Active Monetary or Fiscal Policy and Stock-Bond Correlation *

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First draft: October 9, 2017
Current draft: March 18, 2019

Abstract

We propose a New Keynesian model with monetary-fiscal policy regime switch to explain the time-varying correlation between returns on the market portfolio and nominal Treasury bonds found in the data. In the active monetary and passive fiscal policy (AMPF) regime, permanent neutral technology (PT) shocks are the most important drivers of stock and bond returns, and lead to positive correlation between them. In the passive monetary and active fiscal policy (PMAF) regime, the effect of the PT shock is depressed due to the weak reaction of short-term nominal interest rate to inflation, while the effect of the MEI shocks becomes the strongest and leads to negative stock-bond correlation. When both monetary and fiscal policies are passive (PMPF regime), the PT shock and monetary policy (MP) shock together dominate the MEI shock, and generate positive stock-bond correlation. Our model provides a coherent explanation for the negative correlation between the market portfolio and long-term nominal Treasury bond returns during 1950s and 2000s when the economy was in the PMAF regime, and for the positive correlation during 1970-2000 when the economy was in the AMPF or PMPF regimes.

Keywords: bond-stock return correlation, monetary-fiscal policy regime

*We thank Eric Leeper for providing us data. We thank Hui Chen, Yang Liu, Deborah Lucas, and Pengfei Wang, as well as seminar and conference participants at Boston Fed, Cheung Kong Graduate School of Business, Fudan University, MIT, Tsinghua University, Shanghai University of Finance ad Economics, CICM annual conference, and CICF annual conference for helpful comments. Correspondence: xnli@ckgsb.edu.cn, zmail@tzha.net, zhangji@pbcsf.tsinghua.edu.cn, zhouh@pbcsf.tsinghua.edu.cn.

JEL classification codes: E52, E62, G12.

1 Introduction

Stocks and long-term nominal Treasury bonds are the two largest classes of assets in the financial markets. Understanding the correlation between returns of those two securities is tremendously important for the purpose of portfolio management and for the design of monetary and fiscal policies. Empirically, an increasing amount of studies (Campbell et al., 2015, 2016; Christiansen and Ranaldo, 2007; Guidolin and Timmermann, 2007; Baele et al., 2010; David and Veronesi, 2013; Gourio and Ngo, 2016; Mumtaz and Theodoridis, 2017) have documented the time-varying feature of the correlation between returns on the market portfolio of stocks and long-term (5- and 10-year) nominal Treasury bonds. The overall stock-bond return correlation is slightly positive in the period 1953-2014. However, this correlation was negative in the 1950s, it became positive between the late 1960s to 2000 and the magnitude was especially large between 1980 and 2000. However, the correlation turned negative again after 2000. The literature has yet provide a satisfactory explanation about the dynamics of this correlation during the post-War period. In this paper, we build a new Keynesian model with monetary-fiscal policy regime switch to explain the time-variation of the correlation between returns on stocks and long-term nominal Treasury bonds.

Since the seminal work of Sargent and Wallace (1981) and Leeper (1991), a growing literature, e.g., Davig and Leeper (2011) and Bianchi and Ilut (2016), has shown that it is essential to consider the joint behavior of monetary and fiscal authorities when examining the efficacy of government polices. Our model embodies interactions between monetary and fiscal policies in an otherwise standard New Keynesian model. In addition, we incorporate the recursive preference with habit formation to generate realistic asset prices and the mix of different monetary-fiscal regimes to match the structural change in the policies found in the literature. The market portfolio, i.e., the stock in the economy, is defined in our model as a levered claim on all future consumption. For simplicity, long-term nominal Treasury bond is modeled as a nominal consol bond, the coupon payment of which decays exponentially over time. We include four structural shocks in the model to match the data: the permanent neutral technology (PT) shock, marginal efficiency of investment (MEI) shock, monetary policy (MP) shock, and fiscal policy (FP) shock.

Monetary policy is modeled as a simple Taylor rule, in which short-term nominal interest rate reacts to inflation and output positively. Under active monetary policy, interest rate reacts to inflation more than one-for-one, while less than one-for-one under passive monetary policy. Following Leeper (1991), fiscal policy is modeled as a lump-sum tax rule that reacts to government debt outstanding, government spending, and output. Higher government spending is coupled with an equivalent increase in lump-sum taxes (in the present value sense) to pay for the spending under passive fiscal policies. However, taxes are not expected to fully finance the increase in spending under active fiscal policies. As shown in Leeper (1991), among the four possible combinations of monetary-fiscal policy mix, the active monetary and passive fiscal (AMPF) and the passive monetary and active fiscal (PMAF) policy regimes lead to unique equilibrium, the passive monetary and passive fiscal policy (PMPF) regime yields multiple equilibria in the model. Those three regimes are our focuses in this paper.

The key mechanism in our paper that can explain the time-varying stock-bond correlation is that, different shocks dominate in different policy regimes, and each of the dominant shocks generates different return dynamics. Among the four shocks in the model, the PT shock is the key driver of both the macroeconomic dynamics and the time-varying riskiness of nominal Treasury bonds in the AMPF regime. Under the AMPF regime, because nominal interest rate reacts strongly to the drop in inflation resulting from a positive PT shock, the real interest rate tends to go down and further stimulates the output and encourages consumption. The rise in consumption and persistent drop in nominal interest rate leads to higher stock and long-term nominal Treasury bond prices. Therefore, the PT shock leads to positive correlation of returns on stock and long-term nominal bonds. However, under the PMAF regime, because nominal interest rate responds mildly to the drop in inflation, the real interest rate tends to go up. Consequently, the stimulus effect of the PT shock is mitigated.

On the contrary, the MEI shock plays a key role in determining the stock-bond return correlation in the PMAF regime. Since a positive MEI shock leads to higher output level, under the PMAF regime, fiscal policy reacts to higher output through raising the tax-to-output ratio, and this reaction of tax pushes down the price. The short-term nominal interest rate declines persistently with the price, which implies a higher price of and hence a higher return on long-term nominal bonds. Stock return goes down since consumption is crowded out by investment. Therefore, the MEI shock replaces the PT shock as the dominant force of driving the return dynamics, and leads to a negative correlation of returns on the stock and the long-term nominal bond under PMAF regime.

A positive MP shock acts similarly in the standard New Keynesian model: it depresses the economy and lowers both stock and bond returns no matter what regimes the economy is in.

The time-variation of the stock-bond correlation is driven by the changing relative importance of the PT and MEI shocks under different monetary-fiscal policy regimes. Under the AMPF regime, the effect of the PT shock dominates that of the MEI shock, while the opposite happens under the PMAF regime because the effects of the PT shock is largely weakened. Under the PMPF regime, the PT and MP shocks together dominates. Our model thus predicts that the stock-bond correlation is positive under the AMPF and PMPF regimes and negative under the PMAF regime.

Narrative descriptions of the US monetary-fiscal policy history and the structural estimations in various studies, such as Davig and Leeper (2011), show consistently that the mid 1950s to the mid 1960s (with the exception of the late 1950s to early 1960s) and the post 2000 are the two longest period of PMAF regimes, while the 1980s to 2000 is a prolonged period of AMPF regime. The PMPF regime generally does not last as long as AMPF and PMAF regimes, and it mainly distributes in the 1970s. Our model thus provides a coherent explanation for the negative correlation between stock and bond returns during the mid 1950s to mid 1960s and post 2000 and the positive correlation during 1970-2000 under the

PMAF and PMPF regimes.

We show that our results are robust. The results hold for alternative preferences including recursive preferences without habit formation, and the CRRA preference. Our results also hold at the effective lower bound (ELB), which is an extreme scenario of the PMAF regime and resembles the Great Recession post-2007. Empirically, the beta of the nominal Treasury bonds drop to an extremely low level during that period.

Literature There are three papers that are closely related to our work. Campbell et al. (2015) propose that the change in the bond-stock return correlation is driven by the changes in the sensitivity of monetary policies to inflation and output gap, and the persistence of the monetary policy shocks. However, their model cannot explain the negative beta of nominal Treasury bonds in the 1950s.

Similar to our model, Mumtaz and Theodoridis (2017) also uses the switch of monetary-fiscal policy interaction to explain the sign change in the bond-stock return correlation. However, our mechanisms are different. Their model relies on the fiscal policy shock, which leads to different sign of correlation during different regimes. Our model, on the other hand, relies on the PT and MEI shocks, which have the largest contribution to business cycle fluctuations.

The most related study is Gourio and Ngo (2016), who focus on the zero lower bound (ZLB) period post 2008. Their New Keynesian model generates positive term premia and inflation risk premia during normal times, but these premia fall when the economy are at or close to the ZLB. The similarity of this paper and ours lies in the fact that the ZLB regime, where monetary policy is completely inactive, is an extreme case of the passive monetary policy in our setup. However, our results do not rely on the extreme inactiveness of the monetary policy. In fact, negative correlation between bond and stock returns happen not only during the ZLB period, but also in 1950's and the period between 2000 and 2008. Therefore, our framework is capable of explaining the dynamics of the correlation between stock and nominal bonds in the post-War period.

Finally, our paper belongs to the growing literature that study the asset pricing implications of government policies in a general equilibrium framework. Recent papers in this literature includes Andreasen (2012), Van Binsbergen et al. (2012), DewBeck (2014), Kung (2015), Li and Palomino (2014), Palomino (2012), Rudebusch and Swanson (2012), Croce, Kung, Nguyen and Schmid (2012), Hsu, Li and Palomino (2018), and Bretscher, Hsu and Tamoni (2018) in addition to the ones mentioned above.

The rest of the paper proceeds as follows. Section 2 provides empirical evidence on the shifts of bond-stock return correlation and monetary-fiscal policy regime. Section 3 proposes a New Keynesian model with bond, equity, and different monetary-fiscal policy regimes, and discusses the asset pricing implications of the model. Section 4 discusses the calibration of the model, the quantitative results, and the determinants of the correlation of stock and bonds. Section 5 concludes.

2 Empirical Evidence

In this section, we discuss the regime switches of monetary-fiscal policies and the betas of the nominal and real Treasury bonds during the post-war period.

2.1 Policy regimes

The post-war U.S. monetary and fiscal policies exhibit frequent changes of monetary and fiscal regimes. Both monetary and fiscal polices can be either active or passive. Structural estimation in Davig and Leeper (2006, 2011), corroborating with narrative accounts of policy behaviors, shows that the duration of each regime ranges from 11 to 22 quarters and the changing of fiscal policy regime is more frequent than that of monetary policy regime.

The regime of monetary polices is classified based on the response of short-term nominal interest to inflation. In the majority of macroeconomic studies, monetary policy is modeled as a Taylor rule of the following form:

$$i_t - i = \phi_i(i_{t-1} - i) + (1 - \phi_i)[\phi_\pi(\pi_t - \pi^*) + \phi_y(\Delta y_t - \Delta y^*)] + \sigma_i e_{i,t}\,. \tag{2.1}$$

where i_t is the short-term nominal interest rate. The policy rule has an interest-rate smoothing component captured by the sensitivity ϕ_i to the deviation of lagged interest rate, i_{t-1}, from the steady state value, i, and responds to the difference between inflation π_t and inflation target π^*, the deviation of output growth Δy_t from its value under flexible prices Δy^*, and a money policy (MP) shock $e_{i,t} \sim \text{IID}\mathcal{N}(0,1)$. The coefficients ϕ_π and ϕ_y capture the responses of the monetary authority to the deviations of inflation and the output growth from their targets, respectively. Under active monetary policy, the short rate increases more than one-for-one with increase in inflation, i.e., $\phi_\pi > 1$, while under passive monetary policy, $\phi_\pi < 1$.

