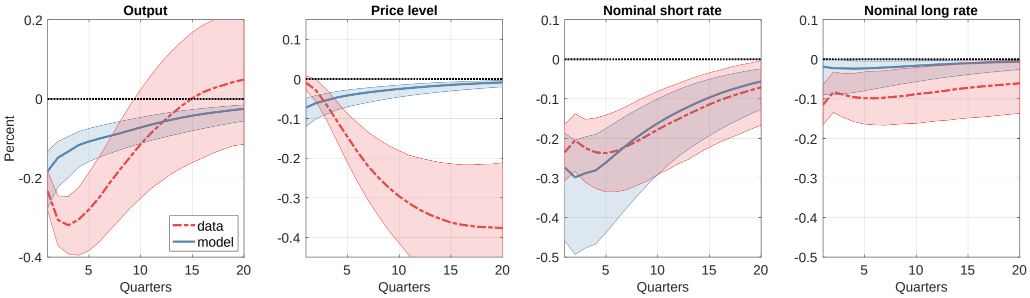
(a) Capital asset pricing model.

(b) Market plus government spending.

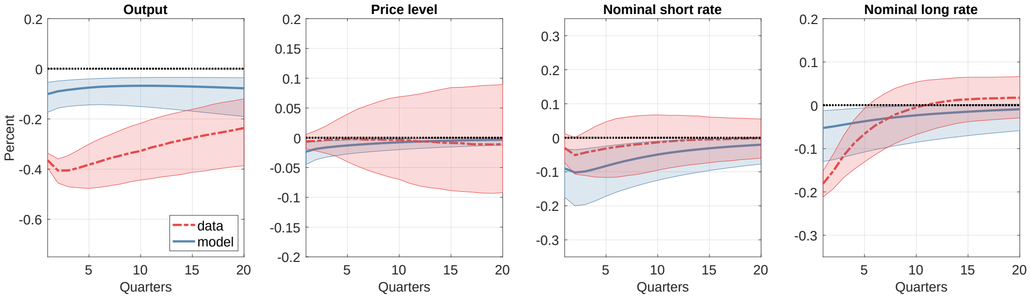
Fig. 2. Realized vs. fitted returns: stock and bond portfolios. In this figure, we plot realized against fitted returns for our test assets that consist of (i) the 25 Fama-French portfolios (each two-digit number represents one portfolio where the first digit refers to the size quintiles (1 indicating the smallest firms, 5 the largest), and the second digit refers to book-to-market quintiles (1 indicating the portfolio with the lowest book-to-market ratio, 5 with the highest)); (ii) the market portfolio consisting of a value-weighted stock index (NYSE, AMEX, and NASDAQ from CRSP) and a long-term government bond index; and (iii) six government bond portfolios with maturities 1–2, 2–3, 3–4, 4–5, 5–10, and 10+ years from CRSP.



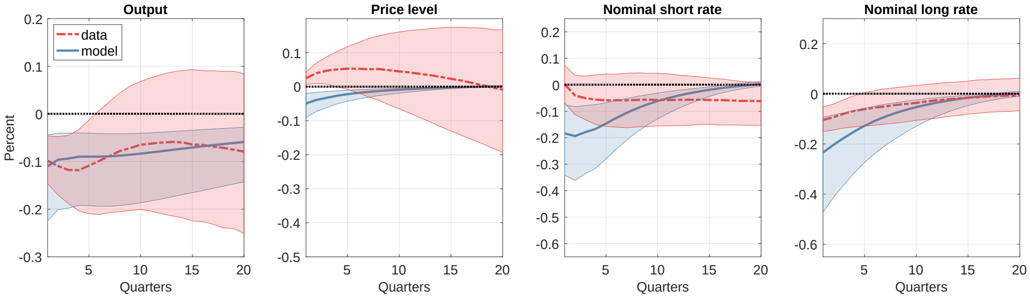
(a) Government spending level shock.



(b) Government spending uncertainty shock.

