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ABSTRACT

We explore an important role of monetary-fiscal policy interactions in explaining three stylized facts:(1) a positive correlation of stock and bond returns in 1971-2001 and a negative one after 2001, (2) a negative correlation of consumption and inflation in 1971-2001 and a positive one after 2001, and (3) the coexistence of a positive bond risk premium and a negative correlation of stock and bond returns. Our general equilibrium model shows that these correlation changes across two policy regimes are driven by a combination of technology and investment shocks, while positive risk premiums are driven by the technology shock only.

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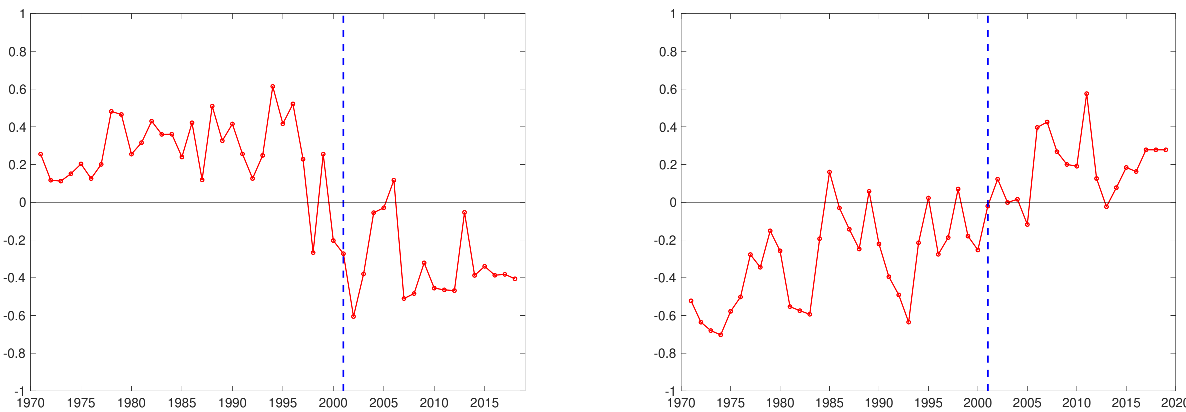
1 Introduction

Empirical studies have documented the time-varying correlation between returns on the market portfolio of stocks and those on long-term (5-10 years) nominal Treasury bonds (Campbell et al., 2016; 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). In addition, the risk premiums of long-term nominal Treasury bonds remain positive before and after 2001 as shown in Section 2.[1]

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



Panel A: Stock-bond return correlation

Panel B: Consumption-inflation correlation

Notes: Panel A of this figure 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 real personal consumption expenditures per capita, and inflation is based on the quarterly GDP deflator. Both data series are obtained from the Federal Reserve Bank of St. Louis.

Existing explanations for the sign change of the 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 Leeper et al. (2017) in accounting for the changes of correlation signs observed in both the

[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.

financial market and the real economy.[2] To this end, we develop a general equilibrium framework that incorporates regime switching between the monetary regime (the M regime) and the fiscal regime (the F regime). We follow Leeper et al. (2017) and 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.

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 government outstanding 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, prices increase with government deficits to reduce the real debt burden. We provide empirical evidence in Section 2 that a regime switching from the M regime to the F regime happened around the same time when the consumption-inflation correlation and the stock-bond return correlation changed signs in the early 2000s.

Our general equilibrium framework is a new Keynesian 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 technology shocks, Justiniano et al. (2010) and Kogan et al. (2017) show that MEI shocks as investment shocks contribute significantly to business cycle fluctuations and economic growth. Moreover, as shown in Papanikolaou (2011) and Kogan and Papanikolaou (2013), these investment shocks command significant risk premiums in financial markets. 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 the critical structural shocks in 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 Sargent and Wallace (1981) and Leeper (1991), a growing literature has studied the joint behavior of monetary and fiscal authorities. We extend the standard new

[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 Andreasen (2012), Van Binsbergen et al. (2012), Rudebusch and Swanson (2012), Dew-Becker (2014), Kung (2015), Li and Palomino (2014), Bretscher, Hsu and Tamoni (2018), and Hsu, Li and Palomino (2019).

Keynesian model (Smets and Wouters, 2007) 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 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 a 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 a 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.

Under the F regime, the investment shock becomes the dominating force for generating the stock-bond return and consumption-inflation correlations. A positive investment shock makes the transformation of investment into capital more efficient. In response to this positive demand shock, both output and investment increases but consumption decreases in the short run as an intertemporal substitution for higher consumption in the long run. The dominating effect of decreased consumption in the short-run causes stock price to fall. An increase in output leads to an increase in tax income and a decrease in the debt-to-output ratio. With active fiscal policy, taxes do not respond to a fall of the debt-to-output ratio. Thus, a combination of higher output, higher tax income, and lower debt-to-output ratio reduces 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 following the Taylor rule, and as a result, bond prices go up. Hence, under the F regime, the investment shock causes negative stock-bond return correlation and positive consumption-inflation.

Consistent with the empirical observation, risk premiums of long-term Treasury bonds remain positive under the F regime in the model while the stock-bond 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 the policy regime. Since stock and bond risk premiums are both positive under the technology shock, positive bond risk premium and negative stock-bond correlation coexist in the F regime.

In summary, the technology shock drives negative stock-bond correlations and positive consumption-inflation correlations under the F regime, while the investment shock drives positive stock-bond correlations and negative consumption-inflation correlations under the M regime. Unlike typical one-factor asset pricing models such as the CAPM, our model has multiple fundamental shocks and a nonlinear pricing kernel. This feature enables the model to generate positive risk premiums in long-term bonds, even when the stock-bond return correlation is negative. These results are robust to alternative preferences—such as the CRRA and recursive preferences without habit formation—and to an expanded model with additional fundamental shocks commonly seen in the literature. Moreover, all our results hold when the nominal interest rate is at the ZLB, which is an extreme case of the F regime.

The rest of the paper is organized as follows. Section 2 presents the empirical evidence discusses stylized facts and policy regimes. Section 3 presents the general equilibrium framework with a regime switching between monetary and fiscal policies. Section 4 proposes a solution method for our regime-switching model, calibrates this model to U.S. macroeconomic and financial variables, and discusses the asset pricing implications of the model. Section 5 discusses the robustness of our model outcomes. Section 6 offers concluding remarks.

2 Empirical evidence

Campbell et al. (2020) document a structural break in 2001Q2 in the correlation between output gap (defined as detrended consumption) and inflation and the correlation between returns on stocks and long-term treasury bonds for the data sample between 1979Q3 and 2011Q4. We argue in this paper that these breaks are likely the manifestations of regime change in the mix of monetary and fiscal policies. In this section, we define the regimes of U.S. monetary and fiscal policies and provide empirical evidence on the change of policy regime in 2001Q2. We also show that the bond risk premiums are positive both before and after 2001Q2. Our data sample extends Campbell et al. (2020)'s and is from 1971Q1 to 2018Q4.[3]

2.1 Policy regimes

Following 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 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).

[3] We use the daily yield data on 5-year Treasury bonds constructed by Gürkaynak et al. (2007) for the baseline results and the daily yield data on 10-year Treasury bonds for robustness. The earliest date of available data is 1971Q1. Results based on nominal Treasury bonds with 10-year maturity are qualitatively similar and are available upon request.

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 taxes-to-output ratio (τ_t) to lagged government-debt-to-output ratio (b_{t-1}) and government expenditures-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. If taxes respond strongly to government debt with $\varsigma_b > e^{r-\pi-\Delta y} - 1$, where r and π are the steady-state nominal interest rate and inflation, fiscal policy is passive.[4] If taxes do not respond strongly to outstanding government debt ($\varsigma_b \leq e^{r-\pi-\Delta y} - 1$), fiscal policy is active. 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 incomes (taxes plus new debt issuances) are insufficient to meet its spending and liabilities. Passive fiscal policy influences macroeconomic fluctuations only through the level of outstanding government debt. Active fiscal policy, however, influences the price level directly, which in turn affects other macroeconomic variables.

2.2 Testing the structrural break in 2001Q2

Campbell et al. (2020) find that a structural break in the stock-bond return correlation and the output-inflation correlation occurred in 2001Q2. We run the following regressions to test whether 2001Q2 was a break point for these correlations as well as for regime switching between the two policy regimes:[5]:

$$\begin{aligned}
\pi_t &= \alpha_0^\pi + \alpha_1^\pi \, \Delta c_t + \alpha_2^\pi \, \mathbb{I}_{t\geq 2001Q2} \times \Delta c_t + \epsilon_t^\pi \,, && (2.3)\\
r_{s,t} &= \alpha_0^s + \alpha_1^s \, r_{b,t}^{(5)} + \alpha_2^s \, \mathbb{I}_{t\geq 2001Q2} \times r_{b,t}^{(5)} + \epsilon_t^s \,, && (2.4)\\
r_t &= \alpha_0^r + \alpha_1^r \, \pi_t + \alpha_2^r \, \mathbb{I}_{t\geq 2001Q2} \times \pi_t + \alpha_3^r \, \Delta y_t + \epsilon_t^r && (2.5)\\
\tau_t &= \alpha_0^\tau + \alpha_1^\tau \, b_{t-1} + \alpha_2^\tau \, \mathbb{I}_{t\geq 2001Q2} \times b_{t-1} + \alpha_3^\tau \, g_{yt} + \epsilon_t^\tau \,, && (2.6)
\end{aligned}$$

where $\mathbb{I}_{t\geq 2001Q2}$ is an indicator variable that equals one for the post-2001Q2 period and zero otherwise, Δc is consumption growth, r_s is a return on the market-index stock, and $r_b^{(5)}$ is a return on

[4]Substituting the fiscal policy into the linearized government budget constraint in equation (3.15) in Section 3.5 leads to the process of debt: $\tilde{b}_t = [e^{r-\pi-\Delta y} - \varsigma_b]\tilde{b}_{t-1}$ (other terms are omitted for illustration), where $\tilde{b}_t$ is the linear deviation from the mean. 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.

