What do Treasury Bond Risks Say about Supply and Demand Shocks?

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Abstract

This paper analyzes how the risks of nominal and inflation-indexed Treasury bonds vary with the presence of supply and demand shocks through the lens of a small-scale New Keynesian model with habit formation preferences, where investors become more risk averse following adverse economic shocks. We calibrate the model separately for the time periods 1979.Q4-2001.Q1 and 2001.Q2-2019.Q4. For the 1980s calibration, volatile supply shocks raise inflation and the Fed responds by raising interest rates, leading to a recession and simultaneous drops in nominal bond and stock prices. For the 2000s calibration, volatile demand shocks lower the output gap and raise interest rates at the same time, leading to simultaneous increases in nominal and real bond prices and a stock market downturn. The model matches equity Sharpe ratios and stock return predictability through habit formation preferences. Partially backward-looking inflation expectations by price-setters are important to match predictability of bond excess returns as in Campbell and Shiller (1991). We find that the high risks of nominal Treasury bonds in the 1980s were the result of a "perfect storm" of volatile supply shocks and a non-inertial monetary policy rule.

Keywords: inflation, risk premia, bond return predictability, stagflation, monetary policy
JEL Classifications: E43, E52, E58

1   Introduction

Did the severe stagflation of the 1980s occur because the economy was subject to supply shocks or because the Volcker Fed raised interest rates and therefore engineered a recession? And, given recent supply shocks to oil prices and supply chain disruptions, should we expect a return to a similarly stagflationary regime and risky Treasury bond markets?

Figure 1 shows that the risks of nominal and inflation-indexed government bonds underwent significant changes along with these macroeconomic changes.[1] Because 10-year nominal bond prices should fall with long-term inflation expectations, they should be expected to serve as a good indicator of the inflation risks that the economy faces. In Panel A, we see that nominal 10-year Treasury bonds had strongly positive betas with respect to the stock market, meaning that nominal Treasury bonds tended to fall at the same time as the stock market. Inflation-indexed bonds shared some of these properties but their betas were much smaller in magnitude, indicating a substantial role for inflation expectations. During the 2000s, however, the betas of both nominal and inflation-indexed bonds became negative and the gap narrowed, indicating less volatile inflation expectations that tended to fall along with the stock market. For the first two post-pandemic years 2020.Q1-2022.Q2, maybe surprisingly the picture looks markedly different from the 1980s, with inflation-indexed bond betas turning positive, while nominal bond betas remained predominantly negative. We use a simple model of supply and demand shocks with monetary policy and time-varying risk premia to understand these changes in nominal and inflation-indexed bond betas.

We integrate a New Keynesian model with supply and demand shocks with macro-asset pricing habit formation preferences by building on Campbell et al. (2020).[2] We introduce a new demand shock, modeled as a preference shock for holding bonds that leads to higher consumption at a given short-term interest rate. We also newly model partially adaptive inflation expectations of wage-setters, allowing us to generate a more backward-looking Phillips curve (Fuhrer (1997)). We use the model to link the presence of supply vs. demand shocks with important moments in the bond market, and study how supply and demand shocks interact with the monetary policy rule to generate either risky Treasury bond markets and stagflations, or conversely safe Treasury bond markets and low inflation recessions.

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[1] We show 5-year rolling betas of quarterly bond excess returns onto quarterly stock returns (Panel A) for the full sample and 6-month rolling betas of daily bond returns onto stock returns post-2018. All bond returns are computed from zero-coupon nominal and inflation-indexed yields, holding the bond duration constant at 10 years. We use UK inflation-linked bond yields prior to 1999 when data on US Treasury Inflation Protected Securities becomes available.

[2] While Campbell et al. (2020) and Pflueger and Rinaldi (2020) make steps towards integrating a simple New Keynesian model with asset prices via habit formation preferences, the published versions of neither paper feature supply or demand shocks, so they cannot provide a decomposition of bond risks into these fundamental economic driving forces.

We provide two main exercises. First, we calibrate the model to macroeconomic dynamics of long macroeconomic periods, and show that our model provides a reasonable link between macroeconomic changes of the 1980s vs. the 2000s and Treasury bond markets. We choose our break date to be 2001.Q2 following Campbell et al. (2020) when the correlation between inflation and the output gap turned from negative (i.e. "stagflations") to positive. This exercise shows that if we calibrate the shock volatilities and monetary policy to macroeconomic impulse responses, we obtain volatile supply shocks and monetary policy shocks but almost no demand shocks for the 1980s. Because during this period the policy rate responds fairly swiftly to inflation surprises in the data, we calibrate a monetary policy rule with little inertia. Partially adaptive inflation expectations generate predictability in inflation forecast errors in surveys in line with the empirical evidence of Coibion and Gorodnichenko (2015) and reconcile volatile nominal Treasury bond yields with much less volatile long-term survey inflation expectations.

Even though the betas of nominal and real bond betas were not explicitly targeted in the calibration, the model generates a highly positive nominal bond-stock beta and a small but positive real bond-stock beta for the 1980s. The channel is simple: A positive Phillips curve or supply shock drives up inflation and inflation expectations, leading to lower nominal bond prices. Because monetary policy seeks to counteract this increase in inflation, real rates also rise, and prices of real bonds fall, though the change is much smaller than for nominal bonds. The higher real interest rates leads consumers to postpone consumption, and consumption falls toward habit, leading investors to put a lower valuation on risky stocks. Time-varying risk premia in the model are not a free parameter but are disciplined by the equity Sharpe ratio, the persistence of the equity price dividend ratio, and the predictability of equity returns from the lagged price-dividend ratio, which the model matches equally well as Campbell and Cochrane (1999) and Campbell et al. (2020).

The 1980s calibration of the model also generates strong bond return predictability from the yield spread, consistent with the corresponding empirical moment. A strong backward-looking component in the Phillips curve gives rise to a persistent inflation process, so under the expectations hypothesis long-term and short-term nominal rates are expected to respond similarly to a supply shock. Because risk premia in the model increase as consumption falls towards habit, a supply shock therefore drives up the model yield spread through risk premia, and a positive yield spread predicts model bond excess returns positively. We therefore show that a strongly backward-looking Phillips curve, that has been found necessary to explain several features in macroeconomic data, is also necessary to explain the empirical predictability of bond excess returns.

For the 2000s calibration of the model, we match the positive output gap-inflation and

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positive output gap-policy rate relationships in the data with volatile demand shocks, moderately volatile monetary policy shocks, and much less volatile supply shocks. A more inertial monetary policy rule is consistent with a delayed empirical policy rate response to inflation surprises during this sample period. For the 2000s calibration we set inflation expectations to be rational and perfectly forward-looking, in line with a lack of predictability of survey inflation forecast errors during this period. While our model of monetary policy is purely descriptive and cannot speak to why the monetary policy rule has changed, the estimates seem intuitively in line with the gradual monetary policy rule of the recent decades.

Even though the 2000s nominal and real bond betas were not targeted in the calibration stage, their broad features are well-matched by the model. The 2000s calibration generates negative stock market betas for both nominal and real bonds. The key channel depends on demand shocks, which tend to raise interest rates and inflation just as the output gap rises, and a gradual monetary policy response, which mutes and even reverses the output gap response to supply shocks. While the model counterfactually implies that nominal and real bond betas should have been the same during the 2000s, whereas in the data the nominal bond beta was more negative, we do not see this as a significant issue because the demand shock volatility is estimated with substantial noise from macroeconomic data. For the 2000s calibration, the model generates no return predictability in bonds, but strong return predictability in stocks, both of which are in line with the empirical evidence.

Our second exercise is to use the calibrated model to conduct counterfactual exercises, effectively asking what changes in shocks could turn nominal Treasury bonds similarly risky as in the stagflationary 1980s when starting from a monetary policy rule and inflation expectations formation process from the 2000s. The main finding here is that positive nominal Treasury bond betas are the result of the interaction of volatile supply shocks with a non-inertial monetary policy rule. Conversely, this implies that starting from the 2001.Q1-2019.Q4 regime, several changes would be required to make Treasury bonds equally risky as during the stagflationary 1980s. Volatile supply shocks in the model are not sufficient, but instead a non-inertial monetary policy rule would also be needed. Instead, changing only the model shock volatilities back to their 1980s values leads to positive real bond betas and negative nominal bond betas in the model, in line with the empirical evidence towards the end of the sample in Figure 1. Asset pricing moments from Treasury markets therefore support the view that supply shocks matter for the real economy through the monetary policy rule (Bernanke et al. (1997)). This prediction also lines up well with our initial observation that while the recent episode bears some resemblance to the 1980s supply shocks, the risks of nominal Treasury bonds in the data are very different from the 1980s.

This paper contributes to the broad literatures linking monetary policy and asset prices,

understanding the sources of stagflations, and the drivers of changes in bond-stock correlations. While several papers have documented the changing risks in Treasury bonds and studied their drivers (e.g. Baele et al. (2010), Viceira (2012), David and Veronesi (2013), Campbell et al. (2017), Bianchi et al. (2020)), the link between demand and supply shocks with bond betas has remained elusive. While some studies have focused on nominal bonds (Piazzesi and Schneider (2006), Song (2017), Gourio and Ngo (2020), Campbell et al. (2020)) and others on real bonds (Chernov et al. (2021)), we add to this literature by showing that the combination of real and nominal bond betas is informative about changes in the economy.

We view our contribution as complementary to Chernov et al. (2021), who use rolling correlations rather than betas to argue that the time-varying bond-stock comovements were very similar for inflation-indexed and nominal bonds. However, if the same structural shock drives both real bond yields and inflation expectations, as in most New Keynesian models, a correlation measure may be uninformative about their separate economic roles. Betas, however, will be intuitively informative about how inflation expectations and real rates load onto a structural shock. Similar to them, we generate a negative bond beta during the post-2000 period primarily through the real bond beta. Different from them, our focus on betas reveals distinct differences between nominal and real bond risks pre-2000 and we aim to decompose the drivers into demand, supply, and monetary policy shocks.

We also contribute to the long literature seeking to explain the extraordinary inflation dynamics in the 1980s. This literature can broadly be divided into a strand emphasizing changes in shocks (Stock and Watson (2002), Sims and Zha (2006), Justiniano and Primiceri (2008)) and a strand emphasizing changes monetary policy (Clarida et al. (2000), Lubik and Schorfheide (2004)). One narrative that has emerged from this literature is that supply shockcs were initially not recognized by monetary policy, forcing the Fed to raise interest rates drastically under Volcker, which resulted in a severe stagflation (Primiceri (2006)). We contribute by bringing new asset pricing moments to this literature to speak to the question of shocks vs. policy. We show that these new moments support a narrative whereby the interaction of both supply shocks and monetary policy was essential to generate the risky nominal Treasury bond markets of the stagflationary 1980s, and would be needed to turn Treasury markets back into a similar regime.

The rest of the paper proceeds as follows. We present the model in Section 2. We estimate macroeconomic impulse responses and inflation forecast error regressions by subperiod and describe our calibration strategy in Section 3. Section 4 describes the model's fit for macroeconomic and asset pricing moments for the 1980s and 2000s subperiods. Section 5 conducts the counterfactual exercises and maps nominal and real bond-stock betas to implied standard deviations of structural shocks. Finally, Section 6 concludes.

2   Model

The model combines a small-scale log-linearized New Keynesian model on the macroeconomic side with a model of habit-formation preferences for asset prices, following Campbell and Cochrane (1999) and Campbell et al. (2020). Different from Campbell et al. (2020) the model features a monetary policy rule and monetary policy shocks, and different from Pflueger and Rinaldi (2020) it features supply and demand shocks.[3] We use lower-case letters to denote logs throughout and use π_t to denote log price inflation and π_t^w to denote log wage inflation.