The regime of fiscal policy is classified based on its role in balancing the government budget constraint. Under passive fiscal policy, the lump-sum taxes adjust to absorb the changes in government spending by reacting strongly to government debt outstanding and keep the budget constraint balanced. On the contrary, under active fiscal policy, increases in government spending is not expected to be fully financed by taxes when taxes do not react strongly enough to debt outstanding and the price level has to adjust so that the present value of future government surpluses equals the outstanding government liabilities in real terms. Therefore, passive fiscal policies do not influence the macroeconomic quantities except for the level of government debt, while active fiscal policies do.

In standard New Keynesian models (Davig and Leeper, 2011; Bianchi and Ilut, 2016), fiscal policy is modeled as a lump-sum tax rule that responds to economic fundamentals, similar to the form of the Taylor rule:

$$\tau_t - \tau = \varsigma_\tau(\tau_{t-1} - \tau) + \varsigma_b(b^\infty_{t-1} - b^\infty) + \varsigma_g(g_{yt} - g_y) + \varsigma_y(y_t - y), \tag{2.2}$$

where b^{∞}_{t-1} is the lagged government-debt-to-output ratio, g_t is the government-expenditure-to-output ratio, y_t is the detrended output, and y is the steady state of the detrended output. The coefficients ς_τ, ς_b, ς_g, and ς_y represent the persistency of the tax policy and the sensitivity of tax policy to government debt, government spending, and output, respectively. Under passive fiscal policy, taxes responds strongly to the movements of government debt with $\varsigma_b > \beta^{-1}-1$, while under active fiscal policy, taxes do not respond or negatively respond to government debt.

Leeper (1991) is the first to show that, among four possible combinations of active/passive monetary and fiscal mixes, only two of them yield determinacy and unique solution: the active monetary policy and passive fiscal policy (AMPF) regime, and the passive monetary policy and active fiscal policy (PMAF) regime. When both policies are passive (PMPF regime), the economy has multiple equilibria, and when both policies are active (AMAF regime), the economy has no equilibrium. In this paper, we consider the AMPF, PMAF, and PMPF regimes, and ignore the AMAF regime. The estimation of Davig and Leeper (2011) among many others, shows that except for a brief active period in 1959-60, monetary policy was passive from 1948 until the Fed changed operating procedures in October 1979 and policy became active. Monetary policy was consistently active except immediately after the two recessions in 1991 and 2000 and turns passive after the Great Recession in 2007.

After the World War II, Federal Reserve policy supported high bond prices to the exclusion of targeting inflation, an extreme form of passive monetary policy (Woodford 2001), until the Treasury Accord of March 1951. Through the Korean War (June 1950 - July 1953), monetary policy largely accommodated the financing needs of fiscal policy (Ohanian, 1997). From the mid-50s, through the Kennedy tax cut of 1964, and into the second half of the 1960s, fiscal policy was active, paying little attention to debt. Another prolonged period of active fiscal policy started with President Bush's tax reductions in 2002 and 2003 and continued with the drastically increased government spending and tax cuts included in the Economic Stimulus Act of 2008 and the American Recovery and Reinvestment Act of early

2009.

In summary, both the structural estimation and the narrative account of U.S. policy history single out two longest periods of passive monetary and active fiscal (PMAF) policy regime, mid-50s to mid-60s and post-2000, and one prolonged period of active monetary and passive fiscal (AMPF) policy regime, the beginning of 1980s to 2000.

2.2 Risks of nominal Treasury bonds and TIPS

To explore the correlation between stock and bond returns, we follow Campbell et al. (2016) to estimate the realized betas of 5-year zero-coupon nominal U.S. Treasury bonds using rolling window regressions of daily data. We use the Capital Market Asset Pricing Model (CAPM) and the return on CRSP value-weighted stock index as the market return.

Yield of 5-year nominal Treasury bonds in daily frequency is available from April 5th, 1962 to September 29th, 2017, obtained from the Wharton Research Data Services (WRDS). Yields of 5-year nominal Treasury bond yield between January, 1947 and April, 1962 are in monthly frequency and obtained from McCulloch and Kwon (1993). Daily return on the market portfolio is from Kenneth French's website.[1] The classification for policy regimes between the first quarter of 1949 to the third quarter of 2008 is based on the estimation in Davig and Leeper (2011).[2]

Figure 1 plots the beta of 5-year Treasury bond for the period of 1947-2017 in blue, which is obtained by regressing daily return of 5-year Treasury bond on the return on market portfolio using 3-month rolling window. The same figure also shows that the two longest PMAF regimes, in medium grey, during 1947 to 2017 are the periods of 1956-1965 and 2002-2017. Even though the estimation in Davig and Leeper (2011) ends in 2008, the PMAF regime is likely to go well beyond 2008. After the financial crisis, the U.S. government implemented the $787 billion American Recovery and Reinvestment Act, approved in February 2009, and provided large fiscal stimulus to the economy. Meanwhile, the interest rate has stayed at

[1]We thank Kenneth French for providing the data.
[2]We thank Eric Leeper for providing us the data.

zero between 2008 to 2015. All of these facts are strong signals of the PMAF regime for the post-2008 period. For these aforementioned reasons, we will treat the period of 2002-2017 as a PMAF regime. During those two periods, 1956-1965 and 2002-2017, the beta of 5-year nominal Treasury bonds is largely negative. On the contrast, the bond beta is consistently positive during the AMPF regime, i.e., the periods of 1984-1990 and 1995-2001, plotted as the dark grey area. The bond beta is also slightly positive during the PMPF regime (the light grey area in the figure), which dominated in the economy during most of the 1970s.

In sum, the data suggests that the correlation between stock and nominal bonds is negative in the PMAF regime while positive in the other regimes, especially in the AMPF regimes. In the rest of the paper, we explain these observed dynamics of the correlation between stock and nominal bond in a DSGE model with different policy regimes.

3 Model

In this section, we generate stock and bond returns in a DSGE model with microfoundations. The main structure of our model follows Christiano et al. (2014) in modeling the households, financial intermediaries, final good sector, and intermediate good sector, and the setup for monetary and fiscal policies is consistent with the convention of Leeper (1991) and Bianchi and Ilut (2016).

3.1 Household

Household maximizes life-time utility

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

and

$$U_t \equiv U(C_{h,t}, L_t) = \frac{C_{h,t}^{1-\psi}}{1-\psi} - A_t^L \int_0^1 \frac{L_{j,t}^{1+\phi}}{1+\phi} dj \,,$$

where $C_{h,t}$ is the habit adjusted consumption, defined as $C_{h,t} = C_t - b\bar{C}_{t-1}$ with $\bar{C}_t$ representing the aggregate consumption.[3] A_t^L is the disutility parameter of labor, growing at rate $(z_t^+)^{1-\psi}$, where (z_t^+) is the growth rate of the economy and is defined later in equation (3.7). $L_{j,t}$ is the number of household members with labor type j who are employed. The parameters are defined as follows: b is the habit parameter, ψ is the reciprocal of the degree of intertemporal elasticity of substitution, γ is the risk aversion parameter, and ϕ is the Frisch elasticity of labor supply parameter.

Households' utility maximization is subject to the budget constraint

$$\begin{aligned} & P_t C_t + Q_t^\infty B_t^\infty + B_t + \frac{P_t}{\Psi_t} I_t + P_t a(u_t)\bar{K}_{t-1} \\ \leq \; & B_{t-1}^\infty (Q_t^\infty \rho + 1) + R_{t-1}B_{t-1} + P_t r_t^k u_t \bar{K}_{t-1} + P_t L I_t + P_t D_t - P_t T_t + P_t T_t^e \, , \end{aligned}$$

and the law of capital accumulation

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

where P_t is the price of consumption goods, I_t is investment made at t, and Ψ_t is the relative price of consumption to investment goods, which will be defined later. $S(\cdot)$ is the investment adjustment cost, 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 $S'(\exp(\mu_{z^+} + \mu_\psi)) = 0$. ζ_t^I measures the marginal efficiency of investment, and evolves as follows:

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

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

where $e_t^{\zeta^I}$ denotes the marginal efficiency of investment (MEI) shock. Note that investment I_t is measured in terms of investment goods instead of consumption goods. r_t^k is the real rental rate of productive capital paid by producers, and u_t is the capital utilization rate. 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 $\sigma_a > 0$. Note that the maintenance cost $a(u_t)$ is measured in terms of capital goods, whose relative price to consumption goods is $1/\Psi_t$. The capital used in production is

$$K_t = u_t \bar{K}_{t-1}. \tag{3.4}$$

LI_t is the real wage income defined as

$$LI_t = \int \frac{W_{j,t}}{P_t} L_{j,t} \, dj \,,$$

D_t is the real dividend paid by firms, T_t is tax, T_t^e is the net transfer from entrepreneurs, and B_t is the face value of one-period debt lent to entrepreneurs at $t-1$ with gross nominal return R_t. To avoid numerical complication, we follow Woodford (2001) and define B_t^∞ as the amount of long-term government bonds issued at t, each of which has a stream of infinite coupon payments that starts in period $t+1$ with \$1 and decay every period at the rate of ρ. The price of one such long-term bond, Q_t^∞, is given by

$$Q_t^\infty = \mathbb{E}_t \left[\sum_{s=1}^{\infty} M_{t,t+s}^{\$} \rho^{s-1} \right] = \mathbb{E}_t \left[M_{t,t+1}^{\$} \left(1 + \rho Q_{t+1}^\infty \right) \right] \,,$$

where $M_{t,t+s}^{\$}$ is the nominal stochastic discount rates (or pricing kernels) from period t to

$t+s$. The gross nominal return on long bond, R_t^B, is thus given by

$$R_t^B = \frac{1+\rho Q_t^{\infty}}{Q_{t-1}^{\infty}}\,. \tag{3.5}$$

It can be easily shown that the yield y_d on this bond is given by $1/Q_t^{\infty} - (1-\rho)$ and the effective duration is $1/(1-\rho/(1+y_d))$.

3.2 Final-Good Production Sector

There are two industries in the production sector: the final goods industry and the intermediate goods industry. The final goods industry is perfectly competitive. The production of the final consumption goods uses a continuum of intermediate goods, indexed by $i \in [0,1]$, via the Dixit-Stiglitz aggregator:

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

where Y_t is the output of the final goods, $Y_{i,t}$ is the amount of intermediate goods i used in the final goods production, which in equilibrium equals the output of intermediate goods i, and λ_p measures the substitutability among different intermediate goods. When λ_p is larger, the intermediate goods are more substitutable and the demand to intermediate goods is more price elastic.