[5]Our model focuses on the correlation between consumption growth and inflation, rather than between detrended log real consumption and inflation as in Campbell et al. (2020).

the nominal long-term Treasury bond with the 5-year maturity. Except for daily returns on stocks and long-term bonds, all other variables are quarterly.[6]

Table 1: **Structural break in 2001Q2**

Panel A: Tests on the structural break		
	$\alpha_1^{\cdot}$	$\alpha_2^{\cdot}$
Regression (2.3): consumption-inflation regression	-0.30*** (-4.66)	0.54** (2.28)
Regression (2.4): stock-bond return regression	0.53*** (14.76)	-2.03*** (-20.19)
Regression (2.5): monetary policy regression	3.83*** (9.95)	-5.72*** (-9.38)
Regression (2.6): fiscal policy regression	0.0084** (2.29)	-0.0095*** (-4.48)
Panel B: Data Moments pre- and post-2001Q2		
	1971Q1-2001Q1	2001Q2-2018Q4
$\text{corr}(\Delta c, \pi)$	-0.34	0.19
$\text{corr}(r_s, r_b^{(5)})$	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: Panel A reports the regression coefficients in equations (2.3) - (2.6) and Panel B reports the data moments in the two subperiods: 1971Q1-2001Q1 and 2001Q2-2018Q4. Real consumption growth (Δc_t) is based on quarterly real personal consumption expenditures per capita, and inflation (π_t) is based on the quarterly GDP deflator. Taxes (τ_t) are based on quarterly federal government tax receipts. All 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). Superscripts *** and ** indicate significance at 1% and 5% level, and numbers presented in parentheses are t-statistics based on robust standard errors.

Panel A of Table 1 reports the estimated coefficients $\alpha_1^{\cdot}$'s, corresponding to the relation of interest before 2001Q2, and $\alpha_2^{\cdot}$'s, corresponding to the change after 2001Q2. Our results confirm the findings in Campbell et al. (2020). The correlation between consumption growth and inflation indeed changed from negative ($\alpha_1^{\pi} = -0.30$) to positive ($\alpha_1^{\pi} + \alpha_2^{\pi} = 0.24$) in 2001Q2, and the change is statistically significant at the 1% level. At the same time, the correlation between sock returns and nominal long-term bond returns changed from positive ($\alpha_1^{s} = 0.53$) to negative ($\alpha_1^{s} + \alpha_2^{s} = -1.5$) in 2001Q2, and the change is statistically significant at the 1% level as well.

Most importantly, Panel A of Table 1 shows that the monetary-fiscal policy mix changed from

[6] Details of the data are provided in Appendix A.

the M to F regime in 2001Q2. Specifically, the short-term interest rate responded to inflation more than one-for-one before 2001Q2 ($\alpha_1^r = 3.83$) but the responsiveness reduced to less than one afterwards, with the change being $\alpha_2^r = -5.72$ and highly significant. The responsiveness of the taxes-to-output ratio to government-debt-to-output ratio was 0.0084 before 2001Q2 but decreased to -0.0011 ($\alpha_2^\tau = -0.0095$ and significant at the 1% level) afterwards. Given that the threshold $e^{r-\pi-\Delta y} - 1$ equals 0.00145 computed based on the average interest rate, inflation, and output growth between 1971Q1 and 2018Q4, these estimated coefficients indicate the switch from a passive fiscal policy to an active one in 2001Q2.

Note that the above empirical evidence on the regime change date in monetary and fiscal policies is largely consistent with previous findings in the literature. According to Sims and Zha (2006) and Davig and Leeper (2011), monetary policy remained largely active after 1971 until the early 2000s. The estimation in Davig and Leeper (2011) shows that monetary policy became passive around 2001 to combat the 2000-2001 and 2007-2009 recessions with active fiscal policies. These empirical results are also consistent with the narrative account of U.S. economic policy history. In particular, the post-2001 period contains two large-scale fiscal actions: President Bush's tax cuts in 2001 and 2003 and the tax cuts enabled by the Economic Stimulus Act of 2008 and the American Recovery and Reinvestment Act of early 2009 around global financial crisis, both followed by drastically increased government spendings. In addition, the Federal Reserve kept the Federal funds rate at zero after the financial crisis from 2008 to 2015, which is the extreme form of passive monetary policy. Based on the evidence in this section, we confirm 2001Q2 as the break date for the consumption-inflation correlation, stock-bond return correlation, and monetary-fiscal policy regime.

2.3 Data moments in the subperiods pre- and post-2001Q2

Panel B of Table 1 presents the key data moments in the two subperiods: 1971Q1-2001Q1 (the M regime) and 2001Q2-2018Q4 (the F regime). Specifically, the correlations between consumption growth (Δc_t) rate and inflation (π_t) in the two subperiods are -0.34 and 0.19, respectively; the correlations between (daily) returns on the stock market index ($r_{s,t}$) and returns on nominal (zero-coupon) Treasury bonds of 5-year maturity ($r_{b,t}^{(5)}$) are 0.21 and -0.31; and the (annualized) average monthly excess returns on the 5-year Treasury bonds are 1.87% and 2.03%. We summarize the key facts from Table 1 that motivate this paper as follows.

- The annual correlation between consumption growth rate and inflation was negative in the M regime and positive in the F regime.
- The correlation between returns on stocks and nominal long-term Treasury bonds was positive in the M regime and negative in the F regime.
- Nominal long-term Treasury bonds earned positive risk premiums in both 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.

3 Model

Our model follows Smets and Wouters (2007), Leeper (1991), 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

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

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 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.[7] 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

[7] In equilibrium, $C_t = \bar{C}_t$. When making decisions at time t, however, households take $\bar{C}_{t-1}$ as given.

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 $M_{t,t+s} \equiv \prod_{i=1}^{s} M_{t+i}$.

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

$$K_t = u_t \bar{K}_{t-1}. \tag{3.2}$$

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

$$\bar{K}_t = (1-\delta) \bar{K}_{t-1} + \left[1 - S \left(\frac{I_t}{\zeta_t^I I_{t-1}} \right) \right] I_t \,. \tag{3.3}$$

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

$$\log \left(\frac{\zeta_t^I}{\zeta^I} \right) = \rho_{\zeta^I} \log \left(\frac{\zeta_{t-1}^I}{\zeta^I} \right) + \sigma_{\zeta^I} e_t^{\zeta^I} , \quad \text{and} \;\; e_t^{\zeta^I} \sim \text{IID}\mathcal{N}(0,1), \tag{3.4}$$

where $e_t^{\zeta^I}$ denotes the marginal efficiency of investment (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:

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

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

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

$$Y_{i,t} = \omega\left(z_t L_{i,t}\right)^{1-\alpha} K_{i,t}^{\alpha} - z_t^{+}\varphi, \tag{3.5}$$

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

$$z_t^{+} = \Psi_t^{\frac{\alpha}{1-\alpha}} z_t, \tag{3.6}$$

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

$$\mu_t^z \;=\; \mu_z(1-\rho_z) + \rho_z\,\mu_{t-1}^z + \sigma_z e_t^z\,, \quad \text{and } \; e_t^z \sim \text{IID}\mathcal{N}(0,1), \tag{3.7}$$

where

$$\mu_t^z = \Delta \log z_t \tag{3.8}$$

and the neutral technology (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

$$\tilde{\pi}_{p,t} = \left(\pi^*\right)^{\ell}\left(\pi_{t-1}\right)^{1-\ell} \tag{3.9}$$

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, i.e.,

$$\max_{\{P_{i,t}\}} \mathbb{E}_t \sum_{\tau=0}^{\infty} \xi_p^{\tau} M_{t,t+\tau} \left[\tilde{\theta}_{p,t\oplus\tau} P_{i,t} Y_{i,t+\tau\,|\,t} - s_{t+\tau} P_{t+\tau} Y_{i,t+\tau\,|\,t} \right]$$

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. The real marginal cost, $s_{t+\tau}$, is given by

$$s_{t+\tau} \equiv MC_{t+\tau} = \frac{1}{z_{t+\tau}^{1-\alpha} P_{t+\tau}} \left(\frac{W_{t+\tau}}{1-\alpha} \right)^{1-\alpha} \left(\frac{r_{t+\tau}^k}{\alpha} \right)^{\alpha}. \tag{3.10}$$

The value of $s_{t+\tau}$ depends on the economic condition at $t + \tau$, and does not depend on firm i's actions.

The first order condition for the profit maximization problem with respect to $P_{i,t}$ is

$$\sum_{\tau=0}^{\infty} \xi_p^{\tau} M_{t,t+\tau} \left[\tilde{\theta}_{p,t\oplus\tau}^{1+\epsilon_p} (1 + \epsilon_p) P_{i,t}^{\epsilon_p} P_{t+\tau}^{-\epsilon_p} Y_{t+\tau} - \epsilon_p s_{t+\tau} \tilde{\theta}_{p,t\oplus\tau}^{\epsilon_p} P_{i,t}^{\epsilon_p - 1} P_{t+\tau}^{1-\epsilon_p} Y_{t+\tau} \right] = 0,$$

where $\epsilon_p = \lambda^p / (1 - \lambda^p)$.

All firms that reoptimize prices at period t set the same price: $P_{i,t} = P_t^*$. The aggregate price evolves as

$$P_t^{\frac{1}{1-\lambda^p}} = (1 - \xi_p)(P_t^*)^{\frac{1}{1-\lambda^p}} + \xi_p (\tilde{\pi}_{p,t} P_{t-1})^{\frac{1}{1-\lambda^p}}. \tag{3.11}$$

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 their profit maximization leads to the demand function for labor type j as

$$L_{j,t} = L_t \left(\frac{W_{j,t}}{W_t} \right)^{\frac{\lambda^w}{1-\lambda^w}}.$$

Labor unions face Calvo (1983)-type wage rigidities. In each period, with probability ξ_w, labor union j cannot reoptimize the wage rate of labor type j and sets the wage rate according to

$$W_{j,t} = \tilde{\pi}_{w,t} e^{\tilde{\mu}_{w,t}} W_{jt-1} \, ,$$

where

$$\tilde{\pi}_{w,t} = \left(\pi_t^*\right)^{\ell_w} \left(\pi_{t-1}\right)^{1-\ell_w} \tag{3.12}$$

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. With probability $1-\xi_w$, labor union j chooses $W_{j,t}^*$ to maximize its profits, and all labor unions that reoptimize wages in period t set the same wage as $W_{j,t}^* = W_t^*$.

The aggregate wage level evolves as

$$W_t^{\frac{1}{1-\lambda^w}} \;\; = \;\; (1-\xi_w)\left(W_t^*\right)^{\frac{1}{1-\lambda^w}} + \xi_w \left(\tilde{\pi}_{w,t} e^{\tilde{\mu}_{w,t}} W_{t-1}\right)^{\frac{1}{1-\lambda^w}} . \tag{3.13}$$

3.5 Monetary and fiscal authorities

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

$$r_t - r = \phi_r (r_{t-1} - r) + (1-\phi_r)[\phi_\pi(\pi_t - \pi^*) + \phi_y \Delta y_t] + \sigma_r e_{r,t} \, , \tag{3.14}$$

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 2.1, 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:

$$\frac{P_{b,t} B_t}{P_t} = R_{b,t} \frac{P_{b,t-1} B_{t-1}}{P_t} + G_t - T_t \tag{3.15}$$

holds at any time t. We rewrite the government budget constraint as

$$b_t = \frac{R_{b,t} Y_{t-1}}{\Pi_t Y_t} b_{t-1} + g_y - \tau_t \, , \tag{3.16}$$

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_t is government spending, and g_{yt} is the ratio of government expenditures to output[8].

