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Welfare and bond pricing implications of fiscal stabilization policies



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Welfare and Bond Pricing Implications of Fiscal Stabilization Policies*

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Abstract

How do cyclical fiscal stabilisation policies affect welfare and government bond risk premia? Using a new Keynesian model we find that the effects of fiscal policy rules on the bond premium and welfare crucially depend on the source of business cycle fluctuations. The overall effect is estimated using Bayesian methods and the mechanism is deconstructed by examining the propagation mechanism of the different shocks. We find that the impact of fiscal policy cyclicality on welfare and risk premia is highly non-linear and that these effects are of a policy relevant magnitude. Finally, we find that the welfare cost of highly procyclical fiscal policies are very large, but also excessive fiscal stabilization can generate non-negligible welfare losses.

Keywords: New Keynesian models, fiscal policy, bond risk premium, monetary policy.

JEL: E5, E6, G1

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1 Introduction

The crisis has returned fiscal policy to center stage as a tool for macroeconomic stabilization. In particular, the lack of fiscal space observed in many developed economies emphasizes the limits of discretionary fiscal policy and the need to design better automatic stabilizers (e.g. Blanchard, Dell’Ariccia, and Mauro, 2010).

The implications of fiscal rules, and more specifically, of the cyclicity of fiscal policy rules, are however not well-established in the DSGE literature. Gali (1994) for instance studies the role of fiscal stabilizers in a real business cycle model and finds that, while government purchases have a stabilizing impact on the cycle, income taxes are destabilizing. Jones (2002) estimates fiscal policy rules using U.S. data and finds that fiscal policy in general fails to reduce output volatility or shorten recessions. In the framework developed by Gordon and Leeper (2005), countercyclical policies can even be counterproductive.¹

Moreover these studies focus on the business cycle properties and volatility of output but neglect the role of fiscal rules on the cost of government financing. While empirical studies have found relations between fiscal rules and the price of government bonds, this effect has not yet been widely explored in microeconomically founded macroeconomic models.² From both a government financing perspective as well as from a welfare perspective, the bond pricing implications of fiscal policy are bound to play an important role. As shown by Tallarini (2000), the welfare effects of business cycle fluctuations are quite different when studied in models that are able to explain asset pricing data. Very few studies have however attempted to investigate the welfare implications of automatic stabilizers in a dynamic general equilibrium model (DSGE) that is able to generate realistic bond pricing predictions. This work fills that gap by studying the question in a New Keynesian model (e.g. Gali, Clarida and Gertler, 1999; Woodford, 2003) augmented with a novel preference specification (Jaccard 2013).

We estimate the stance of fiscal policy in a framework in which several additional sources of disturbance compete with the real-business-cycle model’s technology shock in driving aggregate fluctuations. Our main finding is that the effects of automatic stabilizers on risk premia and welfare depend crucially on the mix of shocks hitting the economy. This result is essentially due to the tradeoff between output and infla-

¹See Fatàs and Mihov (2012) for a more comprehensive literature review.

²Feld et al. (2013) find evidence that the presence and strength of strict fiscal rules contribute significantly to lower cantonal bond spreads in Switzerland. Also Poterba and Rueben (1997), using data on U.S states find evidence that tighter fiscal rules lead to narrower bond spreads.

tion stabilization created by markup shocks, which as in Ireland (2004), emerge as an important contribution to movements in inflation.

In terms of bond pricing implications, the effects of markup shocks on risk premia can be explained by the implied co-movement of marginal utility, bond prices and inflation. A contraction in aggregate supply induced by an increase in markups reduces output and bond prices but raises the inflation rate. Over the business cycle, this co-movement implies that inflation erodes the value of long-term bonds precisely when the desire to smooth consumption is the most pressing (e.g., Piazzesi and Schneider 2007; Rudebusch and Swanson 2012). If markup shocks are the only source of business cycle fluctuations, the active use of fiscal policy exacerbates inflation risk since output stabilization can only be achieved by generating larger fluctuations in inflation. In this case, we therefore find that a major side effect of counter-cyclical fiscal policy via its effect on inflation is to increase the premium required by investors for holding long-term bonds.

By contrast, if shocks that generate positive co-movement between inflation and output are predominant, countercyclical fiscal policy will stabilize output fluctuations and reduce the bond premium. In this case, inflation acts as a hedge against business cycle fluctuations by increasing the value of long-term bonds in periods of recession. The favorable cyclical property of inflation makes fiscal policy a very effective stabilization tool in that it reduces the volatility of output without increasing the risk premium on long-term bonds.

The effect of the fiscal policy stance on the bond premium depends on the relative strength of these two opposing effects. Our estimation results suggest that the overall relationship is nonlinear and asymmetric. In particular, when the fiscal policy stance is mildly procyclical, small increases in the degree of procyclicality can generate large increases in the bond premium. By contrast, the bond premium is considerably less sensitive to changes in the cyclicity of automatic stabilizers when the actual stance of fiscal policy is countercyclical.

Finally, we find that the relationship of fiscal policy stance to welfare is inverted-U-shaped, asymmetric and nonlinear. Although the welfare cost of highly procyclical fiscal policy is very large, this result suggests that excessive fiscal stabilization could be more costly than is usually assumed. In our framework, this latter effect, which prevails when the stance of fiscal policy becomes strongly countercyclical, shows that fiscal policy is not an ideal tool to stabilize fluctuations caused by markup shocks. Intuitively, while expansionary fiscal policies increase consumption and output, in models with

sticky prices, they also give rise to large increases in the number of hours worked. For reasonable parameter values, this increase in labor effort, which is required to finance the expansionary fiscal stance, more than offsets the increase in consumption. Fiscal stabilization therefore exacerbates the reduction in welfare triggered by the initial supply shock: risk premia rise, and, because the aggregate of consumption and leisure becomes more volatile, overly aggressive stabilization policies can generate sizeable welfare losses.

This paper combines two strands of literature, one focusing on the macroeconomic effects of fiscal policy and the other on the bond pricing implications of New Keynesian models. On the fiscal side, Baxter and King (1993) augment a real business cycle model with a fiscal block, to study fiscal multipliers, debt dynamics and the effects of distortionary taxation. Leeper, Plante and Traum (2010) and Coenen, Straub and Trabandt (2012) use Bayesian methods to estimate a DSGE model with nominal rigidities that incorporates a rich description of fiscal policy. McKay and Reis (2013) study the role of fiscal stabilizers in a model that merges the standard incomplete market model with the standard sticky price model of business cycles.

On the asset pricing front, Hördhal, Tristani and Vestin (2008) show that the market price of risk, a key determinant of term premia, is smaller in a New Keynesian model with nominal rigidities than in a corresponding model with flexible prices. Rudebusch and Swanson (2008) introduce slow moving habits (e.g. Campbell and Cochrane, 1999) into a standard New Keynesian framework and find that the modified model can help fit the term premium but only at the cost of seriously distorting the DSGE model's ability to explain other macroeconomic variables. In a model with capital adjustment costs and habit formation, Wei (2008) finds that, under a standard monetary policy rule, the real effects of monetary policy shocks are too weak and short-lived to generate a reasonable equity premium.

De Paoli, Scott and Wecken (2010) show that in a world dominated by productivity shocks, increasing nominal rigidities reduces risk premia, and their results suggest that the composition of shocks plays an important role. Rudebusch and Swanson (2012) introduce Epstein-Zin-Weil preferences into a standard New Keynesian model and find that this mechanism can produce a large and variable term premium without compromising the model's ability to reproduce the standard deviation of macroeconomic variables.

Swanson (2012) shows that the household's labor margin has a substantial effect on risk aversion and that standard estimates of risk aversion can be misleading if the labor

margin is ignored. Van Binsbergen, Fernández-Villaverde, Koijen, and Rubio-Ramirez (2013) estimate a DSGE model with Epstein-Zin-Weil preferences by maximum likelihood using the particle filter and by computing a third-order perturbation to the equilibrium dynamics of the economy. Dew-Becker (2012) studies and estimates the bond pricing implications of a medium-scale New Keynesian model with a time-varying price of risk. Finally, Croce, Nguyen, and Schmid (2013) study fiscal policy design in a neoclassical growth model and find that tax policies aimed at short-run stabilization may reduce average growth and welfare.

The rest of the paper is organised as follows. Section 2 presents the model and Section 3 discusses its estimation and evaluates the model’s ability to fit stylized business cycle facts. Section 4 explains in detail what drives risk premia in the model. Section 5 studies the importance of fiscal policy for the size of the bond premium and section 6 discusses the welfare implications of different fiscal stabilization policies. Section 7 concludes.

2 The model

We present a variant of a textbook New Keynesian model (e.g. Gali, 2008) where the government collects taxes, issues long-term non-defaultable bonds, uses the proceeds to consume private goods produced by monopolistically competitive firms, and makes lump sum transfers to households. Households consume, pay taxes, provide labour for the monopolistic firms, trade one-period bonds, and invest in long-term bonds issued by the government. Firms hire labour from the households and produce differentiated goods with identical technologies. Firms price their products subject to a pricing friction a la Calvo (1983). Monetary and fiscal authorities control the short-term nominal interest rate as well as government consumption, the labour income tax rate and lump-sum transfers, respectively.

2.1 Households

The economy is populated by representative, infinitely-lived households who solve the following dynamic optimization problem:

$$\begin{aligned} & \max_{C_t, N_t, B_t^S, B_t^L, X_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_t, X_{t-1}, N_t) \\ & s.t \end{aligned}$$

$$\int_0^1 P_t(i)C_t(i)di + Q_t^S B_t^S + Q_t^L B_t^L = (1 - \mathbf{t}_t)W_t N_t + P_t T R_t + B_{t-1}^S \quad (1)$$

$$+ \delta_c Q_t^L B_{t-1}^L + B_t^L + \mathcal{D}_t$$

$$C_t \equiv \left(\int C_t(i)^{1-\frac{1}{\epsilon_t}} di \right)^{\frac{\epsilon_t}{\epsilon_t-1}} \quad (2)$$

$$X_t = mX_{t-1} + (1 - m)C_t v(1 - N_t) \quad (3)$$

$$N_t = 1 - L_t \quad (4)$$

where $C_t(i)$ is the quantity of good i consumed by the household in period t ; $P_t(i)$ is the price of good i ; N_t is the quantity of labour; L_t is leisure; W_t is the nominal wage; B_t^S are nominally riskless one-period bonds (purchased at time t and maturing at $t + 1$), with nominal price Q_t^S ; B_t^L are nominally riskless coupon bonds with price Q_t^L that pay a geometrically decaying coupon in perpetuity, with decay factor δ_c ; $T R_t$ is the lump sum component of income (transfers); ϵ_t is the (time-varying) own price elasticity of demand of good i ; \mathbf{t}_t is labour tax rate; X_t denotes the habit stock; m is the habit stock parameter; β is the discount factor; and $U(\cdot)$ is a concave and $v(\cdot)$ a convex function in its arguments (specified below). \mathbb{E} is the mathematical expectations operator. The representative agents also own the firms, and \mathcal{D}_t is the aggregate dividend that households receive from the final goods-producing sector.