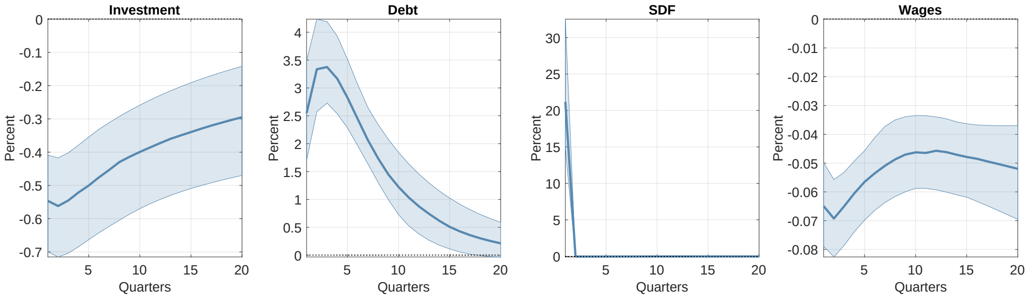


(c) Capital tax level shock.

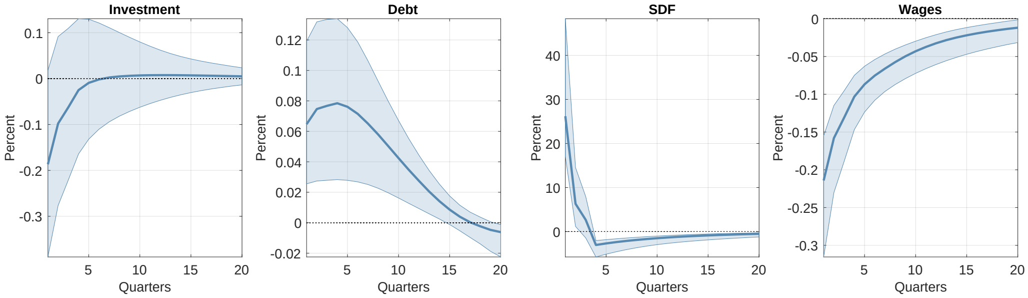


(d) Capital tax uncertainty Shock.

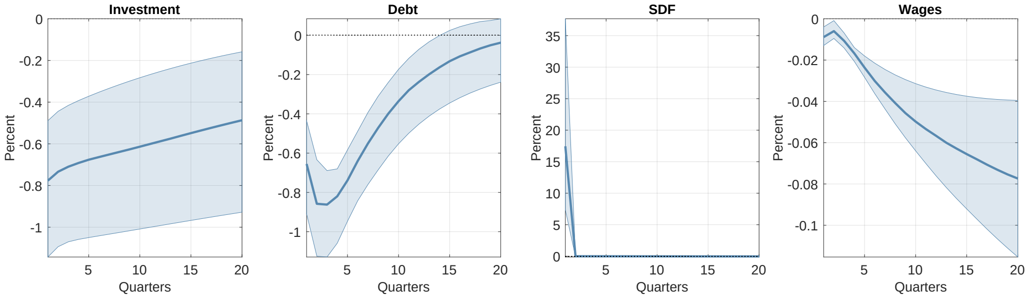
Fig. 3. Impulse responses for fiscal shocks. In this figure, we plot the impulse responses of output, inflation, the nominal short- and long-term bond yields to a positive one standard deviation shock to government spending level, government spending uncertainty, capital tax level, and capital tax uncertainty. The figure shows model-implied responses (solid line), empirical responses (dashed line), and corresponding 95% confidence bands (shaded areas).



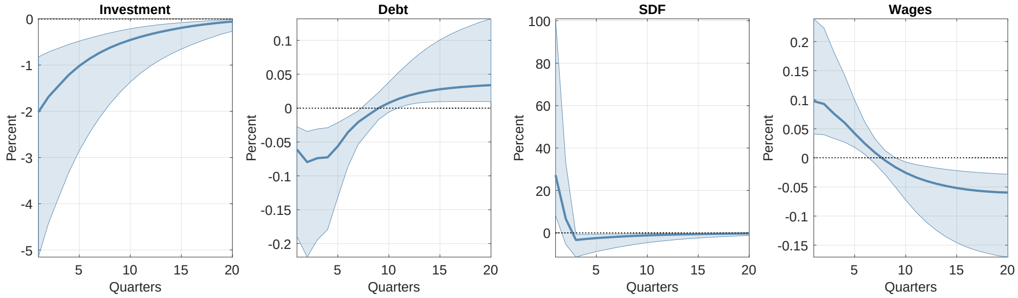
(a) Government spending level shock.



(b) Government spending uncertainty shock.