In the standard new Keynesian model (Davig and Leeper, 2011; Bianchi and Ilut, 2017), the

[8] Government spending is assumed to be a fixed fraction of output in the paper.

fiscal authority adjusts the tax as a share of output according to the tax policy rule specified as:

$$\tau_t - \tau = \varsigma_\tau(\tau_{t-1} - \tau) + (1 - \varsigma_\tau)\left[\varsigma_b(b_{t-1} - b) + \varsigma_g(g_{yt} - g_y) + \varsigma_y(y_t - y)\right] + \sigma_\tau e_{\tau,t}, \tag{3.17}$$

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 fiscal policy (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 2.1.

3.6 Equilibrium

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

$$Y_t = C_t + I_t/\Psi_t + G_t + a(u_t)\bar{K}_{t-1}\,. \tag{3.18}$$

3.7 Asset pricing implications

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

$$M_{t+1} \equiv e^{m_{t+1}} = \beta\left(\frac{C_{h,t+1}}{C_{h,t}}\right)^{-\psi}\left(\frac{V_{t+1}^{1/(1-\psi)}}{\mathbb{E}_t\left[V_{t+1}^{(1-\gamma)/(1-\psi)}\right]^{1/(1-\gamma)}}\right)^{\psi-\gamma}\left(\frac{P_{t+1}}{P_t}\right)^{-1}. \tag{3.19}$$

The risk-free short-term interest rate is given by $e^{-r_t} = \mathbb{E}_t\left[M_{t+1}\right]$. Appendix B shows that the log pricing kernel can be written as

$$m_{t+1} = \theta\log\beta - \gamma\Delta c_{h,t+1} - (1-\theta)\tilde{r}_{u,t+1} - \pi_{t+1}\,, \tag{3.20}$$

where $\theta = \frac{1-\gamma}{1-\psi}$ and $\tilde{r}_{u,t+1}$ is related to returns on the household's wealth portfolio, the dividend of which equals consumption minus the disutility of labor in monetary terms. 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.

3.7.2 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

$$P_{s,t} = P_t C_t^{\lambda} + \mathbb{E}_t \left[M_{t+1} P_{s,t+1} \right], \tag{3.21}$$

$$R_{s,t+1} = \frac{P_{s,t+1}}{P_{s,t} - P_t C_t^{\lambda}}. \tag{3.22}$$

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

$$\log \mathbb{E}_t \left[e^{r_{s,t+1} - r_t} \right] = -\text{cov}_t \left(m_{t+1}, r_{s,t+1} \right), \tag{3.23}$$

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

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

$$R_{b,t} = \frac{1 + \rho P_{b,t}}{P_{b,t-1}}. \tag{3.24}$$

The expected excess bond return is

$$\log \mathbb{E}_t \left[e^{r_{b,t+1} - r_t} \right] = -\text{cov}_t \left(m_{t+1}, r_{b,t+1} \right), \tag{3.25}$$

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 $1/(1 - \rho/(1 + \iota_t))$. See Appendix C for the derivation.

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. The log return on this bond, $r_{b,t+1}^{(n)}$, can be written as[9]

$$\log \mathbb{E}_t \left[e^{r_{b,t+1}^{(n)} - r_t} \right] = \text{cov}_t \left[m_{t+1}, \sum_{s=1}^{n-1} r_{t+s} \right]. \tag{3.26}$$

This equation holds regardless of whether the bond risk premium is constant or not. Intuitively, nominal bonds are risky for investors if the bond price falls when the marginal utility rises, the latter of which can be driven by lower consumption growth or/and lower returns on wealth.[10] The bond price falls 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 (3.26).

[9] See Appendix D for detailed derivations.

[10] 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.

4 Results and analysis

4.1 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 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

$$X = X_q \equiv -Q_2/Q_1. \tag{4.1}$$

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

$$X = X_r \equiv -R_2/R_1. \tag{4.2}$$

and

$$X = X_{qr} \equiv -\begin{bmatrix} Q_2 \\ R_2 \end{bmatrix} \Big/ \begin{bmatrix} Q_1 \\ R_1 \end{bmatrix}. \tag{4.3}$$

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

4.2 Calibration

The model is calibrated at quarterly frequency. Table A.1 lists the values of the structural parameters. Most of the parameter values are taken from the literature and the rest are chosen to match the key moments in our sample period.

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 0.65% 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 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 A.1. 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 an annual nominal risk free rate of 5.18%. 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). Risk aversion parameter in a production economy is generally much larger than the value in an endowment economy due to household's ability 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 $\phi_\pi = 0.4995$. 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 persistences 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).

Table 2: **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 stock ($r_s - r$)	7.99	16.68	1.84	3.86
excess return on 5-year nominal bond ($r_b - r$)	2.62	6.18	0.61	1.64

Notes: This table reports 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.

We solve the model using the method discussed in Section 4.1 and generate the moments of key macroeconomic and finance variables. These moments are presented in Table 2, along with the corresponding moments in the data. Among the model moments, the computation of the equity premium and long-term bond premium are 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 (3.23) and (3.25). These equations hold exactly if m, r_s, and r_b follow the multivariate normal distribution.[11]

As shown in Table 2, all moments of macroeconomic variables—consumption, investment, inflation, and short rate—are matched quite closely. For moments of financial variables, our model accounts for a half of the observed excess return on a nominal 5-year Treasury bond and one-third of the observed excess return on the market portfolio. This turns out to be a reasonable success for such a small scale new Keynesian model, which is intended mainly to transpire economic intuition. Next, we explain the economic mechanisms through variance decomposition and impulse responses to the four structural shocks.

4.3 Variance decomposition

Table 3 reports variance decomposition of key macroeconomic and financial variables under the M and F regimes in our calibrated regime-switching model. Under 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%). Under 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 under both M and F regimes—almost 100%. The effects of monetary and fiscal policy shocks are negligible in both M and F regimes. These results are crucial for understanding regime-dependent dynamics of the consumption-inflation correlation, the stock-bond return correlation, and stock and bond risk premiums.

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, the 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 3 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.

The risk premiums of stock and bond depend on the covariances between the pricing kernel and the returns on stock and bond, as shown in equations (3.23) and (3.25). Because the pricing kernel variation is dominated by the technology shock under both regimes, the risk premiums of stock and bond are mostly determined by the technology shock as well. In the next several subsections, we discuss the dynamic responses of financial market and macroeconomic variables to the two most important structural shocks, technology and investment shocks, and show that our results are qualitatively consistent with the observed stylized facts. For brevity, the impulse responses to

[11] We solve our model up to the first order approximation, therefore the means of the simulated equity and bond returns are both zero. However, we can compute the equity and bond risk premiums using the the covariance between return and pricing kernel based on the first order approximation. The reason is that the value of the covariance is mainly driven by the first order terms in return and pricing kernel. The second and higher orders terms have negligible effects on covariance.

Table 3: **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 regime switching model: excess return on stock ($r_s - r$), which is a claim on consumption, excess return on 5-year nominal bond ($r_b - r$), 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.

monetary and fiscal shocks are discussed in Appendix E.

4.4 Impulse responses to the technology shock

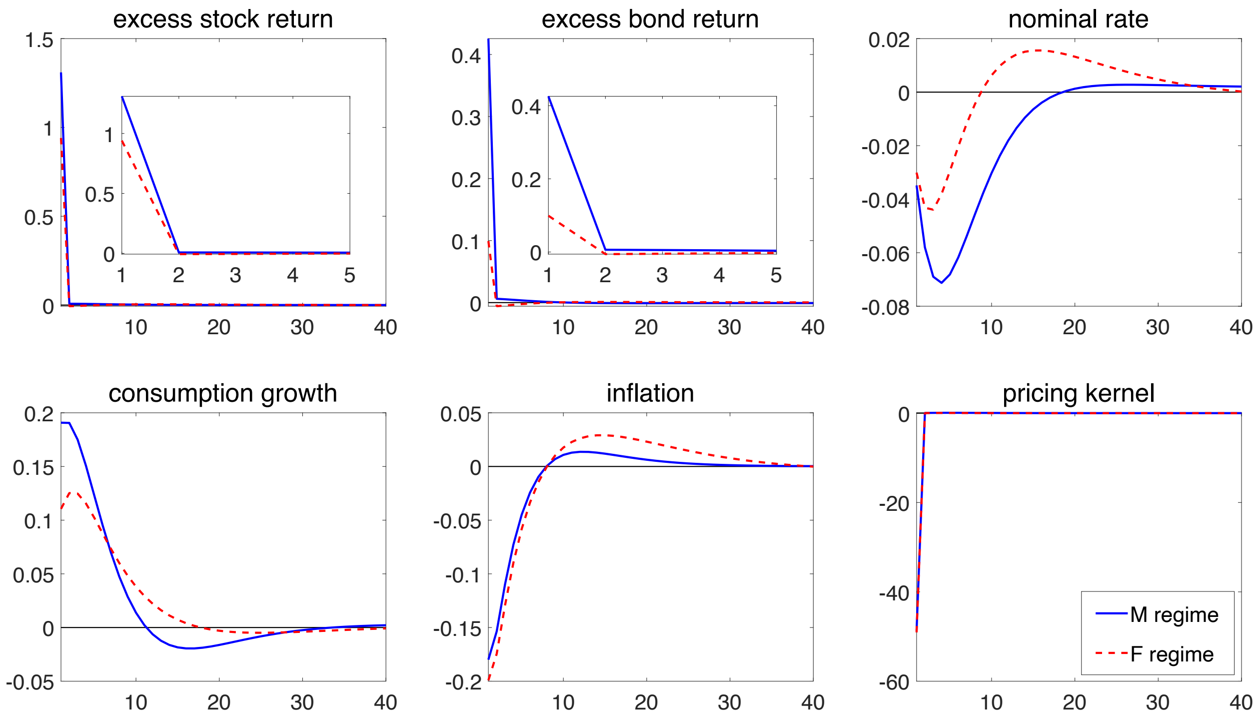
Figure 2 presents the impulse responses of excess returns of stock and bond, the nominal interest rates, consumption growth, and inflation to a one-standard-deviation positive technology shock in the M (blue solid lines) and F (red dashed lines) regimes.[12] In response to a positive technology shock, consumption rises, but inflation falls; because the technology shock is a supply shock. In response to the falling inflation, the nominal interest rate declines under the Taylor rule. Stock prices rise with rising consumption, and bond prices rise with falling nominal interest rates. Therefore, the technology shock leads to a negative consumption-inflation correlation and a positive stock-bond return correlation.