2.1   Preferences

As in Campbell et al. (2020) and Pflueger and Rinaldi (2020), a representative agent derives utility from real consumption C_t relative to a slowly-moving habit level H_t

$$U_t = \frac{(C_t - H_t)^{1-\gamma} - 1}{1 - \gamma} \tag{1}$$

Habits are external, meaning that they are shaped by aggregate consumption and households do not internalize how habits might respond to their personal consumption choices. The parameter γ is a curvature parameter. Relative risk aversion equals $-U_{CC}C/U_C = \gamma/S_t$, where surplus consumption is the share of market consumption available to generate utility:

$$S_t = \frac{C_t - H_t}{C_t}. \tag{2}$$

As equation (2) makes clear, a model for market habit implies a model for surplus consumption and vice versa. Market consumption habit is modeled implicitly by assuming that log surplus consumption, s_t, satisfies:

$$s_{t+1} = (1 - \theta_0)\bar{s} + \theta_0 s_t + \theta_1 x_t + \theta_2 x_{t-1} + \varepsilon_{c,t}, \tag{3}$$

$$\varepsilon_{c,t+1} = c_{t+1} - \mathrm{E}_t c_{t+1}. \tag{4}$$

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[3]An earlier working paper version of Campbell et al. (2020) had a small-scale New Keynesian macroeconomic model, though it did not feature demand shocks to the Euler equation, and instead suffered from an over-reliance on shocks to the central bank inflation target. This earlier working paper version also did not match macroeconomic impulse responses as we do.

The sensitivity function $\lambda(s_t)$ takes the form:

$$\lambda(s_t) \;=\; \begin{cases} \frac{1}{\bar{S}}\sqrt{1 - 2(s_t - \bar{s})} - 1 & s_t \leq s_{max} \\ 0 & s_t > s_{max} \end{cases}, \tag{5}$$

$$\bar{S} \;=\; \sigma_c\sqrt{\frac{\gamma}{1 - \theta_0}}, \tag{6}$$

$$\bar{s} \;=\; \log(\bar{S}), \tag{7}$$

$$s_{max} \;=\; \bar{s} + 0.5(1 - \bar{S}^2). \tag{8}$$

Here, σ_c denotes the standard deviation of the consumption surprise $\varepsilon_{c,t+1}$ and $\bar{s}$ is the steady-state value for log surplus consumption. The consumption surprise is an equilibrium object depending on fundamental shocks, which in equilibrium is conditionally homoskedastic and lognormal. As shown in Campbell et al. (2020), the specification for log surplus consumption (3) implies that log market habit follows approximately a weighted average of moments of past log consumption.

Here, x_t equals stochastically detrended consumption (up to a constant):

$$x_t \;=\; c_t - a_t, \tag{9}$$

$$a_t \;=\; (1 - \phi)\sum_{j=0}^{\infty} \phi^j c_{t-1-j}, \tag{10}$$

where ϕ is a smoothing parameter. For the microfoundations presented in the appendix, consumption equals output and x_t equals the log output gap, or the difference between between log output and log potential output under flexible prices and wages, a_t. For details, see the Appendix.

2.2 Macroeconomic Euler Equation and Demand Shocks

Different from Campbell et al. (2020) and Pflueger and Rinaldi (2020) and new to this paper, we allow for a preference shock for bonds acting as a demand shock. The stochastic discount factor (SDF) M_{t+1} in this economy equals:

$$M_{t+1} = \beta\frac{\frac{\partial U_{t+1}}{\partial C}}{\frac{\partial U_t}{\partial C}} = \beta\exp\left(-\gamma(\Delta s_{t+1} + \Delta c_{t+1})\right). \tag{11}$$

We assume that investors have an iid preference shock for bonds ξ_t, implying that the Euler equation for the one-period risk-free rate equals

$$1 \;=\; E_t \left[M_{t+1} exp \left(r_t - \xi_t \right) \right]. \tag{12}$$

For example, a 10 bps increase in ξ_t would mean that consumers increase their current consumption as if the real risk-free rate was lower by 10bps than it actually is. Such an increase in ξ_t could represent a shock to the convenience of risk-free bonds or frictions in credit and banking markets driving a wedge between market interest rates and consumers' borrowing and savings decisions. The preference shock ξ_t is assumed to be conditionally homoskedastic, serially uncorrelated, and uncorrelated with other shocks.

Substituting for the SDF and surplus consumption dynamics gives (up to a constant):

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\begin{aligned}
r_t \;&=\; \gamma E_t \Delta c_{t+1} + \gamma E_t \Delta s_{t+1} - \frac{\gamma^2}{2} \left(1 + \lambda(s_t) \right)^2 \sigma_c^2 + \xi_t, \tag{13} \\
&=\; \gamma E_t \Delta c_{t+1} + \gamma \theta_1 x_t + \gamma \theta_2 x_{t-1} + \underbrace{\gamma(\theta_0 - 1) s_t - \frac{\gamma^2}{2} \left(1 + \lambda(s_t) \right)^2 \sigma_c^2}_{=0} + \xi_t. \tag{14}
\end{aligned}
$$

For the assumed sensitivity function the two bracketed terms drop out. Using equation (10) and rearranging gives the loglinear **Euler equation:**

$$x_t = f^x E_t x_{t+1} + \rho^x x_{t-1} - \psi r_t + v_{x,t}. \tag{15}$$

Imposing the restriction that the forward- and backward-looking terms in the Euler equation add up to one, the Euler equation parameters equal

$$\rho^x \;=\; \frac{\theta_2}{\phi - \theta_1}, f^x = \frac{1}{\phi - \theta_1}, \psi = \frac{1}{\gamma(\phi - \theta_1)}, \theta_2 = \phi - 1 - \theta_1. \tag{16}$$

Pflueger and Rinaldi (2020) show that non-zero values for the habit parameters, θ_1 and θ_2, are needed to generate a New Keynesian block with forward- and backward-looking coefficients, and match empirical hump-shaped output impulse responses to a monetary policy shock. The new demand shock in the Euler equation equals

$$v_{x,t} \;=\; \psi \xi_t. \tag{17}$$

The demand shock $v_{x,t}$ is conditional homoskedastic, serially uncorrelated and uncorrelated with supply and monetary policy shocks because ξ_t is. The standard deviation of $v_{x,t}$ is denoted by σ_x.

2.3 Phillips Curve and Supply Shocks

The supply side of the model can be summarized by the log-linearized wage **Phillips curve:**

$$\pi_t^w \;=\; f^\pi E_t \pi_{t+1}^w + \rho^\pi \pi_{t-1}^w + \kappa x_t + v_{\pi,t}, \tag{18}$$

for constants ρ^π, f^π and κ. The supply or Phillips curve shock $v_{\pi,t}$ is assumed to be conditionally homoskedastic with standard deviation $\sigma_{\pi,t}$, and serially uncorrelated and uncorrelated with other shocks. This supply shock can arise from a variety of sources, such as variation in optimal wage markups charged by unions or shocks to the marginal utility of leisure.[4]

In deriving the Phillips Curve (18), we allow for adaptive subjective inflation expectations of the form

$$\tilde{E}_t \pi_{t+1}^w \;=\; (1-\zeta) E_t \pi_{t+1}^w + \zeta \pi_{t-1}^w, \tag{19}$$

where E_t denotes the rational expectation conditional on state variables at the end of period t. The case $\zeta = 0$ corresponds to rational forward-looking inflation expectations, while $\zeta > 0$ reflects partially adaptive and backward-looking inflation expectations. A long-standing Phillips curve literature has found that adaptive inflation expectations and a strongly backward-looking Phillips curve are helpful to capture the empirical persistence of inflation (Fuhrer and Moore (1995), Fuhrer (1997)).[5] We will newly show that partially adaptive inflation expectations help capture the evidence of bond return predictability by Fama and Bliss (1987) and Campbell and Shiller (1991), and drive bond-stock betas. If $\rho^{\pi,0}$ is the backward-looking component obtained under rational inflation expectations ($\zeta = 0$) because wage-setters index their wages to past inflation, the backward-looking Phillips curve parameter with hybrid inflation expectations equals

$$\rho^\pi = \rho^{\pi,0} + \zeta - \rho^{\pi,0}\zeta. \tag{20}$$

The backward- and forward-looking Phillips curve parameters add up to one:

$$f^\pi \;=\; 1 - \rho^\pi. \tag{21}$$

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[4]Up to the distinction between wage and price inflation, Phillips curve shocks would also isomorphic to shifts to potential output that are unrecognized by the central bank and consumers, in which case $x_t + \frac{1}{\kappa} v_{\pi,t}$ would be the output gap and x_t the output gap perceived by consumers and the central bank.

[5]Consistent with this older literature that emphasized aggregate inflation dynamics, a quickly growing literature has documented deviations from rationality (Coibion and Gorodnichenko (2015), Bianchi et al. (2022a)) and excess dependence on lagged inflation (Malmendier and Nagel (2016)).

Assuming sticky wages rather than sticky prices allows us to marry the traditional view of equities as a levered levered claim on consumption from the consumption-based literature (Abel (1990)) with the definition of stocks as a levered claim on real firm profits, since these definitions are equivalent in our model. This distinction is inconsequential for the macroeconomic dynamics of the output gap, inflation, and interest rates in our model, but it matters for the cyclicality of firm profits and hence for asset prices. This is in line with Christiano et al. (1999) who find that sticky wages are much more important for aggregate inflation dynamics than sticky wages. It is also in line with Favilukis and Lin (2016) who find that wage-setting frictions are important to capture pro-cyclical firm profits and ensure that claim to firm profits behaves similarly to a claim to consumption in an asset pricing sense. Our microfoundations with flexible prices and sticky wages convey particular tractability because they imply that real firm profits are proportional to real output and hence real consumption, and therefore a claim to consumption is identical to a claim to firm profits.

In the appendix we present a simple set of microfoundations for the log-linearized wage Phillips curve (18). We consider the simplified case with flexible product prices but sticky wages. Specifically, we assume that wage-setters face a quadratic cost as in Rotemberg (1982) if they raise wages faster than past inflation. The indexing to past inflation is analogous to the indexing assumption in Smets and Wouters (2007) and Christiano et al. (2005). The Phillips curve describing the wage inflation dynamics arises from log-linearizing the intratemporal first-order condition of wage-setting unions. The parameter κ is a wage-flexibility parameter. Because prices are flexible, price inflation then equals wage inflation minus productivity growth:

$$\pi_t \;=\; \pi_t^w - \Delta a_t \;=\; \pi_t^w - (1-\phi)x_t. \tag{22}$$

In our calibrations, price and wage inflation are very similar and the gap between them is small.