The first-order conditions with respect to bond holdings and consumption give rise to the familiar Euler equations

$$Q_t^S = \beta \mathbb{E}_t \left\{ \frac{U_C(C_{t+1}, X_t, N_{t+1})}{U_C(C_t, X_{t-1}, N_t)} \frac{P_t}{P_{t+1}} \right\} \quad (5)$$

$$Q_t^L = 1 + \delta_c \beta \mathbb{E}_t \left\{ \frac{U_C(C_{t+1}, X_t, N_{t+1})}{U_C(C_t, X_{t-1}, N_t)} \frac{P_t}{P_{t+1}} Q_{t+1}^L \right\} \quad (6)$$

where U_C denotes the marginal utility of consumption. Note that $Q_t^S = (1 + i_t)^{-1}$, where $1 + i_t$ is the yield of a one-period discount bond.³ The second Euler equation (6) is the pricing formula for government long-term bonds. The optimal choice of labour supply yields the intratemporal condition

$$\frac{(1 - \mathbf{t}_t)W_t}{P_t} = - \frac{U_N(C_t, X_{t-1}, N_t)}{U_C(C_t, X_{t-1}, N_t)}, \quad (7)$$

where U_N denotes the marginal disutility of labour. The representative household also

³Note that this equation implies that, approximately, $i_t = -\log(Q_t^S)$.

decides on the allocation of its consumption expenditures among differentiated goods. This gives rise to the usual demand equation:

$$C_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\epsilon_t} C_t. \quad (8)$$

where $P_t \equiv \left(\int P_t(i)^{1-\epsilon_t} di \right)^{\frac{1}{1-\epsilon_t}}$ is the aggregate price index, and C_t denotes aggregate private consumption.

2.2 Specification of utility

We assume that the utility function takes the following form (e.g. Jaccard, 2013):

$$U(C_t, X_{t-1}, N_t) = \frac{(C_t (\phi + (1 - N_t)^\zeta) - bX_{t-1})^{1-\sigma}}{1 - \sigma} \quad (9)$$

where σ is the curvature parameter of utility, C_t is consumption, X_{t-1} is the pre-determined habit stock, and where ϕ and ζ satisfy the usual regularity conditions.⁴ The curvature parameter σ is the coefficient of relative risk aversion for the composite good $C_t (\phi + (1 - N_t)^\zeta)$. The law of motion of the habit stock X_t depends on the composite good, reflecting the key assumption that habits are formed in respect of the aggregate of consumption and leisure. Compared to a standard specification of habit formation (e.g. Abel, 1990; Constantinides, 1990; Campbell and Cochrane, 1999), the inclusion of leisure gives households an additional margin which can be used to control the evolution of the habit stock. The habit parameter m controls the rate at which the stock of habits depreciates, while $1 - m$ determines the sensitivity of the reference level with respect to changes in the composite good. The second habit parameter $0 \leq b < 1$ is a measure of the importance of the habit motive in utility.⁵

Given this specification of utility and assuming internal habit formation, it follows

⁴Note that ϕ is pinned down by the steady state of the model while ζ controls the Frisch elasticity of labor supply. These parameter values are restricted to ensure that consumption and leisure are always normal goods.

⁵Compared to the specification used in Jaccard (2013), we use a specification with b and m allowing for an additional degree of freedom in order to facilitate the estimation procedure. When b is set to zero, the model reduces to a specification without habit formation.

that

$$U_C(C_t, X_{t-1}, N_t) = [C_t(\phi + (1 - N_t)^\varsigma) - bX_{t-1}]^{-\sigma} (\phi + (1 - N_t)^\varsigma) + (1 - m)(\phi + (1 - N_t)^\varsigma) \varphi_t, \quad (10)$$

$$U_N(C_t, X_{t-1}, N_t) = [C_t(\phi + (1 - N_t)^\varsigma) - bX_{t-1}]^{-\sigma} C_t \varsigma (1 - N_t)^{\varsigma-1} + (1 - m) \varphi_t C_t \varsigma (1 - N_t)^{\varsigma-1}, \quad (11)$$

where φ_t is the Lagrange multiplier associated with the habit accumulation equation.

2.3 Firms

Following the standard New Keynesian setup, we assume that there is a continuum of firms indexed by $i \in [0, 1]$. Each firm is owned by the households, produces a differentiated good using a homogeneous technology. Firms' production possibilities are given by the production function: $Y_t(i) = A_t N_t(i)^{1-\alpha}$. A_t represents the common level of technology that follows an $AR(1)$ process. We assume that capital is fixed at unity. All firms face identical isoelastic demand schedules (8) and take aggregate prices and quantities as given. We maintain the usual assumption that each firm can re-set its price only with probability $1 - \theta$. The average price duration is given by $1/(1 - \theta)$. A firm re-optimizing in period t chooses the price P_t^* that maximizes the current market value of profits generated while that price remains effective, $\sum_{k=0}^{\infty} \theta^k \mathbb{E}_t \{ \mathbf{m}_{t,t+k} (P_t^* Y_{t+k|t} - \Psi_{t+k}(Y_{t+k|t})) \}$ subject to the demand function $Y_{t+k|t} = \left(\frac{P_t^*}{P_{t+k}} \right)^{-\epsilon_t} C_{t+k}$, for $k = 0, 1, 2, \dots$. Note that Ψ_{t+k} is the cost function at time $t + k$ and $Y_{t+k|t}$ denotes output in period $t + k$ for a firm that last reset its price in period t .

The nominal stochastic discount factor from period t to period $t + k$ is given by

$$\mathbf{m}_{t,t+k} \equiv \beta^k \frac{U_{C,t+k} P_t}{U_{C,t} P_{t+k}}. \quad (12)$$

The first-order condition can be written as:

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ \mathbf{m}_{t,t+k} \left(Y_{t+k|t} \left(\frac{P_t^*}{P_{t-1}} - \mathcal{M} \mathcal{M} C_{t+k|t} \Pi_{t-1,t+k} \right) \right) \right\} = 0 \quad (13)$$

where $\mathcal{M} \equiv \frac{\bar{\epsilon}}{\bar{\epsilon}-1}$ denotes the steady-state (frictionless) price mark-up and $\Psi'_{t+k}(Y_{t+k|t})$ denotes the marginal cost function at time $t + k$ for the firm that last re-set its price at time t . Inflation is defined as $\Pi_{t,t+k} \equiv P_{t+k}/P_t$ and $\mathcal{M} C_{t+k|t} \equiv \frac{\Psi'_{t+k}(Y_{t+k|t})}{P_{t+k}}$ denotes

real marginal cost. Typically, this optimal price setting condition is linearized around the zero-inflation steady state (e.g. Gali, 2008). However, since we use higher-order approximation, we re-write condition (13) in a recursive form, and use perturbation methods to evaluate the recursive form of the first-order condition around the deterministic steady state price level where $\frac{P_t^*}{P_{t-1}} = 1$ and $\Pi_{t-1,t+k} = 1$. For details, see Appendix C.

2.4 Pricing of long-term bonds and risk premium

The pricing of the assets in this economy is based on the households' valuation of future payoffs of the assets, whether based on future profit streams of the firms or the payment structure associated with government bonds. Future payoff streams are valued on the basis of the stochastic discount factor introduced in equation (12). Following Rudebusch and Swanson (2008), we simplified the computational burden associated with the introduction of a 10-year bond by assuming that the government issues long-term, default-free bonds that pay a geometrically declining coupon in each period in perpetuity. Hence, the nominal price of the bond per one dollar of coupon in period t satisfies⁶

$$Q_t^L = 1 + \delta_c \mathbb{E}_t (\mathbf{m}_{t,t+1} Q_{t+1}^L), \quad (14)$$

where δ_c is the rate of decay of the bond coupon and \mathbf{m}_{t+1} is the (nominal) stochastic discount factor between period t and $t+1$.⁷ The decay factor δ_c controls the duration or maturity of the bond. When $\delta_c \rightarrow 0$, this bond behaves increasingly like a short-term asset, while higher values of δ_c imply an increasing duration of the bond.

The risk-free (or rather risk neutral) price of the bond is given by

$$\hat{Q}_t^L = \mathbb{E}_t \sum_{j=0}^{\infty} e^{-i_{t,t+j}} \delta_c^j = 1 + \delta_c \exp(-i_t) \hat{Q}_{t+1}^L, \quad (15)$$

where $i_{t,t+j} \equiv \sum_{s=0}^j i_s$ and the second equality in equation (15) follows from the first-

⁶The price of a default-free n -period zero coupon bond that pays one dollar at maturity satisfies

$$Q_t^{(s)} = \mathbb{E}_t [\mathbf{m}_{t,t+1} Q_{t+1}^{(s-1)}] = \mathbb{E}_t (\Pi_{j=1}^s \mathbf{m}_{t,t+j})$$

where $Q_t^{(s)}$ denotes the price of a bond with maturity s .

⁷This is essentially the Euler condition for long-term bonds given in equation (6), but computationally far less burdensome, since pricing of long-term financial claims based on the exact Euler equation involves the pricing of all claims up to maturity L . Using equation (14) involves only one additional state variable.

order expansion of equation (14).

One commonly-used measure of the bond risk premium is based on the difference between the bond's risk adjusted yield-to-maturity and risk-neutral yield-to-maturity (e.g. Rudebusch and Swanson, 2008, 2012).⁸ The continuously-compounded yield-to-maturity i_t^L on the bond is given by

$$i_t^L \equiv \log \left(\frac{\delta_c Q_t^L}{Q_t^L - 1} \right). \quad (16)$$

Correspondingly, the yield of a risk-free bond is

$$\widehat{i}_t^L \equiv \log \left(\frac{\delta_c \widehat{Q}_t^L}{\widehat{Q}_t^L - 1} \right). \quad (17)$$

Hence, the implied bond risk premium is

$$\psi_t^L \equiv i_t^L - \widehat{i}_t^L = \log \left(\frac{\delta_c Q_t^L}{Q_t^L - 1} \right) - \log \left(\frac{\delta_c \widehat{Q}_t^L}{\widehat{Q}_t^L - 1} \right). \quad (18)$$

2.5 Government

The government collects taxes, issues non-defaultable long-term bonds and uses the revenues for government consumption and transfers. There is no seigniorage. The government's (nominal) flow budget constraint in this economy can be expressed as

$$Q_t^L B_t^L + P_t S_t = B_t^L + \delta_c Q_t^L B_{t-1}^L, \quad (19)$$

$$S_t = \tau_t (W_t / P_t) N_t - (G_t + TR_t), \quad (20)$$

where S_t denotes the primary surplus. τ_t , G_t and TR_t denote the labour income tax rate, government consumption and lump sum net transfers respectively. In order to facilitate aggregation, we implicitly assume that the government consumes the same basket of goods as the households. B_t^L denotes the dollar value of long-term nominal bonds outstanding and Q_t^L denotes the nominal price of bonds sold at time t . Note importantly that, in contrast to one-period debt, the nominal value of debt ($Q_t^L B_t^L$) depends on bond prices, which in turn depend on expected future inflation. Hence, the current nominal value of debt outstanding depends on the expected path of future

⁸Yield-to-maturity is the constant rate of discount that equates the net present value of future coupon payments with the current market price of the bond.

inflation, and hence on monetary policy. In contrast to the case of a one-period bond, this implies that the nominal value of debt outstanding at time t is not predetermined.