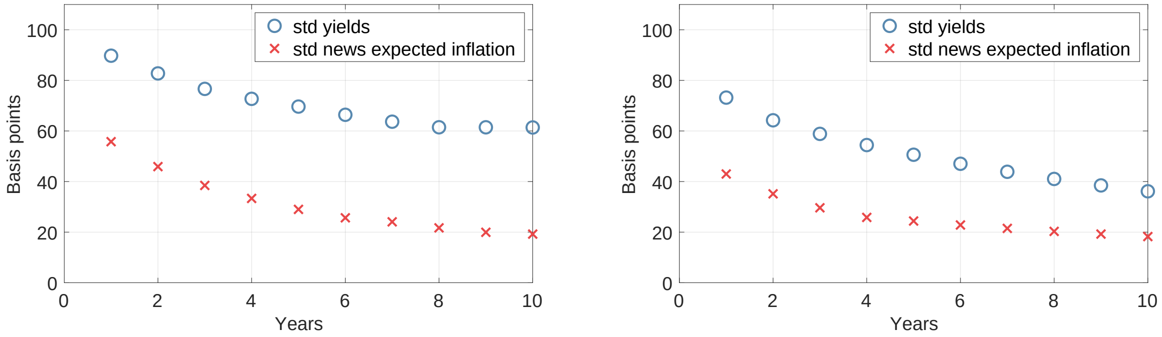


(c) Capital tax level shock.



(d) Capital tax uncertainty Shock.

Fig. 4. Impulse Responses for Fiscal Shocks. In this figure, we plot the model-implied impulse responses of investment, debt, the stochastic discount factor, and wages to a positive one standard deviation shock to government spending level, government spending uncertainty, capital income tax level, and capital income tax uncertainty. The shaded areas correspond to 95% confidence bands when considering parameter uncertainty.



(a) Data. (b) Model.

Fig. 5. Yield shock decomposition. In this figure, we plot empirical and model-implied unconditional standard deviations of quarterly shocks. Empirical standard deviations of yields (the circles in Panel a) and news about expected inflation (the Xs in Panel a) are for the period from 1970Q1 to 2016Q4. Unconditional model-implied standard deviations of yield shocks (the circles in Panel b) and news about expected inflation (the Xs in Panel b) are determined using simulated data from our model. Corresponding theoretical model-implied standard deviations are plotted in Panel a of Figure E.3 in the Online Appendix.

Tables

Table 1:
Fiscal Parameters.
This table reports the estimated parameter values for the law of motion of the fiscal variables, see Eq. (1) - (2). For each parameter, we report the posterior median and, in brackets, a 95% probability interval.

	θ_x	ϕ_x	$\phi_{x,y}$	$\phi_{x,d}$	θ_{σ_x}	ϕ_{σ_x}	σ_{σ_x}
Government spending	0.202	0.985	-0.018	-0.011	-5.934	0.890	0.345
		[0.951;0.992]	[-0.031;-0.001]	[-0.018;-0.001]	[-6.264;-5.265]	[0.832;0.959]	[0.178;0.610]
Capital income tax	0.374	0.963	0.010	0.006	-4.838	0.869	0.544
		[0.900;0.991]	[0.003;0.019]	[0.001;0.017]	[-5.264;-4.687]	[0.743;0.928]	[0.288;0.757]

Table 2:
Forecasting excess returns to Treasury bonds: 1970Q1 to 2016Q4.
This table reports coefficient estimates, corresponding reverse regression p-values, and R^2s for regressions of annual excess returns of Treasury bonds (for 2- and 5-year maturities) on fiscal variables, an indicator variable for the zero lower bound, and other predictors measured in quarter t. The column F-test reports the p-value for the hypothesis that the fiscal variables have jointly no incremental explanatory power beyond other control variables. Reverse regression p-values (in parentheses) are calculated using the delta method of Wei and Wright (2013). Control variables include the maturity-weighted debt-to-GDP ratio, MWD/GDP (see Greenwood and Vayanos, 2014) and the first three PCs of the Treasury yield curve. Bold values indicate significance at least at the 10% level.