In order to present the simplest possible model of monetary policy and finance habits we do not explicitly model real investment and the aggregate resource constraint says that consumption equals output:

$$C_t = Y_t. \tag{23}$$

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2.4 Monetary Policy

Let i_t denote the log nominal risk-free rate available from time t to $t+1$. Monetary policy is described by the following rule (ignoring constants):

$$i_t = \rho^i i_{t-1} + \left(1 - \rho^i\right) \left(\gamma^x x_t + \gamma^\pi \pi_t\right) + v_{i,t}, \tag{24}$$

$$v_t \sim N\left(0, \sigma_i^2\right). \tag{25}$$

Here, $\gamma^x x_t + \gamma^\pi \pi_t$ denotes the central bank's interest rate target, to which it adjusts slowly with a lag coefficient ρ^i. The monetary policy shock, $v_{i,t}$, is assumed to be mean-zero, serially uncorrelated and conditionally homoskedastic. A positive monetary policy shock represents a surprise tightening of the short-term nominal interest rate above and beyond what would be predicted by the rule. The policy rate then mean-reverts slowly at rate ρ^i. To keep the solution for macroeconomic dynamics log-linear we use the common log-linear approximation for the real risk-free rate $r_t = i_t - E_t \pi_{t+1}$.[6]

2.5 Asset Prices

Investors price bonds and stocks with the stochastic discount factor given by (11), and a preference shock that enters into the asset pricing equations for bonds but not for stocks. We assume that price-setters have adaptive expectations (19) but that asset prices are formed with rational expectations, so markets are more sophisticated and more attentive to macroeconomic dynamics than individual price-setters. A similar assumption has been used by Bianchi et al. (2022a). Bond prices are given by the recursions:

$$P_{1,t}^\$ = exp(-i_t), \; P_{1,t} = exp(-r_t), \tag{26}$$

$$P_{n,t}^\$ = exp(-\xi_t)E_t\left[M_{t+1}exp(-\pi_{t+1})P_{n-1,t+1}^\$\right], \; P_{n,t} = exp(-\xi_t)E_t\left[M_{t+1}P_{n-1,t+1}\right], \tag{27}$$

where one-period real and nominal interest rates are given by equation (12) and the Fisher equation

$$i_t = E_t \pi_{t+1} + r_t. \tag{28}$$

The last equation is an approximation, effectively assuming that the inflation risk premium in one-period nominal bonds is zero. The assumption that all bonds are priced with the

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[6]We do not model the zero-lower-bound here, because we are interested in longer-term regimes, and a substantial portion of the zero-lower-bound period appears to have been governed by expectations of a swift return to normal (Swanson and Williams (2014)). The zero-lower-bound may however be important for more cyclical changes in bond-stock betas and we leave this to future research.

preference shock ξ_t ensures that in the case with no uncertainty the expectations hypothesis holds for nominal and real bonds.

Consumption claims do not benefit from this preference shock and the recursion for a zero-coupon consumption claim is

$$\frac{P_{n,t}^c}{C_t} \;=\; E_t\left[M_{t+1}\frac{C_{t+1}}{C_t}\frac{P_{n-1,t+1}^c}{C_{t+1}}\right]. \tag{29}$$

The price-consumption ratio for a claim to all future consumption then equals

$$\frac{P_t^c}{C_t} \;=\; \sum_{n=1}^{\infty}\frac{P_{n,t}}{C_t}. \tag{30}$$

We model stocks as a levered claim on consumption or equivalently firm profits, while preserving the cointegration of consumption and dividends as in Campbell et al. (2020). Let P_t^c denote the price of a claim to the entire future consumption stream C_{t+1}, C_{t+2},... At time t the aggregate firm buys P_t^c and sells equity worth δP_t^c, with the remainder of the firm's position financed by one-period risk-free debt worth $(1-\delta)P_t^c$. The price of the levered equity claim equals $P_t^\delta = \delta P_t^c$. Leverage hence scales stock returns roughly proportionally, increasing stock return volatility but leaving the Sharpe ratio unchanged.

We model the demand shock as a preference shock to bonds rather than a shock to the discount factor β shared by bonds and stocks as in Albuquerque et al. (2016), because a shock to the discount factor β would generally drive down both bonds and stocks at the same time, and generate strongly positive bond-stock correlations, in stark contrast to the post-2001 data. However, the demand shock ξ_t shares the feature of the valuation shocks of Albuquerque et al. (2016) of driving a wedge between consumption news and interest rates, thereby capturing an important feature in the data (Duffee (2022)). The demand shock ξ_t, by contrast, drives down only the price of bonds, while stock prices respond according to the general equilibrium changes in expected consumption and the stochastic discount factor M_{t+1}. The demand shock ξ_t can therefore be thought to capture changes in the convenience benefit of bonds (Krishnamurthy and Vissing-Jorgensen (2012), Du et al. (2018a), Du et al. (2018b), Jiang et al. (2021)), demand for safety not immediately driven by aggregate risk aversion (Pflueger et al. (2020)), or a finance sector shock driving a wedge between interest rates in the real economy and financial markets. We also show in the appendix that the shock ξ_t is close to isomorphic to a shock to expected productivity growth for the dynamics of the output gap, interest rates, inflation, and asset prices, though it would of course have a more persistent effect on consumption in line with Chernov et al. (2021)'s explanation of the negative post-2000 real bond-stock correlation.

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2.6 Model Solution

The model solution proceeds in two steps, utilizing that the form of Campbell et al. (2020) preferences implies that the surplus consumption ratio is a state variable for asset prices but not for macroeconomic dynamics. First, we solve for log-linear macroeconomic dynamics. Second, we use numerical methods to solve for highly non-linear asset prices. We solve for the dynamics of the log-linear state vector

$$Y_t = [x_t, \pi_t^w, i_t]'. \tag{31}$$

Equilibrium macroeconomic dynamics are determined by the consumption Euler equation (15), the Phillips curve (18), and the monetary policy rule (24). We solve for a minimum state variable equilibrium of the form:

$$Y_t = BY_{t-1} + \Sigma v_t, \tag{32}$$
$$v_t = [v_{x,t}, v_{\pi,t}, v_{i,t}], \tag{33}$$

where B and Σ are $[3 \times 3]$ and $[3 \times 3]$ matrices, and v_t is the vector of structural shocks. We solve for the matrix B using Uhlig (1999)'s formulation of the Blanchard and Kahn (1980) method. Having solved for the state vector Y_t, equilibrium consumption dynamics follow by inverting the relationship (10). In both our calibrations, there exists a unique equilibrium of the form (32) with non-explosive eigenvalues. We acknowledge that, as in most New Keynesian models, there may be further equilibria with additional state variables or sunspots (Cochrane (2011)), but resolving these issues is beyond this paper. Note that equation (32) implies that macroeconomic dynamics are conditionally log-normal, so combined with the output gap-consumption link (10) consumption surprises $\varepsilon_{c,t+1}$ are indeed conditionally lognormal in equilibrium.

The solution for asset prices uses the numerical value function iteration algorithm of Campbell et al. (2020) to implement the asset pricing recursions (26) through (30) while accounting for the new demand shock and the link between wage and price inflation (22). As a result of the new demand shock asset prices have five state variables, the three state variables included in Y_t, the lagged output gap x_{t-1}, and the surplus consumption ratio s_t. We need x_{t-1} as an additional state variable because the expected surplus consumption ratio depends on it through (3). In the absence of demand shocks the lagged output gap did not enter as a separate state variable even though it enters into the surplus consumption ratio because x_{t-1} could be expressed as a linear combination of the time t state vector Y_t. This is no longer possible in the presence of the new demand shock in this paper, thereby adding

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x_{t-1} as a new state variable for asset prices.

3 Empirical Analysis and Calibration Strategy

3.1 Calibration Strategy

Because we are interested in economic changes over time, we calibrate the model separately for two subperiods, where we choose the 2001.Q2 break date from Campbell et al. (2020). Importantly, this break date was chosen by testing for a break date in the inflation-output relationship, and did not use asset prices. We start our sample in 1979.Q4, when Paul Volcker was appointed to be Fed chairman. We end our sample in 2019.Q4 prior to the pandemic, leaving the analysis of how shocks changed during the pandemic period for a separate discussion at the end of the paper. However, because the pandemic period represents a small portion of our sample, little would change if we folded it into our post-2001.Q2 sample period. We do not account for the possibility that agents might have anticipated a change in regime.[7]

Our calibration procedure proceeds in three steps. First, we set some parameters to values following the literature. Those parameter values are held constant across both subperiods and are shown in the top panel of Table 1. The expected consumption growth rate, utility curvature, the risk-free rate, and the persistence of the surplus consumption ratio (θ_0) are from Campbell and Cochrane (1999), who found that a utility curvature of $\gamma = 2$ gives an empirically reasonable equity Sharpe ratio and set θ_0 to match the quarterly persistence of the equity price-dividend ratio in the data. The consumption-output gap link parameter $\phi = 0.99$ is chosen similarly to Campbell et al. (2020) to maximize the empirical correlation between stochastically detrended real GDP and the output gap from the Bureau of Economic Analysis. We choose a somewhat higher value compared to Campbell et al. (2020) because the correlation between the output gap and stochastically de-trended real GDP is basically flat over a range of values ($correlation = 76\%$ at $\phi = 0.93$ vs. $correlation = 73\%$ at $\phi = 0.99$), but a larger value for ϕ minimizes the gap between price and wage inflation and therefore simplifies the model by avoiding the need to model sticky wages separately from sticky wages. The backward-looking habit parameter θ_1 is set so that the Euler equation coefficients ρ^x and f^x take the same values as in Pflueger and Rinaldi (2020). This is achieved by setting $\theta_1 - \phi$ to take the same value as in Pflueger and Rinaldi (2020), where it was chosen to replicate the hump-shaped empirical response of output to an identified monetary

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[7] Cogley and Sargent (2008) have shown that an approximation with constant transition probabilities often provides a good approximation of fully Bayesian decision rules.

policy shock in the data. Because the model impulse responses to a monetary policy shock are invariant to the shock volatilities, and vary little with monetary policy rule and Phillips curve parameters, θ_1 is effectively matched to the output response to an identified monetary policy shock. The second habit parameter θ_2 is implied and set to ensure that the backward-and forward-looking components in the Euler equation sum up to one. In addition to those consumption and preference parameters, we set the slope of the Phillips curve to a value from the literature. The Phillips curve slope is set to $\kappa = 0.0062$ as recently estimated from cross-regional inflation and output data in Hazell et al. (2022), who also find little variation in this parameter over time periods.

In a second step, we choose subperiod-specific monetary policy parameters γ^x, γ^π, and ρ^i and the volatilities of shocks σ_x, σ_π, and σ_i to match macroeconomic impulse responses and volatilities, while holding the inflation expectations parameter constant at $\zeta = 0$. We target macroeconomic lead-lag moments that are intuitively informative about the combination of demand, supply, and monetary policy shocks and the monetary policy rule. In addition, we match the macroeconomic volatilities of the output gap, inflation expectations, and the policy rate. Formally, we choose the monetary policy parameters $(\gamma^x, \gamma^\pi, \rho^i)$ and shock volatilities $(\sigma_x, \sigma_\pi, \sigma_i)$ to minimize an objective function that equals a weighted sum of squared distances between model and data moments. Our objective function includes the standard deviation of annual real consumption growth, the annual change in the federal funds rate, and the annual change in survey 10-year inflation expectations.[8] To match macroeconomic lead-lag relationships, the objective function also includes the impulse responses of the output gap to price inflation, the output gap to the fed funds rate and the fed funds rate to price inflation at 1, 3, and 7 quarter forecast horizons. For the 2000s period when data on wage inflation is available, we also include the difference between the output gap responses to contemporaneous price inflation and the output gap response to contemporaneous wage inflation. We include only one moment on wage inflation because we want to avoid over-weighting inflation moments by including many nearly-identical moments in our objective function. The estimation of empirical impulse responses is described in detail in Subsection 3.2. Our objective function then equals the sum of squared z-scores measuring the gap between simulated model and data moment, with empirical standard deviations computed via the delta method for the standard deviations of macroeconomic annual changes and with Newey-West standard errors with h lags for impulse responses.[9]

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[8]Empirical 10-year CPI inflation expectations are from the Survey of Professional Forecasters after 1990 and from Blue Chip before that. Long-term inflation forecast available from the Philadelphia Fed research website. Model 10-year inflation expectations are computed assuming that inflation expectations are adaptive, i.e. $\tilde{E}_t \pi_{t \to t+40} = \zeta \pi_{t-41 \to t-1} + (1 - \zeta) E_t \pi_{t \to t+40}$, where E_t denotes rational expectations.