For further use, we define

$$\begin{aligned} S_{Y,t} &\equiv \tau_t(W_t N_t / P_t Y_t) - \left(\frac{G_t}{Y_t} + \frac{TR_t}{Y_t} \right) \\ &= \tau_t(W_t N_t / P_t Y_t) - (G_{Y,t} + TR_{Y,t}). \end{aligned} \quad (21)$$

as the ratio of the real value of the primary surplus to current output. As for the law of motion of government bonds, we define $B_{PY,t}^L \equiv B_t^L / (Y_t P_t)$ as the ratio of the real value of long-term bonds to output. Then we can express the real government budget constraint as⁹

$$Q_t^L B_{PY,t}^L = B_{PY,t}^L + \delta_c \frac{Q_t^L B_{PY,t-1}^L}{(Y_t / Y_{t-1}) \Pi_t} - S_{Y,t}, \quad (22)$$

Fiscal policy is characterized by the following feedback equations

$$G_{Y,t} = G_Y - \phi_{GY} \left(\frac{Y_t}{\bar{Y}} - 1 \right) - \phi_{GB} \left(\frac{D_{Y,t-1}}{D_Y} - 1 \right) + \varepsilon_t^G, \quad (23)$$

$$\tau_t = \tau + \phi_{\tau Y} \left(\frac{Y_t}{\bar{Y}} - 1 \right) + \phi_{\tau B} \left(\frac{D_{Y,t-1}}{D_Y} - 1 \right) + \varepsilon_t^\tau, \quad (24)$$

$$TR_{Y,t} = TR_Y - \phi_{TRY} \left(\frac{Y_t}{\bar{Y}} - 1 \right) - \phi_{TRB} \left(\frac{D_{Y,t-1}}{D_Y} - 1 \right) + \varepsilon_t^{TR}, \quad (25)$$

$$\varepsilon_t^G = \rho_G \varepsilon_{t-1}^G + \eta_t^G, \quad \eta_t^G \sim N(0, \sigma_G^2), \quad (26)$$

$$\varepsilon_t^\tau = \rho_\tau \varepsilon_{t-1}^\tau + \eta_t^\tau, \quad \eta_t^\tau \sim N(0, \sigma_\tau^2), \quad (27)$$

$$\varepsilon_t^{TR} = \rho_{TR} \varepsilon_{t-1}^{TR} + \eta_t^{TR}, \quad \eta_t^{TR} \sim N(0, \sigma_{TR}^2), \quad (28)$$

where G_Y , D_Y and τ denote the steady state values of the ratio of government consumption to output, the debt ratio and the labour income tax rate. ε_t^G , ε_t^τ and ε_t^{TR} capture exogenous (autocorrelated) shocks in government spending, labour income taxes and

⁹Note that $B_{PY,t}$ and $S_{Y,t}$ are stationary variables such that the steady state version of (22) collapses to $S_Y = (1 - \beta)D_Y$, when $\Pi = 1$, $\Delta Y = 1$, and where $D_Y \equiv \delta_c Q^L B_{PY}^L$ is the steady state real government debt to output ratio. This follows from the Euler equation (6) which in the steady state with zero-inflation and zero-growth implies that $1/Q^L = (1 - \delta_c \beta)$.

transfers. η_t^G , η_t^τ and η_t^{TR} are unexpected (discretionary) changes to government spending, taxes and transfers and ρ_j captures the degree of serial correlation of the fiscal shocks. Parameters ϕ_{jB} , for $j = G, \tau$ and TR capture the feedback of government spending, taxes and transfers on the government debt to output ratio, while ϕ_{jY} captures the extent to which fiscal policy co-moves with the business cycle, because of automatic stabilizers. In general, these feedback coefficients direct (in a reduced form way) the systematic features of fiscal policy. Note that transfers are lump-sum in our model and have an allocative role only through the "second-round" feedback effects on labour taxes and government spending.

Finally, monetary policy is characterized by the usual interest rate feedback rule, given by

$$i_t = \rho_i i_{t-1} + (1 - \rho_i)[\log(1/\beta) + \phi_\pi(\log(\Pi_t/\Pi^*)) + \phi_y(\log(Y_t/\bar{Y}))] + \eta_t^i, \quad (29)$$

where $\eta_t^i \sim N(0, \sigma_i^2)$, ρ_i is the interest rate smoothing coefficient and ϕ_π and ϕ_y are the usual feedback coefficients on inflation and trend output gap, and $\Pi_t \equiv P_t/P_{t-1}$. The equilibrium real interest rate in the model is given by $\log(1/\beta)$. $\eta_{i,t}$ captures *iid* shocks to monetary policy.

2.6 Market Clearing

There are three markets (goods, labour and bond markets) that need to be in equilibrium at each point of time. We assume that the household's initial long-term bond holdings are positive such that $Q_{-1}^L B_{-1}^L > 0$, while net holdings of one-period bonds are zero in equilibrium. Market clearing in the goods market requires that at time t : $Y_t(i) = C_t(i) + G_t(i)$ for all $i \in [0, 1]$. Assuming that the government decides on the allocation of its expenditures (G_t) among differentiated goods similarly to the household such that $G_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon_t} G_t$, we obtain

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon_t} Y_t, \quad Y_t = C_t + G_t \quad (30)$$

The market clearing condition in the labour markets requires that $N_t = \int_0^1 N_t(i) di$. Furthermore, inverting the production function $Y_t(i) = A_t N_t(i)^{1-\alpha}$ and using (30), it

follows from the labour market clearing condition that:

$$N_t = (Y_t/A_t)^{\frac{1}{1-\alpha}} \Delta_{p,t}, \quad \Delta_{p,t} \equiv \int_0^1 (P_t(i)/P_t)^{\frac{-\epsilon_t}{1-\alpha}} di, \quad (31)$$

where $\Delta_{p,t}$ is a measure of price dispersion across firms. Consequently, in the symmetric equilibrium, the aggregate supply condition satisfies $Y_t = A_t (N_t \Delta_{p,t}^{-1})^{1-\alpha}$.

See Appendix B for a description of the treatment of the price dispersion term.

3 Estimation

The model is estimated using Bayesian full information estimation methods as in An and Schorfheide (2007). For our data sample, we use U.S. quarterly data from 1971Q1 to 2007Q4. As observable variables, we use consumption, inflation, Federal funds rate (short-term nominal interest rate), the government consumption-to-output ratio, labour income tax revenues, and the transfers-to-output ratio. All quantity variables are linearly de-trended and measured in real terms. Inflation and short-term interest rate are de-measured and expressed in annualized terms. A detailed description of the construction of the variables is provided in Appendix D. Corresponding to the six observable variables, there are six exogenous shocks: productivity shocks, government spending shocks, labour income tax shocks, transfer shocks, interest rate shocks and markup shocks. Interest rate shocks are assumed to be *iid*, and price mark-up shocks follow a first order ARMA process. All other shocks follow a first order process.

We estimate the model using the first-order Taylor approximations around the deterministic steady state, but stochastically simulate the second and third-order Taylor approximation of the model around the non-stochastic steady state in order to compute the bond risk premium and evaluate welfare.¹⁰

3.1 Calibrated parameters

The model is calibrated around a steady state with zero inflation and zero growth. Note that the risk premium is zero in the deterministic steady state.¹¹

¹⁰Estimation and simulations were done using *Dynare*, available at <http://www.dynare.org>; See Adjemian et al. (2011) for a detailed description.

¹¹In higher-order approximations the assumption on steady state inflation is not innocuous (e.g., Ascari and Rossi, 2011). To avoid possible repercussions of mean inflation on the determination of

Table 1 below shows the values assigned to the parameters of the model that are calibrated. In the fiscal block of the model, the key parameters are the government debt to output ratio D_Y , the government consumption-to-output ratio G_Y , lump-sum transfers TR_Y , and the decay parameter δ_c , which controls the maturity of the government bonds. D_Y , G_Y and TR_Y are calibrated using U.S. quarterly data from 1971 to 2007, such that $D_Y = 0.33$, $G_Y = 0.076$ and $TR_Y = 0.104$. Following Leeper, Plante and Traum (2010), we target the fiscal variables relevant for the federal government. These, together with other parameters of the model, imply that the steady state labour income tax rate τ is 0.23 and the steady state primary surplus-to-output ratio S_Y is 0.003.¹² δ_c is set at 0.9848, following Rudebusch and Swanson (2008, 2012). This implies a Macaulay duration for the government bond of 10 years (40 quarters).¹³ The discount rate β is set at 0.997, which is a standard value used in the literature.

TABLE 1—CALIBRATED PARAMETERS

FIRMS AND HOUSEHOLDS						FISCAL POLICY			
ς	1.66	β	0.997	$\bar{\epsilon}$	6	G_Y	0.076	D_Y	0.33
σ	1	\bar{N}	0.20	$1 - \alpha$	1	TR_Y	0.104	δ_c	0.9848

Regarding labour supply, we firstly choose ϕ such that the representative household devotes 20% of its time to market activities in the model's steady state, *i.e.* $\bar{N} = 0.2$. Normalizing the total time endowment to 1, this implies a steady state value for leisure of $\bar{L} = 0.8$. With this specification of preference, the Frisch elasticity of labor supply, denoted e_F , depends not only on ς but also on the value of the two habit parameters. An approximate closed form expression for the Frisch elasticity can be derived by log-linearizing the model's first-order conditions¹⁴ yielding

$$e_F = \frac{1}{\xi_c \omega_N - \xi_N}$$

the risk premium we calibrate the model around a zero inflation steady state. When estimating the model we bridge the difference between the means implied by data and by the model via suitable measurement equations.

¹²See Appendix D for exact definitions of the variables and other details of the data.

¹³Macaulay duration is a measure of the average length of time for which money is invested, where the present values of each coupon payment are used to construct the average. The formula is $D = \sum_{t=1}^m \frac{tC_t}{(1+i)^t} / Q$, where D denotes the Macaulay duration of the bond, m is the maturity, i is the yield and Q is the price of the bond. In the case of continuous compounding $D = \sum_{t=1}^m tC_t \exp(-it) / Q$.