3.3 Intermediate-Good Production Sector

The production of intermediate goods i uses both capital and labor via the following homogenous production technology:

$$Y_{i,t} = \left(z_t L_{i,t}\right)^{1-\alpha} K_{i,t-1}^{\alpha} - z_t^{+}\varphi, \tag{3.6}$$

where z_t is the level of the neutral technology, $L_{i,t}$ and $K_{i,t}$ are the labor and capital services, respectively, employed by firm i. α is the capital share of the output, and φ is the fixed production cost. Finally, z_t^+ is defined as:

$$z_t^+ = \Psi_t^{\frac{\alpha}{1-\alpha}}\, z_t, \tag{3.7}$$

where Ψ_t is the level of the investment-specific technology, measured as the relative price of consumption goods to investment goods. We assume that z_t and Ψ_t evolve as follows:

$$\begin{aligned} \mu_t^z &= \mu_z(1-\rho_z) + \rho_z\, \mu_{t-1}^z + \sigma_z e_t^z\,, \quad \text{and } \; e_t^z \sim \mathrm{IID}\mathcal{N}(0,1), && (3.8) \\ \mu_t^\psi &= \mu_\psi && (3.9) \end{aligned}$$

where

$$\mu_t^z = \Delta \log z_t, \tag{3.10}$$

$$\mu_t^{z^+} = \Delta \log z_t^+, \tag{3.11}$$

$$\mu_t^\psi = \Delta \log \Psi_t. \tag{3.12}$$

e_t^z represents the neutral (NT) shock. The intermediate goods industry is assumed to have no entry and exit, which is ensured by choosing a fixed cost ψ that brings zero profits to the intermediate goods producers in the steady state.

he producer takes the nominal rent of capital service $P_t r_t^k$ and nominal wage rate W_t as given but has market power to set the price of its product in a Calvo (1983) staggered price setting to maximize profits. With probability ξ_p, producer i cannot reoptimize its price at period t, and has to set it according to the following rule,

$$P_{i,t} = \tilde{\pi}_{p,t}\, P_{i,t-1},$$

where

$$\tilde{\pi}_{p,t} = (\pi^*)^{\ell} (\pi_{t-1})^{1-\ell} \tag{3.13}$$

is the inflation indexation, π^* is the target inflation rate or steady state inflation rate, and $\pi_t \equiv P_t/P_{t-1}$ is the inflation rate. Then the law of motion for inflation can be expressed as:

$$1 = (1-\xi_p)\left[\frac{\epsilon_p}{1+\epsilon_p}\frac{J_t}{H_t}s_t\right]^{\frac{1}{1-\lambda_p}} + \xi_p\left[\frac{\tilde{\pi}_{p,t}}{\pi_t}\right]^{\frac{1}{1-\lambda_p}} . \tag{3.14}$$

3.4 Labor Unions

There are labor contractors who hire workers of different labor types through labor unions and produce homogenous labor service L_t, according to the following 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 production. Labor contractors are perfectly competitive, and their profit maximization leads to the demand function for labor type j:

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

Assume that labor unions face the same Calvo (1983) type of wage rigidities. In each period, with probability ξ_w, labor union j cannot reoptimize the wage rate of labor type j and has to set the wage rate according to the following rule:

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

where

$$\tilde{\pi}_{w,t} = (\pi_t^*)^{\ell_w} (\pi_{t-1})^{1-\ell_w} \tag{3.15}$$

is the inflation indexation and $\tilde{\mu}_{w,t} = \ell_\mu \mu_{z^+,t} + (1-\ell_\mu)\mu_{z^+}$ is the growth indexation. With probability $1-\xi_w$, labor union j chooses $W^*_{j,t}$ to maximize households' utility.

3.5 Policies

The central bank implements a Taylor (1993)-type monetary policy rule, specified in Equation 2.1:

$$i_t - i = \phi_i(i_{t-1} - i) + (1-\phi_i)[\phi_\pi(\pi_t - \pi^*) + \phi_y(\Delta y_t - \Delta y^*)] + \sigma_i e_{i,t}\,;$$

and the fiscal authority adjusts taxes according to the tax policy Equation 2.2:[4]

$$\tau_t - \tau = \varsigma_\tau(\tau_{t-1} - \tau) + \varsigma_b(b^\infty_{t-1} - b^\infty) + \varsigma_g(g_{yt} - g_y) + \varsigma_y(y_t - y),$$

Government's flow budget identity follows:

$$\frac{Q^\infty_t B^\infty_t}{P_t} = R^B_t \frac{Q^\infty_{t-1} B^\infty_{t-1}}{P_t} + G_t - T_t$$

holds at any time t. Equivalently, government budget constraint can be written in the following form:

$$b^\infty_t = \frac{R^B_t b^\infty_{t-1} Y_{t-1}}{\Pi_t Y_t} + g_{yt} - \tau_t \tag{3.16}$$

The government spending G_t is exogenously given to be a fixed proportion of output.

There are two relevant monetary/fiscal policy regimes that yield determinacy and unique solution of the model according to the policy regime literature, as discussed in Subsection 2.1: the AMPF regime and PMAF regime.

[4]For simplicity, we do not include a fiscal shock to the tax policy. Our unreported result shows that fiscal shock is not important for the stock-bond return correlation quantitatively.

3.6 Equilibrium

In equilibrium, all intermediate good producers take the same actions and all markets clear:

$$P_{i,t} = P_t, \quad Y_{i,t} = Y_t, \quad L_{i,t} = L_t.$$

— Resource constraint:

$$Y_t = C_t + I_t/\Psi_t + G_t + a(u_t)\bar{K}_{t-1} + \mathcal{D}_t, \tag{3.17}$$

where $\mathcal{D}_t$ is the bankruptcy cost, equal to $\mu_b G(\bar{\omega}_t) R^k_t \frac{Q_{k,t-1}\bar{K}_{t-1}}{P_t}$.

3.7 Asset Pricing Implications

In this section, we discuss the asset pricing implications of the model.

3.7.1 Returns on Stock

The definition of stock return follows Abel (1999), in which a stock is the claim on consumption raised to a power of λ, C_t^λ, and $\lambda > 1$ reflects leverage. Since dividend in the data is four to five times more volatile than consumption, the leverage ratio λ is needed to create the wedge between dividend and consumption. The stock price and excess stock return are thus given by

$$S^c_t = P_t C^\lambda_t + \mathbb{E}_t \left[M^{\$}_{t,t+1} S^c_{t+1} \right] \tag{3.18}$$

$$R^c_{s,t+1} = \frac{S^c_{t+1}}{S^c_t - P_t C^\lambda_t} - R_t \,. \tag{3.19}$$

3.7.2 Returns on Long-Term Real and Nominal Bonds

In our model, the long-term bond has a maturity of infinity and pays coupon every period. The duration of the bond is finite though because the coupon exponentially decays. To illustrate the intuition behind the return on the bond, we analyze the risk premium in a default-free zero-coupon bond with maturity of n periods. Real and nominal default-free zero-coupon bonds with maturity at $t+n$ pay a unit of real and nominal consumption, respectively, at maturity. Their prices are

$$B_t^{c,(n)} = \mathbb{E}_t[M_{t,t+n}], \quad \text{and} \quad B_t^{\$,(n)} = \mathbb{E}_t[M_{t,t+n}^{\$}], \tag{3.20}$$

for real and nominal bonds, respectively, where $M_{t,t+n}$ and $M_{t,t+n}^{\$}$ are the real and nominal discount factors for payoffs at $t+n$.[5] The associated real and nominal yields are defined, respectively, as

$$r_t^{(n)} = -\frac{1}{n}\log B_t^{c,(n)}, \quad \text{and} \quad i_t^{(n)} = -\frac{1}{n}\log B_t^{\$,(n)}.$$

The returns on real and nominal bonds are given by

$$\tilde{R}_{b,t+1}^{c,(n)} = \frac{B_{t+1}^{c,(n-1)}}{B_t^{c,(n)}}, \quad \text{and} \quad \tilde{R}_{b,t+1}^{\$,(n)} = \frac{B_{t+1}^{\$,(n-1)}}{B_t^{\$,(n)}}, \tag{3.21}$$

respectively.

It is useful to decompose expected excess returns on real and nominal bonds into real term and inflation risk premia, which are compensations for real and nominal risks, respectively. The one-period real term premium of a bond with maturity n-period is defined as

$$rTP_t^{(n)} \;\; \equiv \;\; \log \mathbb{E}_t\left[\tilde{R}_{b,t+1}^{c,(n)}\right] - r_t\,, \tag{3.22}$$

and the one-period inflation risk premium $\pi TP_t^{(n)}$ is the log difference between the real returns for investing in an n-period nominal bond and an n-period real bond for one-period:

$$\pi TP_t^{(n)} \;\; \equiv \;\; \log \mathbb{E}_t\left[\tilde{R}_{b,t+1}^{\$,(n)} P_t/P_{t+1}\right] - \log \mathbb{E}_t\left[\tilde{R}_{b,t+1}^{c,(n)}\right], \tag{3.23}$$

[5]Notice that $B_t^{c,(n)}$ is the real price of the real bond, while $B_t^{\$,(n)}$ is the nominal price of the nominal bond.

where r_t, $\tilde{R}^{\$,(n)}_{b,t+1}$, and $\tilde{R}^{c,(n)}_{b,t+1}$ are the net real interest rate, returns on nominal and real bonds, respectively. The excess returns on real and nominal bonds are defined as $R^{\$,(n)}_{b,t+1} = \tilde{R}^{\$,(n)}_{b,t+1} - R_t$, and $R^{c,(n)}_{b,t+1} = \tilde{R}^{c,(n)}_{b,t+1} - R_t$, respectively.

Next, in order to illustrate the mechanism that drives the return on long-term bond, we derive the bond risk premium analytically under the simplifying assumption that all the variables follow log-normal distribution and are homoskedastic.

3.7.3 Real Term Premium and Inflation Risk Premium

The one-period real term premium of a bond with maturity n-period can be written as

$$rTP^{(n)}_t = -\mathrm{cov}_t\left[m_{t,t+1}, \sum_{s=2}^{n} m_{t+s-1,t+s}\right]. \tag{3.24}$$

The above equation indicates that the real term premium of a long-term bond is positive if the stochastic discount factor (SDF) of the first period is negatively correlated with the SDFs of the future periods until maturity on average, and vice versa.

Inflation risk premium can be written as

$$\pi TP^{(n)}_t = \mathrm{cov}_t\left(m_{t,t+1}, \sum_{s=1}^{n} \pi_{t+s}\right). \tag{3.25}$$

Therefore, inflation risk premium of a bond with maturity n depends on the covariance between the $t+1$-period pricing kernel and the inflation between $t+1$ to maturity. To compute the inflation risk premium of the nominal consol bond, we define the long-term inflation as $\pi^{\infty}_t = \sum_{s=1}^{\infty} \rho^{s-1}\pi_{t+s}$ and examine the correlation between π^{∞} and the pricing kernel M.

4 Results and Analysis

4.1 Calibration

We calibrate the model to match key macroeconomic moments. Table 1 lists the calibrated values of structural parameters. The steady state growth rate of the economy μ_{z^+} is set to be 0.0044, and the steady state growth rate of the investment-specific technological change μ_ψ is set to 0.0020, implying the average annual growth rate of the economy is 1.76%. Steady state or targeted inflation rate, π^*, is 0.7725%, indicating the targeted annual inflation rate is 3.09%. Government spending is assumed to be 20% of total output. Following the convention of the macro literature, the power on capital in production function α is 0.33; deprecation rate on capital δ is 0.025; and the wage markup, λ_w, is 1.05. The long-term bond parameter ρ is 0.9511 so that the duration of the bond is 5 years. The preference parameters are taken from the long-run risk literature: the elasticity of intertemporal substitution, ψ, is 1/1.2, and the risk aversion parameter γ is 40 so that the return on stock (consumption claim) has the same Sharpe ratio as the return on CRSP market portfolio. The Frisch elasticity of labor supply ϕ is 1, taken from Christiano et al. (2014). We set the habit parameter, b, at 0.85, which is within the wide range of values estimated from the literature. The objective discount factor β is chosen to yield a 4.96% annual risk free rate, closer to 4.47% in the data.