[9]Our grid search procedure is relatively simple and draws 50 random values for $(\gamma^x, \gamma^\pi, \rho^i)$ and $(\sigma_x, \sigma_\pi,$

In a third step, we choose the adaptive inflation expectations parameter ζ to match the empirical evidence on Campbell and Shiller (1991) return predictability regressions in the data for each subperiod, while holding all other parameters constant at their values chosen in the second step. We use a separate step because the computation of asset prices is substantially slower than macroeconomic dynamics. This separate step also allows the algorithm to put special weight on this asset pricing moment and transparently links this moment to the adaptive inflation expectations parameter ζ.[10]

It is well-known that the term spread, or the difference between long- and shorter-term bond yields predicts excess returns on long-term bonds. This leads us to set $\zeta = 0.6$ for the 1979.Q4-2001.Q1 subperiod and $\zeta = 0$ for the 2001.Q2-2019.Q4 subperiod. For the earlier subsample we choose $\zeta = 0.6$ because the Campbell-Shiller regression coefficient appears to have converged for this value and barely changes as we increase ζ further. The resulting implied Phillips curve coefficient equals $\rho^\pi = 0.8$, consistent with Fuhrer (1997)'s estimation based on the empirical properties of inflation. For the more recent 2001.Q2-2019.Q4 sample, we set $\zeta = 0$ while acknowledging that this parameter is poorly identified for the sample period 2001.Q2-2019.Q4 of extremely stable inflation. While the distance between the empirical and model Campbell-Shiller return predictability is minimized at $\zeta = 0$ for the 2001.Q1-2019.Q4 calibration, it also shows little variation with ζ, leaving ζ poorly identified. We discuss in our counterfactual analysis in Section 5 how model implications change when inflation expectations in 2001.Q2-2019.Q4 are instead assumed to be adaptive similarly to the 1979.Q4-2001.Q1 calibration. Finally, the leverage parameter is chosen to roughly match the volatility of equity returns. Notably, we do not need a high leverage parameter, with $\delta = 0.5$ for the 1980s calibration corresponding to a leverage ratio of 50%, and $\delta = 0.66$ for the 2000s calibration corresponding to a leverage ratio of 33%.

3.2   Macroeconomic Impulse Responses

What changed in the economy from the earlier sample with positive nominal bond-stock betas to the more recent period with negative nominal bond-stock betas? Before turning to the model and asset prices, we use simple reduced-form analyses of macroececonomic data. We are interested in three dynamic cross-correlations between the output gap-inflation, output-

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σ_i) and picks the combination with the lowest objective function for each subperiod calibration. We verify that the algorithm has converged by checking that when we re-run the code with new random draws we still obtain the same parameter values. We also verify that this algorithm has sufficient precision to clearly reject the parameter values for the 1980s calibration against the 2000s data and vice versa. The only parameter value that reaches our externally set upper bound is $\gamma^x = 2$ for the 2000s calibration. We regard this as a plausible upper bound based on economic priors.

[10]Appendix Figure A1 shows that this change in ζ does not materially impact the model's performance for the other matched macroeconomic moments.

wage inflation, output gap-policy rate, and policy rate-inflation, which we visualize through four impulse responses. We estimate Jordà (2005)-type impulse for the output gap to inflation and policy rate surprises and similar impulse responses for the policy rate to an inflation surprise. Output gap impulse responses to inflation and interest surprises are included because they are intuitively informative about the presence of demand, supply and monetary policy shocks in the tradition of the lead-lag relationships estimated by Fuhrer (1997), Galı and Gertler (1999) others. For the 2000s subsample, when wage index data is easily available, we also separately show the output gap responses to wage and price inflation to assess whether the model-implied gap between prices and wages is reasonable. The fourth impulse responses is the fed funds response to an inflation surprise to capture information about the nature of the monetary policy rule in the tradition of Taylor (1993).[11] It is important to keep in mind that the empirical analysis in Figure 2 does not attempt to identify different structural shocks, but instead provides reduced-form lead-lag relationships. In this Section, we discuss how these reduced-form relationships should intuitively load onto different shocks and the monetary policy rule. In the results Section 4, we will discuss which changes the model requires to match these reduced-form impulse responses, where we estimate identical empirical results in actual and model-simulated data. Because we find economically and statistically significant changes in the output, inflation, and interest rate lead-lag relationships, and stocks are likely to be more exposed to output and nominal and real bonds more exposed to nominal and real rates, respectively, this empirical evidence suggests that if investors expectations are rational these macroeconomic changes will also change the comovement of nominal and real Treasury bonds. Our initial empirical evidence is consistent with popular macroeconomic accounts and reaches a different conclusion than Duffee (2022) because we rely on realized output, inflation, and interest rates rather than innovations to surveys, which may be subject to underreaction to news (Coibion and Gorodnichenko (2015)).[12]

Figure 2 Panel A analyzes the empirical inflation-output relationship for our two sample periods. The corresponding model relationships are also included in the plots. Panel A plots

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[11]We to put inflation and the policy rate on the right-hand-side of our empirical impulse responses because those are robust to noise in output gap surprises, which could be larger if the true output gap moves smoothly but is occasionally mismeasured.

[12]We also take a more structural view of stocks being linked to output and bonds to nominal and real interest rates, rather than allowing for flexible loadings of bonds and stocks onto all macroeconomic factors as in Duffee (2022). While a full analysis of the differences between realized and survey-based inflation-output covariances is beyond this paper, we find that incorporating time-varying risk premia through habit formation preferences and partially backward-looking inflation expectations can account not only for inflation forecast error predictability, but also for bond excess return predictability, and relatively low volatility of 10-year survey inflation expectations.

the forecast horizon h in quarters on the x-axis against the coefficient $a_{1,h}$ on the y-axis:

$$x_{t+h} = a_{0,h} + a_{1,h}\pi_t + a_{2,h}\pi_{t-1} + \varepsilon_{t+h}. \tag{34}$$

Panel B estimates an analogous impulse response function for the 2000s period using wage inflation (ECIWAG, available starting in 2000 from the St. Louis Fred). The impulse responses in Panels A and B paint an intuitive picture for the dominance of supply vs. non-supply shocks (i.e. demand and monetary policy shocks) in the economy. When supply shocks in the Phillips curve (18) are dominant, inflation surprises should mostly reflect supply shocks, leading to a decline in the output gap. The more backward-looking the Phillips curve the more persistent the decline in the output gap, as lower lagged inflation on the righ-hand-side of (18) should continue to push the output gap down. This is exactly the empirical pattern we see in the left figure of Panel A for the earlier subperiod 1979.Q4-2001.Q1, giving a first empirical indication that this was a period driven by Phillips curve shocks. By contrast, the right figure in Panel A and the right figure in Panel B show that a positive inflation surprise during the 2001.Q2-2019.Q4 period tended to be followed by an increase in output, as we would expect when supply shocks are small and inflation surprises instead reflect surprises in the output gap moving inflation along a stable Phillips curve. The relationship between the output gap and wage inflation is even more positive than for the output gap and price inflation, consistent with a higher output gap being associated with an increase in productivity, as in our model.

While the empirical output-inflation lead-lag relationships in Panel A are indicative of a change from large supply shocks to smaller supply shocks in the recent period, they are not informative for the distinction between monetary policy and demand shocks. We therefore turn to the policy rate-output gap relationship estimated as follows:

$$x_{t+h} = a_{0,h} + a_{1,h}i_t + a_{2,h}i_{t-1} + \varepsilon_{t+h}. \tag{35}$$

If the economy is driven by monetary policy shocks, we would expect an increase in the policy rate to be followed by a hump-shaped decline in the output gap, as estimated in a large literature estimating identified how identified monetary policy shocks affect output and consumption (see e.g. Ramey (2016) for a survey). Conversely, when demand shocks are present, we would expect this pattern to be reversed, with increases in the output gap tending to go along with an increase in the monetary policy rate. The left figure in Panel C shows that during the earlier subsample high interest rates were indeed followed by a lower output gap, suggesting that in during this sample interest rate surprises reflected large monetary policy shocks. Conversely, the right figure of Panel C shows a positive relationship between

interest rate innovations and the output gap, suggesting that this period was dominated by demand shocks and a strong monetary policy stabilization coefficient on the output gap, γ^x.

Finally, we turn to impulse responses of interest rates to inflation of the form:

$$i_{t+h} = a_{0,h} + a_{1,h}\pi_t + a_{2,h}\pi_{t-1} + \varepsilon_{t+h}. \tag{36}$$

These impulse responses are useful, because we would expect them to reflect the speed and strength of the monetary policy response to inflation. Panel D shows that interest rates showed a somewhat more than one-for-one response to an inflation surprise in both subsamples, though the interest rate response peaks earlier during the first subperiod. By contrast, during the second subperiod the interest rate response peaks later, as would be the case if the Federal Reserve followed a more inertial monetary policy rule.

Taken together, the macroeconomic impulse responses support an intuitive narrative of the broad economic changes from the 1979.Q4-2001.Q1 subsample to the more recent 2001.Q2-2019.Q4 subsample. The reduced-form empirical evidence from macroeconomic data supports the notion that the 1979.Q4-2001.Q1 period was dominated by supply and monetary policy shocks, while the 2001.Q2-2019.Q4 period was dominated by demand shocks. Monetary policy appeared to counteract inflation fluctuations more than one-for-one in both subsamples, as it should to satisfy the Taylor principle and avoid sunspots. However, while the monetary policy response was immediate in the Volcker sample, it was more gradual during the more recent period, as would be the case if the central bank can communicate future monetary policy more credibly.

3.3 Predictability of Inflation Forecast Errors

To validate our calibration of the inflation expectations parameter, we run some simple reduced-form analysis testing for the rationality of inflation expectations by subperiod. Table 2 runs the well-known tests for the rationality of inflation expectations of Coibion and Gorodnichenko (2015) by subperiod in the model and in the data:

$$\pi_{t+4} - \tilde{E}_{t+1}\pi_{t+4} = a_0 + a_1\left(\tilde{E}_{t+1}\pi_{t+4} - \tilde{E}_t\pi_{t+4}\right) + \varepsilon_{t+4}, \tag{37}$$

where a tilde denotes potentially subjective inflation expectations. If expectations are full information rational the forecast error on the left-hand-side of (37) should be unpredictable, and the coefficient a_1 would equal zero. Our empirical specification follows Coibion and Gorodnichenko (2015) as closely as possible, using the Survey of Professional Forecasters 4-quarter and 3-quarter GDP deflator inflation forecasts to compute forecast revisions. The

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first column in Table 2 uses a long sample 1968.Q4-2001.Q1 and confirms the well-known empirical result. An upward-revision in inflation forecasts tends to predict a positive forecast error. Said differently, realized inflation tends to come in even higher than the revised forecast. This is generally interpreted as evidence that forecasters under-react to incoming information about inflation. The second and third columns run the same empirical regressions for our subperiods 1979.Q4-2001.Q1 and 2001.Q2-2019.Q4. We find that for both subperiods the evidence becomes insignificant. While this is potentially due to the smaller sample size and weaker statistical power, the point estimate for the most recent sample even switches sign and becomes negative. When we formally test for the significance of the interaction with a time dummy, the difference between the 1968.Q4-2001.Q1 and 2001.Q2-2019.Q4 forecast revision coefficients is statistically significant. The reduced-form evidence is therefore consistent with the notion inflation expectations during the 2001.Q2-2019.Q4 period were full information rational, different from the empirical evidence from earlier decades.

The literature has not found an agreement on whether inflation expectations have become more or less rational over time. Previous research has found that inflation expectations respond less to oil price shocks in recent decades. Like us, Bianchi et al. (2022b) find less inflation forecast error predictability from past forecast revisions post-1995, and Davis et al. (2012) finds that inflation expectations have become less responsive to oil prices shocks in recent decades. However, Coibion and Gorodnichenko (2015) and Maćkowiak and Wiederholt (2015) provide evidence and a model of decreasing attention to inflation as economic volatility declined during the 1990s. Because the inflation expectations formation process is fundamentally hard to estimate when inflation is low and stable, it will therefore be important to check how results for the 2001.Q2-2019.Q4 calibration change when the expectations parameter ζ takes different values.