	Predictors							
	G	G vol	MWD/GDP	PC1	PC2	PC3	R^2	F-test
Panel A: Excess returns on 2-year Treasury bond								
(1)	**0.50**						0.06	
	(0.02)							
(2)		**0.25**					0.04	
		(0.07)						
(3)	**0.58**		**0.41**				0.12	
	(0.01)		(0.06)					(0.00)
(4)		**0.31**	**0.41**				0.09	
		(0.06)	(0.07)					(0.03)
(5)	**0.61**	**0.33**	**0.52**				0.20	
	(0.00)	(0.04)	(0.01)					(0.00)
(6)				0.39	**0.58**	-0.10	0.11	
				(0.40)	(0.03)	(0.82)		
(7)	**0.83**	**0.32**	**0.60**	0.65	-0.01	-0.36	0.28	
	(0.00)	(0.02)	(0.00)	(0.14)	(0.92)	(0.16)		(0.00)
Panel B: Excess returns on 5-year Treasury bond								
(1)	**1.64**						0.08	
	(0.01)							
(2)		**0.54**					0.02	
		(0.10)						
(3)	**1.89**		**1.35**				0.13	
	(0.00)		(0.05)					(0.00)
(4)		**0.72**	**1.27**				0.07	
		(0.09)	(0.07)					(0.04)
(5)	**1.98**	**0.79**	**1.63**				0.17	
	(0.00)	(0.04)	(0.01)					(0.00)
(6)				0.57	**2.37**	-0.32	0.17	
				(0.65)	(0.00)	(0.86)		
(7)	**1.99**	0.51	**1.37**	1.23	1.10	-0.97	0.24	
	(0.01)	(0.14)	(0.01)	(0.35)	(0.23)	(0.26)	(0.01)	

Table 3:
Forecasting changes in the level, slope, and curvature of the term structure from t to $t+4$: 1970Q1 to 2016Q4.
This table reports coefficient estimates, corresponding reverse regression p-values, and R^2s for regressions of annual changes in the first three principal components (PCs) of the Treasury term structure on the PCs themselves and the fiscal variables measured in quarter t. The column F-test reports the p-value for the hypothesis that the fiscal variables have jointly no incremental explanatory power beyond other control variables. Reverse regression p-values (in parentheses) are calculated using the delta method of Wei and Wright (2013). Bold values indicate significance at least at the 10% level.

	Predictors							
	PC1	PC2	PC3	G	G vol	MWD/GDP	R^2	F-test
Panel A: First PC (level)								
(1)	-0.65	-0.43	0.06				0.03	
	(0.35)	(0.42)	(0.88)					
(2)	-1.35	-0.09	0.51	**-1.04**			0.09	
	(0.20)	(0.80)	(0.45)	(0.06)				
(3)	-1.05	-0.38	0.17		-0.14		0.03	
	(0.30)	(0.45)	(0.96)		(0.62)			
(4)	-1.60	0.61	0.71	**-1.61**	-0.46	**-1.14**	0.16	
	(0.12)	(0.27)	(0.22)	(0.00)	(0.16)	(0.00)		(0.00)
Panel B: Second PC (slope)								
(1)	0.23	**-0.60**	**0.35**				0.38	
	(0.15)	(0.00)	(0.01)					
(2)	0.29	**-0.69**	**0.27**	**0.26**			0.41	
	(0.14)	(0.00)	(0.05)	(0.06)				
(3)	0.20	**-0.670**	**0.369**		**0.166**		0.43	
	(0.26)	(0.00)	(0.01)		(0.08)			
(4)	**0.36**	**-0.96**	0.22	**0.45**	**0.26**	**0.35**	0.53	
	(0.05)	(0.00)	(0.12)	(0.00)	(0.01)	(0.00)		(0.00)
Panel C: Third PC (curvature)								
(1)	0.02	-0.02	**-0.25**				0.32	
	(0.79)	(0.62)	(0.00)					
(2)	0.08	-0.06	**-0.29**	0.10			0.36	
	(0.44)	(0.26)	(0.00)	(0.14)				
(3)	0.05	-0.01	**-0.26**		-0.04		0.34	
	(0.59)	(0.87)	(0.00)		(0.29)			
(4)	0.07	-0.03	**-0.29**	0.09	-0.04	-0.02	0.36	
	(0.45)	(0.52)	(0.00)	(0.11)	(0.34)	(0.85)		(0.15)

Table 4:
First-pass estimates of the betas.
This table reports the portfolios' betas obtained from time-series regressions on actual as well as simulated data. The regression equation is $R^e_{it} = \beta_{i,0} + \boldsymbol{\beta}_i \boldsymbol{f}_t + \epsilon_{it}$, where R^e_{it} is the excess return of portfolio i at time t, and $\boldsymbol{f}_t = (g_t, \sigma_{g,t})$. Panel A reports empirical beta estimates for six Treasury bond portfolios from CRSP. In particular, the bond portfolio returns are equal-weighted averages of unadjusted holding period returns for each constituent bond in excess of the risk-free rate. Return data are quarterly from 1970Q1 to 2016Q4. Panel B reports time-series betas from model-simulated data. R^e_{it} is measured as the quarterly excess return of 1-, 2-, 3-, 4-, 5- and 10-year model-implied Treasury bonds at time t.