Policy parameters in different regimes are set according to the estimation in Bianchi and Ilut (2016). In the active monetary policy regimes, monetary policy responds strongly to inflation to stabilize price and fiscal policy adjusts according to government debt position to satisfy government budget constraint: the sensitivity of interest rate to inflation ϕ_π is 2.7372, the sensitivity of interest rate to output gap ϕ_y is 0.7037, the interest rate persistent parameter ϕ_r is 0.91. In the passive fiscal policy regimes, the sensitivity of tax to bond ς_b is 0.0609, the sensitivity of tax to output ς_y is 0.3504, the sensitivity of tax to government spending ς_g is 0.3677, and the tax persistent parameter ς_τ is 0.9844. In the passive monetary policy regimes, $\phi_y = 0.1520$, and a lower persistency, where $\phi_r = 0.6565$. More importantly, the sensitivity of policy rate to inflation drops below one: $\phi_\pi = 0.4995$. In the active fiscal policy regimes, fiscal policy is active and responsible for stabilizing price. Tax-to-GDP ratio no longer adjusts according to debt position, meaning $\varsigma_b = 0$,[6] and because less persistent, with $\varsigma_\tau = 0.8202$.

Persistence and standard deviation of the shock processes are taken from Christiano, Motto and Rostagno (2014) and Justiniano, Primiceri and Tambalotti (2011), both of which have the similar model structure and shocks as ours, and are presented in Panel D of Table 1.

The model is solved under this set of parameter values perturbation methods for MS-DSGE model introduced by Foerster et al. (2016). The moments of the key macroeconomic and finance variables generated from the model are presented together with the corresponding moments in the data in Panel A of Table 2. Data moments are computed using data during 1948Q2 - 2016Q4.

The transition matrix P is set to

$$P = \begin{bmatrix} 0.97 & 0.00 & 0.07 \\ 0.00 & 0.98 & 0.07 \\ 0.03 & 0.02 & 0.86 \end{bmatrix},$$

where the element $p_{ij} = Pr(s_t = i|s_{t-1} = j)$ is the probability of switching from regime j to regime i, and the regimes 1, 2, and 3 represent AMPF, PMAF, and PMPF regimes, respectively.

Our model matches these macroeconomic moments reasonably well given the intentionally small set of structural shocks in our model in order to illustrate the economic intuition behind the results. Our calibration matches half of the return on nominal 5-year Treasury bonds and one third of the return on market portfolio observed in the data with stock defined as consumption claim, after matching the Sharpe ratio.

[6]Leeper (1991) shows that any value of ς_b less than $1/R^B - 1$ would lead to passive fiscal policies, where R^B is the return on government debt.

4.2 Variance Decomposition

Panel B of Table 2 reports the variance decomposition of the key variables under the AMPF, PMAF, and PMPF regimes.

For a shock to have substantial effect on the correlation between stock and bond returns, it has to contribute significantly to the variations of both returns. Table 2 shows that in the AMPF regime, the correlation between the return on consumption claim and return on nominal bonds mainly depends on the PT shock, which contributes 60.66% and 53.40% of the variations in these two returns, respectively.

In the PMAF regime, the effect of the PT shock on the return on consumption claim become significantly weaker while the effect of the MEI shock stays strong. As a result, the correlation between stock and bond returns largely depends on the MEI shock. Specifically, the MEI shock contributes 61.13% and 60.13% of the variations in the returns on consumption claim and nominal bonds, respectively.

In the PMPF regime, neither the PT nor the MEI shock dominates all other shocks. The PT, MEI, and MP shocks account for 40.40%(22.90%), 33.76%(26.90%), and 25.01%(47.09%) of the fluctuations of stock return (nominal bond return), respectively. However, the total impacts of the PT and MP shocks override the impacts of the MEI shocks on both stock and bond returns.

Given that the PT, MEI, and MP shocks are the most important drivers of the correlation of stock and long-term bond returns, they are the focus of our analysis. The case of the MP shock is quite straight forward. A positive MP shock leads to higher nominal and real interest rates, and thus contracts the economy. Consequently, the values of stock and bond go down, resulting in a positive correlation between stock and bond returns, regardless of the regimes. However, the effects of the PT and MEI shocks on the correlation between stock and bond returns are much more complex and we provide detailed analysis below.

4.3 The PT Shock

The AMPF regime — Under the AMPF regime, the values of the consumption claim and the long-term nominal bond go up after a positive PT shock, resulting in a positive correlation between stock and bond returns. Impulse responses of relevant variables under a positive PT shock in the AMPF regime are presented by the solid blue lines in Figure 3.

The PT shock is a supply shock. Higher productivity leads to increase in output and consumption, but decrease in inflation. Inflation goes down because nominal rigidity prevents real wage from rising as quickly as the productivity, resulting in a reduction in real marginal cost. In the AMPF regime, the nominal interest rate reacts strongly to inflation. Even though real interest rate rises at the beginning due to the interest rate persistence and the reaction of nominal interest rate to higher output, it quickly drops due to the strong reaction of nominal interest rate to inflation. The lower real interest rate boosts the economy further. Taken all together, a positive PT shock under the AMPF regime leads to a strong and long-lasting boom in the economy. Consequently, the claim on consumption goes up and return on stock gets higher.

The price of the nominal long-term bond depends on both the inflation and the real interest rate. Since inflation drops, and the real interest rate from the current period till maturity also drops on average, the price of the nominal bond goes up and the return on nominal long-term bond also goes up.

Therefore, the PT shock leads to a positive correlation between stock and bond returns under the AMPF regime. Moreover, the covariance of the short-term inflation and stochastic pricing kernel is positive.

The PMAF regime — The impulse responses after a positive PT shock in the PMAF regime are presented by the red dotted lines with circles in Figure 3. After a positive PT shock, inflation again goes down. However, under the Taylor rule in the PMAF regime, nominal interest rate weakly reacts to inflation. Consequently, the real interest rate rises persistently in the short and long run, leading to a lower price of the real long-term bond. The price of nominal bond still rises because of lower inflation, however at a much smaller magnitude.

More importantly, the contractionary effect of a higher real interest rate largely cancels out the direct stimulus effect of the higher PT shock on the economy. Consequently, the increase in consumption is also significantly smaller than that in the AMPF regime. The return on consumption claim still rises, however, the magnitude is smaller than that in the AMPF regime. That is, the PT shock is no longer the key driving force of the returns in the PMAF regime.

The PMPF regime — The impulse responses after a positive PT shock in the PMPF regime are presented by the black dashed lines in Figure 3. In this regime, the PT shock affects the economy in a similar way to that in the other two regimes. That is, the PT shock lead to positive correlation between stock and bond returns. And due to the passive monetary policy, the PT shock is no longer the dominant shock in the economy.

4.4 The MEI Shock

The AMPF regime — As shown by the solid blue lines in Figure 4, after a positive MEI shock, the transformation of investment goods into raw capital becomes more efficient, leading to higher investments, lower price of capital, and larger amount of end-of-period capital. The substitution effect of a positive MEI shock leads to higher investment and lower consumption, while the wealth effect leads to higher consumption because the households anticipate a higher level of capital and consumption in the future. The substitution effect dominates the wealth effect and consumption drops initially, but quickly goes up afterwards. The price of capital drops due to the lower cost of capital production and higher supply of capital, leading to a lower return on entrepreneur wealth. The negative effect of the MEI shock on the value of existing capital is discussed in Greenwood and Jovanovic (1999), who document a deep drop of S&P 500 stocks in the 1990s when the new internet and computing technology came out.

Since the MEI shock is a demand shock, a positive MEI shock leads to higher demand for output, and thus higher capital utilization rate and higher demand for labor supply. Consequently, the marginal cost of output go up, resulting in higher inflation. Due to the strong reaction of nominal interest rate to inflation in the AMPF regime, the real interest rate also goes up, dampening the expansionary effect of the positive MEI shock.

The price of real long-term bond goes down due to the higher real interest rate.[7] Even though the nominal interest rate eventually goes down, the effect of the higher rate at the short run dominates and the price of the nominal long-term bond goes down. Therefore, the return on consumption claim negatively correlates with the returns on nominal and real long-term bonds in the AMPF regime.

The PMAF regime — In this regime, the tax policy is active and responsible for price level adjustments. The dotted red lines in Figure 4 presents the impact of a positive MEI shock in the PMAF regime. After a positive MEI shock, output goes up for the same reason as in the AMPF regime. However, the government increases taxes in reaction to higher output. Constrained by the government budget balance, the increase in government surplus is accompanied by lower price level and thus higher government debt outstanding in real terms.[8] Due to the contractionary fiscal policy, inflation goes down and induces a persistently lower short-term nominal interest rate, which implies a higher price of long-term nominal bond. Hence, the return on long-term nominal bond is higher. Stock return declines due to the same reason as in the AMPF regime. As a result, the MEI shock leads to negatively correlated stock and bond returns.

The PMPF regime — The impact of MEI shock in this regime is similar to, but milder than, that in the PMAF regime. In the PMPF regime, the PT and MP shock together are the main drivers of stock and bond returns. This change is critical to the change in the sign of the stock-bond return correlation because the PT shock leads to positive correlation but

[7] The real interest rate goes down at the very beginning but stay higher afterwards, because the policy rate also reacts to higher output

[8] A more intuitive way to interpret the reduction in price is that after an increase in tax, government lowers money supply given that it has more fiscal income and needs not to rely on inflation to balance the budget.

the MEI shock leads to negative correlation of returns on the consumption claim and the nominal long-term bond.

As mentioned previously, the impact of MP shock is standard no matter in which regimes, and the impulse responses under MP shocks are plotted in Figure 5. A positive fiscal policy shock is basically contractionary as well, regardless of the policy regimes, and the impulse responses under FP shocks are plotted in Figure 6.

4.5 Correlation of Stock and Bond Returns

The variance decomposition and impulse response analyses above lead to the following proposition.

Proposition. *The correlation of return on stockand return on nominal long-term bond is positive in the AMPF and PMPF regimes, and negative in the PMAF regime.*

Table 3 reports the correlation matrix of the return on consumption claim (R_s^c), return on long-term nominal bonds ($R_b^{\$}$), and return on long-term real bonds (R_b^c), under both the AMPF, PMAF, and PMPF regimes, from the baseline model with all four shocks. Panels A and B of Table 4 report the correlation matrix of returns and key variables when either the PT shock or MEI shock is shut down, respectively. The following conclusion can be drawn from these two tables. First, the PT shock is key driver of the positive and strong correlation between return on the consumption claim and return on the nominal long-term bond in the AMPF regime. Without the PT shock, even though the correlation in AMPF regime is still positive, its magnitude is smaller, reduced from 0.82 to 0.65, and the correlation in PMPF regime changes from positive (0.05) to negative (-0.20). Second, the MEI shock is the reason why the correlation between return on the consumption claim and return on the nominal long-term bond becomes negative in the PMAF regime. Without the MEI shock, the correlation is positive in every regime.

4.6 The PMAF Regime at the Effective Lower Bound (ELB)

The zero lower bound (ZLB) is an extreme case of the PMAF regime where 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 simple and avoid the computational difficulty, we neither include additional preference or inflation shocks to create the ZLB environment nor discuss the case with completely inactive monetary policy, in which $\phi_\pi = 0$ and $\phi_y = 0$. Instead, we assume an ELB scenario, in which the policy rate is almost constant at its steady state level, and discuss the case with ϕ_π and ϕ_y close to zero. Although the standard New Keynesian model generates some unpleasant features at or close to the ZLB[9], the negative correlation between stock and nominal bond is robust to the value of ϕ_π. In fact, the lower the value of ϕ_π is, the more negative the correlation is, since not only the MEI shock but also the PT shock generates negative return correlation at the ZLB. When the ZLB is binding, under a positive PT shock, stock prices decrease due to the lower consumption growth, hence bond and stock returns move in the opposite directions, which reinforces our result that in the PMAF regime — the bond-stock return correlation is even more negative since both PT shocks and MEI shocks generate negatively correlated bond and stock returns.