4   Model Results for the Macroeconomy and Asset Prices

We first verify that the model captures the macroeconomic changes from the first subperiod to the second subperiod in the data. We then turn to the asset pricing properties, and show that the model replicates both the unconditional and subperiod-specific return predictability in stocks and bonds. It also generates strongly positive nominal bond-stock betas and weakly positive real bond-stock betas in the 1979.Q4-2001.Q1 subperiod calibration, and negative nominal and real bond-stock betas in the 2001.Q2-2019.4 subperiod. This fit for bond betas is achieved despite the fact that they were not directly targeted in the calibration procedure, which only used macroeconomic moments and the predictability of bond returns.

4.1 Structural Macroeconomic Impulse Responses

Figure 3 illustrates the model mechanism by showing model impulse responses of our macroeconomic state vector to one-standard deviation structural shocks for both calibrations. The 1979.Q4-2001.Q1 calibration is shown with black solid lines, while the 2001.Q2-2019.Q4 calibration is shown with red dashed lines. The first column shows a one-standard-deviation demand shock, the second column shows a one-standard-deviation supply shock, and the third columns shows a one-standard deviation monetary policy shock. The rows show the output gap (in %), nominal policy rate (in annualized %), and wage inflation rate (in annualized %). The impulse responses to a monetary policy shock are almost identical to those analyzed in Pflueger and Rinaldi (2020), who showed that by matching the empirical evidence for the output response to monetary policy shocks it is also possible to explain the high-frequency response of the stock market to monetary policy surprises around FOMC announcements. The impulse responses to demand shocks are also intuitive. For the earlier subperiod calibration demand shocks are essentially zero, so there are no meaningful impulse responses. But in the 2001.Q2-2019.Q4 subperiod calibration we see that a demand shock leads to an immediate increase in the output gap and an increase in the policy rate, while having only a very small but positive effect on inflation.

Finally, the Phillips curve shock has impulse responses that differ meaningfully across the two subperiod calibrations. For the 1979.Q4-2001.Q1 calibration a positive Phillips curve shock leads to an immediate and persistent jump in inflation, a rapid increase in the policy rate, and a gradual but large and persistent decline in the output gap. By contrast, for the 2001.Q2-2019.Q4 calibration, a Phillips curve shock leads to a more short-lived increase in inflation, a significantly more gradual increase in the policy rate, and almost no change in the output gap. The inflation increase in the 2001.Q1-2019.Q4 calibration is less persistent due to the forward-looking inflation expectations ($\zeta = 0$), which leads to less persistence in the Phillips curve. The more forward-looking nature of inflation expectations, combined with a monetary policy rule that prescribes very little tightening in response to such a shock, means that the output gap barely declines and initially may even increase in response to such a Phillips curve shock. Hence, these impulse responses show that even if supply shocks had been very volatile during the 2001.Q2-2019.Q4 period, their effect on the macroeconomy would likely have been very different and they likely would not have led to stagflations, unlike the case in the 1980s.

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4.2 Macroeconomic Dynamics in the Model and in the Data

Figure 2 shows the results of running analogous regressions in the model as in the data, using the parameter values shown in the lower panel of Table 1. For the 1979.Q4-2001.Q1 subperiod, the model matches the negative output gap response to inflation surprises, the output gap decline in response to a policy rate surprise, and the lag and size of the peak policy rate increase following an interest rate surprise. The 1979.Q4-2001.Q1 calibration achieves this by setting the demand shock volatility essentially to zero, having a large volatility of supply shocks, and a somewhat smaller volatility of monetary policy shocks. The inflation expectations parameter ζ means that the Phillips curve is strongly backward-looking for this subperiod calibration, leading to a highly persistent inflation process, visible in the left figure in Panel C. While a volatile persistent component in inflation during this period is in line with a long-standing econometrics literature (Stock and Watson (2007)), it means that there is a gap between the empirical and model impulse responses at longer horizons. This discrepancy might arise because our measure of inflation combines persistent and short-lived fluctuations in inflation and because unit roots are hard to estimate and detect in finite samples. Macroeconomic volatilities of consumption growth and fed funds rate changes, shown in the bottom Panel of Table 3 are well-matched by the model. The volatility of 10-year inflation expectations is substantially lower than the volatility of nominal 10-year Treasury yields because the macroeconomic risks lead to endogenously time-varying risk premia in nominal Treasury bonds and because we model long-term inflation forecasts as being formed as a weighted average of a slow-moving average of past inflation and the rational forecast. The weights are disciplined by the same adaptability parameter ζ used to solve for the macroeconomic dynamics.[13]

For the 2001.Q2-2019.Q4 subperiod, the model matches the output gap increases following inflation and interest rate surprises, though the increases in the data seem somewhat more persistent than in the model. It also matches the somewhat slower increase in the policy rate following an inflation surprise compared to the 1979.Q4-2001.Q1 subsample. The volatilities of consumption growth, the fed funds rate, and long-term inflation expectations are also close to their empirical counterparts. As shown in the bottom Panel of Table 1 the model achieves this fit for the 2001.Q2-2019.Q4 subsample with a high volatility of demand shocks, small supply shocks, and a moderate volatility of monetary policy shocks. The monetary policy rule for this subperiod has a greater inertial parameter ($\rho = 0.8$) within the range estimated by Clarida et al. (2000), and higher output and inflation weights than the

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[13]Our ability to match this moment does not hinge on non-rational inflation expectations. A version of the 1980s calibration with rational inflation expectations generates a very similar volatility of 10-year inflation expectations, though also less volatile nominal Treasury bond yields.

monetary policy rule in the earlier subperiod.

The model also matches the predictability of inflation forecast errors documented in the data. The last two columns in Table 2 report analogous inflation forecast error regressions in the model as in the data. In the model, we compute subjective n-quarter inflation forecasts as $\tilde{E}_t \pi_{t+n} = (1-\zeta)E_t\pi_{t+n} + \zeta\pi_{t-1-n\to t-1}$ for all n. The table shows that for the 1979.Q4-2001.Q1 calibration, the model generates predictability of inflation forecast errors from revisions in inflation forecasts, similarly to the data. While the model coefficient is even somewhat larger than in the data it is within a 95% confidence interval of the empirical estimate over the long sample 1968.Q4-2001.Q1. Intuitively, the 1979.Q4-2001.Q1 calibration features partially adaptive inflation expectations, implying that agents under-weight forward-looking information about inflation. By contrast, the model does not generate inflation forecast error predictability for the 2001.Q2-2019.Q4 calibration, similarly to the data. This is again intuitive because the 2001.Q2-2019.Q4 calibration features $\zeta = 0$ and hence full information rational inflation expectations.[14]

We therefore find that the model provides a good empirical fit for the main macroeconomic changes from the Volcker to the post-Volcker period. It does so through intuitive changes in parameters, indicating that demand shocks dominated in the more recent subsample, wheras supply shocks were more important during the earlier period. The model calibration also relies on an intuitive change in the monetary policy rule, from a less inertial monetary policy rule with little weight on output gap fluctuations under Volcker, to a more gradual monetary policy rule with a higher weight on output gap fluctuations more recently.

4.3 Asset Prices in the Model and in the Data

Table 3 reports key asset pricing and macroeconomic moments for both subperiod calibration side-by-side with the corresponding data moments. Having already discussed the main macroeconomic moments, we now turn to the asset pricing moments shown in the top panel. The model does equally well for equity Sharpe ratios, equity volatility, and the persistence of price-dividend ratios as Campbell and Cochrane (1999) and Campbell et al. (2020), showing that adding demand shocks does not hurt the model's performance along this key dimension. Similarly to prior work, stock returns in the model are predictable from the past

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[14]Our choice of ζ represents a trade-off here. While a higher value of ζ matches the predictability of bond returns and the evidence from inflation forecast error regressions, it generates a somewhat too persistent inflation response to interest rate surprises in Figure 2 Panel B. As shown in our counterfactual analysis in Section 5 the inflation expectations parameter ζ has relatively little effect on the betas of nominal and real bonds for the 1979.Q4-2001.Q1 calibration.

price-dividend ratio.[15]

The second panel reports bond moments. The 1979.Q4-2001.Q1 calibration generates a positive regression coefficient of 10-year bond excess returns onto the slope of the yield curve, as in the data and as targeted in our calibration. On the other hand, the 2001.Q2-2019.Q4 calibration does not generate any such bond return predictability, which is also in line with a much weaker and statistically insignificant relationship between bond excess returns and the lagged slope of the yield curve in the 2001.Q2-2019.Q4 subsample. Figure 4 shows why we need a non-zero adaptive inflation expectations coefficient in the earlier subperiod. As we increase the inflation expectations parameter ζ, the predictability of bond excess returns increases, though only for the 1979.Q4-2001.Q1 calibration and not for the 2001.Q2-2019.Q4 calibration. In unreported results we find the model does not generate any return predictability in real bond excess returns. This is broadly in line with the empirical findings of Pflueger and Viceira (2016), who find stronger evidence for return predictability in nominal than in real bond excess returns after adjusting for the time-varying liquidity differential. Figure 5 shows impulse response of the bond yield spread, decomposed into a risk-neutral (or expectations hypothesis) and a risk premium component. Because the short-term policy rate does not contain any risk premia the risk premium component of the term spread equals the risk premium component of long-term bond yields, and hence predicts bond excess returns. The top row shows impulse responses for the 1979.Q4 calibration and the bottom row shows impulse responses for the 2001.Q2-2019.Q4 calibration. The columns correspond to one-standard deviation demand, Phillips curve, and monetary policy shocks.

The top row of Figure 5 shows that the Phillips curve shock generates a strongly positive comovement between the yield spread and bond risk premia, showing that this shock is primarily responsible for the Campbell-Shiller bond return predictability in this subperiod calibration. Intuitively, a positive Phillips curve shock leads to a persistent increase in inflation expectations and the nominal policy rate, therefore having a relatively small effect on the risk-neutral yield spread. The risk premium therefore dominates the increases in the overall yield spread, generating a positive relationship between the yield spread and future bond excess returns. The demand shock similarly generates a positive relationship between the yield spread and bond risk premia, with no countervailing effect from the expectations hypothesis component of the yield spread. By contrast, the monetary policy shock acts to counteract the predictability of bond excess returns from the yield spread. A positive monetary policy shock leads to an increase in the short rate and hence a decline in the yield spread

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[15]While stock returns in the 1979.Q1-2001.Q1 data have a very low regression coefficient onto the lagged price-dividend ratio, this is partly driven by the arguably permanent shift in the level of stock prices in the mid-1990s.

through the expectations hypothesis term. At the same time, a positive monetary policy shock drives down output and consumption through the Euler equation, so consumption falls closer to habit, and investors require higher risk premia on nominal Treasury bonds which are risky in this subperiod calibration.

By contrast, in the 2001.Q2-2019.Q4 calibration interest rates are less persistent and the expectations hypothesis term dominates the overall yield spread responses to all three shocks, so the relationship between premia in long-term nominal Treasury bonds and the yield spread is close to zero. The model yield spread for the 2001.Q2-2019.Q4 calibration is even negatively correlated with the risk premium component, as bond risk premia are primarily driven by the more volatile demand shocks. A positive demand shock raises consumption relative to habit and makes investors less risk averse. Because nominal bonds have negative betas during this subperiod and have hedging value, investors' willingness to pay for this hedging value declines and the required expected excess return on Treasury bond rises. At the same time, the yield spread falls because monetary policy raises the short-term policy rate to counteract a positive demand shock. The mechanism here is reminiscent of an older literature that has documented empirically that the expectations hypothesis is a better description of the term structure of interest rates in time periods and countries where interest rates are less persistent (Mankiw et al. (1987), Hardouvelis (1994)) and consistent with Cieslak and Povala (2015)'s evidence that removing trend inflation is important to uncover time-varying risk premia in the yield curve.