¹⁴See Jaccard (2013) for a more detailed analysis of the impact of this specification of habits on the Frisch and wealth elasticities of labor supply.

where

$$\xi_c = \left(1 - \frac{\sigma}{\Omega(1-b)}\right), \quad \omega_N = \left(1 - \frac{\Omega(1-b)}{\sigma}\right) \frac{\varsigma \bar{L}^\varsigma}{(\phi + \bar{L}^\varsigma)} \frac{\bar{N}}{1 - \bar{N}}$$

and

$$\xi_N = \left\{ (\varsigma - 1) - \frac{\varsigma \bar{L}^\varsigma}{\phi + \bar{L}^\varsigma} \frac{\sigma}{\Omega(1-b)} \right\} \frac{\bar{N}}{1 - \bar{N}}, \quad \Omega = 1 - b\beta \frac{1-m}{1-m\beta}$$

Setting the second labour supply parameter, ς , at 1.66 and the curvature coefficient σ at 1 ensures that the Frisch elasticity will be in line with values considered plausible in the literature for the range of parameter values for m and b that allow the model to generate a reasonable bond premium.¹⁵ As for the supply side of the model, we set the steady state price markup at 20%. This is achieved by setting the price elasticity of demand ϵ to 6 in the model's steady state. The production function curvature parameter is set to unity. All remaining parameters are estimated.

Priors are reported in Table A1. We set the Calvo parameter at 0.5, implying an average contract duration of 2 quarters. The priors on the two habit formation parameter are 0.6 and 0.9. For the interest rate rule we start with a Taylor-type rule with an inflation response coefficient of 2 and an output response coefficient of 0.5. The interest rate smoothing parameter is set at 0.7. These are all quite standard calibrations. Concerning the fiscal rules we set the response to debt at 0.03 for taxes and for expenditures, and at 0.015 for transfers. Our prior on the cyclical response coefficient is 0.0 for expenditures. A negative coefficient for this parameter implies that fiscal policy is procyclical. All priors on the shock persistence are 0.7. The priors on the standard deviations of the innovations are calibrated to roughly reproduce the variances of the observable variables. The remaining parameter values are reported in Table A1.

3.2 Estimation results

The estimation results are reported in Table A1 of the appendix. The estimation results in the posterior mode column give the values of the structural parameters obtained from the maximized log posterior distribution with respect to the model parameters. The next column gives the respective standard deviations. The second set of results gives

¹⁵Given the values of b and m that we estimate in section 3, the implied Frisch elasticity is 0.8.

the mean and 5th and 95th percentiles of the posterior distribution obtained from the Metropolis-Hastings sampling algorithm based on 700,000 draws.

Turning to the parameter estimates we find that most of them are in line with comparable studies. On the household side the sensitivity of habits to overall utility b is estimated at 0.841, implying an important contribution of habit formation to overall utility. The depreciation of the habit level m is estimated to be 0.903, pointing towards a considerable degree of memory in the habit formation process, yet this parameter is rather poorly identified. The specific form of our utility makes it difficult to compare these estimates directly with previous studies. The estimation of the Calvo parameter implies an average price duration of 9 quarters, which is on the high side but in line with the results of comparable studies.¹⁶

Turning to the policy rules and starting with the monetary policy rule our estimates are in line with Smets and Wouters (2007). We find a somewhat stronger response of interest rates to inflation and a weaker response to the output level, but it is important to note that Smets and Wouters have an additional term on the change in output.

On the fiscal side the comparison to other studies is less straightforward. The paper by Leeper, Plante and Traum (2010) is closest to our approach, because they also relate fiscal instruments to output and debt, and we use an equivalent dataset for fiscal variables. The estimated coefficients, however, are not directly comparable because the definitions of explanatory variables are different. The signs of estimated coefficients are the same in both studies, but we find a somewhat stronger role for cyclical elements.

3.3 Model performance

The theoretical business cycle moments are generated by simulating the model with all six shocks using the set of estimated and calibrated parameter values reported in Tables 1 and A1. The simulation results reported in Table A2 of the appendix, are obtained by resorting to a second or third-order approximation of the policy function (e.g. Adjemian et al., 2011).¹⁷

¹⁶Following Eichenbaum and Fisher (2007), Smets and Wouters use a Kimball aggregator to overcome the problem of large estimates for the price duration parameter that commonly arises in DSGE models. The reduced form estimate of the Phillips Curve coefficients in Smets and Wouters is however close to our estimate.

¹⁷In Christoffel, Jaccard and Kilponen (2011) we check the accuracy of the approximation by comparing the value provided by the approximation with the exact value derived from the relevant Euler equation, where expectations are approximated by numerical integration.

Compared to a standard New Keynesian model, the main improvement is that our model augmented with slow-moving habits regarding the composite good is able to generate a bond premium exceeding eighty basis points. This relative improvement is obtained in a model that is able to closely match the volatility of consumption and broadly captures the co-movement between the main macroeconomic variables and consumption.

The risk-free rate generated by the model is on average higher and slightly more volatile than the value found in the data, which is computed from a post-war sample. The low mean risk-free rate that we obtain is however consistent with values considered plausible in the literature (e.g. Weil, 1989). For instance, using a sample that includes pre-war data, Piazzesi, Schneider and Tuzel (2007) report an empirical mean and risk-free rate standard deviation of respectively 0.75% and 3.68%. Despite the introduction of a large number of shocks, our simplified model cannot match the volatility of output, which is about forty percent smaller than in the data. At the same time, the model is able to reproduce the volatility of consumption and of the government spending-to-output ratio, as well as their co-movement, which are the two aggregate demand components that have been introduced.¹⁸

As shown by Rudebusch and Swanson (2008), including standard specifications of habits in New Keynesian models can help fit the term premium but only by seriously distorting the DSGE model's ability to explain other macroeconomic variables. By contrast, the results presented in Table A2 suggest that introducing this particular specification of habits offers a potential solution to several of the problems that have been documented in the literature. Overall, this mechanism helps to bring the asset pricing predictions of a standard New Keynesian model into closer conformity with the data and this relative success does not come at the cost of generating extreme fluctuations in other macroeconomic variables. Moreover, this result is obtained with parameter values that are estimated using macroeconomic variables and without resorting to a procedure that maximizes the model's ability to replicate a specific value for the bond premium.

The role of price stickiness. In terms of asset pricing implications, compared to the mechanism described in Jaccard (2013) in the context of a real business cycle model, the main difference is the role played by inflation. Figure A1 (see Appendix A) illustrates how a variation in the degree of price stickiness affects the asset pricing

¹⁸Since investment is volatile and strongly procyclical, including capital accumulation into the analysis would for instance help to increase the volatility of output.

implications of our New Keynesian model. Increasing the Calvo parameter reduces the bond premium because, with this price-setting mechanism, more rigid prices lead to a reduction in inflation volatility. In the model estimated with all shocks, the fact that a reduction in inflation volatility reduces the bond premium illustrates that price changes are a significant source of risk in our economy. As shown by the negative relationship between the bond premium and the Calvo parameter, nominal rigidities therefore serve as insurance against inflation risk by reducing the uncertainty caused by price changes.

The effect of inflation on the bond premium depends on the co-movement generated by the different shocks. In the case of pure demand shocks, like monetary policy shocks, the cyclical behaviour of inflation provides a hedge against business cycle fluctuations by increasing the real value of bond holdings during periods of recession. In the case of pure supply shocks, by contrast, the fact that recessions are inflationary exacerbates the effects of negative shocks on bond holders, who see their asset holdings eroded by inflation during periods of economic contraction.

As illustrated by Figure A1, our estimation results suggest that the quantitative magnitude of the insurance motive induced by pure demand shocks is however small. In our sample, the dynamics of inflation are driven primarily by supply shocks, which implies that inflation erodes the value of long-term bonds precisely when the desire to smooth consumption is most pressing, which is consistent with the findings of Piazzesi and Schneider (2007) and Rudebusch and Swanson (2012).

4 What drives the risk premium?

In this section, we employ variance decomposition, to first identify the main drivers of economic fluctuations and then to study how the shock-induced co-movements between the different variables affect the bond premium.

In this economy, about eighty five percent of the historical variance of output is explained by technology and government expenditure shocks (see Table A3 in Appendix). The other components of fiscal policy, namely tax and transfer shocks, have a negligible impact on the dynamics of both macroeconomic and financial variables. Technology shocks alone explain thirty seven percent of the total variance of output, and inflation is largely driven by markup shocks. Technology shocks and government and markup shocks explain most of the variance in bond prices. Finally, as shown by the decomposition reported in Table A4, markup and technology shocks explain

more than eighty percent of the mean bond premium. The model therefore generates a 0.72% bond premium when simulated with technology and markup shocks as the only sources of business cycle fluctuations.

Impulse response analysis. The mean bond premium and the dynamics of bond prices are largely driven by markup shocks (See Tables A3 and A4). As shown by the impulse response analysis presented in Figure A2, the importance of these shocks can be explained by the co-movements they generate between different macroeconomic variables. By increasing the substitutability between the different varieties of goods, a positive shock reduces the price markup and temporarily improves the firms' efficiency. As in the real business cycle model, agents take advantage of higher wages to work harder and smooth the variation of the composite good by increasing consumption. The increase in consumption dominates the decline in leisure, leading to a smooth increase in the value of the composite good, as shown in Figure A2. Consequently, the reduction in price markup has a positive effect on households, whose living standards temporarily improve.

As reflected by the negative co-movement between inflation and output, markup shocks work like supply shocks. For standard values of the monetary policy rule parameters, the decline in inflation due to the lower markup triggers a reduction in interest rates that further stimulates output and raises bond prices. The capital gain due to this increase in market value is therefore amplified by the decline in inflation, which contributes to increases in the real value of bonds during boom periods. Likewise, adverse markup shocks are particularly painful for bond investors since higher inflation amplifies the capital losses that they suffer during periods of recession.

In terms of bond pricing implications, the co-movement generated by technology and markup shocks are very similar (see Figure A3). As in the case of markup shocks, technology shocks generate a negative co-movement between inflation and the value of composite good, which in our environment is the relevant metric for the determination of asset prices. As can be seen by comparing the north-west panels of Figures 3 and 4, the macroeconomic implications of the two types of shocks are however very different. In contrast to markup shocks, positive technology shocks lead to a reduction in hours worked (e.g. Smets and Wouters, 2007).

Finally, as shown by Figure A4, the positive co-movement between inflation and the value of composite good generated by monetary policy shocks helps to hedge bond investors against inflation risk. The positive co-movement between the value of composite good and bond prices still means that holding bonds is risky since bond holders

will suffer capital losses in periods of recession, when the value of composite good is low. But if the recession is induced by a monetary policy shock, the capital loss due to a decline in bond prices will be partially offset by a decline in inflation. This inflation limits the risk of holding nominal bonds and explains the small contribution of monetary policy shocks to the overall bond premium reported in Table A4.

Time-variation in the bond premium. As illustrated by the last column of Table A5, the model estimated with all shocks generates a negative correlation between the bond premium and output and is therefore able to reproduce the fact that risk premia are generally higher during recessions (e.g. Fama and French, 1989; Cochrane and Piazzesi, 2005; Piazzesi and Swanson, 2008). The model simulations shown in Table A5, which reports the individual contributions of shocks to the overall result, illustrate that the countercyclical movements in the bond premium are essentially driven by markup shocks. Given that technology and fiscal policy shocks generate procyclical movements in the bond premium, the model without markup shocks would not be able to reproduce this key business cycle correlation, which is 0.55 in the model estimated with all shocks except markup shocks.