Therefore, our result does not rely on the extreme inactiveness of the monetary policy, as in Gourio and Ngo (2016). The negative correlation between stock and nominal Treasury bond holds as long as the monetary policy is passive (and fiscal policy is active to ensure determinacy).

[9] When ϕ_π is lower than certain threshold, the model implies that consumption and output respond negatively to a positive PT shock. Because the nominal interest rate is kept constant, the lower inflation caused by a positive PT shock induces higher real interest rate, which has a significant contractionary impact on the economy. In fact, this is the most criticized feature of the new Keynesian model with the ZLB, which is an extreme case of the PMAF regime. Wieland (2015) and Garín et al. (2017) demonstrate empirically that the sign of output response is the same as the sign of the shock both during normal time and at the ZLB, and Wu and Zhang (2017) proves that the economy has similar behavior when central banks implement unconventional monetary policy at the ZLB in a New Keynesian model.

4.7 Alternative Preferences

In our benchmark model, we use recursive preference with habit formation in order to generate a risk premium with reasonable magnitude. We show in this section that the relation between stock-bond return correlation and policy regime is robust to the choice of preference.

4.7.1 CRRA preference

We first change the preference to constant relative risk aversion (CRRA) preference. Panels A and B of Figure 7 plot the impulse responses to NT and MEI shocks in both regimes, respectively. These impulse responses are qualitatively similar to their counterparts under the recursive preference in the benchmark model. Specifically, a positive PT shock again leads to increases in the returns on consumption claims and long-term nominal bonds in both regimes, while a positive MEI shock leads to opposite movements in these two returns. Panel A of Table 6 shows that the main result in the baseline model, i.e., positive stock-bond return correlation under the AMPF and PMPF regimes and negative under the PMAF regime, holds under the CRRA preference.

4.7.2 Recursive preference without habit

We also solve a model under a recursive preference without habit formation. Panels A and B of Figure 8 plot the impulse responses to NT and MEI shocks in both regimes, respectively. Panel B of Table 6 presents the correlation matrix under the recursive preference without habit. Both the impulse responses and the correlation matrix share similar qualitative characteristics with those under the baseline preference and the relation between the stock-bond correlation and policy regime holds under AMPF, PMAF, and PMPF regimes.

5 Conclusion

We build a New Keynesian model with the recursive preference, and monetary-fiscal policy interaction, which coherently explains the positive bond-stock return correlation during 1970-2000 when the monetary policy is active and the fiscal policy is passive or both policies are passive, and the negative correlation during 1950s and 2000s when the monetary policy is passive and the fiscal policy is active. When the monetary policy is active and the fiscal policy is negative, the PT shocks drive the economy, and induce a positive correlation between bond and stock return. When both monetary and fiscal polices are passive, the impact of PT and MP shocks together overpasses that of the MEI shock, and both shocks lead to positively correlated stock and bond returns. However, when the fiscal policy is active and the monetary policy is negative, the MEI shock dominates in driving the economic dynamics, and induces a negative bond-stock return correlation. In the next step, we plan to solve and estimate a model with regime switching among the four possible monetary-fiscal regimes following Davig and Leeper (2011). Such a model allows us to understand the stock-bond correlation in the other two regimes, namely active monetary and fiscal policies (AMAF) and passive monetary and fiscal policies (PMPF) regimes, both of which have no equilibrium solutions independently. Adding switching policy regimes could potentially change the economic dynamics for any stand-alone regimes as agents anticipate possible future changes of policy regimes. Moreover, we plan to study the effects of volatility shocks on the stock-bond correlation as more and more studies find the importance of time-varying volatility in explaining economic dynamics.

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Table 1: **Parameter Values in the Baseline Model**

This table presents the calibrated parameter values used in the baseline model. Policy parameters are different under the AMPF and PMAF regimes, while other parameters are kept the same. The superscripts "1" and "2" for the policy coefficients represent the AMPF and PMAF regimes, respectively.

Parameter	Description	Value
Panel A: Preference		
β	discount factor	0.9989
ψ	reciprocal of elasticity of intertemporal substitution	1/1.2
γ	risk aversion	40
ϕ	labor supply aversion	1
b	habit parameter	0.85
Panel B: Production		
α	capital share	0.33
δ	capital depreciation rate	0.025
σ_s	investment adjustment cost parameter	10.78
σ_a	utilization rate cost parameter	2.54
ξ_p	probability that cannot re-optimize price	0.74
ℓ	price indexation parameter	0.90
λ_p	degree of elasticity of substitution for goods aggregation	1.9353
ξ_w	probatility that cannot re-optimize wage	0.81
ℓ_w	wage indexation parameter	0.49
λ_w	degree of elasticity of substitution for labor aggregation	1.05
μ_{z^+}	growth rate of the economy	0.0044
μ_ψ	growth rate of investment specific technology	0.002
π^*	target inflation rate	1.0077
W^e	transfer received by entrepreneurs	0.003
μ_b	bankruptcy cost	0.31

Continued on next page

Table 1 – continued from previous page

Parameter	Description	Value
R	steady-state nominal interest rate	1.0124
λ	leverage ratio	3
Panel C: Policies		
ϕ_π^1	sensitivity of interest rate to inflation (AM)	2.7372
ϕ_π^2	sensitivity of interest rate to inflation (PM)	0.4994
ϕ_y^1	sensitivity of interest rate to output (AM)	0.7037
ϕ_y^2	sensitivity of interest rate to output (PM)	0.1520
ϕ_i^1	interest rate persistence (AM)	0.91
ϕ_i^2	interest rate persistence (PM)	0.6565
ς_b^1	sensitivity of tax to debt (PF)	0.0609
ς_b^2	sensitivity of tax to debt (AF)	0
ς_y^1	sensitivity of tax to output (PF)	0.3504
ς_y^2	sensitivity of tax to output (AF)	0.3504
ς_g^1	sensitivity of tax to government spending (PF)	0.3677
ς_g^2	sensitivity of tax to government spending (PAF)	0.3677
ς_τ^1	tax persistence (PF)	0.9844
ς_τ^2	tax persistence (AF)	0.8202
g_y	steady-state government-spending-to-output ratio	0.18
Panel D: Shocks		
ρ_{μ^z}	persistence of the NT shock	0.15
ρ_{ζ^I}	persistence of the MEI shock	0.77
σ_{μ^z}	standard deviation of the NT shock	0.968
σ_{ζ^I}	standard deviation of the MEI shock	1.331
σ_i	standard deviation of the MP shock	0.1482
σ_τ	standard deviation of the FP shock	0.121

Table 2: **Summary Statistics**

Panel A of this table reports the first and second moments of key macroeconomic and financial variables. Column 1 are variable names. Column 2 and 3 give the annualized mean and standard deviation in the data in percentage. Column 4 and 5 give the corresponding simulated mean and standard deviation from the model. Panel B of this table reports the variance decompositions at the business cycle frequency of the key variables in the model: excess return on stock (claim on consumption) (R_s^c), excess return on long-term nominal bond ($R_b^{\$}$), excess return on long-term real bond (R_b^c), inflation (π), nominal interest rate (i), real interest rate (r), nominal pricing kernel ($M^{\$}$), growth rate of consumption (ΔC), growth rate of investment (ΔI), and price of capital (Q^k). The second to fifth columns are contributions of the neutral technology (NT) shock, marginal efficiency of investment (MEI) shock, monetary policy (MP) shock, and fiscal policy (FP) shock, respectively. The three numbers in each cube represent the contribution of the shocks to fluctuations in variables in the AMPF / PMAF / PMPF regime in percentage, respectively. All returns are excess returns, and all variables are annualized.

Panel A: Simulated Moments

Variables	Data		Model	
	Mean	Std.Dev	Mean	Std.Dev.
consumption growth (ΔC)	1.77	2.06	1.77	2.03
investment growth (ΔI)	2.56	15.72	2.56	6.54
inflation (π)	3.09	2.48	3.10	2.03
nominal short-term interest rate (i)	4.47	3.77	4.96	1.45
excess return on stock (consumption claim, R_s^c)	6.95	33.77	4.99	17.92
excess return on long-term (10-year) nominal bond ($R_b^{\$}$)	2.48	15.34	0.53	2.67

Panel B: Variance Decomposition

Variables	NT (e_z)	MEI (e_{ζ^I})	MP (e_r)	FP (e_τ)
R_s^c	60.66 / 29.48 / 40.40	4.92 / 61.13 / 33.76	34.42 / 9.16 / 25.01	0.00 / 0.22 / 0.83
$R_b^{\$}$	53.40 / 3.87 / 22.90	0.61 / 60.13 / 26.90	43.44 / 35.68 / 47.09	2.55 / 0.32 / 3.10
R_b^c	1.22 / 23.25 / 35.25	19.41 / 61.75 / 34.73	79.35 / 14.82 / 29.40	0.02 / 0.18 / 0.62
π	94.87 / 92.87 / 98.92	1.38 / 6.96 / 0.38	3.70 / 0.09 / 0.46	0.06 / 0.09 / 0.24
i	40.84 / 51.47 / 56.18	0.08 / 8.39 / 1.20	59.04 / 40.06 / 42.43	0.04 / 0.07 / 0.20
r	9.81 / 5.62 / 6.67	1.83 / 0.18 / 0.14	88.35 / 94.19 / 93.16	0.01 / 0.01 / 0.04
$M^{\$}$	99.96 / 99.97 / 99.98	0.01 / 0.03 / 0.01	0.02 / 0.01 / 0.01	0.00 / 0.00 / 0.00
ΔC	63.45 / 34.92 / 46.34	5.73 / 55.72 / 30.70	30.82 / 9.18 / 22.36	0.00 / 0.18 / 0.59
ΔI	0.92 / 0.73 / 0.62	99.02 / 99.26 / 99.37	0.06 / 0.00 / 0.01	0.00 / 0.00 / 0.00
Q^k	21.06 / 1.11 / 1.00	37.62 / 90.11 / 77.63	41.33 / 8.65 / 20.93	0.00 / 0.13 / 0.44

Table 3: **Correlation Matrix**

This table reports the correlation matrix of financial and macroeconomic variables with all shocks in the baseline model. The variables include excess return on stock (claim on consumption) (R_s^c), excess return on long-term nominal bond ($R_b^\$$), excess return on long-term real bond (R_b^c), inflation (π), consumption growth (ΔC), and real pricing kernel (M). The three numbers in each cube represent the correlation in the AMPF / PMAF / PMPF regime in percentage, respectively.

	Panel A: Correlation Matrix					
Variables	R_s^c	$R_b^\$$	R_b^c	π	ΔC	M
R_s^c	1.00	0.82 / -0.32 / 0.05	0.64 / 0.51 / 0.69	-0.39 / -0.05 / 0.07	0.55 / 0.51 / 0.51	-0.71 / -0.54 / -0.42
$R_b^\$$		1.00	0.42 / -0.47 / -0.22	-0.36 / -0.15 / -0.18	0.47 / -0.16 / 0.00	-0.71 / -0.19 / -0.40
R_b^c			1.00	0.06 / 0.30 / 0.37	0.34 / 0.24 / 0.30	0.08 / 0.45 / 0.36
π				1.00	-0.69 / -0.29 / -0.17	0.57 / 0.37 / 0.38
ΔC					1.00	-0.40 / -0.30 / -0.28
M						1.00

Table 4: **Correlation Matrices without the NT or MEI Shocks**

Panels A to B of this table report the correlation matrices of financial and macroeconomic variables in the baseline model with all shocks except the NT shock and all shocks except the MEI shock, respectively. The variables include excess return on stock (claim on consumption) (R_s^c), excess return on long-term nominal bond ($R_b^{\$}$), excess return on long-term real bond (R_b^c), inflation (π), consumption growth (ΔC), and real pricing kernel (M). The three numbers in each cube represent the correlation in the AMPF / PMAF / PMPF regime in percentage, respectively.

