Does Fiscal Policy Matter for Stock-Bond Return Correlation? *

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Abstract

Switching between monetary and fiscal regimes is incorporated in a general-equilibrium model to explain three stylized facts: (1) a positive correlation of stock and bond returns in 1971-2001 and a negative correlation after 2001, (2) a negative correlation of consumption and inflation in 1971-2001 and a positive correlation after 2001, and (3) the coexistence of a positive bond risk premium and a negative correlation of stock and bond returns. While the technology shock drives the positive stock-bond and negative consumption-inflation correlations in the monetary regime, the investment shock drives the negative stock-bond and positive consumption-inflation correlations in the fiscal regime.

Keywords: Stock-bond return correlation, consumption-inflation correlation, the M regime, the F regime, bond risk premium, technology shock, investment shock.

JEL classification: G12, G18, E52, E62

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1 Introduction

Empirical studies have documented the time-varying correlation between returns on the market portfolio of stocks and returns on long-term (5-10 years) nominal Treasury bonds (Campbell et al., 2017; Christiansen and Ranaldo, 2007; Guidolin and Timmermann, 2007; Baele et al., 2010; David and Veronesi, 2013; Baele and Holle, 2017). This correlation was positive before 2001 but turned negative afterwards (Panel A of Figure 1). At the same time, the correlation between consumption growth and inflation also changed sign around 2001 from negative to positive (Panel B of Figure 1).[1] Moreover, the risk premiums of long-term nominal Treasury bonds were positive before and after 2001 as shown in Section 2.

Existing explanations for the sign change of stock-bond correlation around 2001 focus on the effects of monetary policy. Song (2017), for example, argues that monetary policy was more aggressive as inflation became procyclical, which led to a shift in the stock-bond correlation. Campbell et al. (2020) rely on the sign switch in the correlation between inflation and output gap, as well as a stronger reaction of monetary policy to output gap after 2001. In this paper, we provide an alternative explanation that emphasizes the role of a mix of monetary and fiscal policies identified by Bianchi et al. (forthcoming) in accounting for sign changes of correlations observed in both the financial market and the real economy.[2] To this end, we develop a general equilibrium framework that incorporates switching between the monetary regime (the M regime) and the fiscal regime (the F regime). We model the M regime as a mix of active monetary policy and passive fiscal policy, and the F regime as a mix of active fiscal policy and passive monetary policy (Bianchi and Ilut, 2017; Bianchi and Melosi, 2017; Leeper et al., 2017).

Monetary policy is modeled as a simple Taylor rule, in which the short-term nominal interest rate reacts to inflation and output gap positively. The policy rate reacts to inflation more than one-for-one under active monetary policy, while less than one-for-one under passive monetary policy. Fiscal policy is modeled as a lump-sum tax rule that reacts to outstanding government debt and output (Leeper, 1991). Under passive fiscal policy, lump-sum taxes increase proportionately (in the present value) with government spending to satisfy the government budget constraint. Under active fiscal policy, the government budget constraint also holds, but taxes do not increase sufficiently to finance government spending; as a result,

[1]Due to differences in data and methodology, the exact break dates of the stock-bond return correlation and consumption-inflation correlation identified by these cited papers range between 1999 to 2002. We provide empirical evidence on the break date in our sample in Section 2.

[2]Our paper contributes to a growing body of literature studying the asset pricing implications of government policies in a general equilibrium framework. In addition to Song (2017) and Campbell et al. (2020), see Van Binsbergen et al. (2012), Rudebusch and Swanson (2012), Dew-Becker (2014), Kung (2015), and Li and Palomino (2014).

prices increase with government deficits to reduce the real debt burden. A switch from the M regime to the F regime took place in the early 2000s (Bianchi et al., forthcoming), around the same time when the consumption-inflation correlation and the stock-bond return correlation changed sign.

To assess how important a switch to the F regime is in explaining sign changes of these observed correlations, we study a general equilibrium model with four structural shocks: the technology shock defined as a shock to neutral technology (NT), the investment shock defined as a shock to the marginal efficiency of investment (MEI), the monetary policy (MP) shock, and the fiscal policy (FP) shock. In addition to the technology shock, Justiniano et al. (2010) show that the MEI shock as an investment shock contributes significantly to the business cycle fluctuation and economic growth. We calibrate the model to match moments of key macroeconomic and financial variables and show that technology and investment shocks, not monetary and fiscal policy shocks, are critical to yielding the following key results:

1. Both the positive stock-bond return correlation and the negative consumption-inflation correlation are driven by the technology shock under the M regime.

2. Both the negative stock-bond return correlation and the positive consumption-inflation correlation are driven by the investment shock under the F regime.

3. The negative stock-bond return correlation coincides with positive bond risk premiums under the F regime.

Since the seminal work of Leeper (1991), a growing literature has studied the joint behavior of monetary and fiscal authorities. We extend the standard new Keynesian model to incorporating this joint policy behavior as well as a recursive preference with habit formation to generate realistic risk premiums. We show that the mix of the M and F regimes is essential to account for the aforementioned correlation patterns and bond risk premiums. A positive technology shock, as a positive supply shock, causes both output and consumption to increase while driving down prices. The resulting consumption-inflation correlation becomes negative. The rise in consumption and the persistent fall in the short-term nominal interest rate as the monetary authority's reaction to falling inflation lead to higher stock prices and higher prices of long-term nominal Treasury bonds. As a result, the stock-bond return correlation is positive in response to the technology shock. Under the M regime, the interest rate falls more than inflation and thus the real interest rate falls as well. A fall in the real interest rate further stimulates output and consumption. Active monetary policy thus amplifies the effect of the technology shock and makes this shock a dominating force behind both the negative consumption-inflation correlation and the positive stock-bond return correlation. On the contrary, under the F regime, the nominal interest rate falls less than inflation due to passive monetary policy and as a result the real interest rate increases in response to a positive technology shock. Therefore, the stimulating effect of the technology shock is largely muted and this shock becomes unimportant for determining the correlations between consumption and inflation and between returns on stocks and on long-term bonds.

In the F regime, the investment shock becomes the dominating force for generating the stock-bond return correlation and the consumption-inflation correlation. A positive investment shock makes the transformation of investment into capital more efficient. In response to this positive shock, both output and investment increase but consumption decreases in the short run as an intertemporal substitution for higher consumption in the long run. The dominating effect of declining consumption in the short run causes the stock prices to fall. An increase in output leads to an increase in tax income and a decrease in government deficits. It follows from the government budget constraint that the price level must fall to make the real value of existing government debt more valuable. The falling price level leads to a reduction in the nominal interest rate according to the Taylor rule; as a result, bond prices rise. Under the F regime, therefore, the investment shock generates the negative stock-bond return correlation and the positive consumption-inflation correction.

Consistent with the empirical observation, risk premiums of long-term Treasury bonds in the model remain positive under the F regime while the stock-bond return correlation is negative. The key to this result is that the dynamics of the pricing kernel, thus risk premiums, in the model are driven mainly by the technology shock, regardless of policy regime. Since stock and bond risk premiums both respond positively to a technology shock, positive bond risk premiums and the negative stock-bond return correlation coexist in the F regime.

In summary, the technology shock drives the positive stock-bond return correlation and the negative consumption-inflation correlations in the M regime, while the investment shock drives the negative stock-bond return correlation and the positive consumption-inflation correlation in the F regime. Unlike standard one-factor asset pricing models such as the Capital Asset Pricing Model (CAPM), our model has multiple fundamental shocks. These features enable the model to generate positive risk premiums in long-term bonds, even when the stock-bond return correlation is negative. Our results are robust to alternative preferences, such as constant relative risk aversion (CRRA) and recursive preferences without habit formation, to an expanded model with additional fundamental shocks commonly seen in the literature, and to alternative parameter values, such as a lower risk aversion parameter, a reasonable range of possible values for shock volatilities, and fixed regime-switching parameters(except for the two that define policy regimes). They hold when the nominal interest rate is at the zero lower bound (ZLB)—an extreme case of the F regime.

The rest of the paper is organized as follows. Section 2 presents stylized facts under the two policy regimes. Section 3 presents a general equilibrium model with regime switching between monetary and fiscal policies. Section 4 discusses the asset pricing implications of the model. Section 5 discusses the robustness of model results. Section 6 offers concluding remarks.

2 Stylized facts and policy regimes

Following Bianchi and Ilut (2017), Bianchi and Melosi (2017), and Leeper et al. (2017), we define the M regime as a mix of active monetary policy and passive fiscal policy, and the F regime as a mix of active fiscal policy and passive monetary policy. Monetary policy is commonly modeled as a linear response function of the short-term nominal interest rate (r_t) to inflation (π_t) and output growth (Δy_t):

$$r_t \sim \phi_\pi \pi_t + \phi_y \Delta y_t \,, \tag{2.1}$$

where the coefficients ϕ_π and ϕ_y measure the corresponding responsiveness. If the interest rate increases more than inflation, i.e., $\phi_\pi > 1$, monetary policy is active; if $\phi_\pi < 1$, monetary policy is passive (Leeper, 1991).

The fiscal authority faces the government's budget constraint that equates taxes and newly issued debt with government spending and debt payments. In the standard new Keynesian model (Davig and Leeper, 2011; Leeper, Traum and Walker, 2017), fiscal policy is modeled as a linear response function of the tax-to-output ratio (τ_t) to the lagged government debt-to-output ratio (b_{t-1}) and the government expenditure-to-output ratio (g_{yt}):

$$\tau_t \sim \varsigma_b b_{t-1} + \varsigma_g g_{yt} \,, \tag{2.2}$$

where the coefficients ς_b and ς_g measure the corresponding responsiveness. Fiscal policy is passive if taxes respond strongly to the government debt with $\varsigma_b > e^{r-\pi-\Delta y} - 1$, where r and π are the steady-state nominal interest rate and inflation.[3] Fiscal policy is active if taxes do not respond strongly to the outstanding government debt ($\varsigma_b \leq e^{r-\pi-\Delta y} - 1$).

[3] Substituting the fiscal policy rule into the log-linearized government budget constraint represented by equation (3.7) in Section 3.5 leads to the debt dynamics as $\tilde{b}_t = [e^{r-\pi-\Delta y} - \varsigma_b]\tilde{b}_{t-1}$ (other terms are omitted for illustration), where $\tilde{b}_t$ is the log-linearized deviation from the steady state. The condition $\varsigma_b > e^{r-\pi-\Delta y} - 1$ guarantees that debt is mean reverting and fiscal policy is passive in the sense that it ensures the debt stability to accommodate the behavior of the monetary authority. Leeper (1991) shows that when this condition is violated, the process of debt can be stabilized by passive monetary policy ($\phi_\pi < 1$) to accommodate fiscal policy.

Whether fiscal policy is active does not depend on the level of government debt, but rather on how sensitive taxes are in response to the ratio of government debt to GDP. When fiscal policy is active, the price level must adjust so that the government budget constraint is satisfied. For example, prices would need to rise to reduce real government liabilities when the government's income (taxes plus new debt issuances) is insufficient to meet its spending and liabilities. Passive fiscal policy influences macroeconomic fluctuations by responding strongly to the level of outstanding government debt. Active fiscal policy, however, influences the price level directly, which in turn affects other macroeconomic variables.

Campbell et al. (2020) find that a structural break in the stock-bond return correlation and the output-inflation correlation occurred in 2001Q2. Around this time, the economy switched from the M to F regime according to the estimation by Bianchi et al. (forthcoming).[4] Table 1 presents key data moments in the two subperiods: 1971Q1-2001Q1 (the M regime) and 2001Q2-2018Q4 (the F regime). Specifically, the correlation between consumption growth rate (Δc_t) and inflation (π_t) is -0.44 for the first subperiod and 0.27 for the second subperiod; the correlation between (daily) returns on the stock market index ($r_{s,t}$) and returns on nominal (zero-coupon) Treasury bonds of 5-year maturity ($r_{b,t}^{(5)}$) is 0.21 for the first subperiod and -0.31 for the second subperiod; and the (annualized) average monthly excess returns on the 5-year Treasury bonds are 1.87% and 2.03% for the two subperiods. We summarize these key facts as follows.

1. The annual correlation between consumption growth and inflation was negative in the M regime and positive in the F regime.

2. The correlation between returns on stocks and nominal long-term Treasury bonds was positive in the M regime and negative in the F regime.

3. Nominal long-term Treasury bonds earned positive risk premiums in both the M and F regimes.

In the rest of the paper, we develop a general equilibrium model with a mix of monetary and fiscal policies to account for these facts.

[4]In earlier work, Bianchi and Ilut (2017) and Bianchi and Melosi (2017) identify a monetarily-led regime from the 1980s to the Great Recession. For the correlations we find for the period 1971Q1-2001Q1, one concern is that these correlations are driven by the subsample in the 1970s and early 1980s. We find that the consumption-inflation correlation is negative and the stock-bond return correlation is positive for the subperiod from the early 1970s to the early 1980s as well as for the subperiod from the late 1980s to the early 2000s.

3 Model

Our model follows Smets and Wouters (2007) and Bianchi and Ilut (2017). We focus on four structural shocks that are most commonly used in the macro-finance literature: the technology shock, the investment shock, the MP shock, and the FP shock.

3.1 Households

The lifetime utility function for the representative household is given by

$$V_t \equiv \max_{\{C_t, L_t, B_t/P_t, B_t^S/P_t, I_t\}} \quad (1-\beta)U(C_{h,t}, L_t) + \beta \mathbb{E}_t \left[V_{t+1}^{\frac{1-\gamma}{1-\psi}} \right]^{\frac{1-\psi}{1-\gamma}} \tag{3.1}$$

with $U_t \equiv U(C_{h,t}, L_t) = \frac{C_{h,t}^{1-\psi}}{1-\psi} - A_t^L \int_0^1 \frac{L_{j,t}^{1+\phi}}{1+\phi} dj$, where β is the discount factor, ψ is the elasticity of intertemporal substitution, and ϕ is the inverse of the Frisch elasticity of labor supply. Habit-adjusted consumption $C_{h,t}$ is defined as $C_{h,t} = C_t - b_h \bar{C}_{t-1}$, where C_t is the household's consumption, $\bar{C}_t$ is aggregate consumption, and b_h is the habit parameter. The disutility of labor, $A_t^L = a^L (z_t^+)^{1-\psi}$, grows at a rate of $(z_t^+)^{1-\psi}$, where a^L is the disutility parameter and z_t^+ is the growth rate of the economy. The supply of type j labor is denoted by $L_{j,t}$.

The household maximizes its utility subject to the budget constraint

$$\begin{aligned} & P_t C_t + P_{b,t} B_t + B_t^S + \frac{P_t}{\Psi_t} I_t + \frac{P_t}{\Psi_t} a(u_t) \bar{K}_{t-1} \\ \leq \quad & B_{t-1}(P_{b,t}\rho + 1) + (1 + r_{t-1}) B_{t-1}^S + P_t r_t^k u_t \bar{K}_{t-1} + P_t LI_t + P_t D_t - P_t T_t \,, \end{aligned}$$

where P_t is the price of consumption goods, I_t investment measured in the unit of investment goods rather than consumption goods, and Ψ_t the relative price of consumption to investment goods, and $\bar{K}_t$ the raw capital stock. The real wage income LI_t is defined as $LI_t = \int \frac{W_{j,t}}{P_t} L_{j,t} \, dj$, where $W_{j,t}$ and $L_{j,t}$ are the nominal wage and supply of type-j labor.

The symbol D_t represents the real dividend paid by firms, T_t the lump-sum tax, and B_{t-1}^S the one-period government bond with zero net supply in period $t-1$, whose nominal return is r_{t-1}. To avoid numerical complication, we follow Woodford (2001) and define B_t as the amount of long-term government bonds issued at t with non-zero net supply, each of which has a stream of infinite coupon payments that begins in period $t+1$ with \$1 and decays every period at the rate of ρ. The price of one such long-term bond, $P_{b,t}$, is given by $P_{b,t} = \mathbb{E}_t \left[\sum_{s=1}^{\infty} M_{t,t+s} \rho^{s-1} \right] = \mathbb{E}_t \left[M_{t+1} \left(1 + \rho P_{b,t+1} \right) \right]$, where M_{t+1} is the nominal stochastic discount factor or pricing kernel from period t to $t+1$ and $M_{t,t+s} \equiv \prod_{i=1}^{s} M_{t+i}$.[5]

The symbol r_t^k represents the real rental rate of productive capital paid by producers, u_t is the capital utilization rate, and the capital used in production is $K_t = u_t \bar{K}_{t-1}$. The nominal cost of utilization per unit of raw capital is $\frac{P_t}{\Psi_t} a(u_t)$, where $a(u_t) = r^k[\exp(\sigma_a(u_t - 1)) - 1]/\sigma_a$, with $\sigma_a > 0$.

The capital accumulation follows

$$\bar{K}_t = (1-\delta)\bar{K}_{t-1} + \left[1 - S\left(\frac{I_t}{\zeta_t^I I_{t-1}}\right)\right] I_t \,. \tag{3.2}$$

The investment adjustment cost, $S(\cdot)$, is defined as

$$S(x_t) = \frac{1}{2}\left\{\exp\left[\sigma_s\left(x_t - \exp(\mu^{z^+} + \mu^{\Psi})\right)\right] + \exp\left[-\sigma_s\left(x_t - \exp(\mu^{z^+} + \mu^{\Psi})\right)\right] - 2\right\},$$

where $x_t = \frac{I_t}{\zeta_t^I I_{t-1}}$ and $\exp(\mu^{z^+} + \mu^{\Psi})$ is the steady state growth rate of investment. The parameter σ_s is chosen such that $S(\exp(\mu^{z^+} + \mu^{\Psi})) = 0$ and $S'(\exp(\mu^{z^+} + \mu^{\Psi})) = 0$. The marginal efficiency of investment is measured by ζ_t^I and evolves as

$$\log\left(\zeta_t^I\right) = \left(1 - \rho_{\zeta^I}\right) log\left(\zeta^I\right) + \rho_{\zeta^I} \log\left(\zeta_{t-1}^I\right) + \sigma_{\zeta^I} e_t^{\zeta^I}, \quad e_t^{\zeta^I} \sim \text{IID}\mathcal{N}(0,1), \tag{3.3}$$

where $e_t^{\zeta^I}$ denotes the MEI shock, which we term as the investment shock throughout the paper.

3.2 Final goods producers

The final goods sector is perfectly competitive. The final goods producers combine a continuum of intermediate goods, $Y_{i,t}$, indexed by $i \in [0,1]$, to produce a homogeneous final goods, Y_t, using the Dixit-Stiglitz technology:

$$Y_t = \left[\int_0^1 Y_{i,t}^{\frac{1}{\lambda^p}}\, di\right]^{\lambda^p} \quad , \quad \lambda^p > 1 \,,$$

where λ^p measures the substitutability among different intermediate goods.

[5] The asset pricing implications of the stochastic discount factor as well as stock and bond returns are discussed in Appendix B.