Figure 2 shows that stock and bond returns rise in larger magnitude under the M regime than under the F regime. The nominal interest rate is more responsive to the fall of inflation, amplifying the effects of the technology shock. Consequently, consumption rises more and so do stock prices in the M regime than in the F regime. There is a more persistent fall in the interest rate under the M regime. Figure 2 shows that the negative effect of the 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 3: a much higher percentage of variations in

[12] The impulse responses of other variables to a positive technology shock are plotted in Panel (a) of Figure A.1.

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



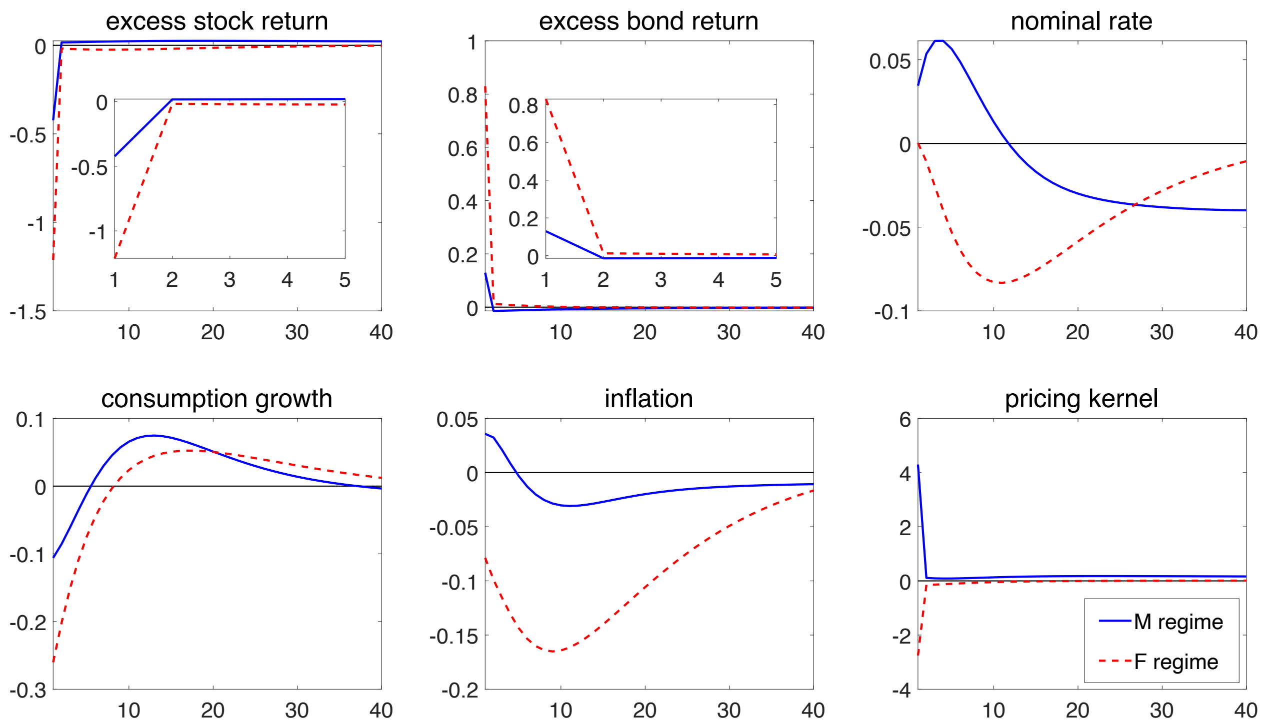
Notes: This figure plots the impulse responses of key macro and finance variables in the model after a one-standard-deviation positive technology shock. The blue solid lines and red dashed lines represent impulse responses under the M and F regimes, respectively. The x-axis shows the time in quarters,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

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 3 shows that the pricing kernel is almost solely determined by the technology shock under both regimes. The impulse responses of the pricing kernel to the technology and investment shocks (Figure 2 and Figure 3) present a consistent picture: the percentage change in the pricing kernel is around 50% in response to one standard deviation of the technology shock, while is only 3-4% in response to one standard deviation of the investment shock.

As shown in equation (3.20), the pricing kernel has two components: the current 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 (shock on the growth rate of the technology level), both the current consumption and return on wealth go up in reaction to a positive shock, resulting in a large drop in the pricing kernel. In contrast, the investment shock is a transitory shock. It mainly impacts the current consumption, but not on the return on wealth. Consequently, the effect of the technology shock on the pricing kernel always dominates that of the investment shock and the risk premiums of stock and bond are

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 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.

positive in both M and F regimes.

4.5 Impulse responses to the investment shock

Figure 3 presents 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.[13] A positive investment shock means a more efficient transformation of investment into capital, generating higher demands for investment goods, i.e., the investment shock is a demand shock. Both output and investment increase, but consumption decreases in the short run, as an intertemporal substitution for higher consumption in the long run.[14] Stock prices fall in general, due to the dominating effect of falling consumption in the short run.

[13]The impulse responses of other variables to a positive investment shock are plotted in Panel (b) of Figure A.1.

[14]Even though the initial responses of consumption and output to an investment shock are in opposite directions (see Panel (b) in Figure A.1), the unconditional correlation between consumption and output is positive in the full model (see Table 4) and in the model with only investment shocks (see Table A.5). The reason is that the response of output is positive first but becomes negative quickly afterwards. The movements in output are the summation of responses to the current and previous shocks. It turns out that the positive response of output to the current shock is dominated by negative responses to the previous shocks, resulting in a positive consumption-output correlation.

In the M regime, general prices rise first in response to higher demands for output and then fall after about 5 quarters. With the Taylor rule, the nominal interest rate similarly rises in short horizons but then 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 long-term bond prices turns out to be positive. Therefore, the investment shock generates a negative stock-bond return correlation and a negative consumption-inflation correlation in the M regime.

In the F regime, however, inflation falls sharply and persistently after a positive investment shock. With active fiscal policy, an increase in output leads to an increase in tax income, and taxes do not respond to the change of the debt-to-output ratio. 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 over all horizons, resulting in a large increase of the long-term bond price. Higher tax income further depresses consumption. 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 directions of these responses are the same under both regimes. The most important finding is that the consumption-inflation correlation turns positive in the F regime in response to the investment shock. These dynamic responses are consistent with the variance decomposition results reported in Table 3: the investment shock dominates the dynamics of stock and bond returns, consumption growth, and inflation in the F regime.

It is worth noting that investment shock has little impacts on stock and bond risk premiums because of its minimal influences on the pricing kernel, as illustrated in the variance decomposition in Table 3. For example, stock returns are positively correlated with the pricing kernel in response to investment shock in the F regime, which would imply a negative equity premium. However, the sign of the equity premium is determined by the technology shock and is always positive regardless of the policy regime both in the model and in the data.

4.6 Discussion

We summarize the above analysis as three main findings:

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 the M and F regimes, mainly driven by the technology shock.

It is informative to relate these findings to the Capital Asset Pricing Model (CAPM). In an economy where the CAPM holds, a negative correlation between returns on the nominal long-term

Table 4: **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 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.

bond and on the stock market implies negative excess bond risk premiums. However, as Fama and French (1993) show, the CAPM fails to explain empirical data. As shown in Belo et al. (2017), the CAPM also fails in models with multiple fundamental risks like ours or in models with the nonlinear pricing kernel.[15] In our model, because the risk premiums of stocks and long-term bonds are driven by the technology shock in both the M and F regimes, they are always positive regardless of regime. By contrast, the stock-bond return correlation, which has the same sign as the market beta of the long-term bond, turns negative in the F regime, because it is mainly driven by the investment shock in this regime. Such a coexistence of positive bond risk premium and negative stock-bond correlation distinguishes our work from others such as Campbell et al. (2020).

The above analysis is confirmed by the simulation-based correlation matrix in Table 4 of the excess stock and long-term bond returns, inflation, consumption growth rate, and pricing kernel in both the M and F regimes, under the baseline model with all four shocks. The stock-bond return correlation is 0.51 under the M regime and -0.57 under the F regime; the consumption-inflation correlation is -0.65 under the M regime and 0.14 under the F regime; and the correlation between the pricing kernel and returns on stock (bond) are always negative under both the M and F regimes, -0.70 and -0.30 (-0.61 and -0.20), indicating positive risk premium in stock (bond).

Although not emphasized in the literature, the correlation between output and inflation exhibits similar dynamics as the consumption-inflation correlation, being negative (-0.25) before 2001Q2 and positive (0.21) after 2001Q2. This pattern is successfully reproduced by the model: The output-inflation correlation is -0.30 in the M regime and 0.21 in the F regime as shown in Table 4.

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

5 Robustness

5.1 An extended model with eight shocks

We extend our baseline model to include four additional shocks that are 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 definitions of these shock processes are provided in Appendix F. The persistence and standard deviations of these additional shocks are taken from prior literature, which are reported in Table A.2 together with the corresponding references. Figure A.2 reports the impulse responses of key financial and macro variables under these four additional shocks. Table A.5 presents the stock-bond return correlation, consumption-inflation correlation, and output-inflation correlation under each shock alone and Table A.6 presents the correlation matrix of key variables in the presence of all 8 shocks.

All key results in the baseline continue to hold in the extended model with 8 shocks for two reasons. First, the variance decomposition in Table A.4 shows that technology and investment shocks are still the most important shocks for stock and bond returns in the M and F regimes, respectively. And the technology shock continues to be the dominating shock for the pricing kernel, although the IST shock, as a permanent shock on the investment-to-consumption price, contributes significantly to variance of the pricing kernel (11.04% and 8.96% in the M and F regimes) as well. Second, majority of the additional shocks imply consistent signs of the consumption-inflation and stock-bond return correlations with those in the baseline. Specifically, as shown in Table A.5, all newly added shocks, except the IST shock, imply positive stock-bond return correlation in the M regime, and all of them imply negative stock-bond return relation in the F regime. The impact of technology shock dominates that of the IST shock in our calibration, and thus the dependence of the stock-bond return relation on policy regimes continues to hold in the 8-shock model. In terms of the consumption-inflation correlation, all newly added shocks imply a negative correlation in the M regime, and all but the transitory productivity shock implies a positive correlation in the F regime. The variance decomposition indicates that the investment shock continues to dominate the consumption-inflation correlation in the F regime.