5 Asset pricing implications of fiscal stabilization policies

The role of fiscal policy can be studied by investigating how changes in the parameters that control the evolution of government spending affect the bond premium. In this section, we focus on the fiscal rule parameters that govern the government consumption-to-output ratio, since as illustrated by the variance decomposition shown in Table A3, this is the component of fiscal policy that has the largest impact on the dynamics of macroeconomic and financial variables. As discussed in section 2.5, we estimated the following fiscal rule,

$$G_{Y,t} = G_Y - \phi_{GY} \left(\frac{Y_t}{\bar{Y}} - 1 \right) - \phi_{GB} \left(\frac{D_{Y,t-1}}{D_Y} - 1 \right) + \epsilon_t^G \quad (32)$$

where the cyclicity of fiscal policy is given by the parameter, ϕ_{GY} , which measures the sensitivity of the government spending-to-output ratio to deviations of output, Y_t , from its steady state value, \bar{Y} . The estimated value $\phi_{GY} = 0.305$ indicates that in the period considered, fiscal policy in the United States was on average mildly countercyclical. The small value found for ϕ_{GB} suggests that the debt-to-output ratio did not have a

significant influence on the reaction function of the fiscal authorities in this particular time period. We therefore concentrate the analysis on the role played by ϕ_{GY} .

The sensitivity of the bond premium to ϕ_{GY} is analyzed in Figure 1 below. The continuous blue line shows how a variation in the cyclicality of fiscal policy affects the bond premium in the model estimated with all shocks. The blue squares, the red diamonds, and the green circles show the individual contributions of respectively technology, markup and government spending shocks to the overall sensitivity of the bond premium with respect to a change in the fiscal rule parameter, ϕ_{GY} .

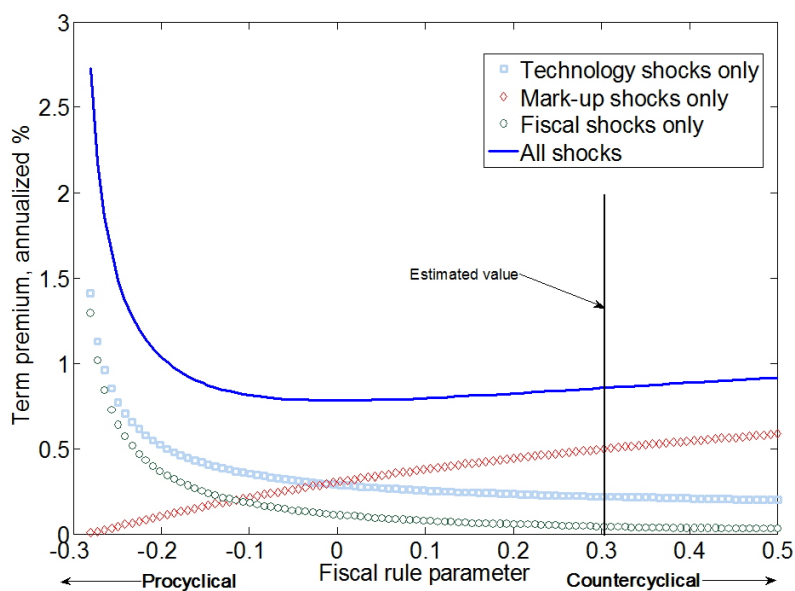


Figure 1: Fiscal policy stance and the bond premium.

The non-linear relationship between bond premium and the fiscal rule parameter depicted by the blue continuous line summarizes the model's main asset pricing prediction. Compared to the estimated fiscal policy stance, a marginal increase in procyclicality of fiscal policy, which in our environment corresponds to values for ϕ_{GY} below 0.305, has a negative effect on the bond premium. But as long as the variation from the estimated value is small, the quantitative magnitude of this effect remains modest. For larger increases in procyclicality, however, the sign of this effect changes and its magnitude becomes sizeable. For values smaller than -0.1, this relationship becomes highly nonlinear, and a small increase in the procyclicality of fiscal policy generates a large increase in the bond premium.

Exogenous changes in the cyclicity of fiscal policy. We can gain insight into what features of the model give rise to this non-linear relationship by firstly examining how exogenous changes in the stance of fiscal policy affect the dynamics of macroeconomic and financial variables. Figure A5 below shows the response of output, hours worked, consumption, the composite good, bond prices, and inflation to a positive government spending shock. In our model, the effects of government spending shocks are very similar to the prediction of a standard IS-LM textbook model. Output, hours worked and consumption increase and the rise in inflation generated by the positive aggregate demand shock triggers a monetary policy tightening.¹⁹

In terms of asset pricing, although a positive shock generates a rise in consumption and output, key is that an increase in government spending reduces the composite good, and therefore generates an increase in agents' marginal utility. The fall in the composite good increases agents' risk aversion and leads to an increase in the bond premium, which explains the positive correlation between the risk premium and output generated by government spending shocks reported in Table A5. In sum, while positive government spending shocks increase consumption and output, the key is that they imply an increase in labor effort that is too large compared to the increase in consumption that they generate. In other words, agents dislike boom periods that are induced by expansionary fiscal policies because they come at the cost of a decline in living standards.

How does the fiscal policy stance affect the transmission of macroeconomic shocks? As illustrated the decomposition shown in Figure 1, the relationship between bond premium and fiscal rule parameter depends crucially on the nature of economic fluctuations. In particular, an increase in the level of procyclicality unambiguously reduces the bond premium when the only shocks are markup shocks. By contrast, if government spending or technology shocks are the only drivers of business cycle fluctuations, a more procyclical fiscal policy stance would always generate higher risk premia.

The positive relationship induced by markup shocks is better understood by examining the impulse response shown in Figure A2. First, a reduction in price markup increases output and the value of composite good while lowering the inflation rate. For positive values of ϕ_{GY} , a countercyclical fiscal policy triggers a reduction in government

¹⁹As shown by Bilbiie (2011), models with sticky prices and non-separability between consumption and leisure can generate positive consumption multipliers without violating the requirement that both consumption and leisure are normal goods. See Jaccard (2013) for a formal derivation of the wealth and the Frisch elasticities of labour supply implied by this preference specification.

spending. As discussed above, a reduction in government spending lowers output and inflation but generates an increase in the value of composite good. Therefore, in the case of markup shocks, while countercyclical fiscal policy helps to contain the increase in output, it exacerbates the fluctuations in the value of composite good and inflation.

From the standpoint of the representative agent, the side effect of macroeconomic stabilization is therefore to make smoothing of the composite good more difficult to achieve. In terms of asset pricing implications, the larger fluctuations in marginal utility serve to amplify the positive co-movement between bond prices and the composite good, which implies that agents will suffer a capital loss precisely when they fear it most. In our setting, this stronger co-movement makes bond holding less attractive and so generates a higher risk premium.

The effect of the cyclicity of fiscal policy on this relationship is amplified by inflation risk which as demonstrated in section 4, is a key determinant of the bond premium. In the case discussed above, the countercyclical stance of fiscal policy triggers a decline in government expenditures that exacerbates the deflationary pressure induced by the positive supply shock. The inflation effect therefore works in the same direction and contributes to a positive relationship between bond premium and fiscal rule parameter, ϕ_{GY} .

The overall shape of this relationship, which is depicted by the blue continuous line, is dominated by the co-movement induced by government spending and technology shocks, which explain about 85 percent of the total variance of output. In contrast to markup shocks, key here is that these two shocks generate both negative co-movement between output and the composite good as well as positive co-movement between output and inflation. In this case, adopting a more procyclical fiscal policy stance increases the volatility of the composite good and inflation, which leads to a potentially sizeable increase in risk premia. Since in this case procyclical fiscal policy also amplifies output volatility, the nonlinear effect on the bond premium can be explained by the unsustainable dynamics that such a policy may induce when macroeconomic fluctuations are driven by these types of shocks.

In terms of co-movement, the effects of technology shocks on the main macroeconomic aggregates that we obtain are very similar to the effects of a demand shock. While the negative response of hours induced by positive technology shocks is a standard feature of New Keynesian models, the main difference is that in our environment they generate a reduction in labor demand that is stronger than usual. In particular, this reduction in labor demand, which leads to a decline in real wages, is sufficiently

large to generate a short-lived contraction in output (e.g. Basu, Fernald and Kimball, 2006). As can be seen by comparing the impulse responses shown in Figures 4 and 7, the effects of a contractionary technology shock are therefore very similar to those of a decline in government spending.

6 Welfare implications of stabilization policies

Finally, Figure 2 below shows how a change in the policy stance, as measured by changes in ϕ_{GY} , affects total welfare in this economy.²⁰ The y axis measures the annualized variation in welfare that would be obtained by changing ϕ_{GY} from its estimated value. As shown by the continuous blue line, which depicts the overall effect obtained in the model estimated with all shocks, the relationship between fiscal policy and welfare is highly nonlinear. Compared to the estimated fiscal rule, an increase in ϕ_{GY} from 0.305 to 0.5, which implies more countercyclical fiscal policy stance, generates a decline in lifetime utility of about 0.4 percent. By contrast, for values of ϕ_{GY} between 0.305 and -0.2, an increase in welfare, which can reach 0.5 percent of lifetime utility, can be obtained by adopting a more procyclical stance. For values of ϕ_{GY} lower than -0.2, however, the direction of the effect changes abruptly and the relationship becomes highly nonlinear. Once this threshold is crossed, any further increase in the degree of procyclicality generates a welfare loss that may exceed three percent of lifetime utility.

²⁰Welfare is given by $V_t = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_t, X_{t-1}, N_t)$.

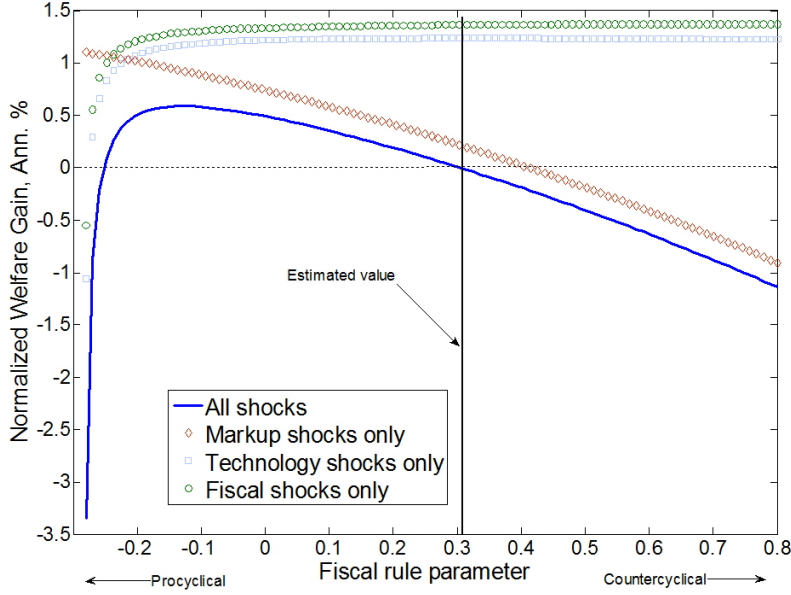


Figure 2: Fiscal policy stance and welfare.