	Panel A: All Shocks except the NT Shock					
Variables	R_s^c	$R_b^{\$}$	R_b^c	π	ΔC	M
R_s^c	1.00	0.65 / -0.51 / -0.20	0.99 / 1.00 / 0.99	0.05 / 0.19 / 0.28	0.62 / 0.61 / 0.64	-0.89 / -0.90 / -0.91
$R_b^{\$}$		1.00	0.69 / -0.44 / -0.14	0.19 / -0.10 / -0.07	0.42 / -0.31 / -0.12	-0.64 / 0.37 / 0.07
R_b^c			1.00	0.05 / 0.18 / 0.27	0.62 / 0.61 / 0.64	-0.92 / -0.92 / -0.93
π				1.00	-0.09 / 0.11 / 0.32	0.12 / 0.14 / 0.00
ΔC					1.00	-0.50 / -0.49 / -0.52
M						1.00

	Panel B: All Shocks except the MEI Shock					
Variables	R_s^c	$R_b^{\$}$	R_b^c	π	ΔC	M
R_s^c	1.00	0.97 / 0.70 / 0.77	0.52 / -0.33 / 0.21	-0.42 / -0.49 / -0.20	0.56 / 0.44 / 0.42	-0.79 / -0.86 / -0.67
$R_b^{\$}$		1.00	0.55 / 0.32 / 0.19	-0.39 / -0.15 / -0.23	0.55 / 0.29 / 0.31	-0.73 / -0.32 / -0.53
R_b^c			1.00	0.16 / 0.48 / 0.49	0.29 / -0.15 / -0.02	0.12 / 0.76 / 0.58
π				1.00	-0.73 / -0.73 / -0.59	0.61 / 0.59 / 0.55
ΔC					1.00	-0.44 / -0.38 / -0.37
M						1.00

Table 6: **Correlation Matrices — Alternative Preferences**

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 (claim on consumption) (R_s^c), excess return on long-term nominal bond ($R_b^\$$), excess return on long-term real bond (R_b^c), inflation (π), consumption growth (ΔC), and real pricing kernel (M). The three numbers in each cube represent the correlation in the AMPF / PMAF / PMPF regime in percentage, respectively.

	Panel A: CRRA Preference					
Variables	R_s^c	$R_b^\$$	R_b^c	π	ΔC	M
R_s^c	1.00	0.82 / -0.32 / 0.07	0.63 / 0.50 / 0.67	-0.40 / -0.06 / 0.06	0.55 / 0.51 / 0.51	-0.71 / -0.54 / -0.44
$R_b^\$$		1.00	0.42 / -0.47 / -0.21	-0.36 / -0.15 / -0.17	0.47 / -0.15 / 0.02	-0.71 / -0.19 / -0.41
R_b^c			1.00	0.06 / 0.30 / 0.37	0.35 / 0.24 / 0.30	0.09 / 0.46 / 0.36
π				1.00	-0.69 / -0.30 / -0.18	0.57 / 0.37 / 0.38
ΔC					1.00	-0.39 / -0.29 / -0.29
M						1.00
	Panel B: Recursive Preference without Habit Formation					
Variables	R_s^c	$R_b^\$$	R_b^c	π	ΔC	M
R_s^c	1.00	0.82 / -0.32 / 0.05	0.63 / 0.50 / 0.68	-0.40 / -0.06 / 0.07	0.55 / 0.51 / 0.52	-0.71 / -0.54 / -0.43
$R_b^\$$		1.00	0.42 / -0.47 / -0.22	-0.37 / -0.15 / -0.18	0.47 / -0.15 / 0.01	-0.71 / -0.19 / -0.41
R_b^c			1.00	0.06 / 0.30 / 0.37	0.35 / 0.24 / 0.30	0.09 / 0.45 / 0.36
π				1.00	-0.69 / -0.29 / -0.17	0.57 / 0.37 / 0.39
ΔC					1.00	-0.39 / -0.29 / -0.29
M						1.00

Figure 1: **CAPM Betas of Long-Term Treasury Bonds**

This figure plots the time series of estimated CAPM beta of the nominal 5-year Treasury bond. CAPM beta in blue is estimated from a rolling window of 3 months of daily return from 1947 to 2017. The shaded areas with dark, medium, and light grey represent the AMPF, PMAF, and PMPF regimes, respectively. The x-axis is time, and y-axis is the size of beta.

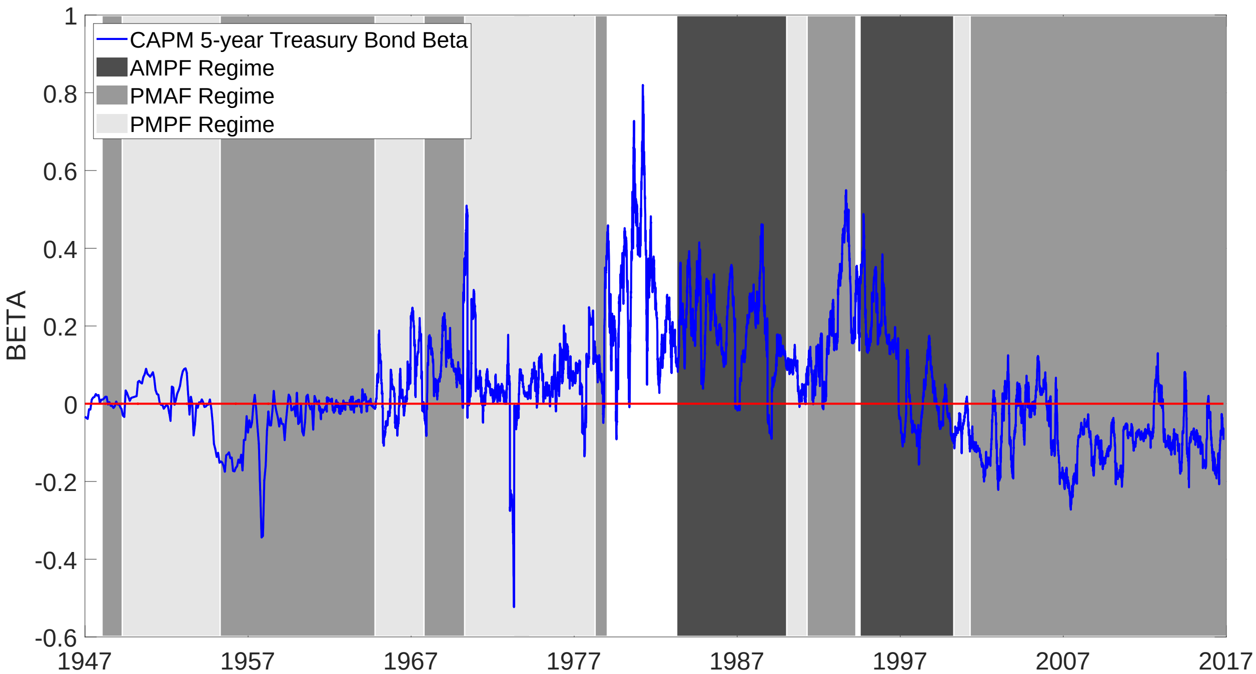


Figure 2: CAPM Beta of the 5-year Treasury Bond

Figure 3: **Impulse Responses of a Positive NT Shock**

This figure plots the impulse responses of key macro and finance variables in the model after a positive NT shock. These variables are excess return on stock (claim on consumption) (R_s^c), excess return on long-term nominal bond ($R_b^\$$), excess return on long-term real bond (R_b^c), inflation (π), short-term nominal interest rate (i), short-term real interest rate (r), nominal pricing kernel ($M^\$$), growth rate of consumption (ΔC), growth rate of investment (ΔI), price of capital (Q^k), lump-sum tax-to-output ratio (τ), and the level of government bond (B_t). The blue solid lines, red dashed lines with circles, and black dashed lines represent impulse responses under the AMPF, PMAF, and PMPF regimes, respectively. The x-axis is the time in quarters, and y-axis represents percentage change from the steady state.

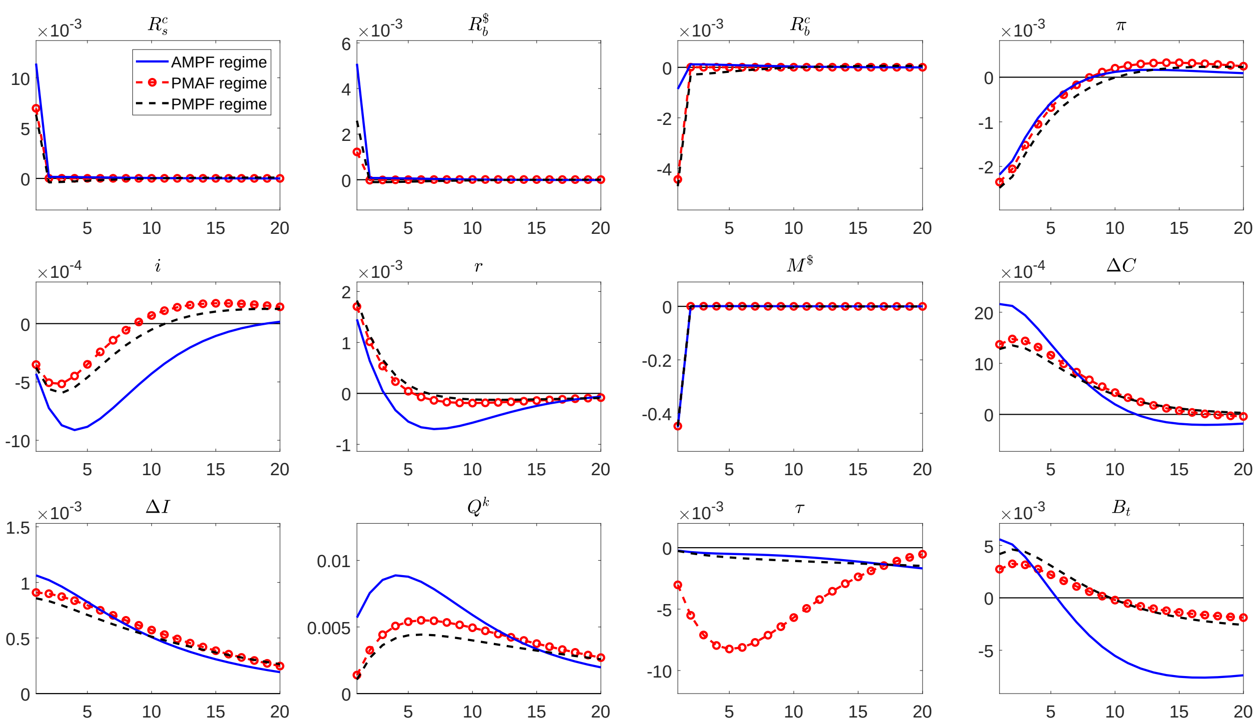


Figure 4: **Impulse Responses of a Positive MEI Shock**

This figure plots the impulse responses of key macro and finance variables in the model after a positive MEI shock. These variables are excess return on stock (claim on consumption) (R_s^c), excess return on long-term nominal bond ($R_b^{\$}$), excess return on long-term real bond (R_b^c), inflation (π), short-term nominal interest rate (i), short-term real interest rate (r), nominal pricing kernel ($M^{\$}$), growth rate of consumption (ΔC), growth rate of investment (ΔI), price of capital (Q^k), lump-sum tax-to-output ratio (τ), and the level of government bond (B_t). The blue solid lines, red dashed lines with circles, and black dashed lines represent impulse responses under the AMPF, PMAF, and PMPF regimes, respectively. The x-axis is the time in quarters, and y-axis represents percentage change from the steady state.