In short, the added shocks do not change the dependence of the stock-bond return and consumption-inflation correlations on policy regimes in the baseline model as shown in Table A.6. In addition, stock and bond risk premiums remain positive under all policy regimes because the technology shock continues to dominate the dynamics of the pricing kernel.

5.2 The F regime at the zero lower bound (ZLB)

The ZLB is an extreme case of 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. To keep the model tractable and avoid the computational difficulty, we do not include additional preference or inflation shocks to create the ZLB environment endogenously. Instead, we assume the ZLB scenario exogenously, in which the policy rate is constant at its steady state level (i.e., $\phi_r = 0.99$ and $\phi_\pi = \phi_y = 0$).[16] The parameters in the fiscal policy rule are the same as in the F regime of our baseline model. Both technology and investment shocks generate a positive consumption-inflation correlation and a negative stock-bond return correlation at the ZLB, while only the investment shock does in general cases of F regime.

Impulse responses in red dashed lines in Panel (a) of Figure A.3 show that when the ZLB is binding, i.e., the policy rate is kept constant, lower inflation caused by a positive technology shock leads to higher real interest rate, which has a significant contractionary impact on the economy.[17] Consumption decreases and that results in a positive consumption-inflation correlation. Stock prices fall due to lower consumption and bond prices go up due to lower inflation. As a result, the bond and stock returns move in opposite directions.

Table A.7 reports the correlation matrix when the economy is constrained by the ZLB in the F regime. As one can see, the negative stock-bond return correlation and positive consumption-inflation correlation in the F regime continue to hold when the ZLB is binding in the F regime. This result echoes the findings in 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 reasonable magnitude. We show in this section that the relation between key correlations and policy regimes is robust to alternative preferences.

5.3.1 CRRA preference Figure A.4 displays the impulse responses to technology and investment shocks in both policy regimes with the constant relative risk aversion (CRRA) preference ($\gamma = \psi = 1/1.5$). Qualitatively, these results are very much similar to those under the recursive preference in the baseline model. Specifically, a positive technology shock leads to an increase in returns on stocks (consumption claims) and the long-term nominal bond in both policy regimes, while a positive investment shock leads to opposite movements in these two returns. Panel A of Table A.8 shows that the positive stock-bond return correlation and negative consumption-inflation correlation in the M regime and the opposite in the F regime still hold under the CRRA preference. This result is not surprising in that the most important difference between the CRRA and recursive preferences is that the latter allows larger risk aversion to generate Sharpe ratios comparable to those in the data.

5.3.2 Recursive preference without habit We solve a model under a recursive preference without habit formation ($b_h = 0$). Figure A.5 reports the impulse responses to technology and investment shocks in both policy regimes. Without habit, consumption becomes more volatile

[16] Under this particular setup, the policy rate does not respond to inflation and output changes at all, but only fluctuates moderately with monetary policy shocks.

[17] The negative effect of a positive technology shock on consumption is a common result of the new Keynesian model at the ZLB as shown in Garín et al. (2019), Wieland (2019) and Wu and Zhang (2019).

as expected. However, signs of the key correlations remain unchanged compared with those in the baseline. Panel B of Table A.8 presents the simulation-based correlation matrix under the recursive preference without the habit. Both the impulse responses and the correlation matrix are qualitatively similar to those of the baseline model.

6 Conclusion

We apply a new Keynesian model with the recursive preference to interactions between monetary and fiscal policies 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 find is that technology shocks drive the fluctuation of the economy in the M regime while investment shocks are a driving force in the F regime. Our findings lay a structural foundation for a general-equilibrium framework that bridges financial markets and monetary-fiscal policies.

Our paper is silent on a number of issues that are beyond the scope of the paper. One issue is to test various possible channels or 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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Appendix A Data

The raw data in quarterly frequency 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^{nom}): price index of nondurable goods, index numbers, 2005=100, seasonally adjusted at annual rates, NIPA.
Price index (PI^{nom}): nominal investment: price index of nominal gross private domestic investment, Nonresidential, Equipment & Software index numbers, 2005=100, seasonally adjusted at annual rates, NIPA.
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-yr 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 A return representation of pricing kernel

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

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

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.1) 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

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

Appendix C Yield and Duration

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

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

Appendix D Risk premium in long-term nominal zero-coupon bonds

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

$$P_{b,t}^{(n)} \equiv e^{-n\iota_t^{(n)}} = \mathbb{E}_t[e^{m_{t,t+n}}], \tag{D.1}$$

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

$$\log\mathbb{E}_t\left[e^{r_{b,t+1}^{(n)} - r_t}\right] = \mathrm{cov}_t\left(m_{t+1}, (n-1)\iota_{t+1}^{(n-1)}\right). \tag{D.2}$$

By the definition of bond price, we have

$$\log P_{t+1}^{(n-1)} = -(n-1)\iota_t^{(n-1)} = \log\mathbb{E}_{t+1}\left[e^{\sum_{i=2}^{n} m_{t+i}}\right] = \mathbb{E}_{t+1}\left[\sum_{i=2}^{n} m_{t+i}\right] + \frac{1}{2}\mathrm{var}_{t+1}\left(\sum_{i=2}^{n} m_{t+i}\right) \tag{D.3}$$

Substituting equation (D.3) into equation (D.2), we have

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

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

Appendix E 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 in stock and in real and nominal long-term bonds all fall, resulting in a positive stock-bond return correlation. At the same time, the consumption-inflation correlation between 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 increase taxes and reduce demand, resulting in 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, economy expands in the M regime while 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 price rises. Stock price moves 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 3, 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 F 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.[18]

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

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

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}:

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

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

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

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

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

[18] Calibrated parameter values of the shock processes and the resulting simulated moments of key macro and financial variables are presented in Table A.2 and Table A.3, respectively.

Table A.1: **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-assets 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)
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)

Continued on next page

Table A.1 – continued from previous page

Parameter	Description	Value	Target moments or references
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 A.2: **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, wage markup (WM) shock, in the extended model with 8 shocks.

Table A.3: **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 stock ($r_s - r$)	7.99	16.68	2.16	4.06
excess return on 5-year nominal bond ($r_b - r$)	2.62	6.18	0.49	1.79

Notes: This table reports the first and second moments of key macroeconomic and financial variables. 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.4: **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 regime switching model: excess return on stock ($r_s - r$), which is a claim on consumption, excess return on 5-year nominal bond ($r_b - r$), growth rate of consumption (Δc), inflation (π), nominal pricing kernel (m), and growth rate of output (Δy). 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.5: **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, and fiscal policy (FP) shock, transitory productivity (TP) shock, investment-specific technology shock (IST), price markup (PM) shock, wage markup (WM) shock. 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 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 stock (claim on consumption) ($r_s - r$), excess return on 5-year nominal bond ($r_b - r$) , 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 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 stock (claim on consumption) ($r_s - r$), excess return on 5-year nominal bond ($r_b - r$) , 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: **Correlation matrices — alternative preferences**

Panel A: CRRA preference

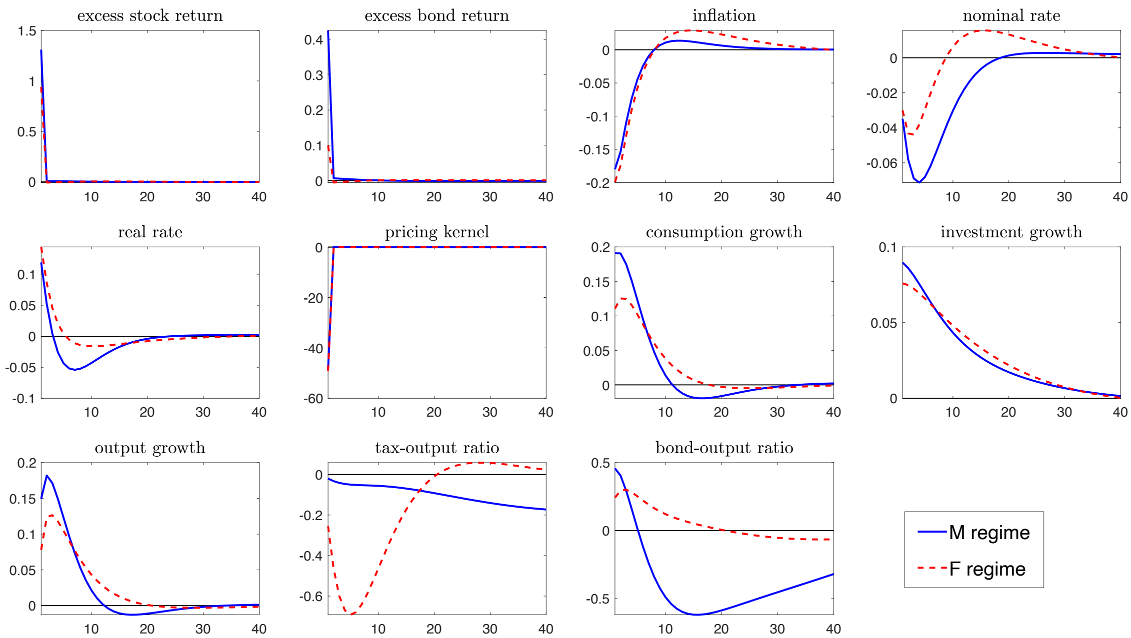
Variables	$r_s - r$ (M / F)	$r_b - r$ (M / F)	π (M / F)	Δc (M / F)	Δy (M / F)	m (M / F)
$r_s - r$	1.00	0.53 / -0.57	-0.46 / 0.13	0.52 / 0.59	0.19 / 0.12	-0.91 / -0.92
$r_b - r$		1.00	-0.29 / -0.14	0.26 / -0.40	0.33 / 0.31	-0.38 / 0.63
π			1.00	-0.65 / 0.14	-0.29 / 0.21	0.23 / -0.41
Δc				1.00	0.44 /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