The model also captures several salient changes of 10-year Treasury bonds between the 1979.Q4-2001.Q1 period and the 2001.Q2-2019.Q4 period that were not targeted in the calibration. Model-implied nominal Treasury bond excess returns are extremely volatile in the 1979.Q4-2001.Q1 subperiod and much less volatile during the more recent subperiod. The slope of the yield curve is highly positive during the 1979.Q4-2001.Q1 subperiod, and declines in the more recent subperiod, though in contrast to the data the model slope even turns negative. Further, the model-implied nominal bond beta is strongly positive for the 1979.Q4-2001.Q1 calibration and negative for the 2001.Q2-2019.Q4 calibration. Finally, the model also achieves a small but positive real bond beta during the 1979.q4-2001.Q1 subperiod and a negative real bond beta during the more recent subperiod.[16] One slight shortcoming of the model is that in the 2001.Q2-2019.Q4 subperiod the nominal bond beta is more negative

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[16]Bond yields are almost three times as volatile as ten-year inflation expectations during the more recent subperiod calibration, thereby generating an "inflation variance ratio" of around 0.16 for the recent subperiod, in line with Duffee (2018)'s finding that habit formation models may be more able to generate volatile bond yields with less volatile inflation expectations than other leading asset pricing models. While we do not fully match the volatility of nominal bond yields in the 2000s, we therefore provide a partial reconciliation of low inflation variance ratios based on partially rational inflation expectations in surveys (1979.Q4-2001.Q1 calibration) and time-varying bond risk premia (both calibrations).

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than the real one, whereas in the model both nominal and real betas are the same. We analyze in Section 5 which alternative combinations of shocks might have generated this gap between the empirical nominal and real bond betas.

5 Counterfactual Analysis and Interpreting the Post-Pandemic Regime

What drove the change from the 1980s to the 2000s and what would it take to change back to a stagflationary regime? In this section, we show how nominal and real bond betas change in the model as we vary the economy's exposure to different types of shocks, the rationality of inflation expectations, and the monetary policy rule. Throughout this counterfactual analysis, the beta of nominal bonds is of particular interest as an indicator of the risks of high inflation recessions, or stagflations.

5.1 Changing Monetary Policy, Inflation Expectations, and Shocks

Figure 6 shows the model-implied nominal and real bond betas as we change parameter groups. Panel A starts from the 1979.Q4-2001.Q1 calibration, analyzing which underlying macroeconomic drivers would have led to the declines in nominal and real bond betas observed in the data. The left two bars in Panel A show the model nominal and real bond betas for the 1979.Q4-2001.Q2 calibration as in Table 3, and the bars to the right of the dashed horizontal line show the model-implied nominal and real bond betas as we change parameter groups to their 2001.Q2-2019.Q4 values. All other parameters are held constant at their 1979.Q4-2001.Q1 values listed in Table 1.

Most strikingly, we see that changing the shock volatilities from an economy driven by supply shocks to an economy driven by demand shocks switches both nominal and real bond betas from positive to negative, with a larger change for nominal bond betas. Moreover, only a change in the shock volatilities can generate negative nominal and real bond betas, suggesting that negative bond betas are closely linked to highly volatile demand shocks. This is intuitive, as the 1979.Q4-2001.Q1 calibration features a high volatility of supply shocks, which tend to generate high inflation and a recession, leading nominal bond prices to drop at the same time as the stock market. Setting the shock volatilities to their 2001.Q2-2019.Q4 values means that we have a large volatility of demand shocks, which generate a negative nominal bond beta and a somewhat smaller but also negative real bond beta.

While the volatilities of shocks seem to matter for bond betas, other changes can also engineer a substantial decrease in the nominal bond beta. Increasing the monetary policy

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persistence parameter to its 2001.Q2-2019.Q4 value depresses nominal bond betas to nearly zero, but makes real bond betas more positive. This happens in the model because when the monetary policy rule is inertial a supply shock does not generate an immediate response in the nominal policy rate and a very small output gap response. This is visible from the model's 2001.Q2-2019.Q4 output gap impulse response to a Phillips curve shock in Figure 3. As in Primiceri (2006), stagflations therefore only happen if there are supply shocks and the Fed responds by raising interest rates. Real bond betas become positive because the real bond-stock covariance gets to be dominated by the monetary policy shock when supply shocks only have a small effect on output and stock returns.

Conversely, Panel A of Figure 6 shows that the inflation expectations formation process and the long-term monetary policy weights on the output gap and inflation, γ^x and γ^π, matter less for bond risks. Changing the inflation expectations parameter ζ to zero so inflation expectations are perfectly rational, as in the 2001.Q2-2019.Q4 calibration, leads to only a small decline in the model's nominal bond beta, holding all other parameters constant at their 1979.Q4-2001.Q1 values. The intuition is that when inflation expectations rise along with inflation, a supply shock leads to a less persistent inflation response but a larger output gap response, leaving the covariance between nominal Treasury bonds and stocks roughly unchanged. Finally, changing the output gap and inflation weights in the monetary policy rule appears to have little effect on nominal or real bond-stock betas.

Panel B of Figure 6 shows counterfactuals starting from the 2001.Q1-2019.Q4 calibration, finding that those are not simply the reverse of the counterfactuals in Panel A. This difference between Panels A and B indicates that positive nominal bond-stock betas and stagflations are the not result of just fundamental economic shocks or monetary policy in isolation, but instead require the interaction of both to create a "perfect storm". In contrast to Panel A, Panel B shows that starting from the 2001.Q1-2019.Q4 calibration none of the changes to individual parameter groups has the power to flip the sign of nominal bond betas. The nominal bond-stock beta changes little if we change to a less persistent monetary policy rule, change the monetary policy output and inflation weights, or if we make inflation expectations adaptive. The last column in Panel B tells us that even if the shock process were to change back to the supply-shock driven 1980s, a more gradual monetary policy could prevent nominal Treasury bonds from becoming risky. Real bond betas become positive because they load onto the monetary policy shock when supply shocks have relatively small effects on the stock market. While exaggerated in terms of magnitude, directionally this last counterfactual lines up well with the recent experience of positive real bond betas and negative nominal bond betas, as shown in Figure 1.

What combination of changes would be required to flip nominal bond-stock betas positive

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and make nominal Treasury bonds risky as in the stagflationary 1980s? This question is of relevance not only for policy makers trying to understand what drives the economy, but also for long-term investors seeking to diversify their portfolios and for the Treasury borrowing from the markets. In our model, a change from demand shocks to supply shocks, combined with a non-gradual monetary policy rule, and adaptive inflation expectations would lead to such a change, as then we would be back in our 1979.Q4-2001.Q1 calibration. What if only two of these elements were to change? The "MP Persistence" column in Panel A of Figure 6 shows bond betas under the combination of volatile supply shocks and forward-looking inflation expectations, but a non-inertial monetary policy rule. We see that in this case model-implied nominal bond betas are marginally positive and real bond betas are positive, so an inertial monetary policy rule by itself would still provide significant protection against nominal Treasury bonds becoming risky. Similarly, the "Inflation Expectations" column in Panel A shows the combination of a supply-shock driven economy and a non-inertial policy rule but forward-looking inflation expectations. We see that in this case model-implied nominal Treasury bond betas are economically meaningfully positive. These simple counterfactuals therefore suggest that an inertial monetary policy rule can provide protection against nominal Treasury bonds turning risky even when the composition of shocks is the same as in the 1980s.

5.2   Dissecting the mechanism

So far, we have shown how changing parameter groups between their 1980s and 2000s calibration values affects bond betas. We next study which shocks and which aspects of the monetary policy rule matter most for bond betas by varying these parameters individually, and allowing them to go outside their historically experienced range. Figure 7 decomposes the role of shock volatilities and Figure 8 decomposes different monetary policy rule parameters starting from the 2001.Q2-2019.Q4 calibration. To highlight the qualitative effects of each volatility or monetary policy parameter we choose very high or low values potentially outside the historically experienced range.

Figure 7 varies the individual volatilities of shocks and shows the counterfactuals for nominal bond-stock betas (Panel A) and real bond-stock betas (Panel B) while holding all other parameters constant at their 2001.Q2-2019.Q4 values. Because the backward-lookingness of inflation expectations is not well-identified during the 2000s period, we also show counterfactuals where the backward-looking component of inflation expectations is set to a very high value at $\zeta = 0.9$. As expected, an increase in the volatility of demand shocks drives down the beta of nominal bonds and real bonds. This happens because a negative

demand shock reduces consumption and output at a given interest rate, leading monetary policy to lower rates, so nominal and real bond prices rise just as the stock market falls. As the red-dashed line shows, backward-looking inflation expectations amplify the effect of demand shock volatility on nominal bond betas, but not real bond betas. Intuitively, if inflation expectations are backward-looking the same decrease in the output gap translates into a more persistent drop in inflation, amplifying the increase in nominal bond prices. However, inflation expectations do not matter for real bond prices or the beta of real bonds.

The middle panel in Figure 7 shows that more volatile supply shocks slightly decrease nominal bond betas but leave real bond betas unchanged. The intuition goes back to the macroeconomic impulse responses in the middle column of Figure 3, where for the 2001.Q2-2019.Q4 calibration a supply shock leads to a sharp increase in inflation, a gradual increase in the nominal short-term rate, and an almost flat output gap response. Because the rise in the nominal policy rate is slow, the real rate falls initially, leading to a small increase in the output gap and then a shallow recession. Because of initially easy monetary policy, consumption rises relative to habit, making investors less risk averse and driving up stock prices just as nominal Treasury bond prices fall due to higher inflation expectations. While the model prediction that the output gap can even increase in response to a positive supply shock is somewhat sensitive to the precise parameters in the monetary policy rule, the model prediction that an inertial monetary policy rule leads to almost flat output gap and stock responses is fairly robust, which is why we view the nominal bond beta-supply shock volatility relationship in Panel A of Figure 7 as essentially flat.

The rightmost panel in Figure 7 shows that increasing the volatility of monetary policy shocks drives up the betas of real bonds and, to a lesser extent, the betas of nominal bonds. This is intuitive and similar to Pflueger and Rinaldi (2020), who focused on the effect of monetary policy shocks on stocks and bonds. A positive monetary policy shock leads to a decline in output and consumption through the Euler equation (14). As consumption falls towards habit, the stock market drops just as yields rise, leading bond and stock prices to fall simultaneously. The drop in the output gap leads to a slow decline in inflation through the Phillips curve (18), so nominal bond prices fall less than real bond prices. As a result, nominal bond betas increase less strongly with the volatility of monetary policy shocks than real bond betas. Taken together, Figure 7 suggests that understanding the interaction between supply shocks with the monetary policy rule is key.

Figure 8 zeroes in on this interaction and plots model-implied nominal bond-stock betas on the y-axis against the volatility of supply shocks on the x-axis for different monetary policy rules. The blue solid line uses the monetary policy rule from our 2001.Q2-2019.Q4 calibration. The red dashed line sets the persistence parameter to a much lower value at

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$\rho^i = 0.5$. The yellow dotted line sets the output gap weight in the monetary policy rule to $\gamma^x = 0$. The purple line with markers sets the inflation weight in the monetary policy rule to a much higher value at $\gamma^\pi = 2$. We see that while the blue solid line is downward-sloping in the volatility of supply shocks, the three other lines are upward-sloping, indicating that supply shocks make nominal Treasury bonds risky if monetary policy less inertial, more focused on inflation, or less focused on output. Intuitively, if monetary policy is less inertial, less focused on output, or more focused on inflation the policy rate rises swiftly following a positive supply shock, leading to an economic contraction and a fall in the stock market just as inflation expectations rise and nominal bond prices fall. Nominal bond prices and stocks fall simultaneously, and the nominal bond beta becomes more negative. Splitting out the effects of γ^x and γ^π shows that big changes in the inflation and output gap weights in the monetary policy rule do matter for bond risks, though the changes in γ^x and γ^π in the 1980s vs. 2000s calibrations are smaller and roughly offset each other in Figure 6. Taken together, in the model positive nominal Treasury bond betas – as observed during the stagflationary 1980s – arise through the interaction of volatile supply shocks and a monetary policy rule that reacts strongly to such shocks.