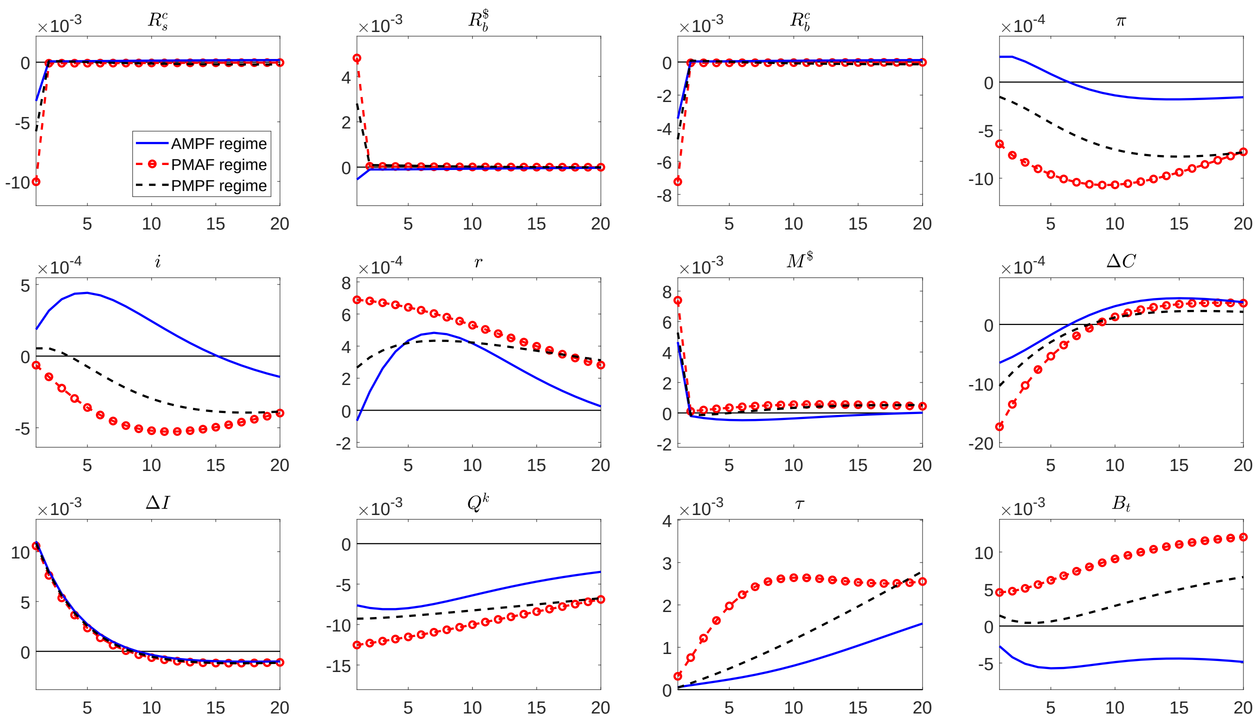


Figure 5: **Impulse Responses of a Positive Monetary Policy Shock**

This figure plots the impulse responses of key macro and finance variables in the model after a positive monetary policy shock. These variables are excess return on stock (claim on consumption) (R_s^c), excess return on long-term nominal bond ($R_b^\$$), excess return on long-term real bond (R_b^c), inflation (π), short-term nominal interest rate (i), short-term real interest rate (r), nominal pricing kernel ($M^\$$), growth rate of consumption (ΔC), growth rate of investment (ΔI), price of capital (Q^k), lump-sum tax-to-output ratio (τ), and the level of government bond (B_t). The blue solid lines, red dashed lines with circles, and black dashed lines represent impulse responses under the AMPF, PMAF, and PMPF regimes, respectively. The x-axis is the time in quarters, and y-axis represents percentage change from the steady state.

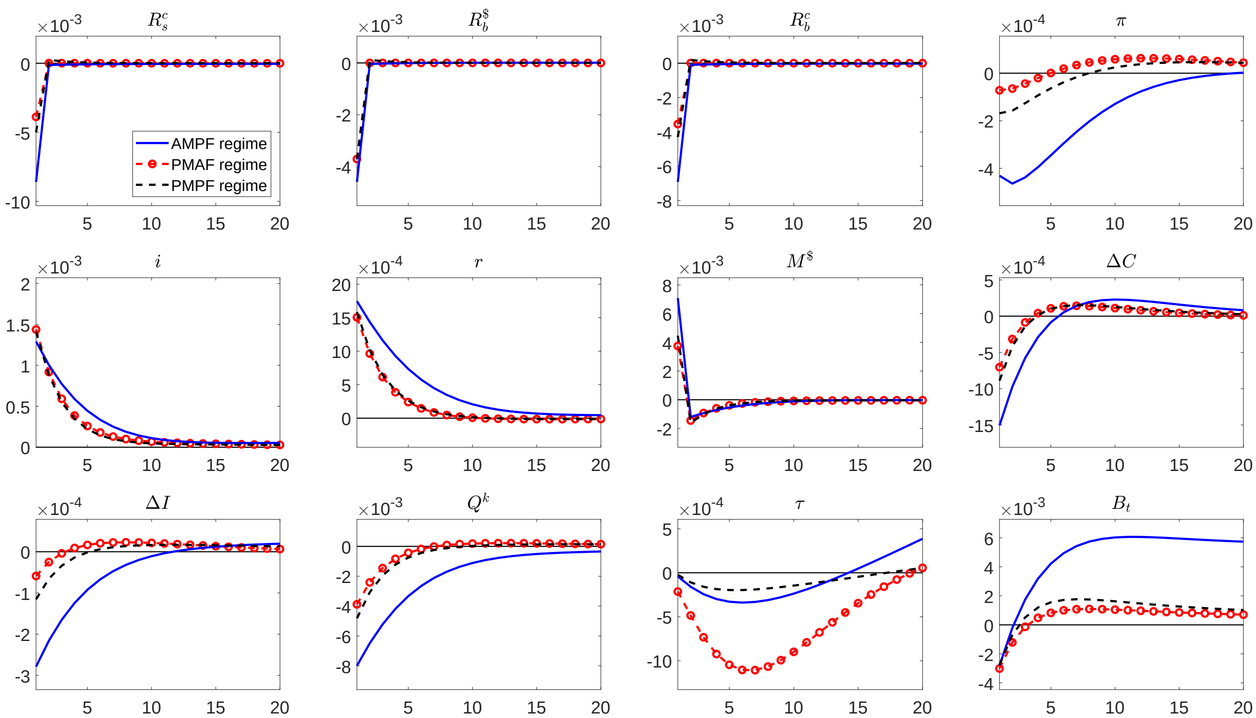


Figure 6: **Impulse Responses of a Positive Fiscal Policy Shock**

This figure plots the impulse responses of key macro and finance variables in the model after a positive fiscal policy shock. These variables are excess return on stock (claim on consumption) (R_s^c), excess return on long-term nominal bond ($R_b^\$$), excess return on long-term real bond (R_b^c), inflation (π), short-term nominal interest rate (i), short-term real interest rate (r), nominal pricing kernel ($M^\$$), growth rate of consumption (ΔC), growth rate of investment (ΔI), price of capital (Q^k), lump-sum tax-to-output ratio (τ), and the level of government bond (B_t). The blue solid lines, red dashed lines with circles, and black dashed lines represent impulse responses under the AMPF, PMAF, and PMPF regimes, respectively. The x-axis is the time in quarters, and y-axis represents percentage change from the steady state.

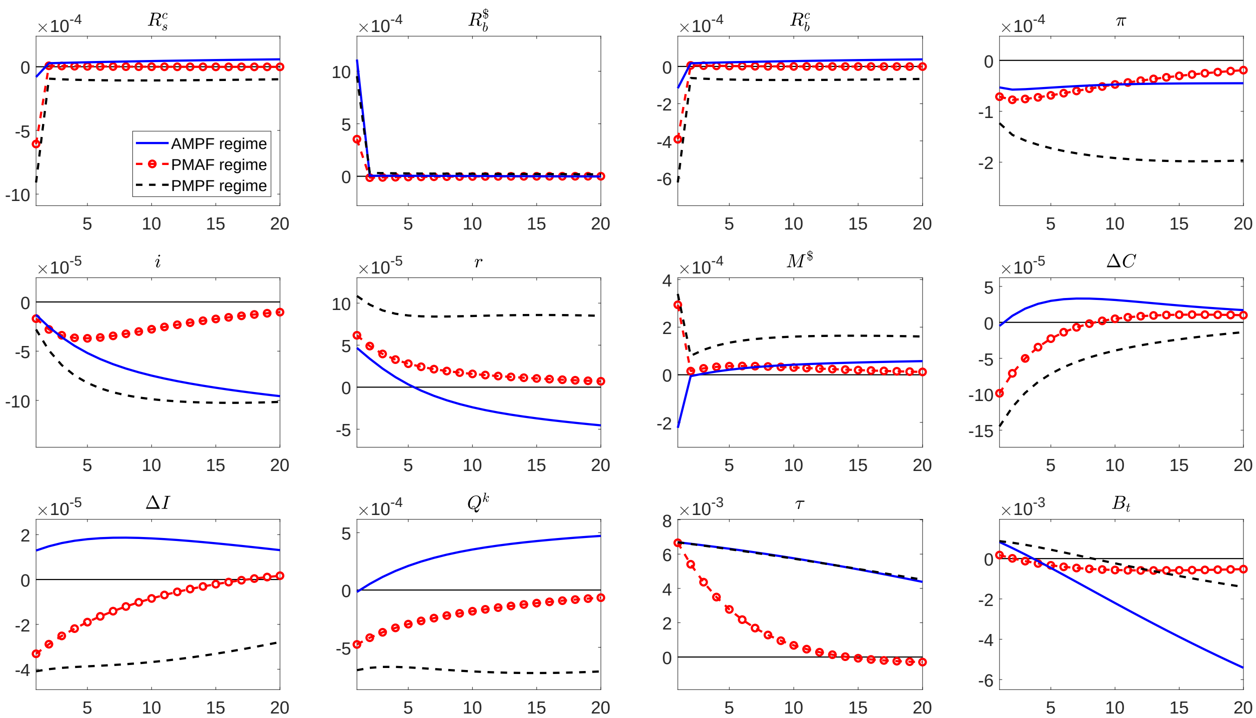
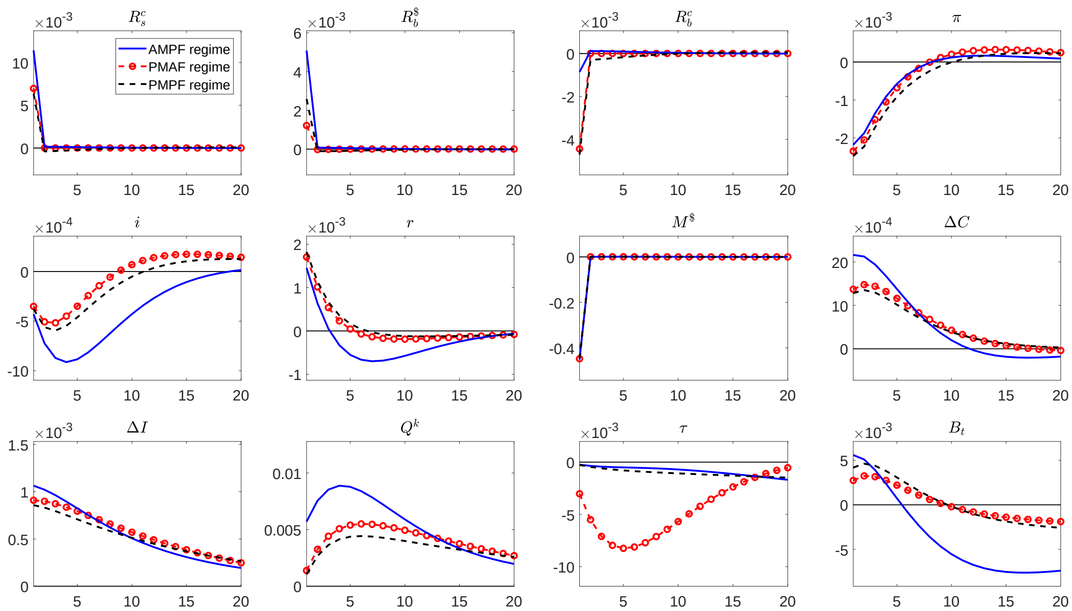
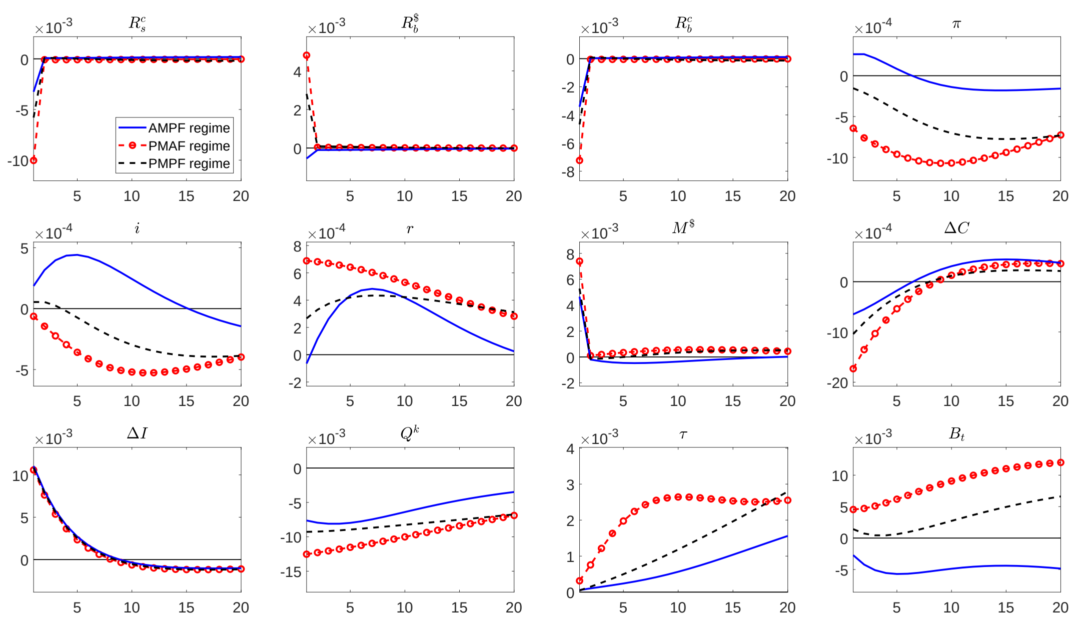