3.3 Intermediate goods producers

The intermediate goods sector is monopolistically competitive. The production of intermediate goods i uses both capital and labor via the homogenous production technology

$$Y_{i,t} = \omega \left(z_t L_{i,t}\right)^{1-\alpha} K_{i,t}^{\alpha} - z_t^{+}\varphi, \tag{3.4}$$

where ω is a total factor productivity, z_t is a non-stationary labor-augmenting neutral technology process, $L_{i,t}$ and $K_{i,t}$ are the labor and capital services employed by firm i, α is the capital share of the output, and φ is the fixed production cost parameter. Following Christiano et al. (2016), we assume that the fixed operating costs grow at the same rate as output to guarantee balanced growth in the nonstochastic steady state. We define z_t^+ as $z_t^+ \equiv \Psi_t^{\frac{\alpha}{1-\alpha}} z_t$, where the relative price of consumption goods to investment goods Ψ_t represents the level of the investment-specific technology. We assume that z_t evolves as

$$\mu_t^z \;\; = \;\; \mu_z(1-\rho_z) + \rho_z\, \mu_{t-1}^z + \sigma_z e_t^z\,, \quad \text{and } \; e_t^z \sim \text{IID}\mathcal{N}(0,1), \tag{3.5}$$

where $\mu_t^z = \Delta \log z_t$, and the NT shock e_t^z is what we refer to as the technology shock. The growth rate of investment-specific technology is constant $\mu^{\Psi} \equiv \Delta \log \Psi_t$. Thus, the growth rate of the economy is $\mu^{z_t^+} = \Delta \log z_t^+$. The intermediate goods industry is assumed to have no entry and exit. A fixed cost φ is chosen so that intermediate goods producers earn zero profits in the steady state.

The producers take the nominal rent of capital service $P_t r_t^k$ and nominal wage rate W_t as given but have the market power to set the price of their products, facing Calvo (1983)-type price stickiness, to maximize profits. With probability ξ_p, producer i cannot reoptimize its price at period t and must set it according to $P_{i,t} = \tilde{\pi}_{p,t}\, P_{i,t-1}$, where $\tilde{\pi}_{p,t} = \left(\pi^*\right)^{\ell} \left(\pi_{t-1}\right)^{1-\ell}$ is the inflation indexation, ℓ is the price indexation parameter, π^* is the targeted (steady state) inflation rate, and $\pi_t \equiv P_t/P_{t-1}$ is the actual inflation rate. Producer i sets price $P_{i,t}$ with probability $1-\xi_p$ to maximize its profits, $\mathbb{E}_t \sum_{\tau=0}^{\infty} \xi_p^{\tau} M_{t,t+\tau} \left[\tilde{\theta}_{p,t\oplus\tau} P_{i,t} Y_{i,t+\tau\,|\,t} - s_{t+\tau} P_{t+\tau} Y_{i,t+\tau\,|\,t}\right]$, subject to the demand function $Y_{i,t+\tau} = Y_{t+\tau} \left(\frac{\tilde{\theta}_{p,t\oplus\tau} P_{i,t}}{P_{t+\tau}}\right)^{-\frac{\lambda^p}{\lambda^p-1}}$, where $\tilde{\theta}_{p,t\oplus\tau} = \left(\prod_{s=1}^{\tau} \tilde{\pi}_{p,t+s}\right)$ for $\tau \geq 1$ and equals 1 for $\tau = 0$. We denote $Y_{i,t+\tau\,|\,t}$ as producer i's output at time $t+\tau$ if $P_{i,t}$ is reoptimized.

All firms that reoptimize prices at period t set the same price: $P_{i,t} = P_t^*$. The aggregate price evolves as $P_t^{\frac{1}{1-\lambda^p}} = (1-\xi_p)(P_t^*)^{\frac{1}{1-\lambda^p}} + \xi_p(\tilde{\pi}_{p,t} P_{t-1})^{\frac{1}{1-\lambda^p}}$.

3.4 The labor market

Labor contractors hire workers of different labor types through labor unions and produce homogenous labor service L_t according to the production function

$$L_t = \left[\int_0^1 L_{j,t}^{\frac{1}{\lambda^w}} \, dj\right]^{\lambda^w} , \quad \lambda^w > 1 ,$$

where λ^w measures the elasticity of substitution among different labor types. The intermediate goods producers employ the homogenous labor service for the production. Labor contractors are perfectly competitive, and face Calvo (1983)-type wage rigidities. Labor contractor j, who cannot reoptimize wage, sets the wage rate according to $W_{j,t} = \tilde{\pi}_{w,t} e^{\tilde{\mu}_{w,t}} W_{jt-1}$, where $\tilde{\pi}_{w,t} = (\pi_t^*)^{\ell_w} (\pi_{t-1})^{1-\ell_w}$ is the inflation indexation and $\tilde{\mu}_{w,t} = \ell_\mu \mu_{z^+,t} + (1-\ell_\mu)\mu_{z^+}$ is the wage growth indexation in which ℓ_w is the wage indexation on wage and ℓ_μ is the wage indexation on output growth. All labor contractors that can reoptimize wages in period t set the same wage as $W_{j,t}^* = W_t^*$. The aggregate wage level evolves as $W_t^{\frac{1}{1-\lambda^w}} = (1-\xi_w)(W_t^*)^{\frac{1}{1-\lambda^w}} + \xi_w \left(\tilde{\pi}_{w,t} e^{\tilde{\mu}_{w,t}} W_{t-1}\right)^{\frac{1}{1-\lambda^w}}$.

3.5 Monetary and fiscal authorities

The central bank implements a Taylor (1993)-type monetary policy rule specified as:

$$r_t - r = \phi_r(r_{t-1} - r) + (1-\phi_r)[\phi_\pi(\pi_t - \pi^*) + \phi_y \Delta y_t] + \sigma_r e_{r,t} , \tag{3.6}$$

where r_t is the log value of the short-term nominal interest rate, and r is the steady state. The policy rule has an interest-rate smoothing component captured by $\phi_r(r_{t-1} - r)$. The interest rate responds positively to both inflation $\pi_t - \pi^*$, where π^* is the central bank's targeted inflation, and output growth Δy_t, where y_t is the log value of detrended output. That is, $\phi_\pi(> 0)$ and $\phi_y(> 0)$. The monetary policy (MP) shock is $e_{r,t} \sim \text{IID}\mathcal{N}(0,1)$. As discussed in Section 2, if $\phi_\pi > 1$, monetary policy is active, and monetary policy is passive, otherwise.

The fiscal authority faces the government's budget constraint that equates taxes and newly issued debt with government spending and debt payments:

$$\frac{P_{b,t}B_t}{P_t} = R_{b,t}\frac{P_{b,t-1}B_{t-1}}{P_t} + G_t - T_t \tag{3.7}$$

In the standard new Keynesian model (Davig and Leeper, 2011; Bianchi and Ilut, 2017), the fiscal authority adjusts the tax as a share of output according to the tax policy rule specified as:

$$\tau_t - \tau = \varsigma_\tau(\tau_{t-1} - \tau) + (1 - \varsigma_\tau)\left[\varsigma_b(b_{t-1} - b) + \varsigma_g(g_{yt} - g_y) + \varsigma_y(y_t - y)\right] + \sigma_\tau e_{\tau,t}, \tag{3.8}$$

where τ_t is the ratio of lump-sum taxes to output, b_{t-1} is the ratio of government debt in the previous period to output, g_{yt} is the ratio of government expenditures to output, y is the steady state of output, and $e_{\tau,t} \sim \text{IID}\mathcal{N}(0,1)$ is the FP shock. The coefficients ς_τ, ς_b, ς_g, and ς_y represent, respectively, the persistence of tax policy and the sensitivities of tax policy to government debt, government spending, and output gap. $\varsigma_b > (\leq) e^{r-\pi-\Delta y} - 1$ corresponds to passive (active) fiscal policy. Our regime-switching model has a stationary and unique solution under the two policy regimes, the M and F regimes, as discussed in Section 2.

In the equilibrium, all markets are clear with the aggregate resource constraint

$$Y_t = C_t + I_t/\Psi_t + G_t + a(u_t)\bar{K}_{t-1}\,. \tag{3.9}$$

4 Results and analysis

4.1 Calibration and moments

We calibrate the model at quarterly frequency, and report the calibrated parameter values in Table 2. Most of the parameter values are taken from the literature and the rest are chosen to match the key moments in our sample period. We follow the strategy of Bianchi and Ilut (2017) and Bianchi and Melosi (2017) by keeping all non-policy parameters unchanged while allowing policy parameters to change.

Specifically, the steady state growth rate of the economy μ^{z^+} is set to 0.0035, and the steady state growth rate of the investment-specific technological change μ^Ψ is set to 0.0037 to match the quarterly consumption growth rate of 0.35% and investment growth rate of 0.72%. The steady state inflation rate π^* is set at 0.80% to match the average annual inflation rate of 3.20%. The power on capital in the production function α to 0.33, to match the labor share in the private non-farm business sector. The price markup parameter λ^p to 1.91, to target the consumption-output ratio of 0.65. The other parameters related to production technology are taken from the literature and the corresponding references are included in Table 2. The long-term bond parameter ρ is calibrated to 0.9627 so that the effective duration of the bond is 5 years. The leverage parameter λ is set to 1.35 to match the average firm-level debt-to-asset ratio of 0.26 in the data (Nikolov and Whited, 2014).

In terms of the preference parameters, the objective discount factor β is set to 0.9974 to yield a quarterly nominal risk free rate of 1.29%. The elasticity of intertemporal substitution

ψ is 1/1.5, which is consistent with estimates in the micro literature (Vissing-Jøorgensen, 2002). The risk aversion parameter γ is set to 55 so that the Sharpe ratio implied by the model (0.48 in stocks and 0.37 in bonds) is close to that in the data (0.48 in stocks and 0.42 in bonds). The risk aversion parameter in a production economy is generally much larger than the value in an endowment economy due to the ability of the households to adjust labor supply and investments to smooth consumption. For example, Rudebusch and Swanson (2012) uses a value of 75 in a recursive preference to generate reasonable term premiums. The Frisch elasticity of labor supply ϕ is set to 1 as in Christiano et al. (2014) and the habit parameter b_h to 0.85 following Justiniano et al. (2011).

Policy rule parameters in the two policy regimes are set to the estimated values in Bianchi and Ilut (2017). In particular, monetary policy responds strongly to inflation with $\phi_\pi = 2.7372$ in the M regime while the response is much weaker in the F regime with $\phi_\pi = 0.4991$. Fiscal policy passively adjusts to changes in government debt with $\varsigma_b = 0.0609$ in the M regime, while it is active with $\varsigma_b = 0$ in the F regime.

The persistence of the technology and investment shocks are calibrated to match the autocorrelations of the HP-filtered consumption and investment, respectively. The standard deviation of the technology and investment shocks are calibrated to match the volatilities of the consumption growth and investment growth rates. The standard deviation parameters for monetary and fiscal policy shocks are set to the estimated values in Bianchi and Ilut (2017). Finally, the transition matrix P between the M and F policy regimes is set to

$$P = \begin{bmatrix} 0.98 & 0.02 \\ 0.02 & 0.98 \end{bmatrix},$$

where the element $p_{ij} = Pr(s_t = i | s_{t-1} = j)$ is the probability of switching from regime j to regime i. Regime 1 corresponds to the M regime, and regime 2 to the F regime. Our choices of transition probabilities are close to the estimated values in the literature. For example, the estimated p_{11} and p_{22} are 0.9215 and 0.9306 in Davig and Leeper (2011), and the 90% confidence intervals for the two probabilities are $[0.9839, 0.9961]$ and $[0.9277, 0.9958]$ in Bianchi and Ilut (2017).

We solve the model using the method discussed in Online Appendix C and generate the moments of key macroeconomic and financial variables. These moments are presented in Table 3, along with the corresponding moments in the data. Among the model moments, computation of the equity premium and long-term bond premium is based on the covariance of the simulated stochastic discount factor m and excess returns on equity and bond, $r_s - r$ and $r_b - r$, according to equations (B.4) and (B.6) in Online Appendix B. These equations hold exactly if m, r_s, and r_b follow the multivariate normal distribution.[6] As shown in Table 3, all moments of macroeconomic variables—consumption, investment, inflation, and the short-term interest rate—match the data closely. For moments of financial variables, the model accounts for half of the observed excess return on the nominal 5-year Treasury bond and one-third of the observed excess return on the market portfolio, a reasonable success for a small scale New Keynesian model. In the following sections, we explore the model's economic mechanism via a variance decomposition and impulse responses of key variables to the four structural shocks.

4.2 Variance decomposition

Table 4 reports a variance decomposition of key macroeconomic and financial variables under the M and F regimes in our calibrated model. In the M regime, the variations of stock returns, nominal long-term bond returns, consumption growth, and inflation are driven mainly by the technology shock (75.04%, 45.16%, 56.21%, and 65.96%). In the F regime, the investment shock drives a majority of variations of these variables (59.88%, 87.83%, 66.81%, and 79.67%). The technology shock, however, drives all the variations of the pricing kernel in both regimes—almost 100%. The effects of MP and FP shocks are negligible in both regimes. These results are crucial for understanding how the consumption-inflation correlation, the stock-bond return correlation, and stock and bond risk premiums are regime-dependent.

The correlation of two variables driven by multiple fundamental shocks depends on the relative importance of each shock in contribution to the fluctuations of these variables. Intuitively, a shock that contributes most to the variances of both variables has the largest impact on their correlation. Thus, the variance decomposition results reported in Table 4 imply that the signs of the consumption-inflation and stock-bond return correlations are dominated by the technology shock under the M regime and by the investment shock under the F regime.

Risk premiums of stocks or bonds depend on the covariance between the pricing kernel and returns on stocks or bonds, as shown in equation (B.4) or (B.6) in Online Appendix B. Because the pricing kernel variation is dominated by the technology shock in both regimes, risk premiums of stocks and bonds are mostly determined by this shock. In the next several sections, we discuss the dynamic responses of financial and macroeconomic variables to the two most important structural shocks—technology and investment, and show that our results

[6] We solve our model up to the first order approximation; thus, the means of the simulated equity and bond returns are both zero. We compute the equity and bond risk premiums using the covariance between return and pricing kernel based on the first order approximation. The covariance is driven mainly by the first order terms for the return and the pricing kernel. The second and higher order terms have negligible effects on the covariance.

are consistent with the observed facts.[7]

4.3 Impulse responses to the technology shock

Figure 2 presents the impulse responses of excess returns of stocks and bonds, the nominal interest rate, consumption growth, and inflation to a positive one-standard-deviation technology shock in the M (blue solid lines) and F (red dashed lines) regimes.[8] In response to a positive technology shock, consumption rises, but inflation falls. As inflation falls, the nominal interest rate declines under the Taylor rule. The stock price rises with consumption, and the bond price rises when the nominal interest rate falls. A positive technology shock, therefore, leads to a negative consumption-inflation correlation and a positive stock-bond return correlation.

Both stock and bond returns in the M regime rise more than they do in the F regime. The nominal interest rate is more responsive to the fall of inflation, amplifying the effects of the technology shock. Consequently, consumption and the stock price in the M regime rise more than in the F regime. There is a more persistent fall in the interest rate in the M regime. As shown in Figure 2, the negative effect of a technology shock on the nominal interest rate lasts up to 20 quarters in the M regime, while it lasts only 10 quarters in the F regime.

The price of a long-term bond depends not only on the current nominal interest rate, but also on nominal interest rates in all horizons until the bond maturity. Therefore, the excess bond return in the M regime rises much more than it does in the F regime, because of the larger and more persistent fall in nominal interest rates in all horizons. These dynamic responses are consistent with the variance decomposition reported in Table 4: much higher percentages of variations in stock and bond returns, consumption growth, and inflation are explained by the technology shock in the M regime than in the F regime.

The variance decomposition in Table 4 shows that the pricing kernel is determined almost by the technology shock alone in both regimes. The impulse responses of the pricing kernel (Figure 2 and Figure 3) indicate that the percentage change in the pricing kernel is around 50% in response to a one-standard-deviation technology shock, but only 3-4% in response to a one-standard-deviation investment shock. As shown in equation (B.3) in Online Appendix B, the pricing kernel has two components: habit-adjusted consumption growth, Δc_h, and the return on household's wealth, $\tilde{r}_u$, the latter of which depends on the expected future consumption streams. Because the technology shock is a persistent shock on the growth rate

[7] The impulse responses to MP and FP shocks are discussed in Online Appendix D.

[8] The impulse responses of other variables to a positive technology shock are displayed in Panel (a) of Figure A.1 in Online Appendix G.

of the technology level, both consumption and the return on wealth increase on impact in response to this shock, resulting in a large fall in the pricing kernel. Since the investment shock is transitory by contrast, it mostly affects current consumption but not the return on wealth. In short, the effect of a technology shock on the pricing kernel dominates that of an investment shock, and as a result the risk premiums of stocks and bonds are positive in both regimes.

4.4 Impulse responses to the investment shock

Figure 3 displays the impulse responses of excess stock and bond returns, consumption growth, inflation, and the nominal interest rate to a one-standard-deviation positive investment shock in the M (blue solid lines) and F (red dashed lines) regimes.[9] A positive investment shock represents an efficient transformation of investment into capital and thus generates higher demand for investment goods. In response to this shock, both output and investment increase, while consumption decreases in the short run as an intertemporal substitution for higher consumption in the long run. As consumption falls in the short run, the stock price falls.

In the M regime, the general price first rises due to higher demand for output and then falls after about 5 quarters. With the Taylor rule, the nominal interest rate rises in the short run but falls in horizons longer than 12 quarters. Because the price of a long-term bond depends on the interest rate in all horizons until the bond maturity, the overall effect of a positive investment shock on the long-term bond price is positive. The investment shock, therefore, generates a negative stock-bond return correlation and a negative consumption-inflation correlation in the M regime.

In the F regime, however, a sharp fall in inflation is persistent in response to a positive investment shock. With active fiscal policy, an increase in output leads to an increase in tax income, and higher tax income reduces government deficits. It follows from the government budget constraint that the price level must fall to make the real value of government debt higher. With the Taylor rule, the nominal interest rate falls in all horizons, resulting in a large increase of the long-term bond price. As a result, the responses of both stock and bond returns to the investment shock are larger in the F regime than in the M regime, although the direction of these responses is the same in both regimes. The most important finding is that the consumption-inflation correlation in positive in the F regime in response to the investment shock. These dynamic responses are consistent with the variance decomposition reported in Table 4: the investment shock dominates the dynamics of stock and bond returns,

[9]The impulse responses of other variables to a positive investment shock are reported in Panel (b) of Figure A.1 in Online Appendix G.

consumption growth, and inflation in the F regime.

As shown in the variance decomposition reported in Table 4, the investment shock exerts little impact on the pricing kernel and thus on risk premiums of stocks and bonds. Stock returns are positively correlated with the pricing kernel in response to the investment shock in the F regime, implying a negative equity premium. Since the sign of the equity premium is determined by the technology shock, however, the equity premium is always positive regardless of the policy regime both in the model and in the data.

4.5 Summary and discussion

Three main findings summarize the analysis in the preceding sections:

1. The stock-bond return correlation is positive in the M regime, mainly driven by the technology shock; this correlation is negative in the F regime, mainly driven by the investment shock.

2. The consumption-inflation correlation is negative in the M regime, mainly driven by the technology shock; this correlation is positive in the F regime, mainly driven by the investment shock.

3. Risk premiums of stocks and nominal long-term bonds are always positive in both policy regimes, mainly driven by the technology shock.

It is informative to relate these findings to the CAPM. In an economy where the CAPM holds, a negative correlation between returns on the nominal long-term bond and on the stock market implies negative excess risk premiums of bonds. As Fama and French (1993) show, however, the CAPM fails to explain empirical data. The CAPM also fails in models with multiple fundamental risks like ours or in models with the nonlinear pricing kernel (Belo et al., 2017).[10] In our model, because the risk premiums of stocks and long-term bonds are driven by the technology shock, they are always positive regardless of policy regime. By contrast, the stock-bond return correlation, which has the same sign as the market beta of the long-term bond, is driven mainly by the investment shock in the F regime. As a result, it becomes negative in the F regime. The coexistence of positive bond risk premiums and the negative stock-bond correlation distinguishes our work from others such as Campbell et al. (2020).