The overall shape depicted by the blue continuous line can be explained by the relative contribution of the different shocks. For instance, as shown by the red diamonds, adopting a more countercyclical fiscal policy always reduces welfare when markup shocks are the only source of business cycle fluctuations. By contrast, if technology or government spending shocks are the only sources of shocks, adopting a more countercyclical fiscal policy stance is always welfare improving.

The overall shape of this relationship can be better understood by examining how a change in the cyclicity of fiscal policy affects the volatility of the composite good and inflation. The left panel of Figure 3, which shows the impact of ϕ_{GY} on $\Delta_{p,t}$, illustrates that the effect of strongly procyclical fiscal policy on welfare works mainly through its effect on the price dispersion term. For small values of ϕ_{GY} , fiscal policy becomes strongly procyclical and generates extreme fluctuations in inflation. In New Keynesian models, the introduction of price stickiness creates a link between inflation volatility and welfare, which can be illustrated by the usual second-order Taylor approximation to $\Delta_{p,t}$ (e.g., Gali, 2008):

$$\Delta_{p,t} \simeq 1 + \frac{\epsilon}{2} \int_0^1 \left[\log \left(\frac{P_t(i)}{P_t} \right) \right]^2 di.$$

Since the price dispersion term directly enters the production function, inflation volatility has a direct effect on welfare that can be captured by a solution method that computes a second or a third-order perturbation to the equilibrium dynamics of the economy (e.g. Adjemian et al., 2012).

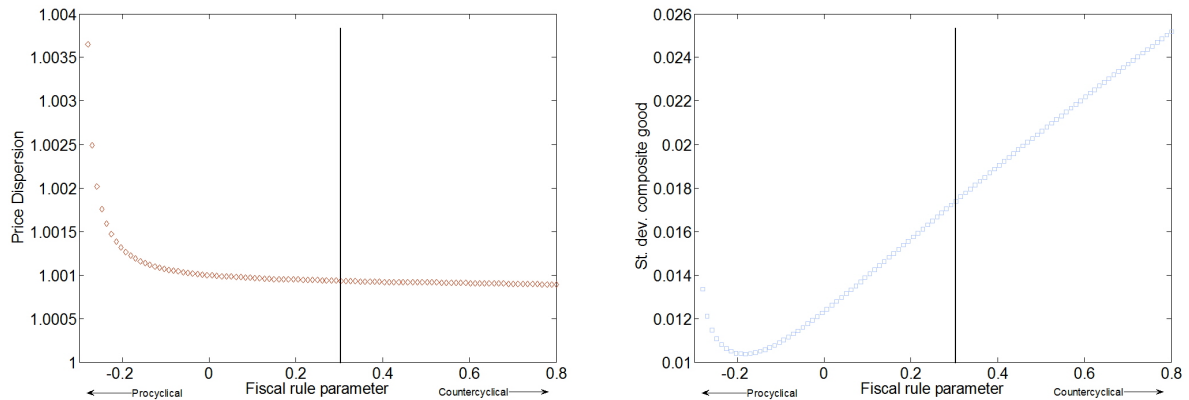


Figure 3: Price dispersion and composite good volatility.

The price dispersion effect cannot, however, explain the inverted U-shape depicted by the blue continuous line. For values of ϕ_{GY} greater than zero, the relationship depicted by the red diamonds flattens out, which shows that inflation volatility cannot account for the negative effect of countercyclical fiscal policy on welfare observed for this particular range of parameter values. As illustrated by the right panel of Figure 3, this effect is rather due to the volatility of the composite good, whose volatility increases with the degree of countercyclicity of fiscal policy for values of ϕ_{GY} greater than -0.2.

In sum, the overall shape of the blue continuous line shown in Figure 2 can firstly be explained by the inflation effect, which dominates for small values of ϕ_{GY} , implying a strongly procyclical fiscal stance. Second, for values of ϕ_{GY} greater than -0.1, the particular co-movement generated by markup shocks implies that countercyclical fiscal policy hampers smoothing of the composite good. For higher degrees of countercyclicity, this latter effect dominates, and excessive fiscal stabilization can become counterproductive. Compared to the estimated value, increasing ϕ_{GY} to 0.8 would for instance cause a decline in welfare of about one percent.

7 Conclusions

The effects of fiscal stabilization on welfare and government bond pricing in a general equilibrium context have not yet been studied widely. Against the background of fiscal stabilization being at the center stage of academic and the public debate since the global financial crises, the failure of standard DSGE model to address these questions is quite apparent. We present a sticky price general equilibrium model which allows us to analyse the interaction between fiscal stabilisation policy, bond risk premia and welfare. We have confronted the model with the data by estimating it via standard Bayesian methods. In the model, the fluctuations in bond prices and bond risk premia over the business cycle are explained by fluctuations in the nominal stochastic discount factor, which in turn is driven by demand and supply shocks.

If the shocks that drive output and inflation in different directions (such as markup shocks) are the only source of business cycle fluctuations, fiscal stabilization policy exacerbates inflation risk and bond risk premia increase. More stable output, due to countercyclical fiscal policy, comes at the cost of more volatile inflation. In this case, active fiscal stabilization policy increases the bond risk premium and reduces welfare. In contrast, if demand shocks that generate positive co-movement between inflation and output are predominant, active fiscal stabilization policy leads to less volatile output. In this case, inflation acts as a hedge against business cycle fluctuations by increasing the value of long-term bonds in periods of recession. This reduces the bond premium and increases welfare. These two opposing effects mean that, overall, the merits of fiscal stabilisation depend on what is driving the business cycle.

Our estimation results suggest when the fiscal policy stance is initially mildly procyclical, small increases in the degree of procyclicality can generate large increases in the bond premium. The welfare costs of highly procyclical fiscal policy are also very large. By contrast, the bond premium is considerably less sensitive to changes in the cyclicity of fiscal policy when the initial stance of policy is countercyclical. Finally, excessive fiscal stabilization can also generate non-negligible welfare losses, suggesting that excessive fiscal stabilization could be more costly than is usually assumed.

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A Additional Figures and Tables

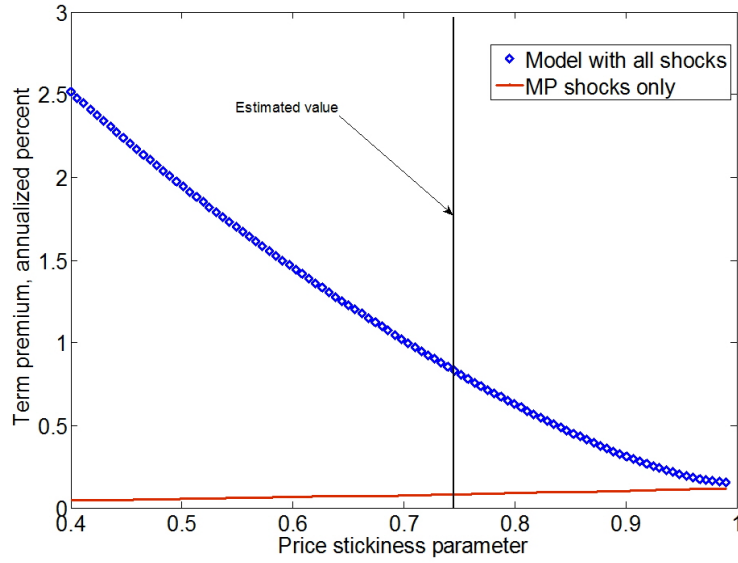


Figure A1: Calvo parameter and the bond premium. Simulated model with all shocks vs. model with monetary policy shocks only.

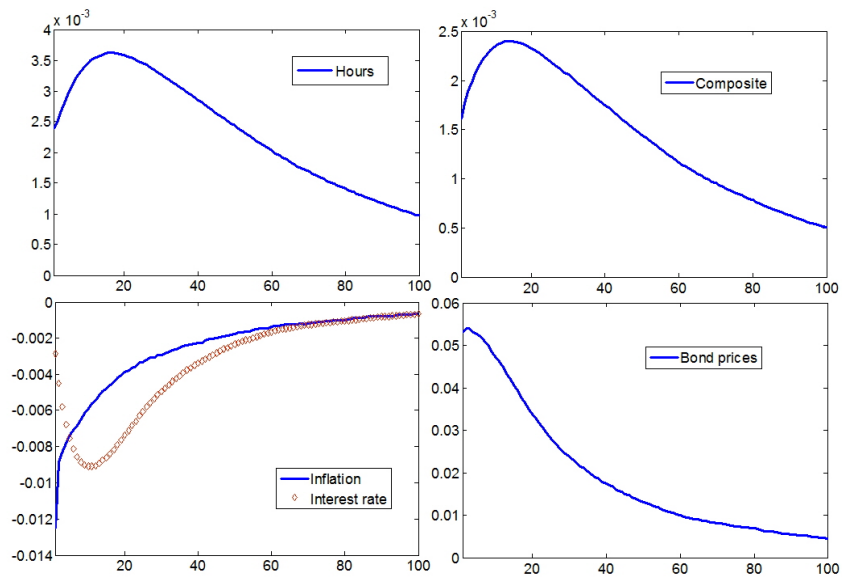


Figure A2: Impulse reponse to an exogenous reduction in price markups.

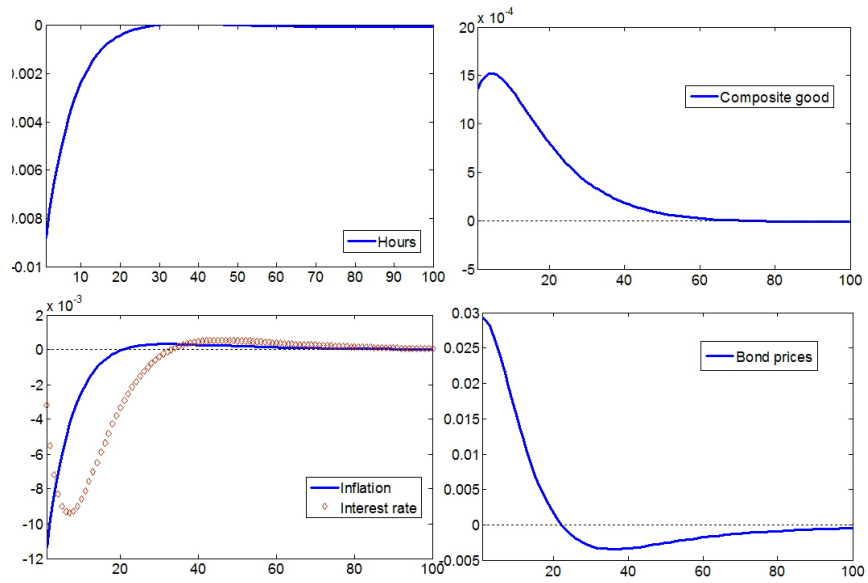


Figure A3: Impulse response to a TFP shock.