Figure 7: **Impulse Responses under CRRA Preference**

Panels (a) and (b) of this figure plots the impulse responses of key macro and finance variables after positive NT and MEI shocks, respectively, in the model with CRRA preferences. These variables are excess return on stock (claim on consumption) (R_s^c), excess return on long-term nominal bond ($R_b^\$$), excess return on long-term real bond (R_b^c), inflation (π), short-term nominal interest rate (i), short-term real interest rate (r), nominal pricing kernel ($M^\$$), growth rate of consumption (ΔC), growth rate of investment (ΔI), price of capital (Q^k), lump-sum tax-to-output ratio (τ), and the level of government bond (B_t). The blue solid lines, red dashed lines with circles, and black dashed lines represent impulse responses under the AMPF, PMAF, and PMPF regimes, respectively. The x-axis is the time in quarters, and y-axis represents percentage change from the steady state.



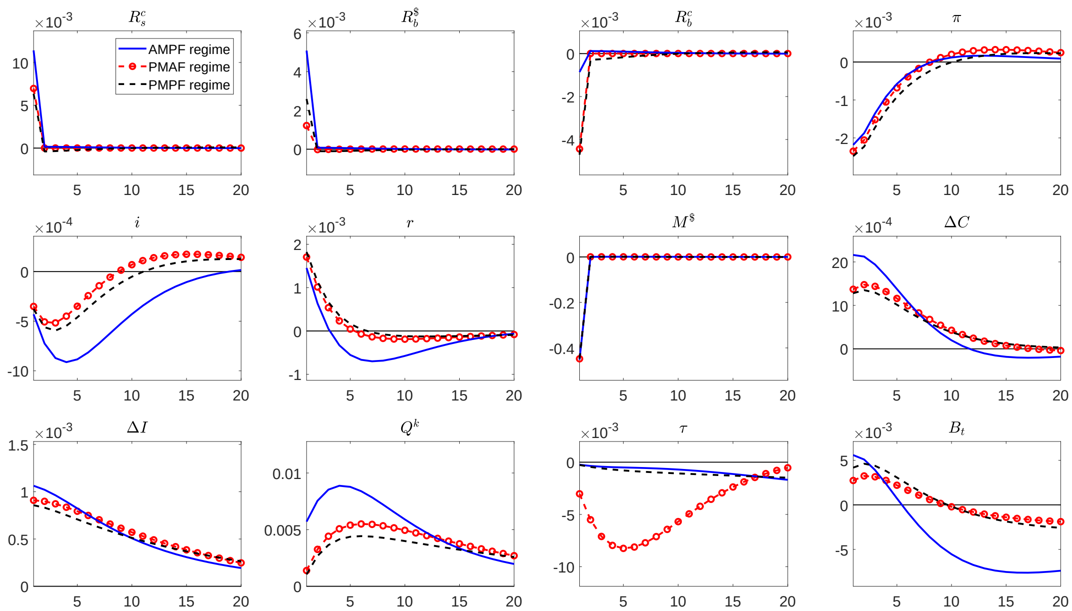
(a) Impulse Responses after a Positive NT Shock



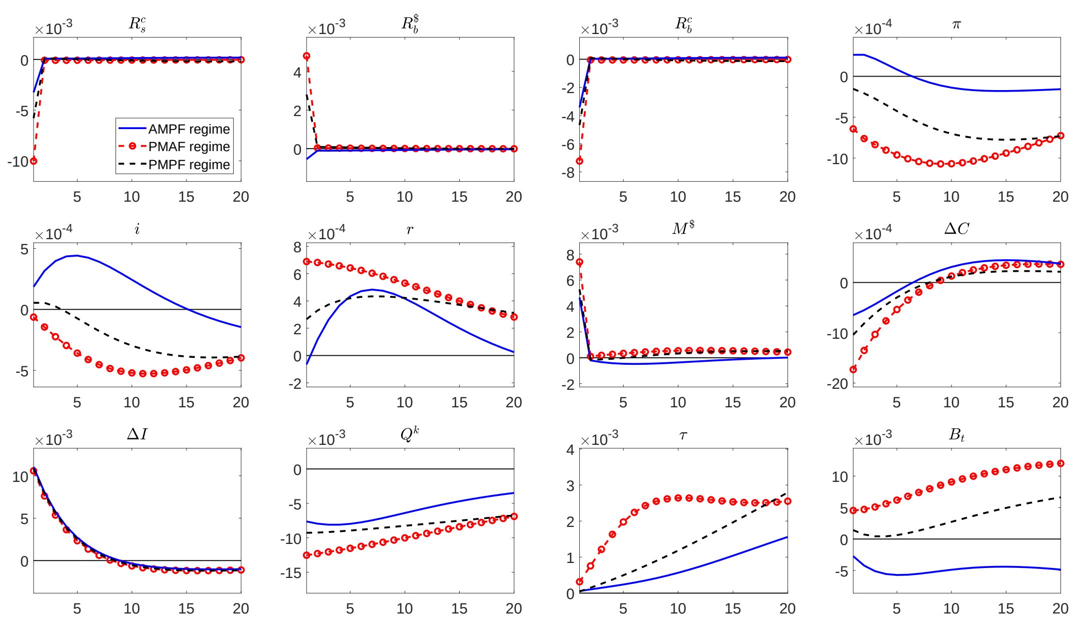
(b) Impulse Responses after a Positive MEI Shock

Figure 8: **Impulse Responses under Recursive Preference without Habit Formation**

Panels (a) and (b) of this figure plots the impulse responses of key macro and finance variables after positive NT and MEI shocks, respectively, in the model with recursive preference without habit formation. These variables are excess return on stock (claim on consumption) (R_s^c), excess return on long-term nominal bond ($R_b^{\$}$), excess return on long-term real bond (R_b^c), inflation (π), short-term nominal interest rate (i), short-term real interest rate (r), nominal pricing kernel ($M^{\$}$), growth rate of consumption (ΔC), growth rate of investment (ΔI), price of capital (Q^k), lump-sum tax-to-output ratio (τ), and the level of government bond (B_t). The blue solid lines, red dashed lines with circles, and black dashed lines represent impulse responses under the AMPF, PMAF, and PMPF regimes, respectively. The x-axis is the time in quarters, and y-axis represents percentage change from the steady state.



(a) Impulse Responses after a Positive NT Shock



(b) Impulse Responses after a Positive MEI Shock

Appendix A Data

The raw data in quarterly frequency used in constructing the observed macroeconomic variables are:
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.
Federal Funds Rate: (FF) effective federal funds rate, H.15 selected interest rates, percent, averages of daily figures, FRED2.

Here NIPA, BLS and FRED2 stand for
FRED2: Database of the Federal Reserve Bank of St. Louis available at:
http://research.stlouisfed.org/fred2/.
BLS: Database of the Bureau of Labor Statistics available at: http://www.bls.gov/.
NIPA: Database of the National Income And Product Accounts available at:
http://www.bea.gov/national/nipaweb/index.asp.
BGOV: Database of the Board of Governors of the Federal Reserve System available at:
http://www.federalreserve.gov/econresdata/default.htm.

The variables used in the estimation is constructed as follows:

- inflation = growth rate of P
- consumption = $C^{nom}_{nondurables} + C^{nom}_{services}$
- nominal investment = $I^{nom} + C^{nom}_{durables}$

The financial market data used include:
Stock return: Market portfolio excess return, percent, Kenneth French's website.
5-yr TIPS: 5-year TIPS yield, percent, WRDS.
5-yr nominal bond (D): 5-year nominal Treasury bonds yield, percent, WRDS.
5-yr nominal bond (M): 5-year nominal Treasury bonds yield, percent, McCulloch and Kwon (1993).
10-yr nominal bond: 10-year nominal Treasury bonds yield, percent, WRDS.

Here Kenneth French's website, WRDS and McCulloch and Kwon (1993) 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.
WRDS: Wharton Research Data Services available at: https://wrds-web.wharton.upenn.edu/wrds/.
McCulloch and Kwon (1993): U.S. Term Structure Data, 1947-1991 available at:
http://www.econ.ohio-state.edu/jhm/ts/mcckwon/mccull.htm.
D: Daily frequency data.
M: Monthly frequency data.