Panel A: Empirical regression betas

	Bond returns					
	1−2 y	2−3 y	3−4 y	4−5 y	5−10 y	> 10 y
G	-0.208	-0.314	-0.367	-0.406	-0.454	-0.508
G vol	0.170	0.242	0.250	0.264	0.270	0.253

Panel B: Simulated regression betas

	Bond returns					
	1 y	2 y	3 y	4 y	5 y	10 y
G	-0.101	-0.195	-0.251	-0.285	-0.308	-0.386
G vol	0.138	0.242	0.277	0.288	0.295	0.356

Table 5:
Pricing model for stocks and bonds
We estimate cross-sectional regressions with and without a constant. In particular, the table reports results from running the cross-sectional regression $\overline{R^e_i} = (\gamma) + \beta_i \lambda + \alpha_i$, where $\overline{R^e_i}$ is the mean excess return of portfolio i and β_i is the vector of factor betas of portfolio i estimated in the first-pass regression. We use the following test assets: 25 equity portfolios sorted on size and book-to-market, the market portfolio (consisting of a value-weighted stock index and a long-term government bond index), and six maturity-sorted Fama bond portfolios obtained from CRSP. The table reports the estimates of the factor risk premia $\widehat{\lambda}$ on the factors and the constant term, Fama and MacBeth (1973) p-values (in parentheses), and the GMM-VARHAC p-values which account for sampling error in the betas (in braces). The penultimate column reports asymptotic p-values of chi-squared tests of the null hypothesis that all pricing errors are jointly zero (Pr. err. = 0). To compute the test statistic, we use the OLS covariance matrix of $\widehat{\alpha}$. The last column reports the R^2 of the cross-sectional regression, and, for the model with the constant, its standard error. In addition, we also report the root mean square error (RMSE) and the mean absolute pricing error (MAPE) across all test assets. These are expressed as percentages per year. Return data are quarterly from 1970Q1 to 2016Q4. Bold values are significant at least at the 10% level.

Table 5:
Pricing model for stocks and bonds (continued)

Panel A: $\overline{R_i^e} = (\gamma) + \beta_{i,MKT}\lambda_{MKT} + \alpha_i$

Constant	λ_g	λ_{σ_g}	λ_{MKT}	RMSE	MAPE	H_0 : Pr. error = 0 , p-value	R^2
			0.062	2.935	2.054	0.000	0.39
			(0.002)				
			{0.004}				
0.005			**0.048**	2.831	2.135	0.000	0.44
(0.096)			(0.056)				(0.27)
{0.097}			{0.067}				

Panel B: $\overline{R_i^e} = (\gamma) + \beta_{i,g}\lambda_g + \beta_{i,MKT}\lambda_{MKT} + \alpha_i$

Constant	λ_g	λ_{σ_g}	λ_{MKT}	RMSE	MAPE	H_0 : Pr. error = 0 , p-value	R^2
	-1.173		**0.053**	2.174	1.638	0.000	0.67
	(0.000)		(0.001)				
	{0.033}		{0.035}				
0.001	**-1.143**		0.050	2.168	1.673	0.001	0.67
(0.739)	(0.001)		(0.047)				(0.28)
{0.868}	{0.069}		{0.189}				

Panel C: $\overline{R_i^e} = (\gamma) + \beta_{i,\sigma_g}\lambda_{\sigma_g} + \beta_{i,MKT}\lambda_{MKT} + \alpha_i$

Constant	λ_g	λ_{σ_g}	λ_{MKT}	RMSE	MAPE	H_0 : Pr. error = 0 , p-value	R^2
		1.389	**0.046**	2.019	1.421	0.000	0.71
		(0.000)	(0.016)				
		{0.051}	{0.047}				
0.003		**1.341**	0.040	1.982	1.501	0.000	0.72
(0.319)		(0.000)	(0.097)				(0.23)
{0.618}		{0.073}	{0.268}				