Panel B: Recursive preference without habit formation

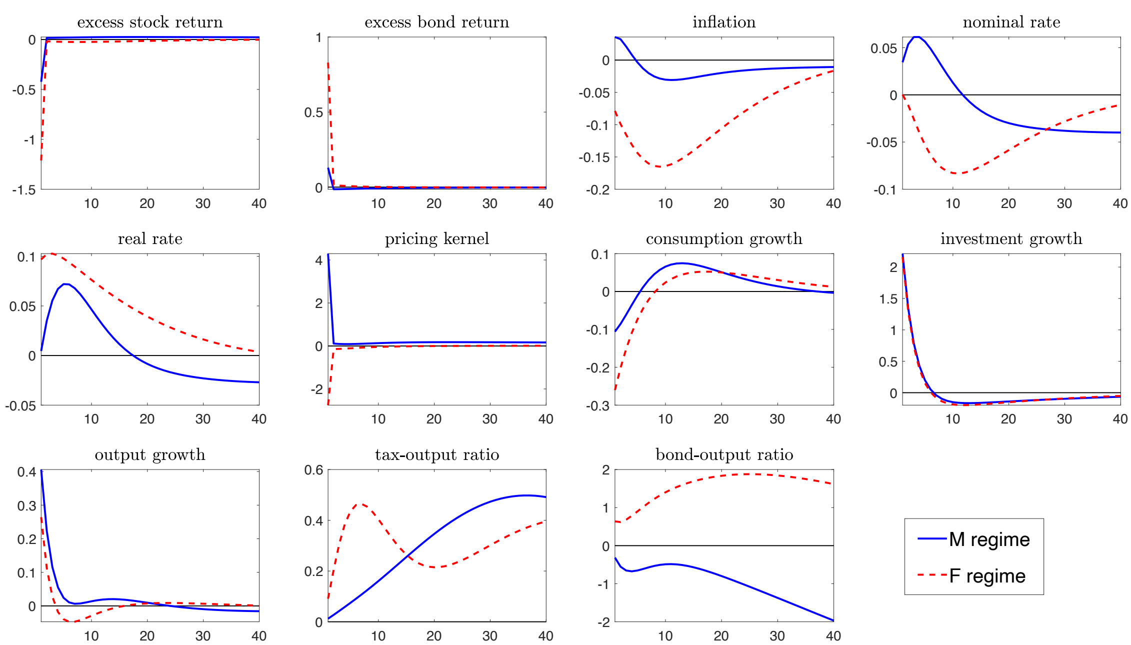
Variables	$r_s - r$ (M / F)	$r_b - r$ (M / F)	π (M / F)	Δc (M / F)	Δy (M / F)	m (M / F)
$r_s - r$	1.00	0.17 / -0.55	-0.31 / 0.22	0.92 / 0.94	0.86 / 0.91	-0.76 / -0.49
$r_b - r$		1.00	-0.10 / -0.25	0.07 / -0.61	0.14 / -0.46	-0.33 / -0.12
π			1.00	-0.31 / 0.06	-0.29 / 0.06	0.48 / 0.18
Δc				1.00	0.90 / 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 stock ($r_s - r$), excess return on 5-year nominal bond ($r_b - r$), 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.

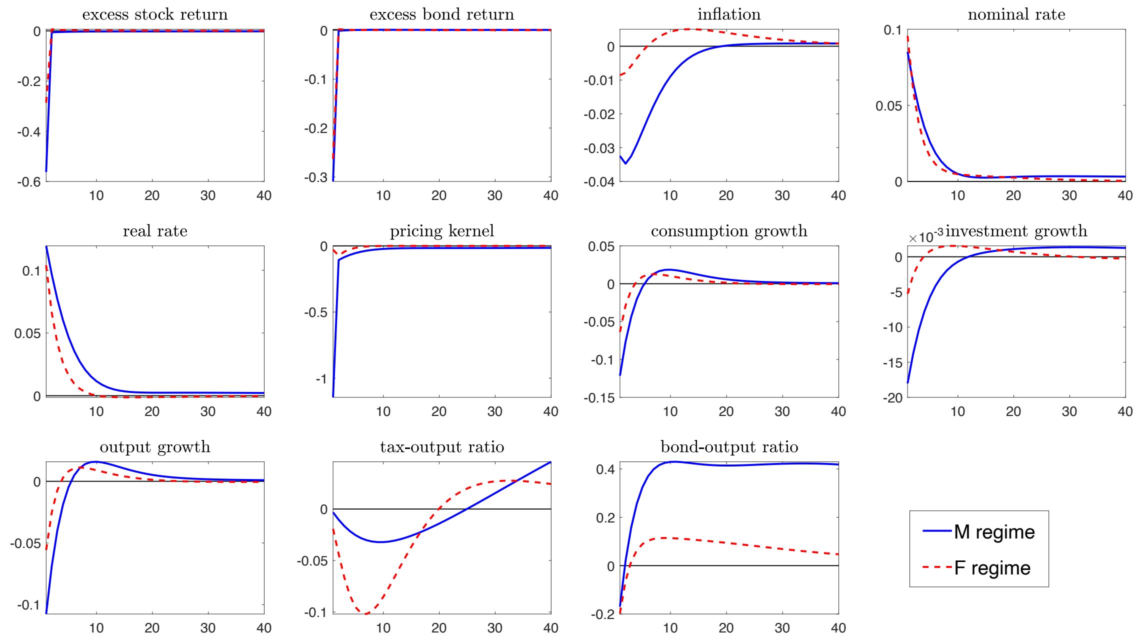
Figure A.1: **Impulse responses in the baseline model**



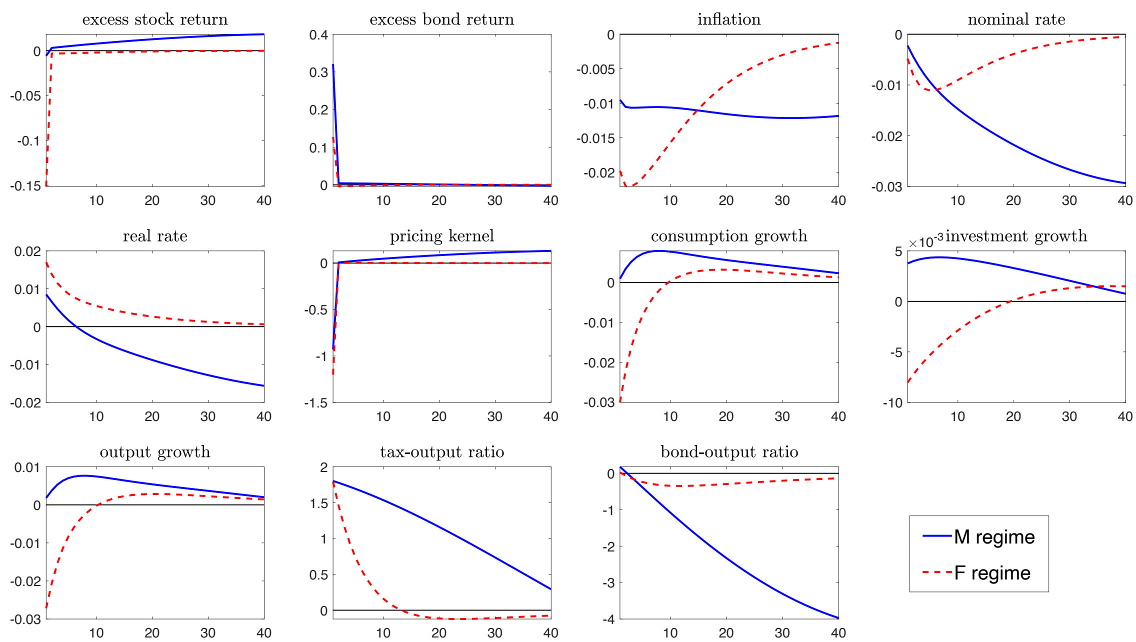
Panel (a): Impulse responses of a positive technology shock



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



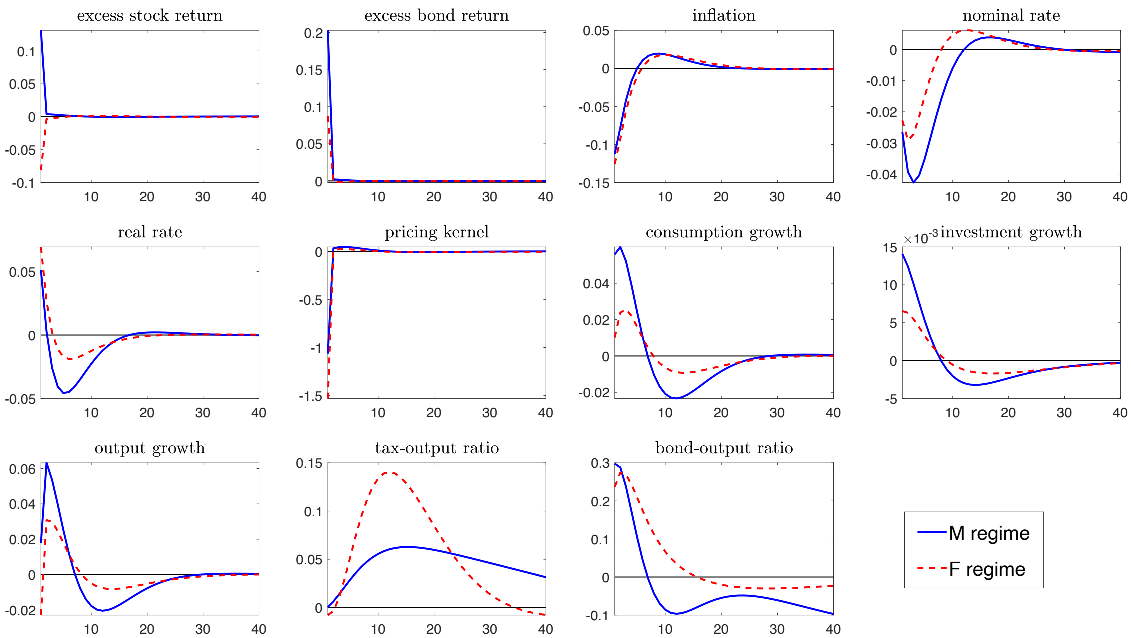
Panel (c): Impulse responses of a positive monetary policy shock