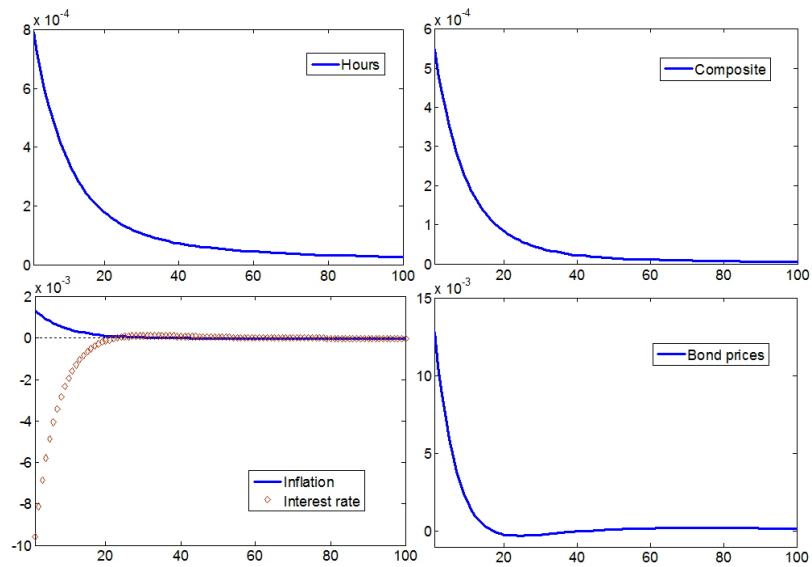


Figure A4: Impulse response to an expansionary monetary policy shock.

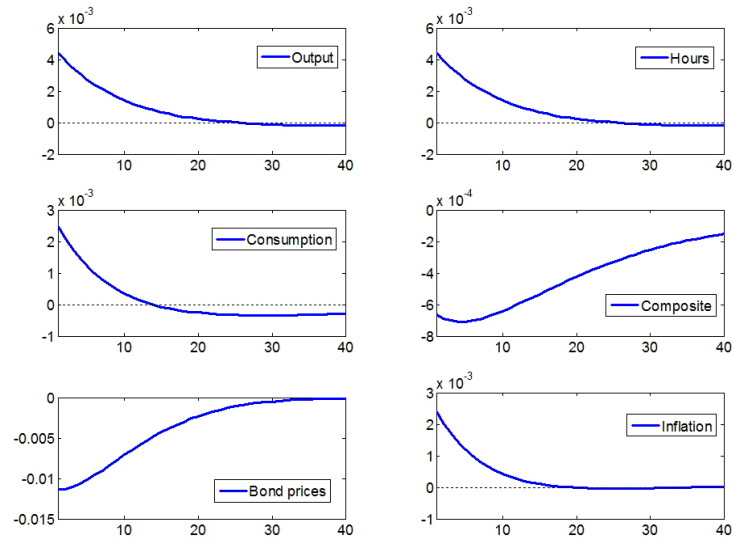


Figure A5: Impulse response to a positive government spending shock.

TABLE A1—ESTIMATION RESULTS

Parameter	Prior			Posterior				
	Type	Mean	Std	Mode	Mean	5% CI	95% CI	
Firms and Households								
Habit formation	b	B	0.60	0.10	0.86	0.84	0.80	0.88
Habit memory	m	B	0.90	0.01	0.90	0.90	0.88	0.92
Calvo	θ	B	0.50	0.05	0.75	0.74	0.69	0.79
Fiscal Policy Rules								
Exp. resp. to debt	ϕ_{GB}	G	0.03	0.02	0.003	0.004	0.001	0.008
Exp. resp. to output	ϕ_{GY}	N	0.00	0.50	0.297	0.305	0.208	0.400
Tax resp. to debt	$\phi_{\tau B}$	G	0.03	0.02	0.010	0.014	0.004	0.020
Tax resp. to output	$\phi_{\tau Y}$	G	0.00	0.5	-0.347	-0.332	-0.411	-0.256
Transfer resp. to debt	ϕ_{TRB}	G	0.015	0.010	0.0018	0.0031	0.0003	0.006
Transfer resp. to output	ϕ_{TRY}	N	0.0	0.5	0.120	0.119	0.045	0.193
Interest rate rule								
Interest rate smoothing	ρ_i	B	0.70	0.15	0.892	0.885	0.854	0.916
Resp. to output	ϕ_x	G	0.50	0.10	0.243	0.215	0.043	0.381
Resp. to inflation	ϕ_π	G	2.00	0.20	2.161	2.138	1.857	2.430
Shock persistence								
Technology shock	ρ_a	B	0.70	0.15	0.907	0.903	0.866	0.940
Markup shock	ρ_π	B	0.70	0.15	0.983	0.977	0.959	0.996
Markup shock	$\rho_{\pi ma}$	B	0.50	0.20	0.198	0.198	0.090	0.306
Expenditure shock	ρ_G	B	0.70	0.15	0.923	0.917	0.869	0.962
Tax shock	ρ_τ	B	0.70	0.15	0.910	0.917	0.848	0.990
Transfer shock	ρ_{TRY}	B	0.70	0.15	0.813	0.817	0.733	0.901
Standard Deviations								
Technology shock	σ_a	G^{-1}	0.01	0.01	0.0049	0.0051	0.0043	0.0059
Mark-up shock	σ_π	G^{-1}	0.50	0.20	0.481	0.478	0.392	0.567
Interest Rate shock	σ_i	G^{-1}	0.002	0.002	0.0025	0.0025	0.0023	0.0028
Expenditure shock	σ_G	G^{-1}	0.005	0.004	0.0030	0.0031	0.0026	0.0036
Tax shock	σ_τ	G^{-1}	0.005	0.004	0.0030	0.0031	0.0028	0.0034
Transfer shock	σ_{TR}	G^{-1}	0.005	0.004	0.0037	0.0037	0.0034	0.0041

Note: \mathcal{B} , \mathcal{G} and \mathcal{G}^{-1} correspond to Beta, Gamma and inverse Gamma distributions. Posterior densities were computed by creating a sample of 700'000 draws with initial burning sample of 105'000 draws. Average acceptance rate of the chain was roughly 25%. The sample period is 1971Q1-2009Q4.

TABLE A2—MODEL VS. DATA

	Standard Deviation		Correlation with consumption	
	$\sigma(\Delta X)$		$\rho(\Delta X, \Delta C)$	
	Data	Model	Data	Model
$\sigma(\Delta Y)$	0.92	0.66	0.67	0.93
$\sigma(\Delta C)$	0.71	0.68	1	1
$\sigma(\Delta N)$	0.90	1.07	0.48	0.95
$\sigma(\Delta w)$	0.64	1.02	0.30	0.91
$\sigma(\Delta G/Y)$	3.15	3.12	-0.25	-0.28
$\sigma(\Delta TR/Y)$	3.54	3.81	-0.15	-0.18
$\sigma(\Delta D/Y)$	1.91	1.47	-0.22	-0.49
$\sigma(\Delta TaxL/Y)$	2.66	1.96	0.17	0.14

Inflation and Interest Rates

	Standard Deviation		Correlation with consumption	
	$\sigma(\Delta X)$		$\rho(\Delta X, \Delta C)$	
	Data	Model	Data	Model
rr_t	2.59	3.84	-0.11	-0.14
π_t	2.31	4.19	-0.29	-0.08

Bond Premium and Real Interest Rate

	Mean		Std. Deviation	
	ψ_t^{40}		rr_t	
	Data	Model	Data	Model
ψ_t^{40}	1.06	0.86	0.54	0.33
rr_t	2.19	0.80	2.59	3.84

Note: This table compares the implication of the estimated model with a series of business cycle and asset pricing stylized facts. Business cycle statistics are expressed in quarterly growth rates, where $\sigma(\Delta X)$ denotes the standard deviation of the variable under study and $\rho(\Delta C, \Delta Y)$ is its correlation with consumption. Inflation, the real interest rate and the bond premium are expressed in annualized percent. The stylized facts for the bond premium are taken from Rudebusch and Swanson (2012). Except for the standard deviation of ψ_t^{40} , all the model implications are computed using a second-order approximation.

TABLE A3: VARIANCE DECOMPOSITION

	Tech. (A_t)	Gov. exp. (G_t)	Mon. pol. (i_t)	Mark-up ($\epsilon_t/(\epsilon_t - 1)$)	Other (τ_t), ($TR_{Y,t}$)
Output (Y_t)	37.0	47.8	1.5	13.0	0.7
Inflation (Π_t)	24.4	1.0	0.4	72.0	2.2
Bond Prices (Q_t^L)	20.0	3.0	4.0	71.9	1.1
Marginal Utility (U_{Ct})	31.4	7.1	17.4	42.6	1.5

Note: This table shows the forecast error variance decomposition of the estimated model. Shocks to transfers and taxes have negligible impact on the dynamics of the variables, so their contributions are not shown separately in this table.

TABLE A4: CONTRIBUTION TO THE BOND PREMIUM IN %

Technology (A_t)	Gov. spending (G_t)	Mon. policy (i_t)	Mark-up ($\epsilon_t/(\epsilon_t - 1)$)	Other (τ_t), ($TR_{Y,t}$)
25.6	5.1	9.7	58.1	1.5

TABLE A5: CORRELATION OF THE BOND PREMIUM WITH OUTPUT

	Technology (A_t)	Fiscal Shocks ($G_t, \tau_t, TR_{Y,t}$)	Mon. policy (i_t)	Mark-up ($\epsilon_t/(\epsilon_t - 1)$)	Model simulated with all shocks
$\rho(\log Y, \psi_t^{40})$	0.81	0.64	-0.86	-0.87	-0.73

Note: Based on a third-order approximation and a sample of 15'000 observations.

B Price dispersion and real marginal costs

The price dispersion term is small up to the first-order approximation (e.g. Gali, 2008), so it is usually dropped from the log linear approximation of the aggregate production function. However, since we work on higher-order approximations, we define

$$\begin{aligned}\Delta_{P,t} &= \left(\frac{1}{P_t}\right)^{\frac{-\epsilon_t}{1-\alpha}} \int_0^1 P_t(i)^{\frac{-\epsilon_t}{1-\alpha}} di, \\ &= \theta \Pi_t^{\frac{\epsilon_t}{1-\alpha}} + (1-\theta) \left(\frac{P_t^*/P_{t-1}}{\Pi_t}\right)^{\frac{-\epsilon_t}{1-\alpha}},\end{aligned}\tag{33}$$

where $\Pi_t^{1-\epsilon_t} = \theta + (1-\theta) \left(\frac{P_t^*}{P_{t-1}}\right)^{1-\epsilon_t}$ gives the aggregate inflation dynamics. In the non-stochastic steady state, $\Delta_{P,t} = 1$ under the assumption that price level is constant in the steady state (e.g. Gali 2008, ch. 3).