6   Conclusion

This paper presents a simple model integrating a standard small scale macroeconomic model of demand shocks, supply shocks and monetary policy with bond and stock prices with time-varying risk premia in the manner of Campbell and Cochrane (1999) Campbell et al. (2020). Our first result is that fitting this model to macroeconomic and inflation expectations data separately for the 1980s and the 2000s yields an intuitive account for the changes observed in Treasury bond markets between these decades. For the 1980s, the model attributes the large and positive comovement between nominal Treasury bond returns and the stock market and the smaller but also positive comovement between real bond returns and stock returns to a dominance of supply shocks, combined with a non-gradual monetary policy rule. The intuitive model account is that during this period, a positive supply shock drives up inflation reducing the value of nominal bonds. Monetary policy raises interest rates in response to this increase in inflation, thereby generating a recession and driving down stock prices. The declines in both bonds and stocks get amplified by risk aversion, as investors' risk aversion increases as consumption falls towards a slowly-moving habit level.

For the 2000s, the model account is that volatile demand shocks, combined with a highly gradual monetary policy rule led to negative betas for both nominal and real bonds. Intuitively, a positive demand shock drives up consumption and reduces investor risk aversion,

but also drives up real and nominal interest rates, leading to declines in nominal and real bond prices. Supply shocks have little effect on the real economy because of the gradual monetary policy rule, so nominal and real bond betas primarily reflect demand shocks.

The model also explains the predictability of bond and stock excess returns, and the changes in bond return predictability across the same broad time periods. We document that while bond return predictability from the lagged yield spread was stronger during the 1980s, it was statistically insignificant during the 2000s. The model matches these empirical findings with partially backward-looking inflation expectations, leading to a strongly backward-looking Phillips curve. As a result, the variation in the yield spread between long- and short-term bond yields is almost unaffected by the expectations hypothesis component, and instead dominated by time-varying risk premia, thereby predicting bond excess returns positively. By contrast, during the 2000s supply shocks are smaller and the model inflation process is less persistent, generating a more volatile expectations hypothesis component in the yield spread and less bond return predictability, in line with the data. The model generates empirically plausible predictability in stock returns from the past price-dividend ratio and persistence of price-dividend ratios for both subperiod calibrations.

This analysis has implications for the recent debate on whether the recent rise in inflation is likely to pre-shadow another 1980s stagflation and suggests that the nature of the monetary policy rule is crucial. During 2021 and the first half of 2022, bond market betas did increase but exhibited marked differences from the 1980s, with nominal bond betas remaining low or even negative. In contrast to the 1980s, inflation-indexed or real bond-betas decoupled from nominal bond betas and turned positive. Our model can make sense of these movements, as it implies that in order for nominal Treasury bond betas to turn as positive as in the 1980s, and the economy to enter a similarly stagflationary regime, two conditions must be satisfied. First, the economy must be dominated by supply shocks. Second, monetary policy must react quickly to increases inflation. While the positive real bond betas experienced during 2021 are interpreted by the model as a turn from a demand-shock driven economy, to an economy with volatile supply and policy shocks, the observed stability in nominal bond betas is consistent with a monetary policy rule that has taken a very gradual approach.

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Table 1: Calibration Parameters

		1979.Q4-2001.Q1	2001.Q2-2022.Q2
Consumption growth	g	1.89	
Utility curvature	γ	2	
Risk-free rate	$\bar{r}$	0.94	
Persistence surplus cons.	θ_0	0.87	
Backward-looking habit	θ_1	-0.84	
PC slope	κ	0.0062	
Consumption-output gap	ϕ	0.99	
MP inflation coefficient	γ^π	1.37	1.63
MP output coefficient	γ^x	0.40	2.00
MP persistence	ρ^i	0.52	0.80
Vol. demand shock	σ_x	0.02	0.60
Vol. PC shock	σ_π	0.59	0.08
Vol. MP shock	σ_i	0.50	0.29
Adaptive Inflation Expectations	ζ	0.6	0.0
Leverage parameter	δ	0.50	0.66

Consumption growth and the real risk-free rate are in annualized percent. The standard deviation σ_x is in percent, and the standard deviations σ_π and σ_i are in annualized percent. The Phillips curve slope κ and the monetary policy parameters γ^π, γ^x and ρ^i are in units corresponding to the output gap in percent, and inflation and interest rates in annualized percent.

Table 2: Forecast Error Regressions by Subperiod

	Data			Model	
$\tilde{E}_t\pi_{t+3} - \tilde{E}_{t-1}\pi_{t+3}$	0.926***	0.433	-0.310	1.43	-0.01
	(0.34)	(0.32)	(0.43)		
Const.	-0.114	-0.795***	-0.046		
	(0.28)	(0.20)	(0.18)		
N	126	87	71		
R-sq	0.09	0.03	0.00		
Sample	1968.Q4-2001.Q1	1979.Q4-2001.Q1	2001.Q2-2019.Q4	1979.Q4-2001.Q1	2001.Q2-2019.Q4

This table estimates Coibion and Gorodnichenko (2015) regressions of the form $\pi_{t+4} - \tilde{E}_{t+1}\pi_{t+4} = a_0 + a_1\left(\tilde{E}_{t+1}\pi_{t+4} - \tilde{E}_t\pi_{t+4}\right) + \varepsilon_{t+4}$ using quarterly GDP deflator inflation forecasts from the Survey of Professional Forecasters. Newey-West standard errors with 4 lags in parentheses. Model subjective n-quarter inflation expectations are computed assuming that inflation expectations are a weighted average of rational expectations and past average inflation $\tilde{E}_t\pi_{t+n} = \zeta\pi_{t-n-1\to t-1} + (1 - \zeta)E_t\pi_{t+n}$.

Table 3: Model and Data Moments

|	1979.Q4-2001.Q1		2001.Q2-2019.Q4	
	Model	Data	Model	Data
Stocks				
Equity Premium	8.03	7.96	9.27	7.64
Equity Vol	16.62	16.42	20.56	16.80
Equity SR	0.48	0.48	0.45	0.45
AR(1) pd	0.96	1.00	0.92	0.84
1 YR Excess Returns on pd	-0.36	-0.01	-0.39	-0.50
1 YR Excess Returns on pd (R^2)	0.06	0.00	0.15	0.28
Bonds				
Yield Spread	2.95	1.53	-0.76	2.06
Return Vol.	17.55	14.81	2.67	9.28
Nominal Bond-Stock Beta	0.95	0.24	-0.11	-0.31
Real Bond-Stock Beta	0.04	0.08	-0.11	-0.08
1 YR Excess Return on slope	1.72	2.55	-0.22	0.86
1 YR Excess Return on slope (R^2)	0.01	0.07	0.00	0.02
Macroeconomic Volatilities				
Std. Annual Cons. Growth	0.96	1.15	1.47	1.15
Std Annual Change Fed Funds Rate	1.64	2.26	1.16	1.40
Std. Annual Change 10-Year Subj. Infl. Forecast	0.63	0.47	0.11	0.12

10-year CPI inflation expectations are from the Survey of Professional Forecasters after 1990 and from Blue Chip before that. Long-term inflation forecast available from the Philadelphia Fed research website. Model 10-year inflation expectations are computed assuming that inflation expectations are adaptive, i.e. $\tilde{E}_t \pi_{t \to t+40} = \zeta \pi_{t-41 \to t-1} + (1-\zeta) E_t \pi_{t \to t+40}$, where E_t denotes rational expectations.

Figure 1: Rolling Treasury Bond-Stock Betas
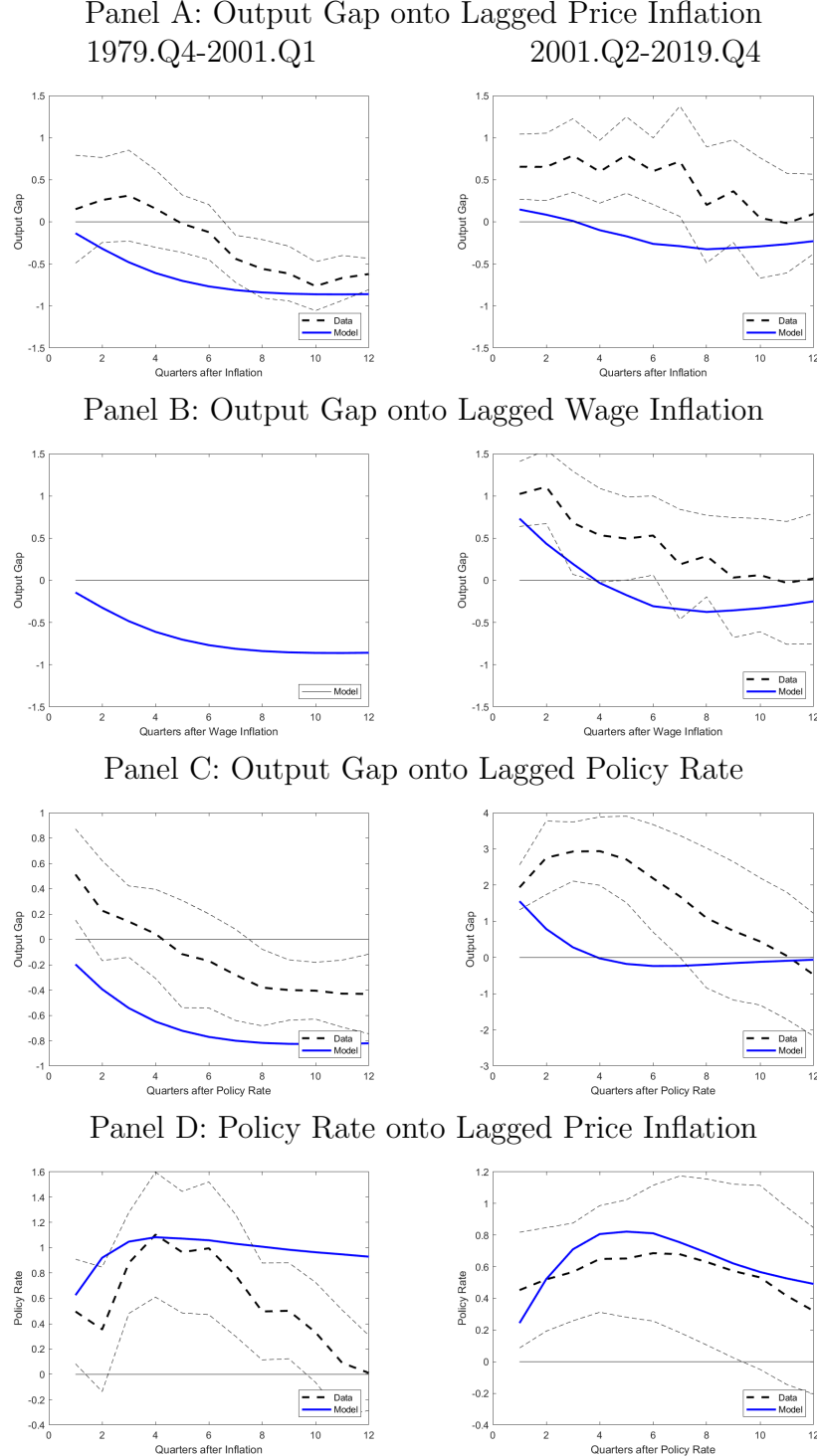
Panel A: 1979.Q4-2022.Q2
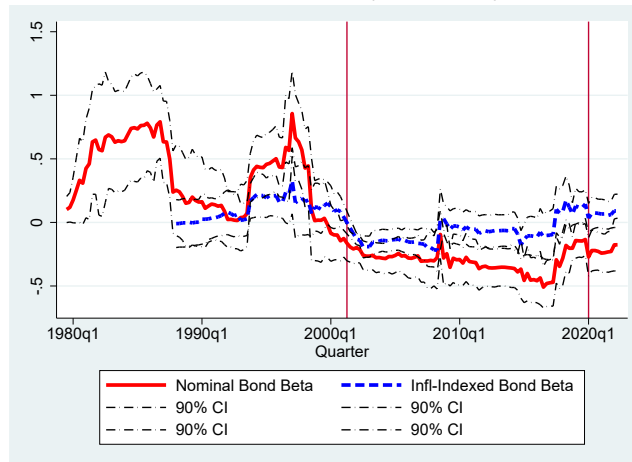
Panel B: January 2018 - June 2022
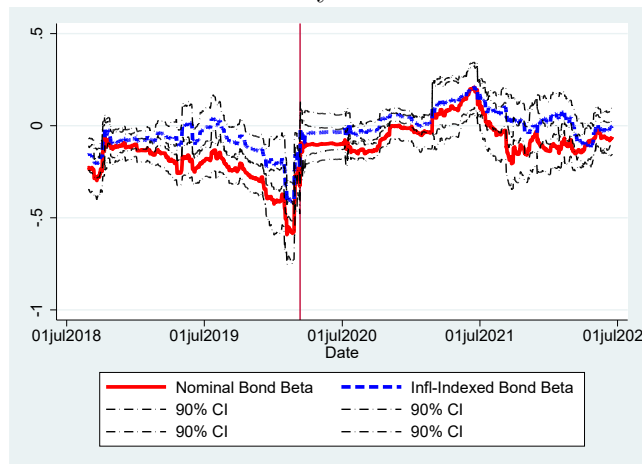
Note: Panel A shows 5-Year rolling betas of quarterly 10-year Treasury bond excess returns onto quarterly US equity excess returns, in excess of 3-month T-bill returns for the period 1979.Q4-2022.Q2. Before 2001 we replace TIPS betas with the rolling beta of UK 10-year linker bonds to quarterly US equity excess returns. Bond excess returns are computed from changes in yields. We use zero-coupon yield curves from Gurkaynak, Sack and Wright (2006, 2008) and the Bank of England. Vertical lines indicate the start of our second sample period 2001.Q2 and the start of the pandemic 2020.Q1. Panel B shows 120-trading day rolling betas of daily 10-year Treasury bond log returns onto quarterly US equity log returns for the sample January 2018 through June 2022. A vertical line indicates the date when the World Health Organization declared Covid-19 a pandemic (March 11, 2020). 90% confidence intervals based on heteroskedasticiry robust standard errors are shown in dashed.