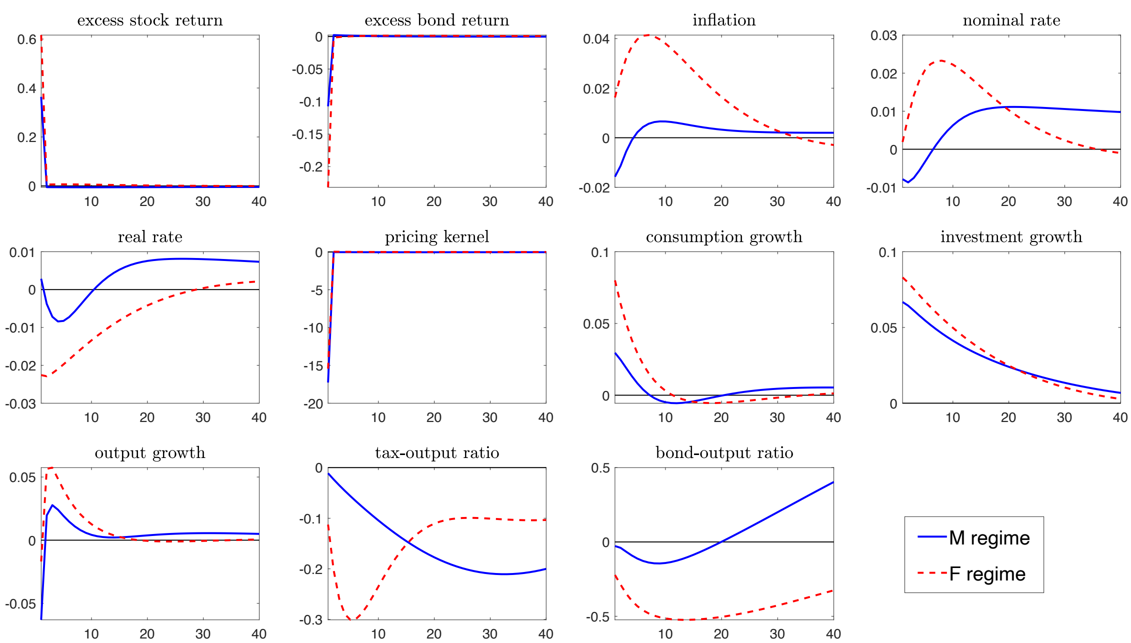
Panel (d): Impulse responses of a positive fiscal policy shock

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.

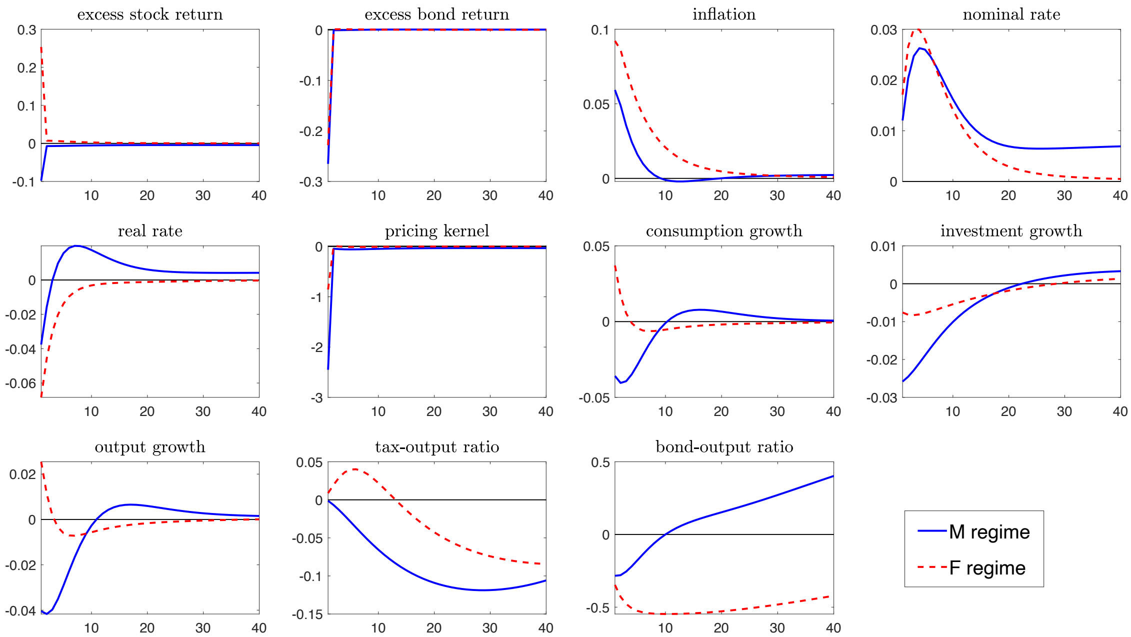
Figure A.2: **Impulse responses of the extended model with 8 shocks**



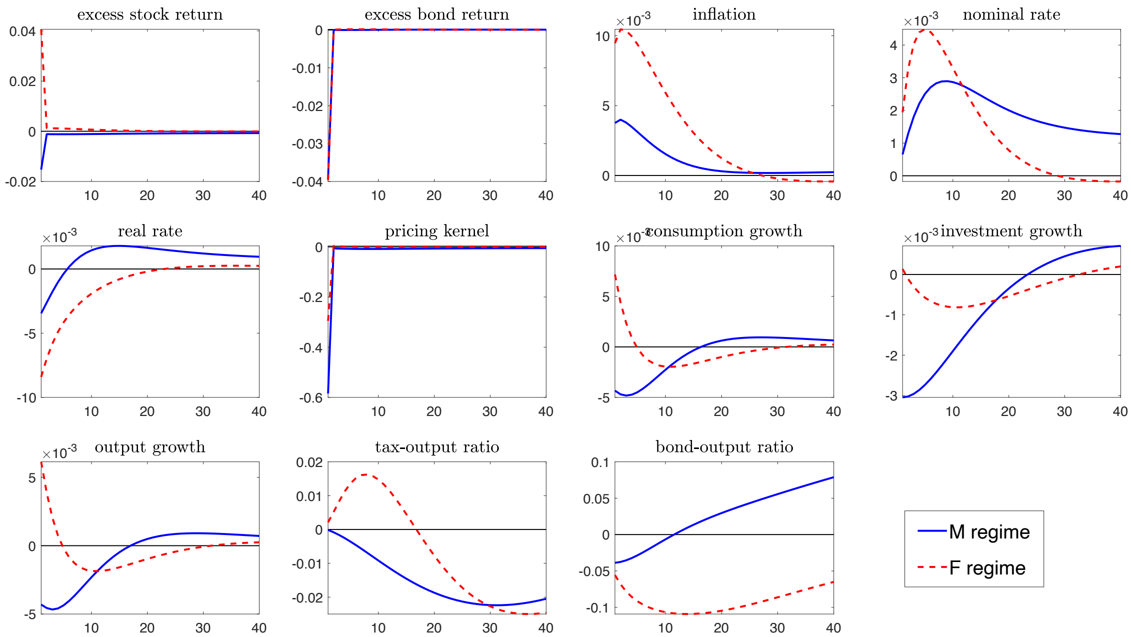
Panel (a): Impulse responses of a positive transitory productivity shock



Panel (b): Impulse responses of an IST shock



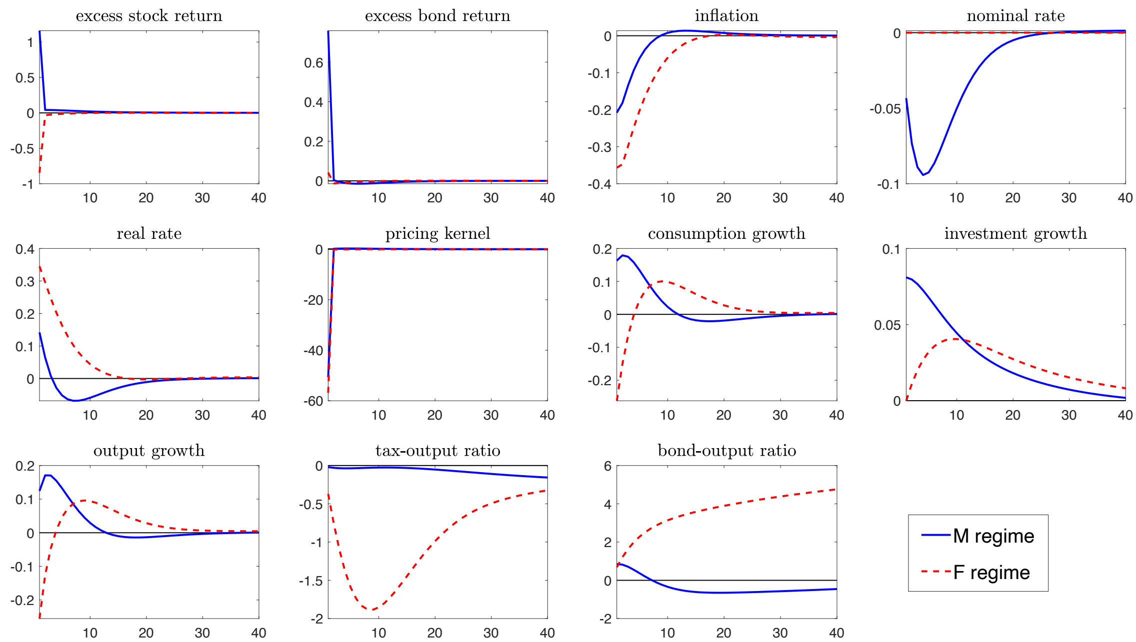
Panel (c): Impulse responses of a price markup shock



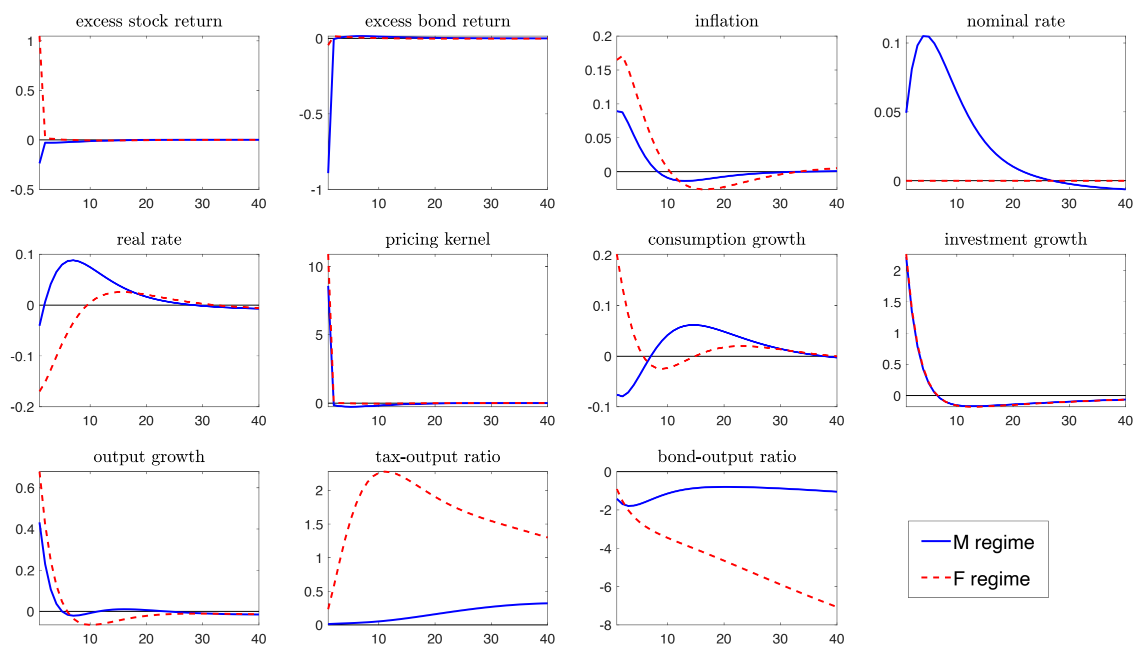
Panel (d): Impulse responses of a wage markup shock