To reinforce the preceding analysis, we simulate the correlation matrix of excess returns of stocks and long-term bonds, inflation, consumption growth, and the pricing kernel in

[10] Bai et al. (2018) show that the CAPM can fail even in models with only one fundamental shock containing a disaster risk, because the disaster risk generates a highly nonlinear pricing kernel.

both policy regimes with our model. The results are reported in Table 5. The stock-bond return correlation is 0.51 in the M regime and −0.57 in the F regime; the consumption-inflation correlation is −0.65 in the M regime and 0.14 in the F regime. The correlation between the pricing kernel and returns on stocks are negative in both regimes: −0.70 and −0.30; the correlation between the pricing kernel and returns on bonds are also negative in both regimes: −0.61 and −0.20. These results indicate positive risk premiums of stocks and bonds. Although not emphasized in the literature, the correlation between output and inflation changed sign around 2001 as did the consumption-inflation correlation: negative (−0.25) before 2001Q2 and positive (0.21) after 2001Q2. This sign change is reproduced by the model: the output-inflation correlation is −0.30 in the M regime and 0.21 in the F regime (Table 5).

5 Robustness analysis

5.1 An extended model with eight shocks

We extend our baseline model to include additional shocks commonly used in the macro-finance literature: a transitory productivity (TP) shock, an investment-specific technological (IST) shock, a price markup (PM) shock, and a wage markup (WM) shock. The stochastic processes of these shocks are provided in Online Appendix E. The parameter values for persistences and standard deviations of these additional shocks are taken from the prior literature and reported in Online Appendix Table A.1 together with the corresponding references. In Online Appendix G, Figure A.2 reports the impulse responses of key financial and macroeconomic variables to these additional shocks; Table A.2 reports the simulated moments of the model with all eight shocks; Table A.3 reports the variance decomposition of the extended model; Table A.4 reports the stock-bond return correlation, the consumption-inflation correlation, and the output-inflation correlation; and Table A.5 reports the correlation matrix of key variables.

All the key results in our baseline model hold in this extended model, and we report these results and provide discussions in Online Appendix E.

5.2 The ZLB as a special case of the F regime

The ZLB is an extreme case of the F regime, where the policy rate does not react to economic fluctuations at all, i.e., ϕ_π and ϕ_y are equal to zero. Bianchi and Melosi (2017) explicitly model the ZLB as a third regime; they identify the Great Recession as part of a prolonged fiscally-led regime. To keep our model tractable, we take the ZLB scenario exogenously, in which the policy rate is constant at its steady state level, and assume that $\phi_r = 0.99$ and $\phi_\pi = \phi_y = 0$.[11] The parameter values in the fiscal policy rule are kept the same as in the F regime of our baseline model.

When the ZLB binds, an investment shock has similar effects on macroeconomic and financial variables to those in the F regime when the ZLB is not binding, but a technology shock has different dynamic effects. A positive technology shock causes lower inflation and results in higher real interest rate.[12] This contractionary impact on the economy leads to lower consumption and thus a positive consumption-inflation correlation. Lower consumption leads to a fall in stock prices; lower inflation leads to an increase in bond prices. Returns on stocks and bonds, therefore, move in opposite directions. The negative stock-bond return correlation and the positive consumption-inflation correlation in the F regime are reinforced by the technology shock when the ZLB binds.

Online Appendix Table A.6 reports the correlation matrix when the economy is constrained by the ZLB. As one can see, the negative stock-bond return correlation and positive consumption-inflation correlation continues to hold. This result is consistent with the finding of Gourio and Ngo (2020), who focus on the correlation between stock returns and inflation at the ZLB.

5.3 Alternative preferences

In our baseline model, we use a recursive preference with habit formation to generate risk premiums with a reasonable magnitude. We show in this section that the relationship between stock-bond and consumption-inflation correlations and policy regime is robust to alternative preferences.

CRRA preference: Online Appendix Figure A.4 displays the impulse responses to technology and investment shocks in both policy regimes with the CRRA preference ($\gamma = \psi = 1/1.5$). The results are qualitatively similar to those for the baseline model with the recursive preference. With the CRRA preference, the finding of positive stock-bond return correlation and negative consumption-inflation correlation continues to hold in the M regime and the opposite finding is also true in the F regime (Panel A of Online Appendix Table A.7).

Recursive preference without habit: We solve a model with a recursive preference but no habit formation ($b_h = 0$). Without habit, consumption becomes more volatile as expected. The signs of key correlations, however, remain unchanged when compared with the baseline

[11] In this scenario, the policy rate does not respond to inflation and output changes at all, but only fluctuates moderately with monetary policy shocks.

[12] See the impulse responses marked by red dashed lines in Panel (a) of Figure A.3 in Online Appendix G. The negative effect of a positive technology shock on consumption is a common result of the new Keynesian model at the ZLB (Wieland, 2019; Wu and Zhang, 2019).

results. Both the impulse responses (Online Appendix Figure A.5) and the correlation matrix (Panel B of Online Appendix Table A.7) are qualitatively similar to the corresponding results for the baseline model.

5.4 Preference shock and lower risk aversion

We show in this section that the parameter value of risk aversion can be reduced to 10 by adding a preference shock to our model as in Corhay et al. (2021)[13], while the model continues to predict these correlations.

The moments simulated from this model (Online Appendix Table A.8) are quantitatively similar to those for our baseline model. While a preference shock leads to positive stock-bond and consumption-inflation correlations in both regimes (Panel (c) of Figure A.6 in Online Appendix G), the variance decomposition reported in Online Appendix Table A.9 shows that the investment shock drives both correlations in the F regime, while the technology shock drives both correlations in the M regime. As a result, the stock-bond correlation remains positive (0.57) in the M regime and negative (-0.52) in the F regime, while the consumption-inflation correlation remains negative (-0.47) in the M regime and positive (0.22) in the F regime (Online Appendix Table A.10).

5.5 Relative importance of shocks

The baseline result depends on the relative magnitude of technology and investment shocks. In this section, we explore how robust this result is within a reasonable range of possible values for the volatilities of these two shocks.

We use Bianchi et al. (2019)'s estimated values of high and low volatilities of technology shocks to set the upper bound of the standard deviation of the technology shock at $\bar{\sigma}_{\mu^z} = 0.87$ and the lower bound at $\underline{\sigma}_{\mu^z} = 0.41$. The lower bound of the standard deviation of the investment shock is calibrated at $\underline{\sigma}_{\zeta^I} = 1.47$ to match the investment growth volatility during the Great Moderation period (1986-2007), as documented by Stock and Watson (2003) and Bernanke (2004), while the upper bound is calibrated at $\bar{\sigma}_{\zeta^I} = 4.13$ to match the investment growth volatility during 1971-1985.

We first replace the baseline value of σ_{μ^z} with the lower bound $\underline{\sigma}_{\mu^z}$. In the M regime, the MP shock contributes most to the stock-bond return correlation, followed by the technology shock; the investment shock contributes most to the consumption-inflation correlation, followed by the technology shock (Panel A of Table A.11 in Online Appendix G). Because both the MP and technology shocks generate a positive stock-bond return correlation and both

[13] See Online Appendix F for the detail of the model when a preference shock is added.

the investment and technology shocks generate a negative consumption-inflation correlation, our baseline correlation results hold for the M regime. We now replace the baseline value of σ_{μ^z} with the upper bound $\bar{\sigma}_{\mu^z}$, or replace the baseline value of σ_{ζ^I} with the lower bound $\underline{\sigma}_{\zeta^I}$. As in our baseline case, the investment shock is the main driver of the stock-bond and consumption-inflation correlations in the F regime (Panels B and C of Table A.11 in Online Appendix G).

When we replace the baseline value of σ_{ζ^I} with the upper bound $\bar{\sigma}_{\zeta^I}$, the technology shock continues to be the driving force for the stock-bond return correlation in the M regime, while the investment shock contributes most to the consumption-inflation correlation, followed closely by the technology shock (Panel D of Table A.11 in Online Appendix G). Because both investment and technology shocks generate a negative consumption-inflation correlation in the M regime, our baseline correlation results hold.

In summary, Online Appendix Table A.12 reports the correlation matrix with various shock sizes. This analysis shows that our baseline results are robust to a wide range of parameter values for the volatilities of technology and investment shocks.

5.6 Importance of regime-switching parameters

Our baseline model allows five policy parameters to vary across regimes: the sensitivities of the nominal short-term interest rate to changes in inflation, the lagged interest rate, output growth (ϕ_π, ϕ_r, and ϕ_y), and the sensitivities of the tax-to-output ratio to changes in the lagged debt-to-output ratio and the lagged tax-to-output ratio (ς_b and ς_τ). The calibrated values in different regimes are based on the estimated results of Bianchi and Ilut (2017).

Two parameters, ϕ_π and ς_b, define policy regimes. If the values of ϕ_π and ς_b stay constant across regimes, the policy regime would be in either the M or F regime throughout our sample. In such a case, the model-generated correlations will not change. That is, the stock-bond return correlation would always be positive or negative, and the consumption-inflation correlation would always be negative or positive throughout the sample. Thus, ϕ_π and ς_b are the most important parameters for the model to account for a sign switch in the stock-bond and consumption-inflation correlations.

To see whether changes in values of the other three parameters are also critical to our results, we allow the values of ϕ_π and ς_b to change when policy switches from the M regime to the F regime as in our baseline case, but keep the values for ϕ_r, ϕ_y, and ς_τ constant at the average of their values calibrated for the M and F regimes in the baseline model. As shown in Online Appendix Table A.13, the model is still able to generate the positive stock-bond correlation and the negative consumption-inflation correlation in the M regime and the sign change of these correlations in the F regime. Except for ϕ_π and ς_b, therefore, other regime-switching parameters are not essential to our correlation results.

6 Conclusion

We incorporate interactions between monetary and fiscal policies into a new Keynesian model with the recursive preference to account for (1) the positive stock-bond return correlation and the negative consumption-growth correlation during 1971-2001 when monetary policy was active and fiscal policy was passive (the M regime) and (2) a sign change of these two correlations after 2001 when monetary policy was passive and fiscal policy was active (the F regime). Moreover, our model generates positive risk premiums of stocks and bonds in both policy regimes, consistent with the data. The key mechanism we discover is that the technology shock drives the fluctuation of the economy in the M regime while the investment shock is a driving force in the F regime. Our findings represent a significant step toward bridging financial markets and monetary-fiscal policy interactions in the general equilibrium framework.

Our paper is silent on a number of issues that are beyond the scope of this paper. One issue is to test various alternative theories for explaining a sign change in the correlation of stock and bond returns and to determine the most plausible explanation. Another issue is to resolve the debate on different timings of regime switching in a mix of monetary and fiscal policies (Davig and Leeper (2011) versus Bianchi and Ilut (2017), for example). It is our hope, however, that our findings lay the groundwork for studying these and other challenging issues in future research.

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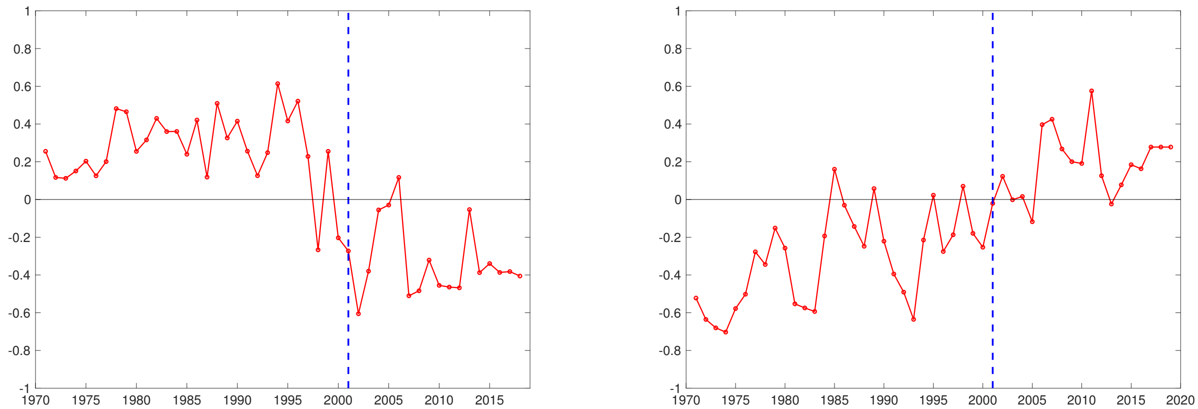
Figure 1: **Time-varying correlations—financial market and real economy**

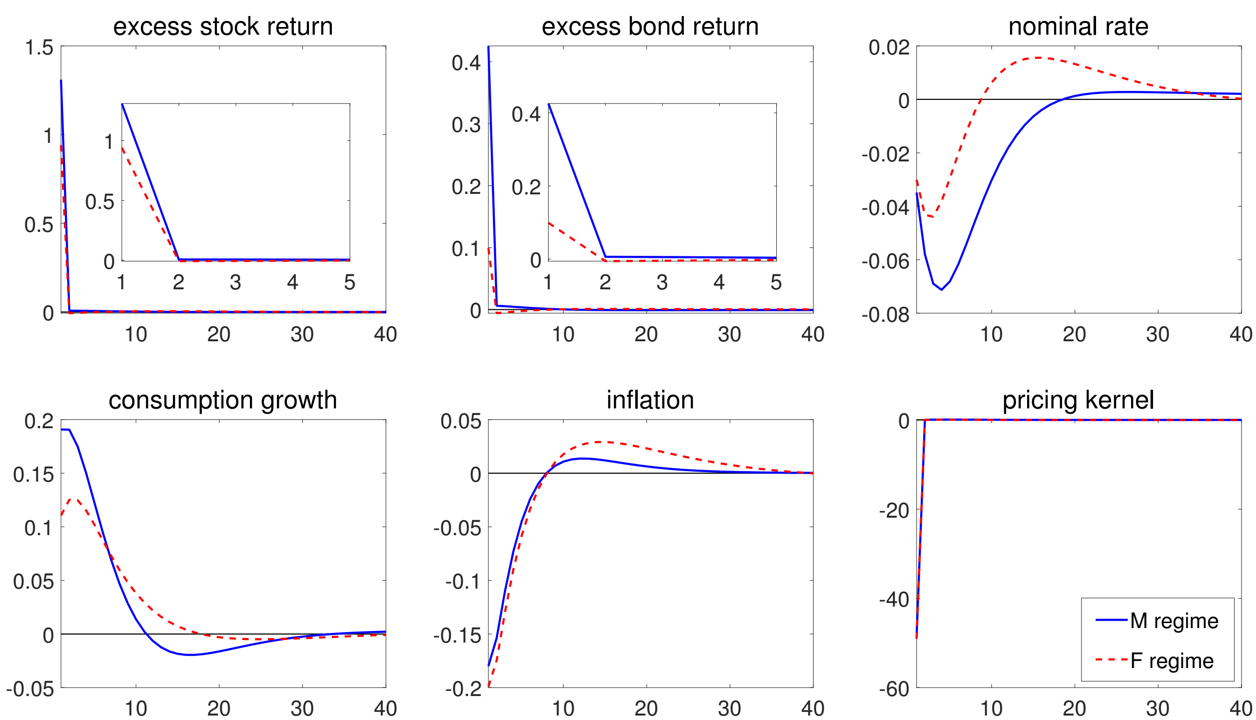


Panel A: Stock-bond return correlation

Panel B: Consumption-inflation correlation

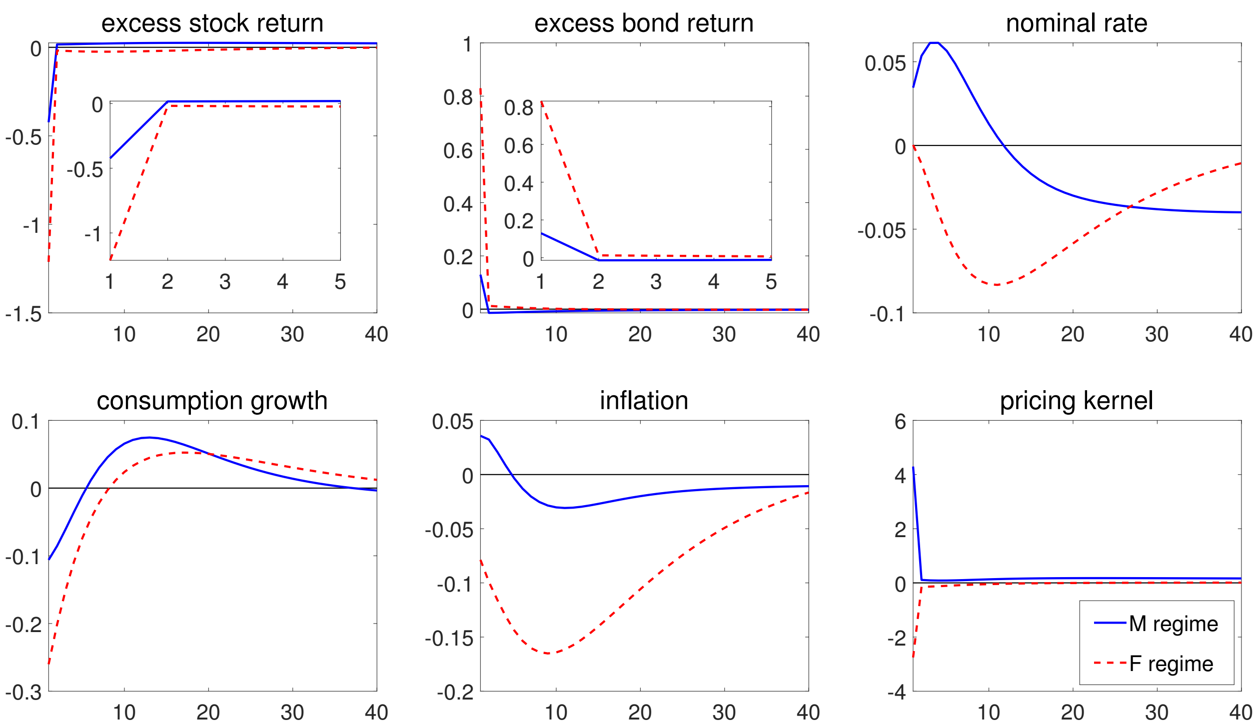
Notes: Panel A reports the correlation between the value-weighted market return and the return on the 5-year (zero coupon) nominal Treasury bonds from 1971Q1 to 2018Q4 in annual frequency. The correlation is estimated based on daily returns for each year. Daily returns on the stock market index are obtained from Ken French's data library. Daily returns on the 5-year Treasury bonds ($r_b^{(5)}$) are computed with the daily yields provided by Gürkaynak et al. (2007). Panel B displays the correlation of real consumption growth and inflation (the consumption-inflation correlation). The correlation in year t is computed with the data within the 5-year period centering at t, i.e., $[t-2, t+2]$. Real consumption growth is based on quarterly total personal consumption expenditures, and inflation is based on the quarterly GDP deflator. Both data series are obtained from the Federal Reserve Bank of St. Louis. The details of the data are described in Online Appendix A.

Figure 2: **Impulse responses of a positive technology shock**



Notes: This figure plots the impulse responses of key macro and finance variables in the model after a one-standard-deviation positive technology shock. The blue solid lines represent impulse responses in the M regime and the red dashed lines represent impulse responses in the F regime. The x-axis marks the time in quarters, and the y-axis represents the percentage change from the steady state.

Figure 3: **Impulse responses of a positive investment shock**



Notes: This figure plots the impulse responses of key macro and finance variables in the model after a one-standard-deviation positive investment shock. The blue solid lines represent impulse responses in the M regime and the red dashed lines represent impulse responses in the F regime. The x-axis marks the time in quarters, and the y-axis represents the percentage change from the steady state.