The equilibrium also entails the derivation of an individual firm's marginal cost in terms of the economy's average real marginal cost to be used in the evaluation of optimal price setting condition. It can be shown that $\mathcal{MC}_{t+k|t} = \left(\frac{P_t^*}{P_{t+k}}\right)^{-\frac{\epsilon_t}{1-\alpha}} \mathcal{MC}_{t+k}$ and where \mathcal{MC}_{t+k} denotes the economy's average real marginal cost, defined as

$$\mathcal{MC}_{t+k} \equiv \frac{W_{t+k}/P_{t+k}}{MPN_{t+k}}.\tag{34}$$

MPN_{t+k} denotes the economy's average marginal productivity of labour and the real wage W_{t+k}/P_{t+k} is evaluated according to the intratemporal condition from the household's problem (7).

C Dynamic model equations

Recursive representation of the optimal pricing equation:

$$z_t^N = \mathcal{M}CY_t\Pi_t^{\frac{(1+\epsilon)}{1-\alpha}} + \theta\beta\mathbb{E}_t\frac{U_{C,t+1}}{U_{C,t}}\Pi_t^{-1}z_{t+1}^N \quad (35)$$

$$z_t^D = Y_t\Pi_t^\epsilon + \theta\beta\mathbb{E}_t\frac{U_{c,t+1}}{U_{c,t}}\Pi_t^{-1}z_{t+1}^D \quad (36)$$

$$(\Pi_t^*)^{1-\epsilon+\frac{\epsilon}{1-\alpha}} = z_t^{NN}/z_t^D \quad (37)$$

$$\Pi_t^{1-\epsilon} = \theta + (1-\theta)(\Pi_t^*)^{1-\epsilon} \quad (38)$$

$$z_t^{NN} = \mathcal{M}z_t^N \quad (39)$$

Price dispersion:

$$\Delta_{p,t} = \theta\Pi_t^{\frac{\epsilon}{1-\alpha}} + (1-\theta)\left(\frac{\Pi_t^*}{\Pi_t}\right)^{-\frac{\epsilon}{1-\alpha}} \quad (40)$$

Short-term bond pricing equation:

$$Q_t^S = \beta\mathbb{E}_t\frac{U_{c,t+1}}{U_{c,t}}\Pi_t^{-1} \quad (41)$$

Yield of short-term bond:

$$i_t = -\log(Q_t^S) \quad (42)$$

Marginal utility of consumption:

$$U_{C,t} = (C_t(\phi + (1-N_t)^\varsigma) - bX_{t-1})^{-\sigma}(\phi + (1-N_t)^\varsigma) \quad (43)$$

$$+(1-m)(\phi + (1-N_t)^\varsigma)\varphi_t \quad (44)$$

Evolution of habit stock:

$$X_t = mX_{t-1} + (1-m)C_t(\phi + (1-N_t)^\varsigma) \quad (45)$$

Evolution of Lagrange multiplier associated with habit stock:

$$\varphi_t = m\beta\mathbb{E}_t\varphi_{t+1} - b\beta\mathbb{E}_t(C_{t+1}(\phi + (1-N_{t+1})^\varsigma) - bX_t)^{-\sigma} \quad (46)$$

Intratemporal condition:

$$\begin{aligned}
(1 - \mathbf{t}_t) U_{C,t} w_t &= (C_t(\phi + (1 - N_t)^\varsigma) - bX_{t-1})^{-\sigma} \\
&\quad (\varsigma C_t(1 - N_t)^{\varsigma-1}) \\
&\quad + (1 - m) \varphi_t C_t \varsigma (1 - N_t)^{\varsigma-1}
\end{aligned} \tag{47}$$

Economy-wide real marginal costs:

$$\mathcal{MC}_t = w_t / ((1 - \alpha) Y_t / N_t) \tag{48}$$

Long-term bond pricing equations (risk-neutral price and risk-adjusted price):

$$\hat{Q}_t^L = 1 + \mathbb{E}_t(\delta_c \hat{Q}_{t+1}^L / \exp(i_t)) \tag{49}$$

$$Q_t^L = 1 + \delta_c \beta \mathbb{E}_t\left(\frac{U_{C,t+1}}{U_{C,t}} \Pi_{t+1}^{-1} Q_{t+1}^L\right) \tag{50}$$

Long-term bond yields (risk-neutral yield and risk-adjusted yield):

$$\widehat{\mathbf{i}}_t^L = \log(\delta_c \hat{Q}_t^L / (\hat{Q}_t^L - 1)) \tag{51}$$

$$\mathbf{i}_t^L = \log(\delta_c Q_t^L / (Q_t^L - 1)) \tag{52}$$

Bond premium:

$$\psi_t^L \equiv \mathbf{i}_t^L - \widehat{\mathbf{i}}_t^L \tag{53}$$

Excess holding return:

$$\epsilon_t^{hr} = (\delta_c Q_t^L + \exp(i_{t-1})) / Q_{t-1}^L - \exp(i_{t-1}) \tag{54}$$

Government real budget constraint:

$$Q_t^L B_{PY,t} = B_{PY,t} + \delta_c Q_t^L B_{PY,t-1} \Pi_t^{-1} (Y_t / Y_{t-1})^{-1} - S_{Y,t} \tag{55}$$

Primary surplus-to-output ratio:

$$S_{Y,t} = (1 - \alpha) \tau_t \mathcal{MC}_t - G_{Y,t} - TR_{Y,t} \tag{56}$$

Aggregate output:

$$Y_t = \exp(A_t) (N_t/\Delta_{p,t})^{1-\alpha} \quad (57)$$

Consumption-to-output ratio:

$$C_{Y,t} = 1 - G_{Y,t} \quad (58)$$

Consumption:

$$C_t = C_{Y,t}Y_t \quad (59)$$

Fiscal rules (Government consumption, labour income tax rate, lump-sum transfers):

$$G_{Y,t} = G_Y - \phi_{GY}\left(\frac{Y_t}{\bar{Y}} - 1\right) - \phi_{GB}\left(\frac{D_{Y,t-1}}{D_Y} - 1\right) + \epsilon_t^G \quad (60)$$

$$\tau_t = \tau + \phi_{\tau Y}\left(\frac{Y_t}{\bar{Y}} - 1\right) + \phi_{\tau B}\left(\frac{D_{Y,t-1}}{D_Y} - 1\right) + \epsilon_t^\tau \quad (61)$$

$$TR_{Y,t} = TR_Y - \phi_{TRY}\left(\frac{Y_t}{\bar{Y}} - 1\right) - \phi_{TRB}\left(\frac{D_{Y,t-1}}{D_Y} - 1\right) + \epsilon_t^{TR} \quad (62)$$

Real value of government debt outstanding:

$$D_{Y,t} = \delta_c Q_t^L B_{PY,t} \quad (63)$$

Monetary policy rule:

$$i_t = \rho_i i_{t-1} + (1 - \rho_i)[\log(1/\beta) + \phi_\pi(\log(\Pi_t/\Pi^*)) + \phi_y(\log(Y_t/\bar{Y}))] + \eta_t^i, \quad (64)$$

Exogenous shocks processes:

$$A_t = (1 - \rho_A) \log(\bar{A}) + \rho_A A_{t-1} + \eta_t^A, \eta_t^A \sim N(0, \sigma_A^2) \quad (65)$$

$$\epsilon_t^G = \rho_G \epsilon_{t-1}^G + \eta_t^G, \eta_t^G \sim N(0, \sigma_G^2) \quad (66)$$

$$\epsilon_t^\tau = \rho_\tau \epsilon_{t-1}^\tau + \eta_t^\tau, \eta_t^\tau \sim N(0, \sigma_\tau^2). \quad (67)$$

$$\epsilon_t^{TR} = \rho_{TR} \epsilon_{t-1}^{TR} + \eta_t^{TR}, \eta_t^{TR} \sim N(0, \sigma_{TR}^2) \quad (68)$$

$$\epsilon_t = \bar{\epsilon} + \rho_\pi \epsilon_{t-1} + \eta_t \sim N(0, \sigma_\pi^2) \quad (69)$$

$$\eta_t^i \sim N(0, \sigma_i^2) \quad (70)$$

D Construction of data

We explain the construction of the data set in detail. Our approach follows Leeper, Plante and Traum (2010) for fiscal variables, Hall (2009) for hours, and Gurkaynak, Sack and Wright (2007) for bond yields. Our complete dataset covers years 1955-2009, but the model is parameterized and estimated using the period 1971Q1-2007Q4.

PY: Gross Domestic Product. *Source*: Bureau of Economic Analysis (BEA), Nipa Table 1.1.5, line 1.

P: GDP deflator for personal consumption expenditures. *Source*: BEA, Nipa Table 1.1.4, line 2.

C: Private consumption. *Source*: Bureau of Economic Analysis, Nipa Table 1.1.6, line 2

N: Hours, measure of labour input. This is computed as $N = H \times (1 - U/100)$, where H and U are the average over monthly series of hours and unemployment. *Source*: Bureau of Labour Statistics, series LNU02033120 for hours and LNS14000000 for unemployment.

INT: Net interest payments of federal government debt. *Source*: Bureau of Economic Analysis, Nipa Table 3.2, (line 29-line 13).

M: Adjusted Monetary Base. *Source*. ST. Louis Database, series AMBSL.

G: Government consumption. This is computed as $G =$ current consumption expenditures (line 21) + gross government investment (line 42) + net purchases of non-produced assets (line 44)-consumption of fixed capital (line 45). *Source*: BEA, Nipa Table 3.2.

TR: Net transfers. This is computed as $TR =$ net current transfers (line 22-line 16)+net capital transfers (line 43-line 39) + subsidies (line 32)- current surplus of government enterprises (line 19). *Source*: BEA, Nipa Table 3.2.

TAXR: Total federal tax revenues. This is computed as $TAXR =$ current tax receipts (line 2)+contributions for government social insurance (line 11). *Source*: BEA, Nipa Table 3.2.

S: Primary surplus. This is computed as $S_t = TAXR_t - (G_t + TR_t)$, where G_t is government consumption, TR_t are net transfers and $TAXR_t$ are total federal tax revenues.

D: Federal government debt. This is computed as $D_t = D_{t-1} + INT_t - S_t - (M_t - M_{t-1})$, where S_t is primary surplus INT_t are net interest payments of federal

government debt and $M_t - M_{t-1}$ is seignorage. The initial value of debt is set equal to the market value of Gross Federal Debt in March 1955. *Source:* BEA, Nipa Table 3.2 and <http://www.dallasfed.org/data/data/natdebt.tab.htm> for the initial value of debt.

WN_t : Labour income tax base. *Source:* Nipa Table 1.12, line 3.

τ : Average effective labour income tax rate. Computed following Jones (2002) and Leeper, Plante and Traum (2010).

$LTAXR$: Labour tax revenues. This is computed as $LTAXR_t = \tau_t \times WN_t$, where WN_t denotes labour income tax base (Nipa Table, 1.12, line 3) and τ_t is effective labour income tax rate.

i : Federal funds effective rate. Quarterly average over monthly series. *Source:* Board of Governors of the Federal System, H.15. Selected Interest rates, Series RIF-SPFF_N.M.

i_t^L : 10-Year Treasury Constant Maturity Rate. *Source:* Board of Governors of the Federal Reserve System, Series ID:GS10.

ψ_t^L : Bond risk premium. Taken from Rudebusch and Swanson (2008, 2012).

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