Panel D: $\overline{R_i^e} = (\gamma) + \beta_{i,g}\lambda_g + \beta_{i,\sigma_g}\lambda_{\sigma_g} + \beta_{i,MKT}\lambda_{MKT} + \alpha_i$

Constant	λ_g	λ_{σ_g}	λ_{MKT}	RMSE	MAPE	H_0 : Pr. error = 0 , p-value	R^2
	-1.209	**1.487**	**0.044**	2.004	1.397	0.000	0.72
	(0.000)	(0.000)	(0.022)				
	{0.064}	{0.067}	{0.057}				
0.004	**-1.086**	**1.541**	0.030	1.915	1.462	0.000	0.74
(0.319)	(0.002)	(0.000)	(0.268)				(0.19)
{0.657}	{0.098}	{0.076}	{0.533}				

Table 6:
Model parameters.
This table reports the calibrated (left column) and estimated (right column) parameter values for the baseline model. The estimated parameters are from the second step in a GMM estimation using the optimal weighting matrix with 10 lags in the Newey-West estimator. Asymptotic standard errors for the estimated parameters are reported in parentheses. See Online Appendix B for a detailed discussion of the estimation methodology.

Calibrated parameters			Estimated parameters (second step GMM)		
Firm:			*Preferences:*		
δ	capital depreciation	0.020	β	time discount parameter	0.984 (0.000)
κ	capital share of production	0.300	ψ	inverse of IES	0.891 (0.031)
α	share of firms with rigid prices	0.650	γ	curvature	181.011 (3.283)
η	markup parameter	6.000	ω	inverse of Frisch labor elasticity	0.301 (0.032)
Monetary policy:			*Firm:*		
Π	target inflation	1.008	ζ	capital adjustment cost	3.162 (0.201)
ρ_r	interest-rate smoothing coefficient	0.400	*Lump-sum taxes:*		
Shocks:			ρ_d	loading on debt	0.601 (0.090)
ϕ_z	AR(1) transitory productivity	0.974	ρ_g	loading on government spending	0.054 (0.011)
ϕ_{σ_z}	AR(1) transitory productivity volatility	0.991	*Monetary policy:*		
θ_{σ_z}	steady-state transitory productivity volatility	-4.820	ρ_x	Taylor rule coefficient on output gap	0.040 (0.008)
σ_{σ_z}	volatility transitory productivity volatility	0.027	ρ_π	Taylor rule coefficient on inflation	1.503 (0.001)
φ	mean labor balanced growth adjustment	0.100	*Shocks:*		
ϕ_φ	AR(1) labor balanced growth adjustment	0.100	σ_u	volatility monetary policy	0.003 (0.000)
			g_a	steady-state permanent productivity	0.007 (0.001)
			ϕ_a	AR(1) permanent productivity	0.145 (0.034)
			σ_a	volatility permanent productivity	0.004 (0.001)

Table 7:
Empirical and model-based unconditional moments.
This table reports the mean, standard deviations, and correlations for observable variables in the baseline model. We group the model variables into macro variables (Panel A), nominal asset prices (Panel B), and real asset prices (Panel C). The sample period for the data is 1970Q1 to 2016Q4. All data in Panel A, except inflation, are in logs, HP-filtered, and multiplied by 100 to express them in percentage deviation from trend. In Panels B and C, interest rates are reported in annualized percentages. Further, the slope is proxied by the spread between the 10-year and 1-quarter rates. Model moments calculations are based on simulated data over 3,000 periods with a burn-in of 1,000 periods. The 90% confidence bands for the corresponding moments when taking into account parameter uncertainty are reported in brackets. Data moments for the real term structure are based on real yield data from Chernov and Mueller (2012) for the sample from 1971Q3 to 2014Q2.