Table 1: **Data Moments pre- and post-2001Q2**

	1971Q1-2001Q1	2001Q2-2018Q4
$\text{corr}(\Delta c, \pi)$	-0.44	0.27
$\text{corr}(r_s, r_b^{(5)})$	0.21	-0.37
$r_s - r$	6.59	6.67
$\sigma(r_s - r)$	16.14	14.54
$r_b^{(5)} - r$	1.87	2.03
$\sigma(r_b^{(5)} - r)$	6.98	4.58

Notes: The table reports the data moments in two subperiods: 1971Q1-2001Q1 and 2001Q2-2018Q4. Real consumption growth (Δc_t) is based on quarterly total personal consumption expenditures on nondurables and services, and inflation (π_t) is based on the quarterly GDP deflator. These data series are obtained from the Federal Reserve Bank of St. Louis. The stock-bond correlation is based on daily excess returns on the stock market index and the nominal 5-year Treasury bonds. Returns on the stock market index ($r_{s,t}$) and one-month Treasury bills (r_t), used as the risk-free rate, are obtained from Ken French's data library. Returns (annualized) on the 5-year Treasury bonds ($r_{b,t}^{(5)}$) are computed with the daily yields provided by Gürkaynak et al. (2007). The details of the data are described in Online Appendix A.

Table 2: **Parameter values in the baseline model**

Parameter	Description	Value	Target moments or references
Panel A: Preference			
β	discount factor	0.9974	steady state interest rate = 1.29%
ψ	reciprocal of elasticity of intertemporal substitution	1/1.5	Vissing-Jøorgensen (2002)
γ	risk aversion	55	match the stock Sharpe ratio
ϕ	labor supply aversion	1	Christiano et al. (2014)
b_h	habit parameter	0.85	Justiniano et al. (2011)
Panel B: Production			
α	capital share	0.33	labor share = 0.65 (private non-farm business sector)
δ	capital depreciation rate	0.025	Christiano et al. (2014)
σ_s	investment adjustment cost parameter	10.78	Christiano et al. (2014)
σ_a	utilization rate cost parameter	2.54	Christiano et al. (2014)
ξ_p	probability that cannot re-optimize price	0.74	Christiano et al. (2014)
ℓ	price indexation parameter	0.90	Christiano et al. (2014)
λ^p	degree of elasticity of substitution for goods aggregation	1.91	$C/Y = 0.65$
ξ_w	probability that cannot re-optimize wage	0.81	Christiano et al. (2014)
ℓ_w	wage indexation parameter	0.49	Christiano et al. (2014)
λ^w	degree of elasticity of substitution for labor aggregation	1.05	Christiano et al. (2014)
ω	total factor productivity	1	normalization
μ^{z^+}	growth rate of the economy	0.0035	consumption growth rate = 0.35%
μ^{Ψ}	growth rate of investment specific technology	0.0037	investment growth rate of investment = 0.72%
π^*	target inflation rate	1.008	average inflation rate = 0.80%
ρ	decay rate of long-term government bonds coupon payment	0.9627	effective bond maturity = 5 years
λ	leverage ratio	1.35	debt-to-asset ratio = 0.26 in data
b	government-debt-to-GDP ratio	0.55	total federal debt as percent of GDP = 59%
g_y	steady-state government-spending-to-output ratio	0.18	Smets and Wouters (2007)
Panel C: Policies			
ϕ_π^1	sensitivity of interest rate to inflation (M regime)	2.7372	Bianchi and Ilut (2017)
ϕ_π^2	sensitivity of interest rate to inflation (F regime)	0.4991	Bianchi and Ilut (2017)

Continued on next page

Table 2 – continued from previous page

Parameter	Description	Value	Target moments or references
ϕ_y^1	sensitivity of interest rate to output (M regime)	0.7037	Bianchi and Ilut (2017)
ϕ_y^2	sensitivity of interest rate to output (F regime)	0.1520	Bianchi and Ilut (2017)
ϕ_r^1	interest rate persistence (M regime)	0.91	Bianchi and Ilut (2017)
ϕ_r^2	interest rate persistence (F regime)	0.6565	Bianchi and Ilut (2017)
ς_b^1	sensitivity of tax to debt (M regime)	0.0609	Bianchi and Ilut (2017)
ς_b^2	sensitivity of tax to debt (F regime)	0	Bianchi and Ilut (2017)
ς_y^1	sensitivity of tax to output (M regime)	0.3504	Bianchi and Ilut (2017)
ς_y^2	sensitivity of tax to output (F regime)	0.3504	Bianchi and Ilut (2017)
ς_g^1	sensitivity of tax to government spending (M regime)	0.3677	Bianchi and Ilut (2017)
ς_g^2	sensitivity of tax to government spending (F regime)	0.3677	Bianchi and Ilut (2017)
ς_τ^1	tax persistence (M regime)	0.9844	Bianchi and Ilut (2017)
ς_τ^2	tax persistence (F regime)	0.8202	Bianchi and Ilut (2017)
Panel D: Shocks			
ρ_{μ^z}	persistence of the technology shock	0.15	autocorrelation of quarterly consumption
ρ_{ζ^I}	persistence of the investment shock	0.65	autocorrelation of quarterly investment
σ_{μ^z}	standard deviation of the technology shock	0.82	volatility of consumption growth
σ_{ζ^I}	standard deviation of the investment shock	2.50	volatility of investment growth
σ_r	standard deviation of the MP shock	0.10	Bianchi and Ilut (2017)
σ_τ	standard deviation of the FP shock	0.33	Bianchi and Ilut (2017)

Table 3: **Simulated moments**

Variables	Data		Model	
	Mean	Std.Dev.	Mean	Std.Dev.
consumption growth (Δc)	0.35	0.44	0.35	0.64
investment growth (Δi)	0.72	3.18	0.72	2.82
autocorrelation of HP-filtered consumption	0.82		0.81	
autocorrelation of HP-filtered investment	0.78		0.62	
inflation (π)	0.80	0.61	0.80	0.70
nominal short-term interest rate (r)	1.29	0.98	1.29	0.45
excess return on stocks ($r_s - r$)	7.99	16.68	1.84	3.86
excess return on 5-year nominal bonds ($r_b - r$)	2.62	6.18	0.61	1.64

Notes: This table reports the first and second moments of key macroeconomic and financial variables. Moments of macroeconomic variables are in quarterly frequency, while moments of returns are annualized. All moments are in percentage. Data moments are computed with the quarterly sample from 1971Q1 - 2018Q4. Model moments are based on simulation of one million quarters.

Table 4: **Variance decomposition**

Variables	Technology (e_z) (M / F)	Investment (e_{ζ^I}) (M / F)	Monetary Policy (e_r) (M / F)	Fiscal Policy (e_τ) (M / F)
$r_s - r$	75.04 / 35.86	9.88 / 59.88	13.85 / 3.33	1.23 / 0.93
$r_b - r$	45.16 / 1.27	4.83 / 87.83	23.83 / 8.84	26.18 / 2.07
π	65.96 / 19.30	18.92 / 79.67	5.21 / 0.10	9.92 / 0.94
Δc	56.21 / 30.44	33.90 / 66.81	8.96 / 2.03	0.92 / 0.72
Δy	34.63 / 46.26	59.86 / 50.36	4.93 / 2.42	0.59 / 0.96
m	98.98 / 99.62	0.87 / 0.32	0.06 / 0.00	0.10 / 0.06

Notes: This table reports the forecast error variance decomposition (in percentage) of the key variables in the baseline model: excess return on stocks ($r_s - r$), which is a claim on consumption, excess return on 5-year nominal bonds ($r_b - r$), inflation (π), growth rate of consumption (Δc), output growth (Δy), and nominal pricing kernel (m). The second to fifth columns are contributions of the technology shock, investment shock, monetary policy shock, and fiscal policy shock. The numbers before and after the slash (/) represent percentage contributions of the corresponding shocks in the M and F regimes.

Table 5: **Correlation matrix**

Variables	$r_s - r$ (M / F)	$r_b - r$ (M / F)	π (M / F)	Δc (M / F)	Δy (M / F)	m (M / F)
$r_s - r$	1.00	0.51 / -0.57	-0.45 / 0.13	0.52 / 0.59	0.19 / 0.12	-0.70 / -0.30
$r_b - r$		1.00	-0.29 / -0.14	0.25 / -0.40	0.32 / 0.31	-0.61 / -0.20
π			1.00	-0.65 / 0.14	-0.30 / 0.21	0.51 / 0.25
Δc				1.00	0.45 / 0.44	-0.29 / -0.08
Δy					1.00	-0.14 / -0.08
m						1.00

Notes: This table reports the correlation matrix of financial and macroeconomic variables with all four shocks in the baseline model based on simulation of one million quarters. The variables include the excess return on stocks ($r_s - r$), the excess return on the 5-year nominal bonds ($r_b - r$), inflation (π), consumption growth (Δc), output growth (Δy), and the pricing kernel (m). The numbers before and after the slash (/) represent the correlations in the M regime and the F regime.

Appendix A Data

The raw data used for constructing the moments of key macro and finance variables:
GDP Deflator (P)**:** price index of nominal gross domestic product, index numbers, 2005=100, seasonally adjusted, NIPA.
Nominal nondurable consumption ($C^{nom}_{nondurables}$)**:** nominal personal consumption expenditures: nondurable goods, billions of dollars, seasonally adjusted at annual rates, NIPA.
Nominal durable consumption ($C^{nom}_{durables}$)**:** nominal personal consumption expenditures: durable goods, billions of dollars, seasonally adjusted at annual rates, NIPA.
Nominal consumption services ($C^{nom}_{services}$)**:** nominal personal consumption expenditures: services, billions of dollars, seasonally adjusted at annual rates, NIPA.
Nominal investment (I^{nom})**:** nominal gross private domestic investment, billions of dollars, seasonally adjusted at annual rates, NIPA.
Price index ($PC^{nondurables}$)**:** price index of nondurable goods, index numbers, 2012=100, seasonally adjusted at annual rates, NIPA.
Price index ($PC^{durables}$)**:** price index of durable goods, index numbers, 2012=100, seasonally adjusted at annual rates, NIPA.
Price index ($PC^{services}$)**:** price index of services, index numbers, 2012=100, seasonally adjusted at annual rates, NIPA.
Price index (PI)**:** nominal investment: price index of nominal gross private domestic investment, Nonresidential, Equipment & Software index numbers, 2012=100, seasonally adjusted at annual rates, NIPA.
Real personal consumption expenditures per capita (PCE)**:** Percent Change, Quarterly, Seasonally Adjusted Annual Rate, FRED2.
Population (POP): civilian noninstitutional population, not seasonally adjusted, thousands, FRED2.
Federal funds rate (FFR)**:** effective federal funds rate, percent, FRED2.
Federal Debt (B/Y)**:** total public debt as percent of gross domestic product, percent of GDP, seasonally adjusted, FRED2.
Tax (T)**:** Federal government current tax receipts, billions of dollars, seasonally adjusted at annual rate, FRED2.
Government spending (G/Y)**:** shares of gross domestic product: Government consumption expenditures and gross investment, percent, not seasonally adjusted, FRED2.

Here NIPA and FRED2 stand for
FRED2: Database of the Federal Reserve Bank of St. Louis available at:
http://research.stlouisfed.org/fred2/.
NIPA: Database of the National Income and Product Accounts available at:
http://www.bea.gov/national/nipaweb/index.asp.

The financial market data used include:
Stock return: Market portfolio excess return, percent, Kenneth French's website.
5-year nominal bond: 5-year nominal Treasury bonds yield, percent, Gürkaynak et al. (2007).

Here Kenneth French's website and Gürkaynak et al. (2007) stand for
Kenneth French's website: Kenneth French's data library available at:
http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html.
Gürkaynak et al. (2007): Daily yields on nominal and real Treasury bonds with maturity ranging from one to 20 years, 1971 to present, available at:
https://www.federalreserve.gov/econres/feds/2006.htm

Appendix B Asset pricing implications

Appendix B.1 The stochastic pricing kernel

The household's maximization over consumption and leisure results in the stochastic pricing kernel

$$M_{t+1} \equiv e^{m_{t+1}} = \beta \left(\frac{C_{h,t+1}}{C_{h,t}} \right)^{-\psi} \left(\frac{V_{t+1}^{1/(1-\psi)}}{\mathbb{E}_t \left[V_{t+1}^{(1-\gamma)/(1-\psi)} \right]^{1/(1-\gamma)}} \right)^{\psi-\gamma} \left(\frac{P_{t+1}}{P_t} \right)^{-1} . \tag{B.1}$$

The risk-free short-term interest rate is given by $e^{-r_t} = \mathbb{E}_t \left[M_{t+1} \right]$.

Define $\tilde{V}_t = \mathbb{E}_t \left[V_{t+1}^{\frac{1-\gamma}{1-\psi}} \right]$ and

$$\begin{aligned} \beta \tilde{V}_t^{\frac{1-\psi}{1-\gamma}} &= \beta \tilde{V}_t \tilde{V}_t^{-\frac{\psi-\gamma}{1-\gamma}} = \mathbb{E}_t \left[V_{t+1} V_{t+1}^{\frac{\psi-\gamma}{1-\psi}} \tilde{V}_t^{-\frac{\psi-\gamma}{1-\gamma}} \right] \\ &= C_{h,t}^{-\psi} \mathbb{E}_t \left[M_{t,t+1} C_{h,t+1}^{\psi} V_{t+1} \right] \end{aligned}$$

where the last equality comes from the definition of the pricing kernel

$$M_{t,t+1} = \beta \left(\frac{C_{h,t+1}}{C_{h,t}} \right)^{-\psi} \left(\frac{V_{t+1}}{\tilde{V}_t^{\frac{1-\psi}{1-\gamma}}} \right)^{\frac{\psi-\gamma}{1-\psi}} .$$

The above result leads to

$$\beta C_{h,t}^{\psi} \tilde{V}_t^{\frac{1-\psi}{1-\gamma}} = \mathbb{E}_t \left[M_{t,t+1} C_{h,t+1}^{\psi} V_{t+1} \right]$$

and

$$C_{h,t}^{\psi} V_t = (1-\beta) C_{h,t}^{\psi} U_t + \mathbb{E}_t \left[M_{t,t+1} C_{h,t+1}^{\psi} V_{t+1} \right] . \tag{B.2}$$

Define

$$D_{u,t} = (1-\psi) C_{h,t}^{\psi} U_t \quad \text{and} \quad P_{u,t} = \frac{1-\psi}{1-\beta} C_{h,t}^{\psi} V_t$$

we can rewrite equation (B.2) as

$$P_{u,t} = D_{u,t} + \mathbb{E}_t \left[M_{t,t+1} P_{u,t+1} \right] \Rightarrow \mathbb{E}_t \left[M_{t,t+1} R_{u,t+1} \right] = 1$$

where

$$R_{u,t+1} = \frac{P_{u,t+1}}{P_{u,t} - D_{u,t}} = \frac{C_{h,t+1}^{\psi} V_{t+1}}{\beta C_{h,t}^{\psi} \tilde{V}_t^{\frac{1-\psi}{1-\gamma}}} = \beta^{-1} \left(\frac{C_{h,t+1}}{C_{h,t}} \right)^{\psi} \left(\frac{V_{t+1}}{\tilde{V}_t^{\frac{1-\psi}{1-\gamma}}} \right) .$$

It can be easily shown that the pricing kernel can be written as

$$M_{t,t+1} = \left[\beta \left(\frac{C_{h,t+1}}{C_{h,t}} \right)^{-\psi} \right]^{\frac{1-\gamma}{1-\psi}} R_{u,t+1}^{\frac{\psi-\gamma}{1-\psi}} .$$

The log pricing kernel can be written as

$$m_{t+1} = \theta \log \beta - \gamma \Delta c_{h,t+1} - (1-\theta) \tilde{r}_{u,t+1} - \pi_{t+1} , \tag{B.3}$$

where $\theta = \frac{1-\gamma}{1-\psi}$ and $\tilde{r}_{u,t+1}$.

So the pricing kernel depends not only on the current (habit-adjusted) consumption growth, but also on the long-term growth of wealth under the recursive preference.

Appendix B.2 Returns on stocks

The definition of stock returns follows Abel (1999), where a stock is a claim to consumption raised to the power λ, C_t^λ, and $\lambda > 1$ is the leverage ratio. Since dividend growth in the data is more volatile than consumption growth, the leverage ratio λ is needed to create a wedge between dividend and consumption. The stock price and nominal stock return are given by

$$P_{s,t} = P_t C_t^\lambda + \mathbb{E}_t \left[M_{t+1} P_{s,t+1} \right],$$

and

$$R_{s,t+1} = \frac{P_{s,t+1}}{P_{s,t} - P_t C_t^\lambda}.$$

The stock return depends positively on the current and expected future consumption growth. Under the assumption of the log normal distribution, the expected excess return can be written as

$$\log \mathbb{E}_t \left[e^{r_{s,t+1} - r_t} \right] = -\text{cov}_t \left(m_{t+1}, r_{s,t+1} \right) , \tag{B.4}$$

where $r_{s,t+1} \equiv \log R_{s,t+1}$.

Appendix B.3 Return and yield on the long-term bond

The gross nominal return on a long-term bond, $R_{b,t}$, is given by

$$R_{b,t} = \frac{1 + \rho P_{b,t}}{P_{b,t-1}} . \tag{B.5}$$

The expected excess bond return is

$$\log \mathbb{E}_t \left[e^{r_{b,t+1} - r_t} \right] = -\text{cov}_t \left(m_{t+1}, r_{b,t+1} \right) , \tag{B.6}$$

where $r_{b,t+1} \equiv \log R_{b,t+1}$. The yield ι_t on this bond is given by $1/P_{b,t} - (1-\rho)$, and the effective duration is $1/(1-\rho/(1+\iota_t))$, which can be derived as follows.

The yield of the long-term bond with decay coefficient ρ is $\iota = 1/P_b - (1-\rho)$ where P_b is the price of the bond:

$$\begin{aligned} P_b &= \frac{1}{1+\iota} + \frac{\rho}{(1+\iota)^2} + \cdots + \frac{\rho^t}{(1+\iota)^{t+1}} + \cdots \\ &= \frac{1}{1+\iota} \times \frac{1}{1-\rho/(1+\iota)} \\ &= \frac{1}{1+\iota-\rho} \\ \Rightarrow \iota &= 1/P_b - (1-\rho) . \end{aligned}$$

It's easy to show that for continuously-compounded yield $\tilde{\iota} = \ln(1/P_b + \rho)$. The consol bond has no finite maturity, however, we can compute its duration. The duration of the consol is given by

$$\begin{aligned} D &= \frac{1}{P_b}\left[1\times\frac{1}{1+\iota}+2\times\frac{\rho}{(1+\iota)^2}+\cdots+(t+1)\times\frac{\rho^t}{(1+\iota)^{t+1}}+\cdots\right] \\ &= \frac{1}{P_b}\frac{1}{1+\iota}\left[1+2\frac{\rho}{1+\iota}+\cdots\right] \\ &= \frac{1}{P_b}\frac{1}{1+\iota}\frac{\partial}{\partial(\rho/(1+\iota))}\left[\frac{1}{1-\rho/(1+\iota)}-1\right] \\ &= \frac{1}{1-\rho/(1+\iota)} \end{aligned}$$

We can also express the relationship between the expected yield and return of a real consol bond. By definition, the expected yield and return on a consol bond is given by

$$\begin{aligned} \mathbb{E}[\iota_t] &= \mathbb{E}\left[1/P_{b,t}\right]-(1-\rho) \\ \mathbb{E}[\log R_{b,t}] &= \mathbb{E}\left[\frac{1+\rho P_{b,t}}{P_{b,t-1}}\right]-1 \\ &= \mathbb{E}\left[1/P_{b,t-1}\right]+\rho\mathbb{E}\left[\frac{P_{b,t}}{P_{b,t-1}}\right]-1\,. \end{aligned}$$

It's straightforward to show that

$$\mathbb{E}[\iota_t]=\mathbb{E}[\log R_{b,t}]+\rho\left(1-\mathbb{E}\left[\frac{P_{b,t}}{P_{b,t-1}}\right]\right)\,.$$

Similarly we get

$$\mathbb{E}[\iota_t^{\$}]=\mathbb{E}[\log R_{b,t}^{\$}]+\rho\left(1-\mathbb{E}\left[\frac{P_{b,t}^{\$}}{P_{b,t-1}^{\$}}\right]\right)\,.$$

To understand the return and yield on a long-term bond in our model, we derive an analytical expression for the risk premium of a zero-coupon, long-term bond with maturity of n periods.