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**



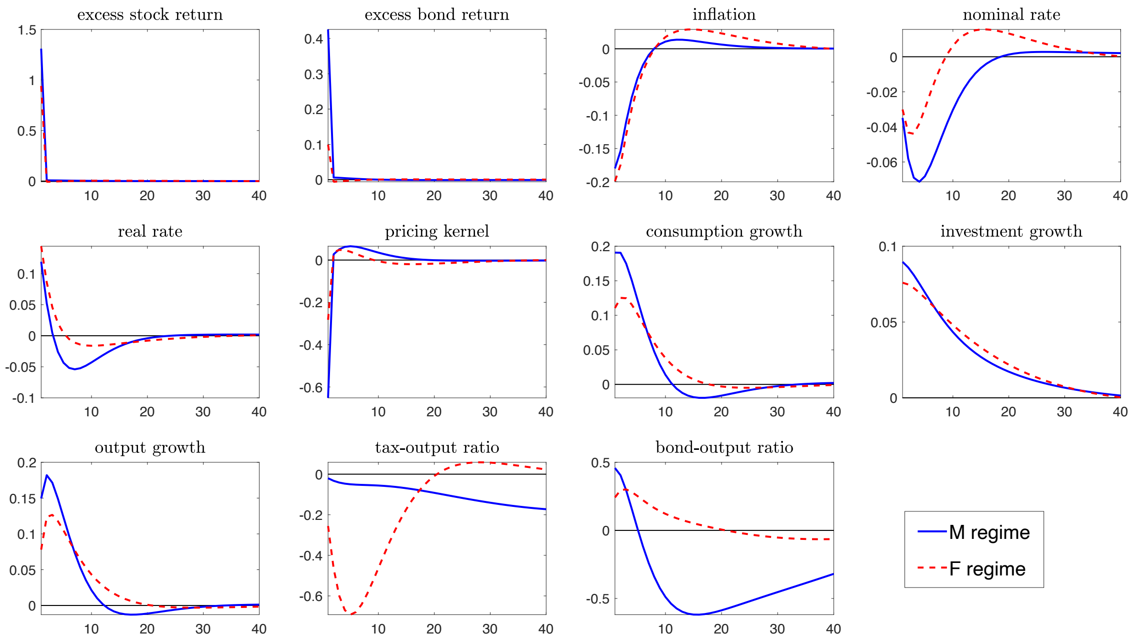
Panel (a): Impulse responses of a positive technology shock



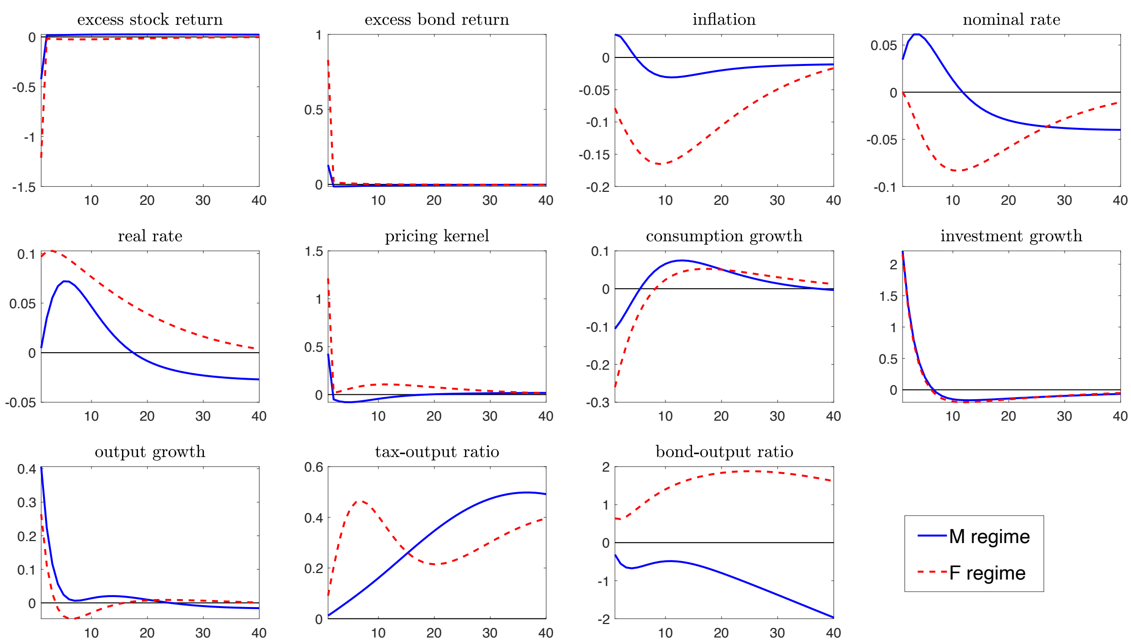
Panel (b): Impulse responses of a positive investment shock

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**



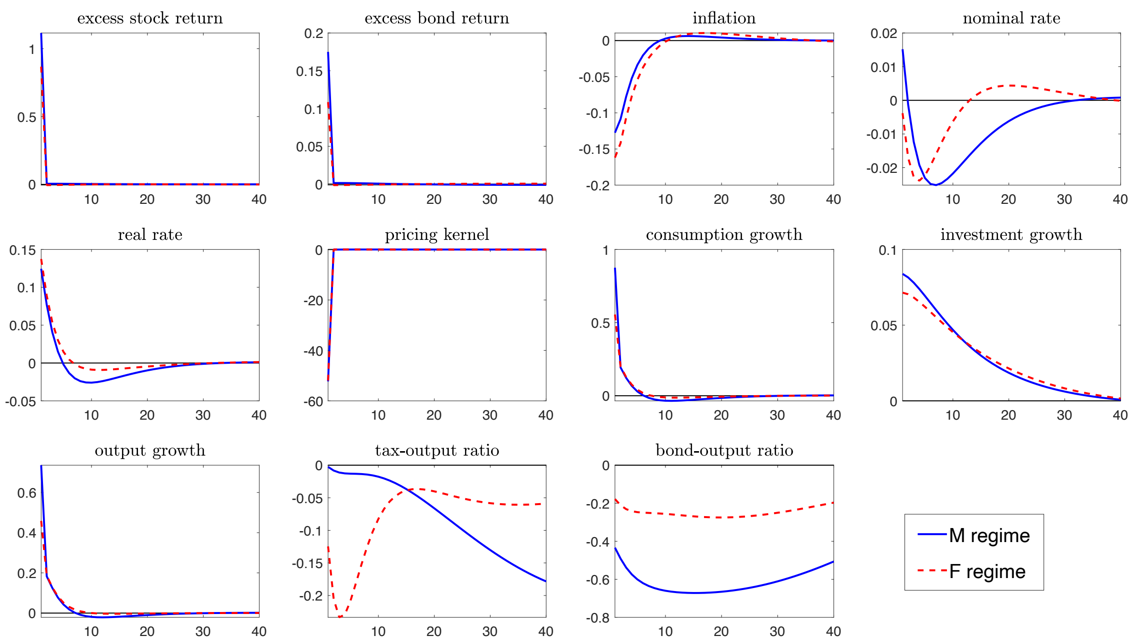
Panel (a): Impulse responses of a positive technology shock



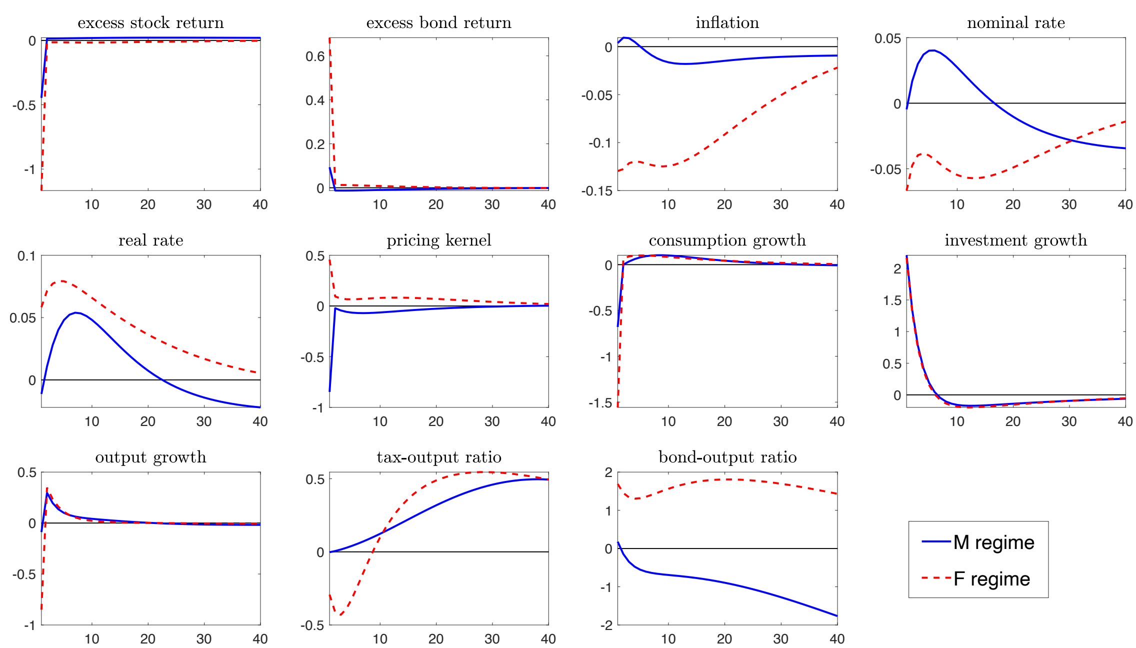
Panel (b): Impulse responses of a positive investment shock

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.