Panel A: Macro variables

	Model			Data		
	SD	AR(1)	Cor(.,yt)	SD	AR(1)	Cor(.,yt)
Targeted:						
Output	1.73	0.72	1.00	1.54	0.87	1.00
	[1.52,1.89]	[0.71,0.73]				
Consumption	1.48	0.72	0.47	1.27	0.89	0.88
	[1.40,1.61]	[0.71,0.72]	[0.28,0.61]			
Investment	5.87	0.70	0.39	7.07	0.85	0.92
	[4.35,8.58]	[0.69,0.71]	[0.28,0.46]			
Inflation	0.63	0.93	0.18	0.61	0.89	0.11
	[0.59,0.69]	[0.92,0.94]	[0.14,0.24]			
Non-targeted:						
Wages	1.31	0.69	0.72	1.13	0.78	-0.29
	[1.27,1.37]	[0.68,0.70]	[0.60,0.79]			
Hours	1.52	0.65	0.71	1.94	0.93	0.87
	[1.26,1.83]	[0.61,0.68]	[0.67,0.75]			

Table 7:
Empirical and model-based unconditional Moments (continued)

Panel B: Nominal asset prices

	Model				Data			
Targeted:	Mean	SD	AR(1)	Cor(.,yt)	Mean	SD	AR(1)	Cor(.,yt)
Nominal 1Q	5.62	3.70	0.98	0.08	5.62	3.88	0.94	0.22
	[4.04,7.06]	[3.50,4.04]	[0.97,0.99]	[0.04,0.14]				
Nominal 10Y	6.85	2.36	0.98	-0.03	6.84	2.71	0.97	-0.05
	[4.59,7.97]	[2.22,2.52]	[0.97,0.99]	[-0.05,0.05]				
Slope	1.23	1.77	0.86	-0.20	1.23	2.09	0.77	-0.47
	[0.62,1.67]	[1.55,2.08]	[0.82,0.89]	[-0.29,-0.13]				
Non-targeted:								
Nominal 3Y	5.85	3.17	0.98	0.04	6.04	3.26	0.97	0.04
	[4.19,7.39]	[2.99,3.43]	[0.97,0.99]	[0.01,0.08]				
Nominal 5Y	6.09	2.91	0.98	0.00	6.34	3.06	0.97	0.00
	[4.40,7.67]	[2.73,3.14]	[0.97,0.99]	[-0.02,0.04]				
Nominal 7Y	6.38	2.68	0.98	-0.01	6.58	2.90	0.97	-0.02
	[4.59,7.98]	[2.50,2.86]	[0.97,0.99]	[-0.03,0.02]				

Panel C: Real asset prices

	Model				Data			
Non-targeted:	Mean	SD	AR(1)	Cor(.,yt)	Mean	SD	AR(1)	Cor(.,yt)
Real 2Y	3.86	1.24	0.96	0.08	2.33	1.51	0.89	0.08
	[3.19,4.35]	[1.17,1.34]	[0.95,0.97]	[0.04,0.14]				
Real 3Y	3.89	1.17	0.97	0.05	2.41	1.36	0.91	0.05
	[3.21,4.39]	[1.10,1.26]	[0.96,0.98]	[0.03,0.12]				
Real 5Y	3.96	1.07	0.98	0.02	2.56	1.17	0.93	-0.01
	[3.29,4.50]	[1.01,1.15]	[0.97,0.99]	[-0.01,0.06]				
Real 7Y	4.05	0.98	0.98	-0.02	2.67	1.05	0.93	-0.04
	[3.36,4.77]	[0.93,1.05]	[0.97,0.99]	[-0.04,0.01]				
Real 10Y	4.20	0.87	0.98	-0.03	2.80	0.92	0.94	-0.08
	[3.49,4.77]	[0.82,0.93]	[0.97,0.99]	[-0.06,-0.00]				
Real Slope	0.37	0.63	0.84	-0.20	0.47	0.75	0.76	-0.27
	[0.13,0.52]	[0.54,0.74]	[0.79,0.88]	[-0.30,-0.14]				

Table 8:
Forecasting excess returns to Treasury bonds.
This table reports the results of model-implied predictive regressions of annual excess returns of Treasury bonds (for 2- and 5-year maturities) on fiscal variables and other predictors measured in quarter t. To generate the data, we simulate the model 100 times. The column F-test reports the p-value for the hypothesis that fiscal variables have jointly no incremental explanatory power beyond other control variables. Since there is no maturity structure of debt encoded in the model, maturity-weighted debt outstanding is effectively debt outstanding. Bold values indicate significance at least at the 10% level.