Nominal default-free, zero-coupon bonds with maturity n pay a unit of real and nominal consumption, respectively, at maturity. Their prices are

$$P_{b,t}^{(n)}\equiv e^{-n\iota_t^{(n)}}=\mathbb{E}_t[e^{m_{t,t+n}}]\,, \tag{B.7}$$

in which $m_{t,t+n}=\sum_{i=1}^{n}m_{t+i}$, and $\iota_t^{(n)}$ is the yield on the bond. In order to illustrate the mechanism that drives the return on long-term bonds, we derive the bond risk premium analytically under the simplifying assumption that all the variables follow log-normal distribution and are homoscedastic. In equilibrium, log return on bond, $r_{b,t+1}^{(n)}=\log\exp\left(-(n-1)\iota_{t+1}^{(n-1)}+n\iota_t^{(n)}\right)$, satisfies $\mathbb{E}_t\left[e^{m_{t+1}r_{b,t+1}^{(n)}}\right]=1$, which leads to

$$\log\mathbb{E}_t\left[e^{r_{b,t+1}^{(n)}-r_t}\right]=\mathrm{cov}_t\left(m_{t+1},(n-1)\iota_{t+1}^{(n-1)}\right)\,. \tag{B.8}$$

By the definition of bond price, we have

$$\log P_{t+1}^{(n-1)}=-(n-1)\iota_t^{(n-1)}=\log\mathbb{E}_{t+1}\left[e^{\sum_{i=2}^{n}m_{t+i}}\right]=\mathbb{E}_{t+1}\left[\sum_{i=2}^{n}m_{t+i}\right]+\frac{1}{2}\mathrm{var}_{t+1}\left(\sum_{i=2}^{n}m_{t+i}\right) \tag{B.9}$$

Substituting equation (B.9) into equation (B.8), we have

$$\log \mathbb{E}_t \left[e^{r^{(n)}_{b,t+1} - r_t} \right] = -\text{cov}_t \left(m_{t+1}, \sum_{j=2}^{n} m_{t+j} \right) = \text{cov}_t \left(m_{t+1}, \sum_{j=1}^{n-1} r_{t+j} \right)$$

which utilizes the fact that under the assumption of log-normality and homoscedasticity, variance and co-variance are constant.

The log return on the long-term bond, $r^{(n)}_{b,t+1}$, therefore can be written as

$$\log \mathbb{E}_t \left[e^{r^{(n)}_{b,t+1} - r_t} \right] = \text{cov}_t \left[m_{t+1}, \sum_{s=1}^{n-1} r_{t+s} \right] . \tag{B.10}$$

This equation holds regardless of whether the bond risk premium is constant. Intuitively, nominal bonds are risky for investors if the bond prices fall when the marginal utility rises, the latter of which can be driven by lower consumption growth or/and lower returns on wealth.[14] The bond prices fall when the expected risk-free interest rate (up to maturity) rises. Thus, positive covariance between the marginal utility and future interest rates until maturity implies positive bond risk premium, as indicated by equation (B.10).

Appendix C Solution method

The regime-switching DSGE model is solved with the method proposed by Foerster et al. (2016). We can express the linearized system in the form of

$$\underset{n\times n}{A_{s_t}} \underset{n\times 1}{x_t} = \underset{n\times n}{B_{s_t}} \underset{n\times 1}{x_{t-1}} + \underset{n\times k}{\Psi_{s_t}} \underset{k\times 1}{\varepsilon_t} + \underset{n\times s}{\Pi} \underset{s\times 1}{\eta_t} ,$$

where x_t is a vector stacking up all the variables including endogenous and exogenous variables (forward-looking and lagged ones) in the model, η_t is a vector of expectational errors, and ε_t is a vector of fundamental IID shocks. The solution for the regime switching model takes the following form:

$$x_t = \underset{n\times(n-s)}{V_{s_t}} \underset{(n-s)\times n}{F_{1,s_t}} x_{t-1} + \underset{n\times(n-s)}{V_{s_t}} \underset{(n-s)\times k}{G_{1,s_t}} \varepsilon_t .$$

Selecting an initial starting point for the solution is the most critical and challenging task. Without a proper starting value, the solution often does not converge (Farmer et al., 2011; Bianchi and Ilut, 2017). In this paper, we propose a new procedure of randomly generating starting points that can lead to a speedy convergence of the solution. The procedure is based on the constant-parameter model in which the policy regime is fixed at all times. For h regimes, there are h constant-parameter models. For each constant-parameter model, we have the corresponding solution form

$$x_t = \underset{n\times(n-s)}{V} \underset{(n-s)\times n}{F_1} x_{t-1} + \underset{n\times(n-s)}{V} \underset{(n-s)\times k}{G_1} \underset{k\times 1}{\varepsilon_t}$$

with

$$\underset{n\times n}{H_1} = V\,F_1,\;\; \underset{n\times k}{H_2} = V\,G_1,$$

where H_1 and H_2 are known matrices obtained by the method of Sims (2002) and s is the dimension of sunspot shocks. Thus, the free parameters for the system have a much smaller dimension than n^2 and can

[14] The dividends of the agent's wealth portfolio in our model are not consumption streams, but a combination of consumption and labor income because of the presence of leisure in the utility function.

be represented by $\underset{s\times(n-s)}{X}$ such that

$$V = A^{-1}\begin{bmatrix} I_{n-s} \\ -X \end{bmatrix},\ A^{-1}\begin{bmatrix} I_{n-s} \\ -X \end{bmatrix} F_1 = H_1,\ A^{-1}\begin{bmatrix} I_{n-s} \\ -X \end{bmatrix} G_1 = H_2.$$

It follows from the above equalities that

$$\begin{bmatrix} I_{n-s} \\ -X \end{bmatrix} F_1 = AH_1 = \begin{bmatrix} Q_1 \\ Q_2 \end{bmatrix} \Rightarrow F_1 = Q_1, -XF_1 = -\underset{s\times(n-s)}{X}\ \underset{(n-s)\times n}{Q_1} = \underset{s\times n}{Q_2},$$

which yields

$$X = X_q \equiv -Q_2/Q_1. \tag{C.1}$$

Similarly,

$$\begin{bmatrix} I_{n-s} \\ -X \end{bmatrix} G_1 = AH_2 = \begin{bmatrix} R_1 \\ R_2 \end{bmatrix} \Rightarrow G_1 = R_1, -XG_1 = -\underset{s\times(n-s)}{X}\ \underset{(n-s)\times k}{R_1} = \underset{s\times k}{R_2},$$

which yields

$$X = X_r \equiv -R_2/R_1. \tag{C.2}$$

and

$$X = X_{qr} \equiv -\begin{bmatrix} Q_2 \\ R_2 \end{bmatrix} \Big/ \begin{bmatrix} Q_1 \\ R_1 \end{bmatrix}. \tag{C.3}$$

One can use a (random) combination of X_q, X_r, and X_{qr} as a starting point.

Appendix D Impulse responses to monetary and fiscal policy shocks

The impacts of the monetary policy (MP) shock on key macroeconomic and financial variables are qualitatively the same in the M and F regimes (see Panel (c) in figure A.1). A positive MP shock is contractionary, resulting in higher nominal and real short rates, lower consumption and output, and falling price and wage inflation. Therefore, prices of stocks and real and nominal long-term bonds all fall, resulting in a positive stock-bond return correlation. At the same time, the consumption-inflation correlation remains positive. Quantitatively, the effect of the MP shock is stronger in the M regime than in the F regime, though the direction is the same.

Impulse responses to a fiscal policy (FP) shock are presented in Panel (d) in figure A.1. A positive FP shock increases taxes and reduces demand, resulting in a lower price level. Nominal interest rate in the M regime reacts more strongly to lower inflation than it does in the F regime, leading to lower real interest in the M regime. As a result, the economy expands in the M regime and contracts in the F regime, leading to negative consumption-inflation correlation in the M regime but positive correlation in the F regime. In reaction to lower nominal interest rates, bond prices rise. Stock prices move in the same direction as consumption.

Therefore, under a positive FP shock, in the M regime, both stock-bond correlation and consumption-inflation correlation are negative; and in the F regime, the stock-bond correlation is negative, while consumption-inflation correlation is positive. However, as shown in Table 4, neither MP shock nor FP shock is a significant driving force for the variations in macroeconomic and financial variables. Hence, neither of the two shocks results in significant changes in the stock-bond return correlation or the consumption-inflation correlation.

Appendix E Additional shocks

Instead of assuming a constant growth rate of relative price of investment good (μ^{Ψ}), total factor productivity (ω), and substitutability among differentiated intermediate goods and labor (λ_p and λ_w) as in the baseline model, now we assume that they face exogenous shocks and follow AR(1) processes with persistence ρ_x's and standard deviation σ_x's.[15]

The growth rate of relative price of investment good, μ_t^{Ψ}, evolves as follows:

$$\mu_t^{\Psi} = \mu_{\Psi}(1-\rho_{\Psi}) + \rho_{\Psi}\,\mu_{t-1}^{\Psi} + \sigma_{\Psi} e_t^{\Psi}\,, \quad \text{and } \; e_t^{\Psi} \sim \text{IID}\mathcal{N}(0,1), \tag{E.1}$$

where e_t^{ψ} denotes the investment-specific technology (IST) shock.

Total factor productivity, ω_t, faces a transitory productivity (TP) shock e_t^{ω}:

$$\log\left(\frac{\omega_t}{\omega}\right) = \rho_{\omega}\log\left(\frac{\omega_{t-1}}{\omega}\right) + \sigma_{\omega} e_t^{\omega}\,, \quad \text{and } \; e_t^{\omega} \sim \text{IID}\mathcal{N}(0,1), \tag{E.2}$$

Substitutability of differentiated goods and labor faces price markup and wage markup shocks, respectively:

$$\log\left(\frac{\lambda_t^p}{\lambda^p}\right) = \rho_{\lambda^p}\log\left(\frac{\lambda_{t-1}^p}{\lambda^p}\right) + \sigma_{\lambda^p} e_t^{\lambda^p}\,, \quad \text{and } \; e_t^{\lambda^p} \sim \text{IID}\mathcal{N}(0,1), \tag{E.3}$$

$$\log\left(\frac{\lambda_t^w}{\lambda^w}\right) = \rho_{\lambda^w}\log\left(\frac{\lambda_{t-1}^w}{\lambda^w}\right) + \sigma_{\lambda^w} e_t^{\lambda^w}\,, \quad \text{and } \; e_t^{\lambda^w} \sim \text{IID}\mathcal{N}(0,1), \tag{E.4}$$

where $e_t^{\lambda^p}$ and $e_t^{\lambda^w}$ denotes the price markup (PM) and wage markup (WM) shocks.

All the key results in our baseline model hold in this extended model, for three reasons. First, as shown by the variance decomposition in Table A.3, the technology and investment shocks continue to be the most important shocks for returns on stocks and bonds in both policy regimes. While the IST shock, as a permanent shock on the relative price of investment to consumption, contributes significantly to the variance of the pricing kernel (11.04% in the M regime and 8.96% in the F regime), the technology shock remains the dominating shock for the pricing kernel. Second, as shown in Table A.4, all newly added shocks generate a negative stock-bond return correlation in the F regime, while all except the IST shock generate a positive stock-bond return correlation in the M regime. Because the impact of the technology shock dominates the impact of the IST shock, the stock-bond return correlation continues to be dependent on policy regime. Third, all newly added shocks generate a negative consumption-inflation correlation in the M regime, while all but the transitory productivity shock generate a positive correlation in the F regime. The variance decomposition shows that the investment shock continues to drive the consumption-inflation correlation in the F regime.

Appendix F Utility with preference shocks

Following Corhay et al. (2021), the lifetime utility function of the representative household is changed to

$$V_t \equiv \max_{\{C_t, L_t, B_t/P_t, B_t^S/P_t, I_t\}} \quad (1-\beta)\varrho_t U(C_{h,t}, L_t) + \beta\mathbb{E}_t\left[V_{t+1}^{\frac{1-\gamma}{1-\psi}}\right]^{\frac{1-\psi}{1-\gamma}}, \tag{F.1}$$

where ϱ_t represents a time-varying time preference, and the time preference shock, $e_{\varrho,t}$, is specified as a shock to ϱ_{t+1}/ϱ_t:

$$\log\frac{\varrho_{t+1}}{\varrho_t} = \rho_{\varrho}\log\frac{\varrho_t}{\varrho_{t-1}} + \sigma_{\varrho} e_{\varrho,t}\,, \tag{F.2}$$

where ρ_{ϱ} is the persistence of the shock, σ_{ϱ} is the standard deviation of the shock, and $e_{\varrho,t}$ follows a standard normal distribution. The values of γ and ρ_{ϱ} are taken from Corhay et al. (2021) and the value of σ_{ϱ} is calibrated to match the Sharpe ratio of 5-year treasury bonds. The values of the other parameters remain the same as those in the baseline calibration.

[15] Calibrated parameter values of the shock processes and the resulting simulated moments of key macro and financial variables are presented in Table A.1 and Table A.2, respectively.

Appendix G Supplementary Tables and Figures

This section provides supplementary tables and figures.

Table A.1: **Parameter values for additional shock processes**

Parameters	Description	Value	Target or source
ρ_{μ^ψ}	persistence of the IST shock	0.16	Justiniano et al. (2011)
ρ_ω	persistence of the TP shock	0.81	Christiano et al. (2014)
ρ_{λ^p}	persistence of the PM shock	0.97	Justiniano et al. (2011)
ρ_{λ^w}	persistence of the WM shock	0.92	Justiniano et al. (2011)
σ_{μ^ψ}	standard deviation of the IST shock	0.63	Justiniano et al. (2011)
σ_ω	standard deviation of the TP shock	0.46	Christiano et al. (2014)
σ_{λ^p}	standard deviation of the PM shock	0.22	Justiniano et al. (2011)
σ_{λ^w}	standard deviation of the WM shock	0.31	Justiniano et al. (2011)

Notes: This table reports the persistences and standard deviations of the 4 additional shocks: transitory productivity (TP) shock, investment-specific technology shock (IST), price markup (PM) shock, and wage markup (WM) shock, in the extended model with 8 shocks.

Table A.2: **Simulated moments under the model with 8 shocks**

Variables	Data		Model	
	Mean	Std.Dev.	Mean	Std.Dev.
mean std consumption growth (Δc)	0.35	0.44	0.35	0.67
investment growth (Δi)	0.72	3.18	0.72	2.84
autocorrelation of HP-filtered consumption	0.82		0.81	
autocorrelation of HP-filtered investment	0.78		0.62	
inflation (π)	0.80	0.61	0.81	0.75
nominal short-term interest rate (r)	1.29	0.98	1.30	0.47
excess return on stocks ($r_s - r$)	7.99	16.68	2.16	4.06
excess return on 5-year nominal bonds ($r_b - r$)	2.62	6.18	0.49	1.79

Notes: This table reports the first and second moments of key macroeconomic and financial variables in the model with 8 shocks. Moments of macroeconomic variables are in quarterly frequency, while moments of returns are annualized. All moments are in percentage. Data moments are computed with the quarterly sample from 1971Q1 - 2018Q4. Model moments are based on simulation of one million quarters.

Table A.3: **Variance decomposition of the extended model with 8 shocks**

Variables	Technology (M / F)	Investment (M / F)	MP (M / F)	FP (M / F)	TP (M / F)	IST (M / F)	PM (M / F)	WM (M / F)
$r_s - r$	70.02 / 30.30	9.22 / 50.60	12.92 / 2.81	1.15 / 0.79	0.71 / 0.23	5.49 / 13.02	0.48 / 2.20	0.01 / 0.06
$r_b - r$	34.46 / 1.10	3.69 / 76.60	18.18 / 7.71	19.98 / 1.80	7.83 / 0.85	2.20 / 5.98	13.37 / 5.79	0.29 / 0.17
π	51.51 / 16.74	14.77 / 69.10	4.07 / 0.08	7.75 / 0.81	15.34 / 4.70	0.84 / 3.30	5.67 / 5.13	0.07 / 0.13
Δc	51.30 / 28.34	30.93 / 62.20	8.18 / 1.89	0.84 / 0.67	5.02 / 0.94	1.09 / 5.29	2.57 / 0.64	0.06 / 0.04
Δy	32.34 / 42.09	55.91 / 45.83	4.60 / 2.20	0.55 / 0.87	2.88 / 1.94	1.72 / 6.45	1.96 / 0.56	0.04 / 0.05
m	87.77 / 90.58	0.77 / 0.29	0.05 / 0.00	0.09 / 0.05	0.04 / 0.09	11.04 / 8.96	0.23 / 0.03	0.01 / 0.00

Notes: This table reports the forecast error variance decomposition (in percentage) of the key variables in the model with 8 shocks: excess return on stocks ($r_s - r$), which is a claim on consumption, excess return on 5-year nominal bonds ($r_b - r$), inflation (π), growth rate of consumption (Δc), output growth (Δy), and nominal pricing kernel (m). Each column represents the contributions of the technology shock, investment shock, monetary policy (MP) shock, fiscal policy (FP) shock, transitory productivity (TP) shock, investment-specific technology shock (IST), price markup (PM) shock, and wage markup (WM) shock, respectively. The numbers before and after the slash (/) represent percentage contributions of the corresponding shocks in the M and F regimes.

Table A.4: **Correlations under each of the 8 shocks**

Shocks	$corr(r_s - r, r_b - r)$ (M / F)	$corr(\Delta c, \pi)$ (M / F)	$corr(\Delta y, \pi)$ (M / F)
Technology	0.99 / 0.79	-0.92 / -0.76	-0.88 / -0.70
Investment	-0.48 / -0.84	-0.52 / 0.26	0.20 / 0.38
Monetary policy	0.99 / 0.89	0.61 / 0.54	0.63 / 0.56
Fiscal policy	-0.04 / -0.48	-0.29 / 0.62	-0.28 / 0.65
Total factor productivity	0.96 / -0.60	-0.85 / -0.65	-0.68 / -0.30
Investment sepcific technology	-0.75 / -0.93	-0.31 / 0.55	0.33 / 0.73
Price markup	0.55 / -0.76	-0.77 / 0.49	-0.80 / 0.41
Wage markup	0.51 / -0.72	-0.76 / 0.38	-0.77 / 0.37
All shocks	0.05 / -0.64	-0.33 / 0.57	-0.33 / 0.59

Notes: This table reports the stock-bond correlation ($corr(r_s - r, r_b - r)$), consumption-growth-inflation correlation ($corr(\Delta c, \pi)$), and output-growth-inflation correlation ($corr(\Delta y, \pi)$) generated by each of the 8 shocks in the extended model. The 8 shocks are: technology shock, investment shock, monetary policy (MP) shock, fiscal policy (FP) shock, transitory productivity (TP) shock, investment-specific technology shock (IST), price markup (PM) shock,and wage markup (WM) shock. The numbers before and after the slash (/) represent the correlations in the M regime and F regime, respectively.

Table A.5: **Correlation matrix under the extended model with 8 shocks**

Variables	$r_s - r$ (M / F)	$r_b - r$ (M / F)	π (M / F)	Δc (M / F)	Δy (M / F)	m (M / F)
$r_s - r$	1.00	0.46 / -0.60	-0.43 / 0.15	0.51 / 0.58	0.17 / 0.13	-0.70 / -0.35
$r_b - r$		1.00	-0.36 / -0.16	0.26 / -0.41	0.32 / 0.27	-0.45 / -0.11
π			1.00	-0.65 / 0.15	-0.32 / 0.23	0.43 / 0.22
Δc				1.00	0.47 / 0.47	-0.28 / -0.10
Δy					1.00	-0.09 / -0.06
m						1.00

Notes: This table reports the correlation matrix of financial and macroeconomic variables with all shocks in the model with 8 shocks. The variables include excess return on stocks (claim on consumption) $(r_s - r)$, excess return on 5-year nominal bonds $(r_b - r)$, inflation (π), consumption growth (Δc), output growth (Δy), and pricing kernel (m). The numbers before and after the slash (/) represent the correlations in the M regime and F regime, respectively.

Table A.6: **Correlation matrix under the model with the F regime at the ZLB**

Variables	$r_s - r$ (M / F)	$r_b - r$ (M / F)	π (M / F)	Δc (M / F)	Δy (M / F)	m (M / F)
$r_s - r$	1.00	0.34 / -0.38	-0.44 / 0.40	0.51 / 0.64	0.22 / 0.67	-0.67 / 0.66
$r_b - r$		1.00	-0.39 / -0.17	0.16 / -0.20	-0.35 / -0.12	-0.65 / -0.18
π			1.00	-0.63 / 0.41	-0.12 / 0.37	0.52 / 0.38
Δc				1.00	0.45 / 0.80	-0.25 / 0.55
Δy					1.00	-0.03 / 0.40
m						1.00

Notes: This table reports the correlation matrix of financial and macroeconomic variables with all shocks in the model with the F regime at the ZLB. The variables include excess return on stocks (claim on consumption) $(r_s - r)$, excess return on 5-year nominal bonds $(r_b - r)$, inflation (π), consumption growth (Δc), output growth (Δy), and pricing kernel (m). The numbers before and after the slash (/) represent the correlations in the M regime and F regime, respectively.

Table A.7: **Correlation matrices — alternative preferences**

Panel A: CRRA preference

Variables	$r_s - r$ (M / F)	$r_b - r$ (M / F)	π (M / F)	Δc (M / F)	Δy (M / F)	m (M / F)
$r_s - r$	1.00	0.53 / -0.57	-0.46 / 0.13	0.52 / 0.59	0.19 / 0.12	-0.91 / -0.92
$r_b - r$		1.00	-0.29 / -0.14	0.26 / -0.40	0.33 / 0.31	-0.38 / 0.63
π			1.00	-0.65 / 0.14	-0.29 / 0.21	0.23 / -0.41
Δc				1.00	0.44 / 0.44	-0.40 / -0.56
Δy					1.00	-0.08 / -0.14
m						1.00

Panel B: Recursive preference without habit formation

Variables	$r_s - r$ (M / F)	$r_b - r$ (M / F)	π (M / F)	Δc (M / F)	Δy (M / F)	m (M / F)
$r_s - r$	1.00	0.17 / -0.55	-0.31 / 0.22	0.92 / 0.94	0.86 / 0.91	-0.76 / -0.49
$r_b - r$		1.00	-0.10 / -0.25	0.07 / -0.61	0.14 / -0.46	-0.33 / -0.12
π			1.00	-0.31 / 0.06	-0.29 / 0.06	0.48 / 0.18
Δc				1.00	0.90 / 0.95	-0.53 / -0.27
Δy					1.00	-0.57 / -0.30
m						1.00

Notes: Panels A and B of this table report the correlation matrices of financial and macroeconomic variables in the models with CRRA preference and recursive preference without habit formation, respectively. The variables include excess return on stocks ($r_s - r$), excess return on 5-year nominal bonds ($r_b - r$), inflation (π), consumption growth (Δc), output growth (Δy), and pricing kernel (m). The numbers before and after the slash (/) represent the correlations in the M regime and F regime, respectively.

Table A.8: **Simulated moments — preference shock**

Variables	Data		Preference shock	
	Mean	Std.Dev.	Mean	Std.Dev.
consumption growth (Δc)	0.35	0.44	0.35	0.73
investment growth (Δi)	0.72	3.18	0.72	2.83
inflation (π)	3.2	2.43	0.80	0.73
nominal short-term interest rate (r)	5.18	3.93	1.29	0.49
excess return on stock (consumption claim, $r_s - r$)	7.99	16.68	1.05	3.99
excess return on 5-year nominal bond ($r_b - r$)	2.62	6.18	0.82	1.90
autocorrelation of HP-filtered consumption	0.82		0.78	
autocorrelation of HP-filtered investment	0.78		0.62	

Notes: This table reports first and second moments of key macroeconomic and financial variables in the model with preference shocks. Moments of macroeconomic variables are in quarterly frequency, while moments of returns are annualized. All moments are in percentage. Data moments are computed with the quarterly sample from 1971Q1 - 2018Q4. Model moments are based on simulation of one million quarters.

Table A.9: **Variance decomposition — preference shock**

Variables	Technology (e_z) (M / F)	Investment (e_{ζ^I}) (M / F)	Preference (e_ϱ) (M / F)	Monetary Policy (e_r) (M / F)	Fiscal Policy (e_τ) (M / F)
$R_s^{\$}$	65.65 / 35.64	8.64 / 59.52	12.51 / 0.60	12.12 / 3.31	1.07 / 0.92
$R_b^{\$,(5)}$	23.64 / 1.21	2.53 / 83.84	47.64 / 4.54	12.48 / 8.43	13.71 / 1.97
π	57.76 / 17.42	16.57 / 71.92	12.42 / 9.73	4.56 / 0.09	8.69 / 0.85
Δc	45.32 / 18.55	27.33 / 40.72	19.38 / 39.05	7.23 / 1.24	0.75 / 0.44
Δy	31.14 / 26.95	53.83 / 29.34	10.06 / 41.75	4.43 / 1.41	0.53 / 0.56
M	3.78 / 3.63	0.06 / 0.02	96.15 / 96.35	0.00 / 0.00	0.01 / 0.00

Notes: This table reports the forecast error variance decomposition (in percentage) of the key variables in the model with preference shocks: excess return on stocks ($r_s - r$), which is a claim on consumption, excess return on 5-year nominal bonds ($r_b - r$), inflation (π), growth rate of consumption (Δc), output growth (Δy), and nominal pricing kernel (m). The second to sixth columns are contributions of the technology shock, investment shock, prefrence shock, monetary policy shock, and fiscal policy shock. The numbers before and after the slash (/) represent percentage contributions of the corresponding shocks in the M and F regimes.

Table A.10: **Correlation matrix — preference shock**

Variables	$r_s - r$ (M / F)	$r_b - r$ (M / F)	π (M / F)	Δc (M / F)	Δy (M / F)	m (M / F)
$r_s - r$	1.00	0.57 / -0.52	-0.45 / 0.13	0.36 / 0.49	0.10 / 0.11	-0.44 / -0.15
$r_b - r$		1.00	-0.31 / -0.14	-0.03 / -0.39	0.08 / 0.19	-0.73 / -0.21
π			1.00	-0.47 / 0.22	-0.21 / 0.28	0.23 / 0.11
Δc				1.00	0.51 / 0.60	0.24 / 0.32
Δy					1.00	0.20 / 0.32
m						1.00

Notes: This table reports the correlation matrix of financial and macroeconomic variables with all four shocks in the model with preference shocks based on simulation of one million quarters. The variables include the excess return on stocks ($r_s - r$), the excess return on the 5-year nominal bonds ($r_b - r$), inflation (π), consumption growth (Δc), output growth (Δy), and the pricing kernel (m). The numbers before and after the slash (/) represent the correlations in the M regime and the F regime.

Table A.11: **Variance decomposition — different shock sizes**

Panel A: Replace σ_{μ^z} with $\underline{\sigma}_{\mu^z}$

Variables	Technology (e_z) (M / F)	Investment (e_{ζ^I}) (M / F)	Monetary Policy (e_r) (M / F)	Fiscal Policy (e_τ) (M / F)
$r_s - r$	42.88 / 12.25	22.61 / 81.93	31.70 / 4.55	2.81 / 1.27
$r_b - r$	17.05 / 0.32	7.31 / 88.68	36.04 / 8.92	39.60 / 2.09
π	32.60 / 5.64	37.45 / 93.16	10.31 / 0.11	19.64 / 1.10
Δc	24.27 / 9.85	58.62 / 86.58	15.50 / 2.64	1.60 / 0.93
Δy	11.68 / 17.69	80.87 / 77.14	6.66 / 3.71	0.80 / 1.47
m	96.02 / 98.50	3.38 / 1.26	0.22 / 0.00	0.38 / 0.24

Panel B: Replace σ_{μ^z} with $\bar{\sigma}_{\mu^z}$

Variables	Technology (e_z) (M / F)	Investment (e_{ζ^I}) (M / F)	Monetary Policy (e_r) (M / F)	Fiscal Policy (e_τ) (M / F)
$r_s - r$	77.17 / 38.59	9.04 / 57.33	12.67 / 3.19	1.12 / 0.89
$r_b - r$	48.07 / 1.42	4.58 / 87.70	22.56 / 8.82	24.79 / 2.06
π	68.53 / 21.19	17.48 / 77.80	4.81 / 0.09	9.17 / 0.92
Δc	59.07 / 32.97	31.69 / 64.37	8.38 / 1.96	0.86 / 0.69
Δy	37.32 / 49.18	57.39 / 47.63	4.72 / 2.29	0.56 / 0.91
m	99.09 / 99.66	0.77 / 0.28	0.05 / 0.00	0.09 / 0.05

Panel C: Replace σ_{ζ^I} with $\underline{\sigma}_{\zeta^I}$

Variables	Technology (e_z) (M / F)	Investment (e_{ζ^I}) (M / F)	Monetary Policy (e_r) (M / F)	Fiscal Policy (e_τ) (M / F)
$r_s - r$	79.58 / 54.81	4.43 / 38.68	14.69 / 5.09	1.30 / 1.42
$r_b - r$	46.45 / 2.57	2.10 / 75.31	24.51 / 17.93	26.93 / 4.19
π	74.04 / 35.75	8.97 / 62.34	5.85 / 0.18	11.14 / 1.74
Δc	69.90 / 49.56	17.81 / 45.96	11.15 / 3.31	1.15 / 1.17
Δy	52.92 / 65.23	38.65 / 30.01	7.53 / 3.42	0.90 / 1.35
m	99.47 / 99.81	0.37 / 0.13	0.06 / 0.00	0.10 / 0.06

Panel D: Replace σ_{ζ^I} with $\bar{\sigma}_{\zeta^I}$

Variables	Technology (e_z) (M / F)	Investment (e_{ζ^I}) (M / F)	Monetary Policy (e_r) (M / F)	Fiscal Policy (e_τ) (M / F)
$r_s - r$	64.13 / 17.65	22.99 / 80.25	11.84 / 1.64	1.05 / 0.46
$r_b - r$	41.69 / 0.50	12.15 / 95.16	22.00 / 3.52	24.17 / 0.82
π	49.75 / 8.14	38.84 / 91.43	3.93 / 0.04	7.48 / 0.40
Δc	35.49 / 14.15	58.27 / 84.57	5.66 / 0.95	0.58 / 0.33
Δy	17.05 / 24.77	80.24 / 73.42	2.43 / 1.30	0.29 / 0.51
m	97.52 / 99.08	2.33 / 0.86	0.06 / 0.00	0.10 / 0.06

Notes: This table reports the forecast error variance decomposition (in percentage) of the key variables under different shock sizes: excess return on stocks ($r_s - r$), which is a claim on consumption, excess return on 5-year nominal bonds ($r_b - r$), growth rate of consumption (Δc), inflation (π), nominal pricing kernel (m), and output growth (Δy). The second to fifth columns are contributions of the technology shock, investment shock, monetary policy shock, and fiscal policy shock. The numbers before and after the slash (/) represent percentage contributions of the corresponding shocks in the M and F regimes.

Table A.12: **Correlation matrix — different shock sizes**

Panel A: Replace σ_{μ^z} with $\underline{\sigma}_{\mu^z}$

Variables	$r_s - r$ (M / F)	$r_b - r$ (M / F)	π (M / F)	Δc (M / F)	Δy (M / F)	m (M / F)
$r_s - r$	1.00	0.27 / -0.67	-0.29 / 0.22	0.54 / 0.62	0.08 / 0.08	-0.38 / 0.04
$r_b - r$		1.00	-0.07 / -0.13	0.14 / -0.45	0.29 / 0.35	-0.35 / -0.23
π			1.00	-0.47 / 0.24	0.00 / 0.34	0.34 / 0.18
Δc				1.00	0.23 / 0.32	-0.14 / 0.09
Δy					1.00	0.05 / 0.02
m						1.00

Panel B: Replace σ_{μ^z} with $\bar{\sigma}_{\mu^z}$

Variables	$r_s - r$ (M / F)	$r_b - r$ (M / F)	π (M / F)	Δc (M / F)	Δy (M / F)	m (M / F)
$r_s - r$	1.00	0.54 / -0.56	-0.47 / 0.12	0.52 / 0.58	0.20 / 0.14	-0.71 / -0.33
$r_b - r$		1.00	-0.31 / -0.15	0.26 / -0.40	0.33 / 0.30	-0.63 / -0.20
π			1.00	-0.66 / 0.13	-0.32 / 0.20	0.51 / 0.26
Δc				1.00	0.48 / 0.47	-0.30 / -0.08
Δy					1.00	-0.15 / -0.09
m						1.00

Panel C: Replace σ_{ζ^I} with $\underline{\sigma}_{\zeta^I}$

Variables	$r_s - r$ (M / F)	$r_b - r$ (M / F)	π (M / F)	Δc (M / F)	Δy (M / F)	m (M / F)
$r_s - r$	1.00	0.67 / -0.37	-0.49 / 0.05	0.52 / 0.56	0.30 / 0.23	-0.79 / -0.46
$r_b - r$		1.00	-0.34 / -0.14	0.35 / -0.29	0.35 / 0.23	-0.65 / -0.22
π			1.00	-0.69 / 0.06	-0.47 / 0.12	0.55 / 0.31
Δc				1.00	0.65 / 0.63	-0.35 / -0.14
Δy					1.00	-0.23 / -0.12
m						1.00

Panel D: Replace σ_{ζ^I} with $\bar{\sigma}_{\zeta^I}$

Variables	$r_s - r$ (M / F)	$r_b - r$ (M / F)	π (M / F)	Δc (M / F)	Δy (M / F)	m (M / F)
$r_s - r$	1.00	0.25 / -0.72	-0.39 / 0.20	0.52 / 0.61	0.07 / 0.04	-0.51 / -0.08
$r_b - r$		1.00	-0.20 / -0.14	0.11 / -0.49	0.30 / 0.37	-0.53 / -0.22
π			1.00	-0.59 / 0.21	-0.09 / 0.30	0.41 / 0.20
Δc				1.00	0.24 / 0.29	-0.19 / 0.03
Δy					1.00	-0.01 / -0.02
m						1.00

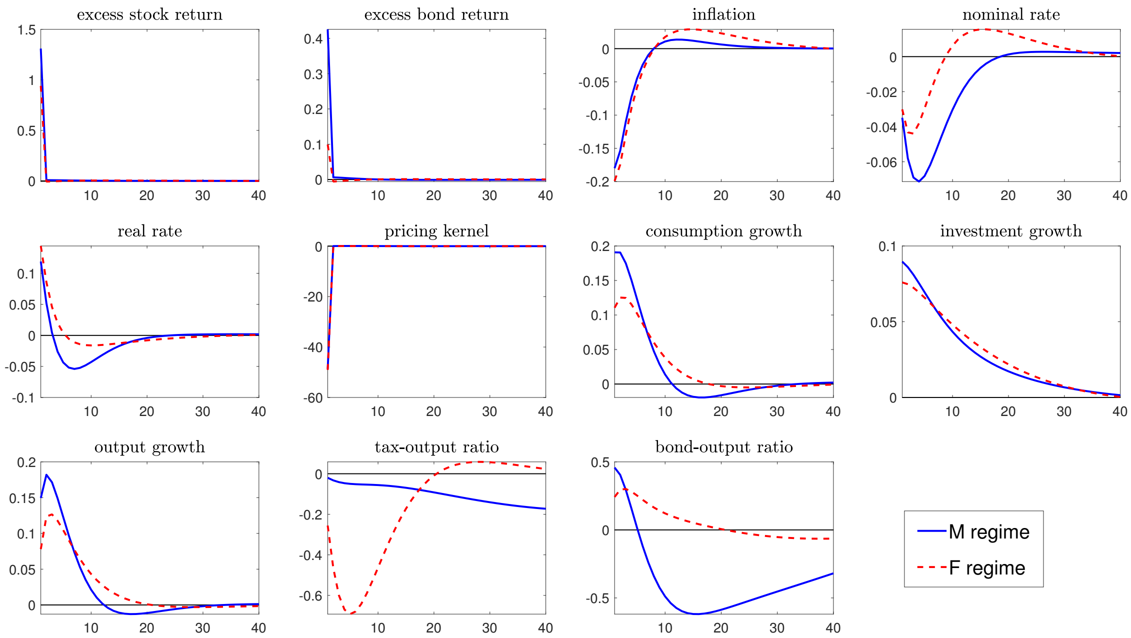
Notes: This table reports the correlation matrix of financial and macroeconomic variables with all four shocks with different shock sizes. The variables include the excess return on stocks ($r_s - r$), the excess return on the 5-year nominal bond ($r_b - r$), inflation (π), consumption growth (Δc), output growth (Δy), and the pricing kernel (m). The numbers before and after the slash (/) represent the correlations in the M regime and the F regime.

Table A.13: **Correlation matrix — Parameter sensitivity**

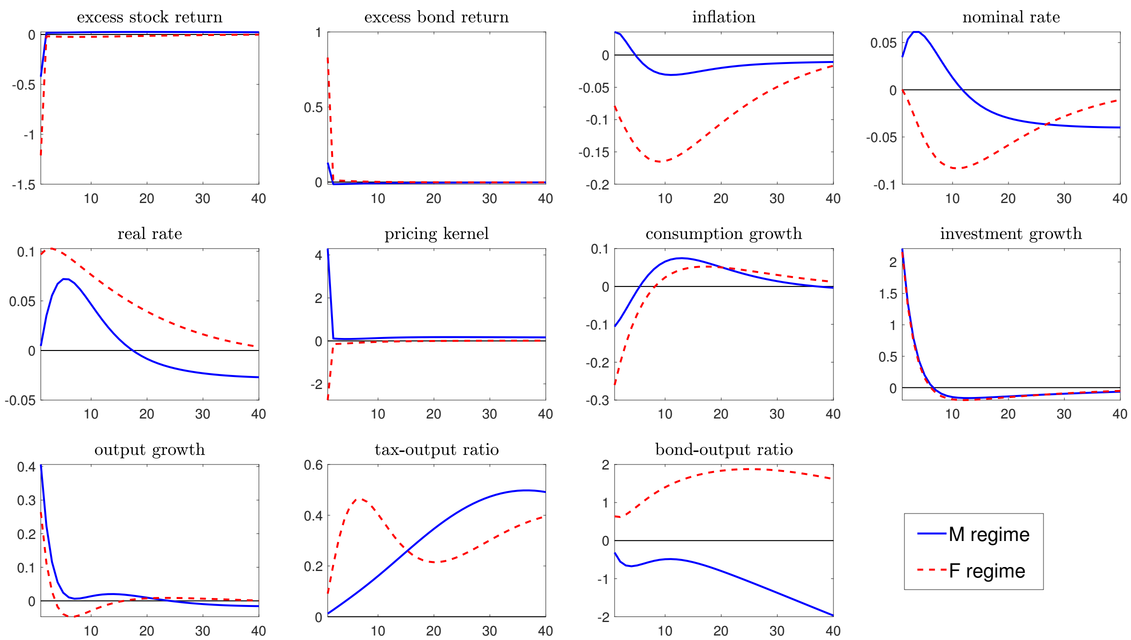
Variables	$r_s - r$ (M / F)	$r_b - r$ (M / F)	π (M / F)	Δc (M / F)	Δy (M / F)	m (M / F)
$r_s - r$	1.00	0.73 / -0.72	-0.54 / 0.13	0.55 / 0.58	0.24 / 0.04	-0.82 / -0.24
$r_b - r$		1.00	-0.48 / -0.14	0.39 / -0.49	0.28 / 0.16	-0.88 / -0.10
π			1.00	-0.76 / 0.10	-0.35 / 0.20	0.52 / 0.26
Δc				1.00	0.49 / 0.36	-0.39 / -0.03
Δy					1.00	-0.23 / -0.04
m						1.00

Notes: This table reports the correlation matrix of financial and macroeconomic variables with all four shocks with different parameter values. The variables include the excess return on stocks ($r_s - r$), the excess return on the 5-year nominal bonds ($r_b - r$), inflation (π), consumption growth (Δc), output growth (Δy), and the pricing kernel (m). The numbers before and after the slash (/) represent the correlations in the M regime and the F regime.