	Predictors							
	G	G vol	MWD/GDP	PC1	PC2	PC3	R^2	F-test
Panel A: Excess returns on 2-year Treasury bond								
(1)	**1.775**						0.12	
	(0.053)							
(2)		**1.897**					0.04	
		(0.075)						
(3)	**1.796**		**0.004**				0.13	
	(0.013)		(0.093)					(0.000)
(4)		**2.183**	**0.005**				0.03	
		(0.050)	(0.098)					(0.004)
(5)	**1.722**	**1.707**	**0.005**				0.15	
	(0.005)	(0.051)	(0.075)					(0.000)
(6)				**-0.402**	**2.620**	**-3.300**	0.09	
				(0.031)	(0.032)	(0.007)		
(7)	**1.354**	**1.006**	**0.006**	0.072	0.327	**-1.119**	0.16	
	(0.002)	(0.064)	(0.042)	(0.284)	(0.333)	(0.054)		(0.000)
Panel B: Excess returns on 5-year Treasury bond								
(1)	**5.181**						0.10	
	(0.059)							
(2)		**3.457**					0.01	
		(0.097)						
(3)	**5.260**		**0.022**				0.11	
	(0.016)		(0.067)					(0.000)
(4)		**4.653**	**0.023**				0.03	
		(0.095)	(0.066)					(0.031)
(5)	**5.078**	**3.321**	**0.023**				0.12	
	(0.007)	(0.098)	(0.040)					(0.000)
(6)				**-0.820**	**9.800**	**-10.060**	0.11	
				(0.070)	(0.020)	(0.010)		
(7)	**2.369**	**6.540**	**0.024**	**0.697**	3.074	**-3.622**	0.17	
	(0.023)	(0.031)	(0.022)	(0.078)	(0.211)	(0.040)		(0.000)

Table 9:
Forecasting changes in the level, slope, and curvature of the term structure.
This table reports the results of model-implied predictive regressions of changes in the first three principal components (PCs) of the model-implied Treasury term structure on the PCs themselves and fiscal variables measured in quarter t. To generate the data, we simulate the model 100 times. The column F-test reports the p-value for the hypothesis that fiscal variables have jointly no incremental explanatory power beyond other control variables. Since there is no maturity structure of debt encoded in the model, maturity-weighted debt outstanding is effectively debt outstanding. Bold values indicate significance at least at the 10% level.

	Predictors							
	PC1	PC2	PC3	G	G vol	MWD/GDP	R^2	F-test
Panel A: First PC (level)								
(1)	-0.071	**1.739**	**-1.324**				0.20	
	(0.131)	(0.004)	(0.009)					
(2)	-0.025	**1.310**	**-0.929**	**-0.183**			0.19	
	(0.270)	(0.015)	(0.018)	(0.090)				
(3)	-0.055	**1.881**	**-1.173**		-0.268		0.21	
	(0.170)	(0.002)	(0.005)		(0.121)			
(4)	-0.039	**1.467**	**-1.075**	-0.131	-0.148	**-0.196**	0.22	
	(0.273)	(0.019)	(0.005)	(0.157)	(0.266)	(0.087)		(0.033)
Panel B: Second PC (slope)								
(1)	**0.038**	**-0.496**	**0.165**				0.22	
	(0.021)	(0.002)	(0.040)					
(2)	0.006	**-0.149**	0.020	**0.155**			0.36	
	(0.296)	(0.059)	(0.375)	(0.001)				
(3)	**0.027**	**-0.599**	0.068		**0.222**		0.36	
	(0.018)	(0.000)	(0.155)		(0.001)			
(4)	0.000	**-0.139**	-0.031	**0.148**	**0.079**	**0.095**	0.45	
	(0.378)	(0.094)	(0.265)	(0.000)	(0.053)	(0.004)		(0.000)
Panel C: Third PC (curvature)								
(1)	0.000	0.001	**-0.046**				0.20	
	(0.374)	(0.414)	(0.003)					
(2)	**-0.002**	**0.022**	**-0.053**	**0.010**			0.27	
	(0.083)	(0.028)	(0.001)	(0.008)				
(3)	-0.001	-0.002	**-0.052**		**0.013**		0.25	
	(0.209)	(0.374)	(0.000)		(0.017)			
(4)	**-0.003**	**0.028**	**-0.058**	**0.010**	0.003	**0.008**	0.30	
	(0.026)	(0.023)	(0.000)	(0.006)	(0.269)	(0.018)		(0.003)