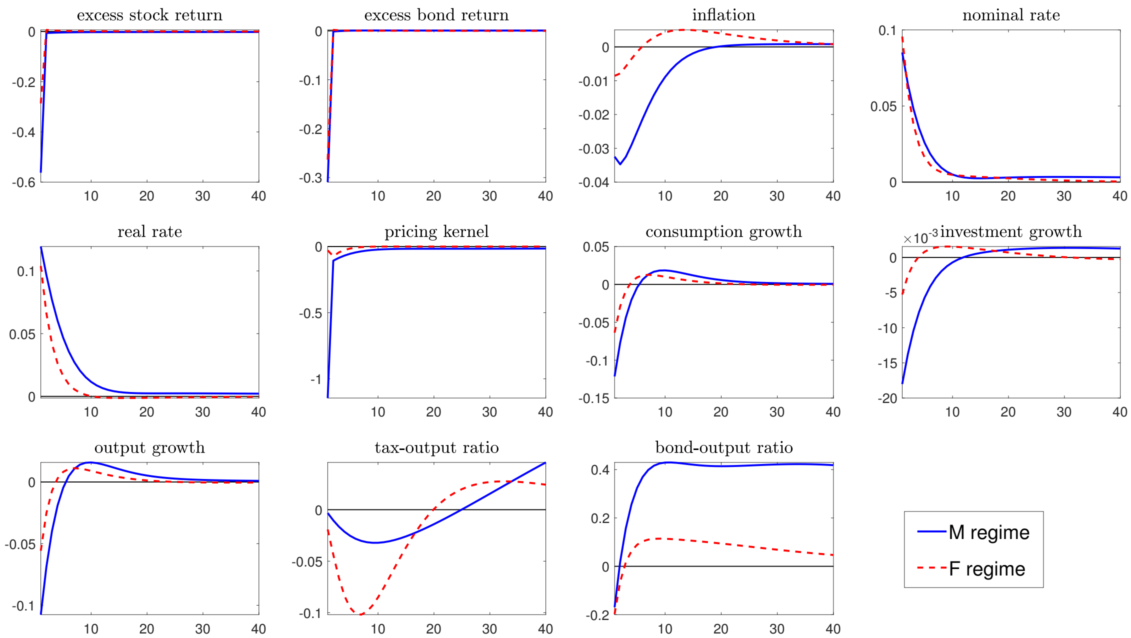
Figure A.1: **Impulse responses in the baseline model**



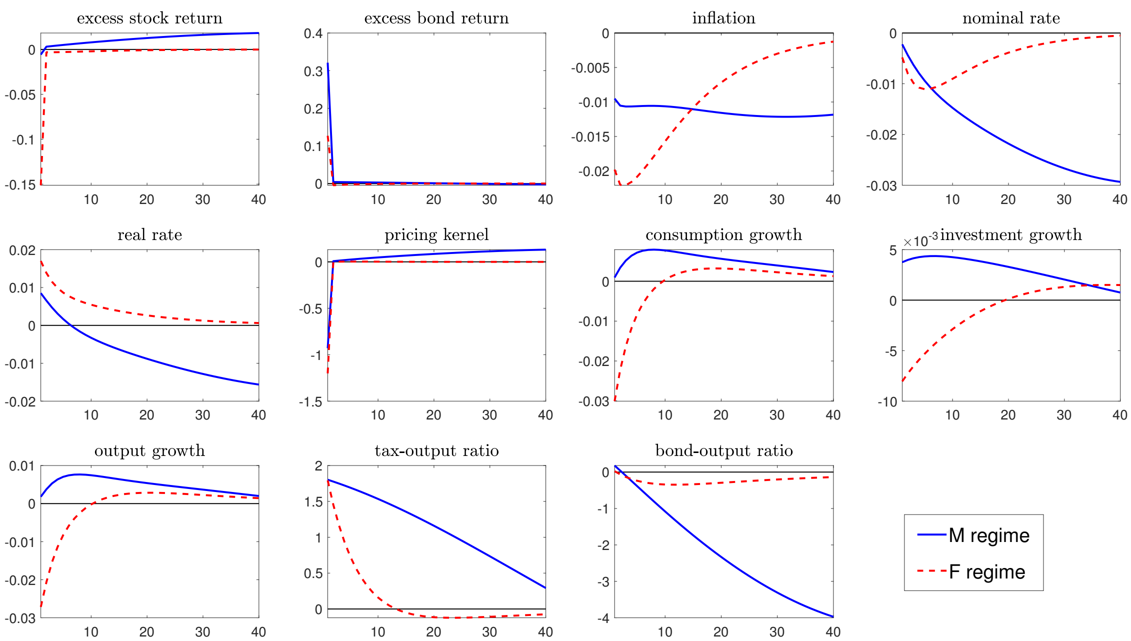
Panel (a): Impulse responses of a positive technology shock



Panel (b): Impulse responses of a positive investment shock



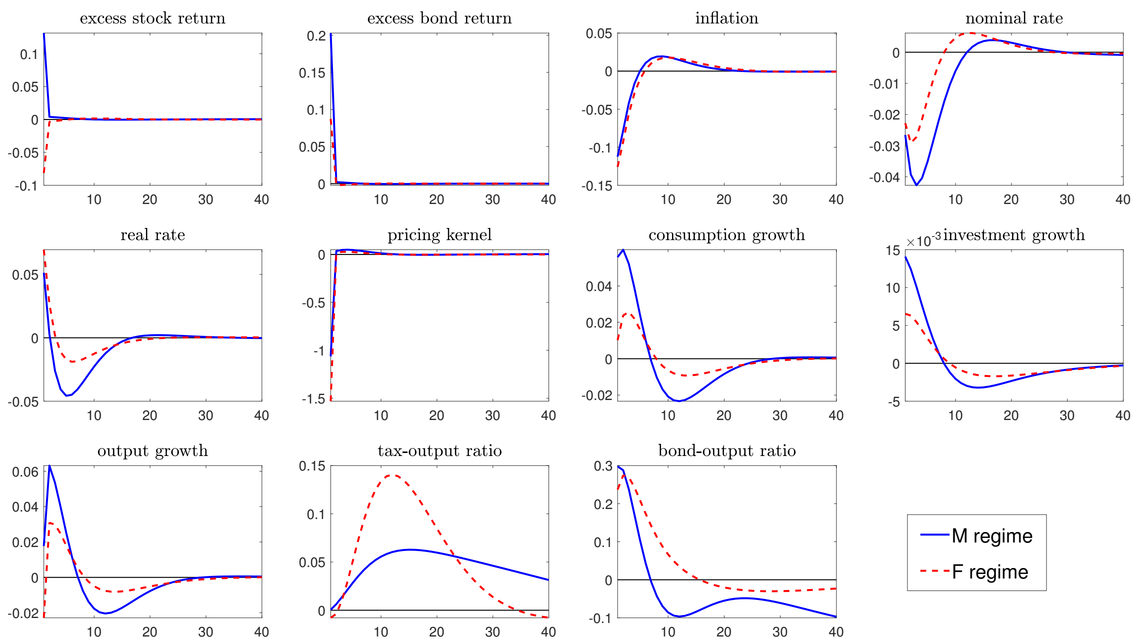
Panel (c): Impulse responses of a positive monetary policy shock



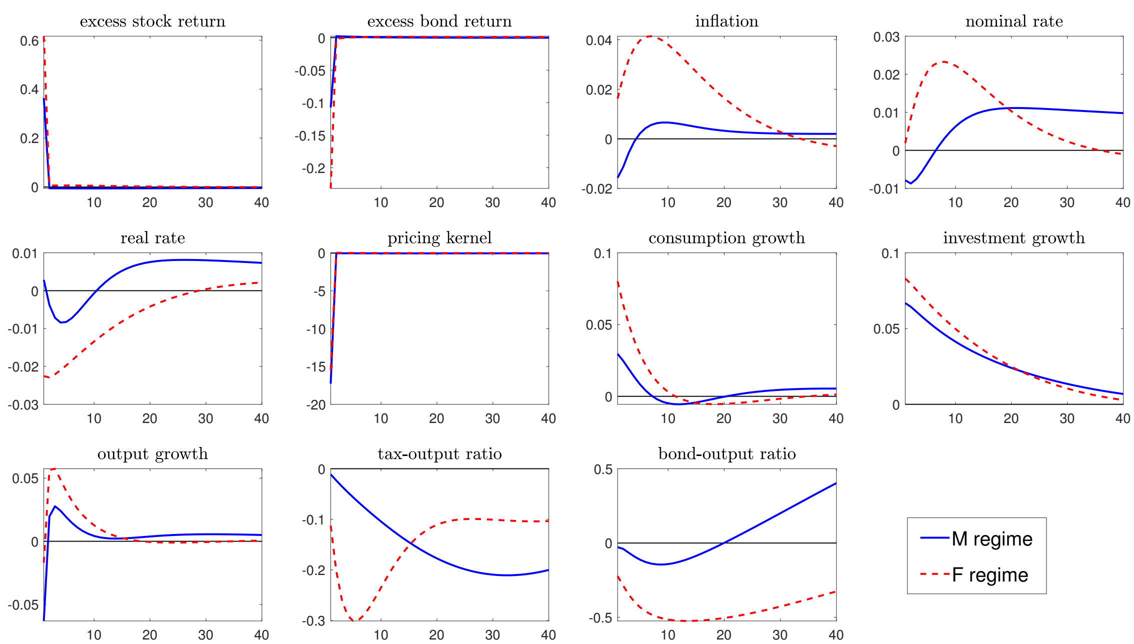
Panel (d): Impulse responses of a positive fiscal policy shock

Notes: This figure plots the impulse responses of key macro and finance variables after a one-standard-deviation posiitve technology shock in Panel (a), investment shock in Panel (b), monetary policy shock in Panel (c), and fiscal policy shock in Panel (d) in the baseline model. The blue solid lines and red dashed lines represent impulse responses under the M and F regimes, respectively. The x-axis shows the time in quarters, and the y-axis represents the percentage change from the steady state.

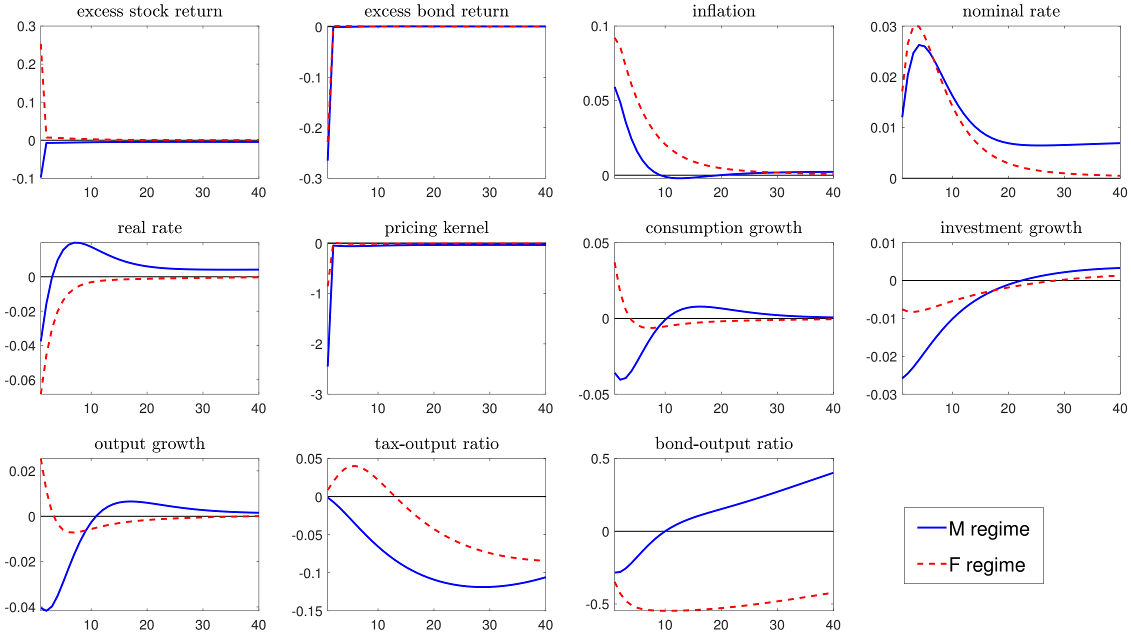
Figure A.2: **Impulse responses of the extended model with 8 shocks**



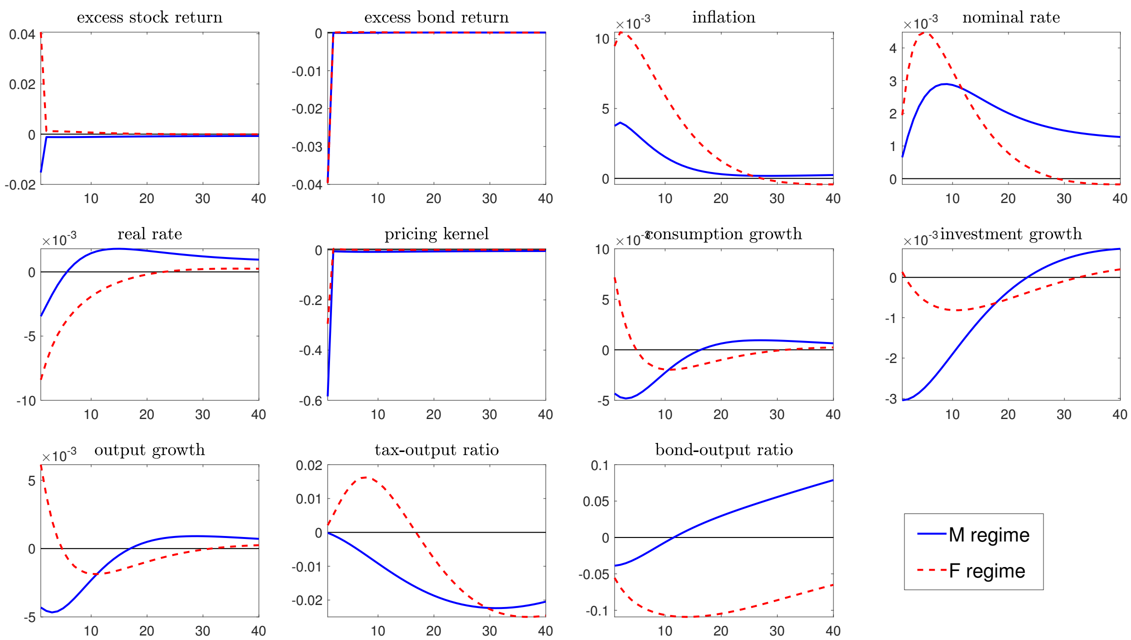
Panel (a): Impulse responses of a positive transitory productivity shock



Panel (b): Impulse responses of an IST shock



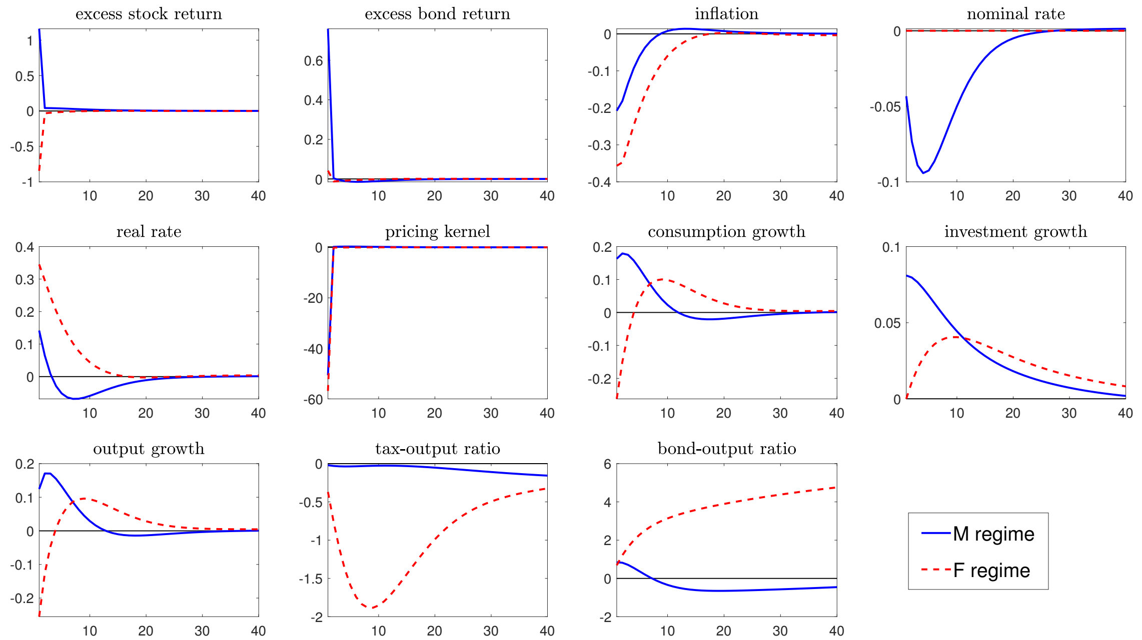
Panel (c): Impulse responses of a price markup shock



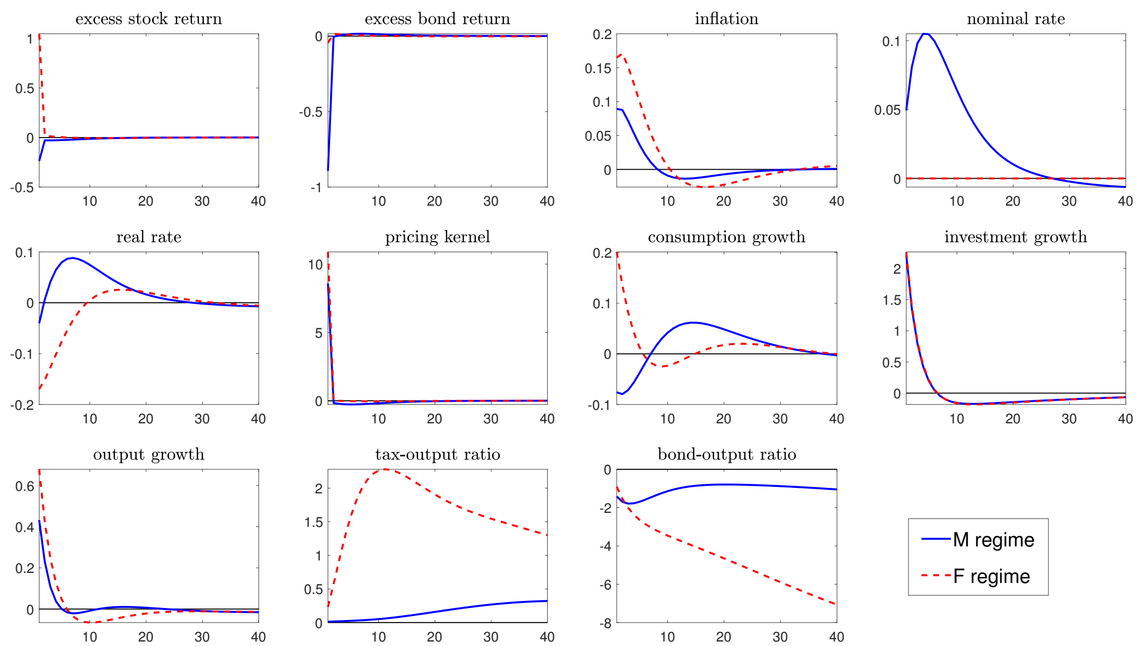
Panel (d): Impulse responses of a wage markup shock

Notes: This figure plots the impulse responses of key macro and finance variables after a one-standard-deviation positive transitory productivity shock in Panel (a), investment-specific technology (IST) shock in Panel (b), price markup shock in Panel (c), and wage markup shock in Panel (d) in the extended model. The blue solid lines and red dashed lines represent impulse responses under the M and F regimes, respectively. The x-axis shows the time in quarters, and the y-axis represents the percentage change from the steady state.

Figure A.3: **Impulse responses in the model with the F regime at the ZLB**



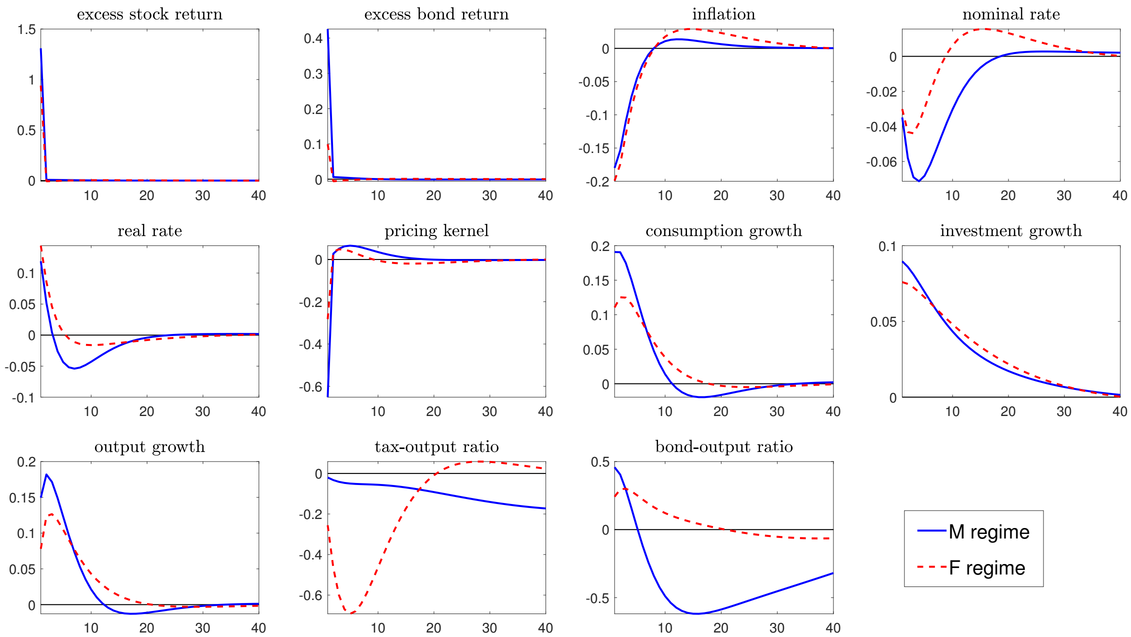
Panel (a): Impulse responses of a positive technology shock



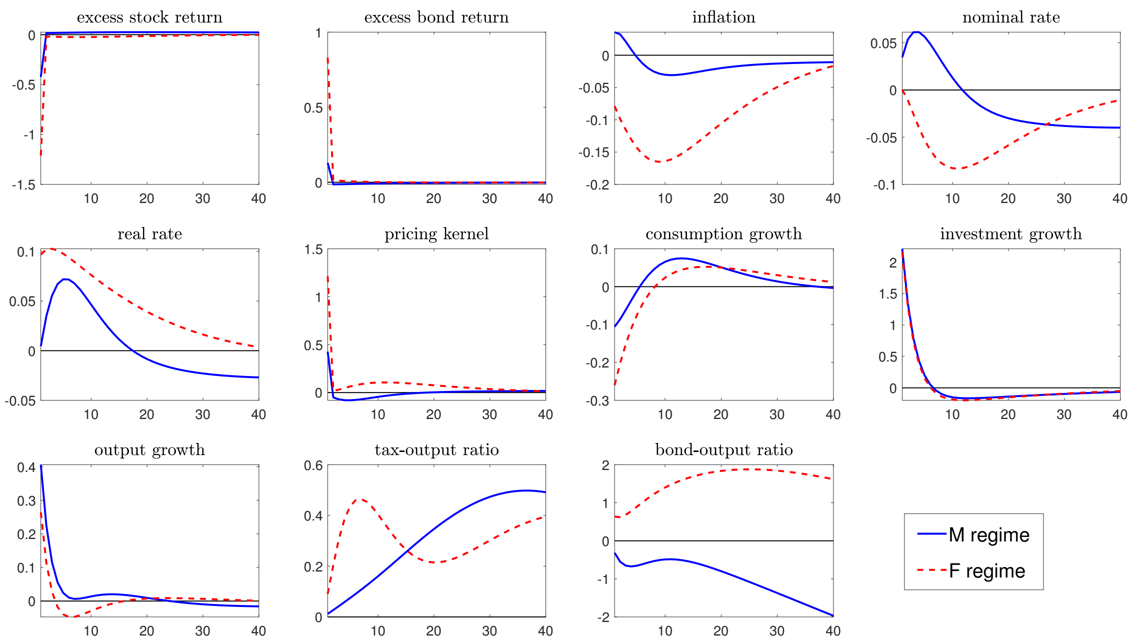
Panel (b): Impulse responses of a positive investment shock

Notes: This figure plots the impulse responses of key macro and finance variables after a one-standard-deviation positive technology shock in Panel (a) and a positive investment shock in Panel (b), in the model with the F regime at the ZLB. The blue solid lines and red dashed lines represent impulse responses under the M and F regimes, respectively. The x-axis shows the time in quarters, and the y-axis represents the percentage change from the steady state.

Figure A.4: **Impulse responses in the model with CRRA preference**



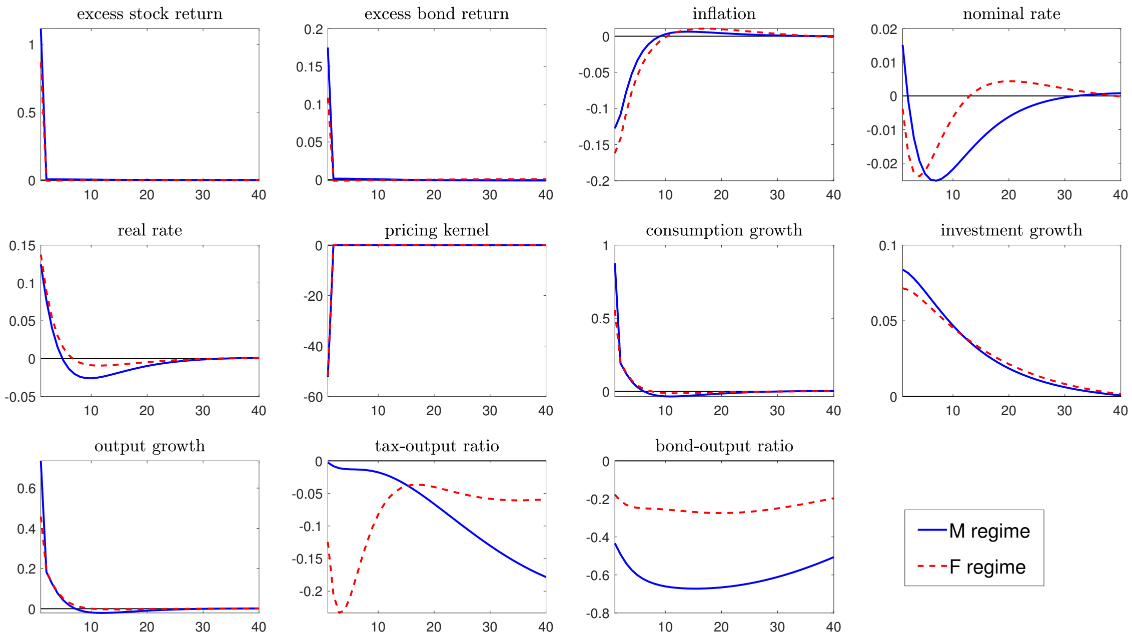
Panel (a): Impulse responses of a positive technology shock



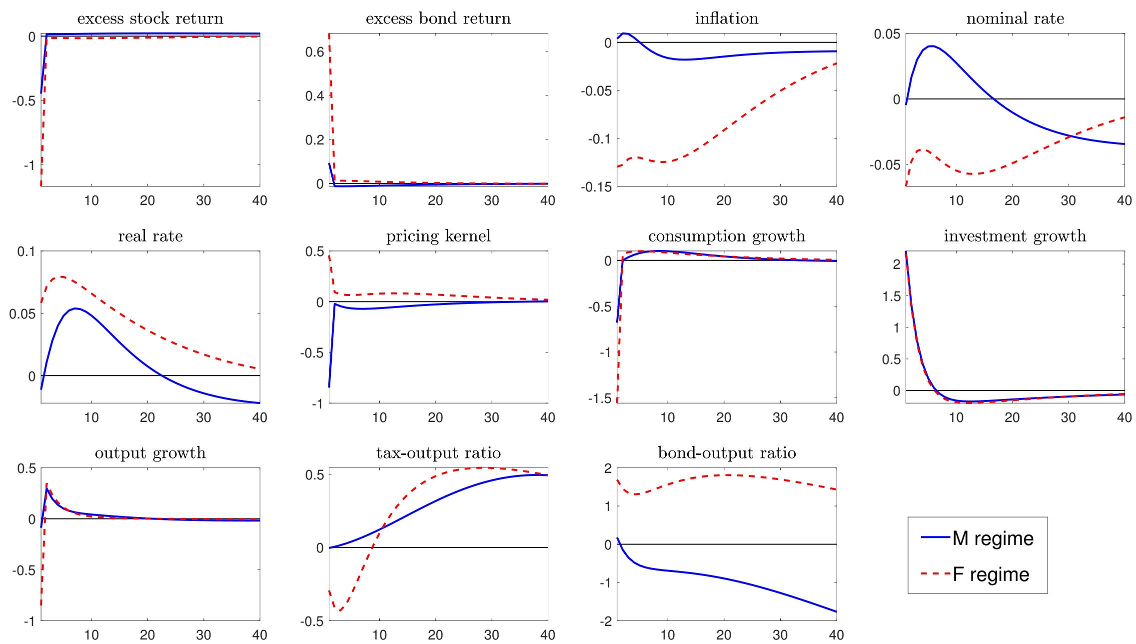
Panel (b): Impulse responses of a positive investment shock

Notes: This figure plots the impulse responses of key macro and finance variables after a one-standard-deviation positive neutral technology shock in Panel (a) and a positive investment shock in Panel (b) in the model with CRRA preference. The blue solid lines and red dashed lines represent impulse responses under the M and F regimes, respectively. The x-axis shows the time in quarters, and the y-axis represents the percentage change from the steady state.

Figure A.5: **Impulse responses in the model without habit formation**



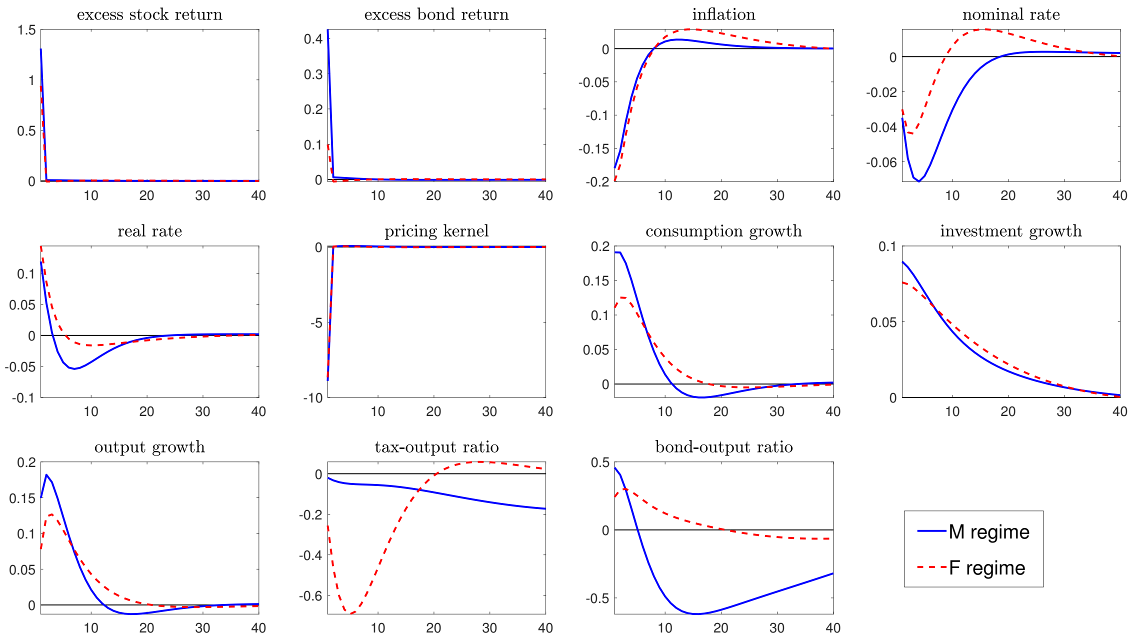
Panel (a): Impulse responses of a positive technology shock



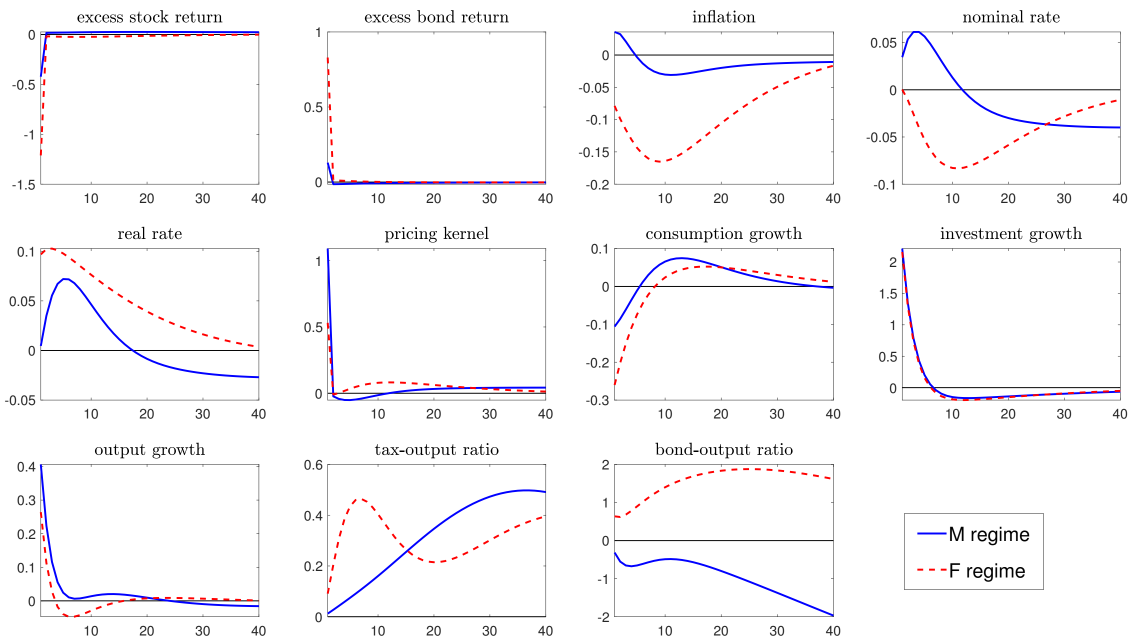
Panel (b): Impulse responses of a positive investment shock

Notes: This figure plots the impulse responses of key macro and finance variables after a one-standard-deviation positive neutral technology shock in Panel (a) and a positive investment shock in Panel (b) in the model without habit formation. The blue solid lines and red dashed lines represent impulse responses under the M and F regimes, respectively. The x-axis shows the time in quarters, and the y-axis represents the percentage change from the steady state.

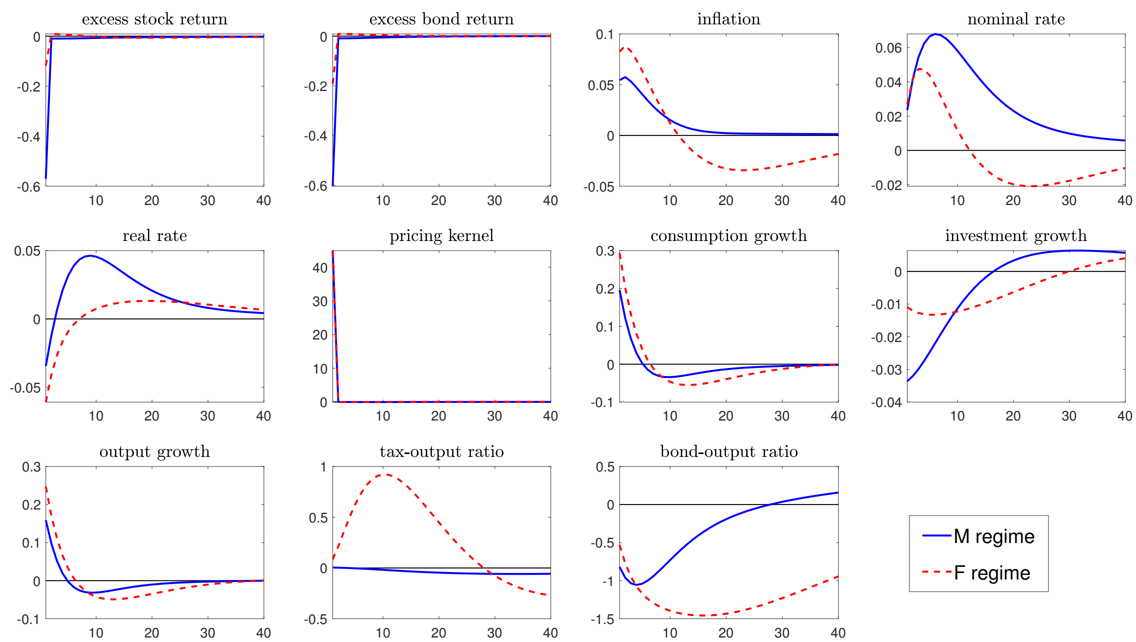
Figure A.6: **Impulse responses in the model with preference shock**



Panel (a): Impulse responses of a positive technology shock



Panel (b): Impulse responses of a positive investment shock



Panel (c): Impulse responses of a positive preference shock

Notes: This figure plots the impulse responses of key macro and finance variables after a one-standard-deviation positive neutral technology shock in Panel (a), a positive investment shock in Panel (b), and a positive preference shock in Panel (c) in the model with preference shocks. The blue solid lines and red dashed lines represent impulse responses under the M and F regimes, respectively. The x-axis shows the time in quarters, and the y-axis represents the percentage change from the steady state.