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Figure 2: Output Gap, Inflation, and Policy Rate Dynamics Pre- vs. Post-2001

Panel A: Output Gap onto Lagged Price Inflation
1979.Q4-2001.Q1   2001.Q2-2019.Q4

Panel B: Output Gap onto Lagged Wage Inflation

Panel C: Output Gap onto Lagged Policy Rate


Panel D: Policy Rate onto Lagged Price Inflation

This figure shows runs quarterly regressions of the form $z_{t+h} = a_{0,h} + a_{1,h}y_t + a_{2,h}y_{t-1} + \varepsilon_{t+h}$ and plots the regression coefficient $a_{1,h}$ on the y-axis against horizon h on the x-axis in the model vs. the data. Panel A uses the output gap on the left-hand-side and GDP deflator inflation on the right-hand-side, i.e. $z_t = x_t$ and $y_t = \pi_t$. Panel B uses the output gap on the left-hand-side and wage index inflation (ECIWAG, available starting 2000) on the right-hand-side, i.e. $z_t = x_t$ and $y_t = \pi_t^w$. Panel C uses the output gap on the left-hand-side and the fed funds rate on the right-hand-side, i.e. $z_t = x_t$ and $y_t = i_t$. Panel D uses the fed funds rate on the left-hand-side and inflation on the right-hand-side, i.e. $z_t = i_t$ and $y_t = \pi_t$. Black dashed lines show the regression coefficients in the data. Thin dashed lines show 95% confidence intervals for the data coefficients based on Newey-West standard errors with h lags. Blue solid lines show the corresponding model regression coefficients averaged across 100 independent simulations of length 1000.

Figure 3: Model Structural Macroeconomic Impulse Responses
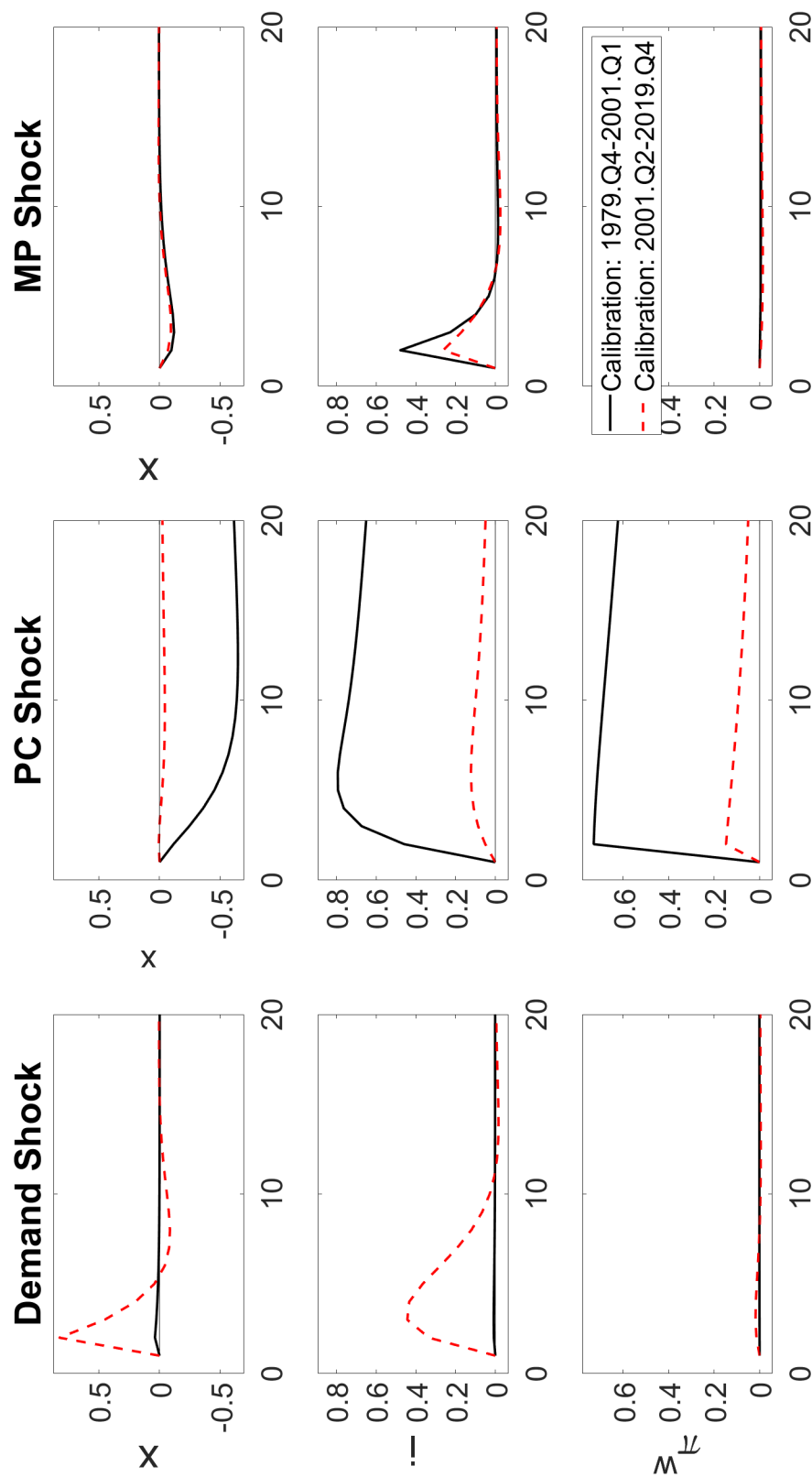
This figure shows model impulse responses for the output gap (top row), nominal policy rate (middle row) and inflation (bottom row). The impulse in the left column is a one-standard deviation demand shock, in the middle column is a one-standard deviation Phillips curve or supply shock, and in the right column is a one-standard deviation monetary policy shock. Impulse responses for the 1979.Q4-2001.Q1 calibration are shown in black, while the impulse responses for the 2001.Q2-2019.Q4 calibration are shown in orange.

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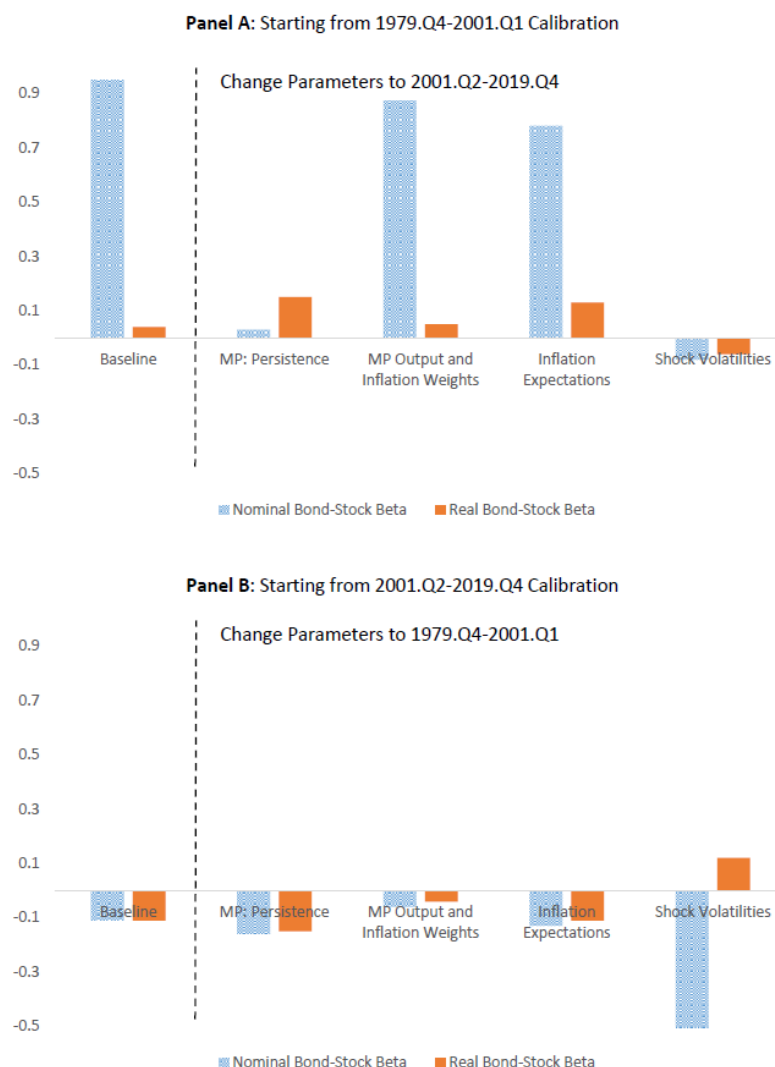Figure 4: Campbell-Shiller Bond Return Predictability by Adaptive Inflation Expectations
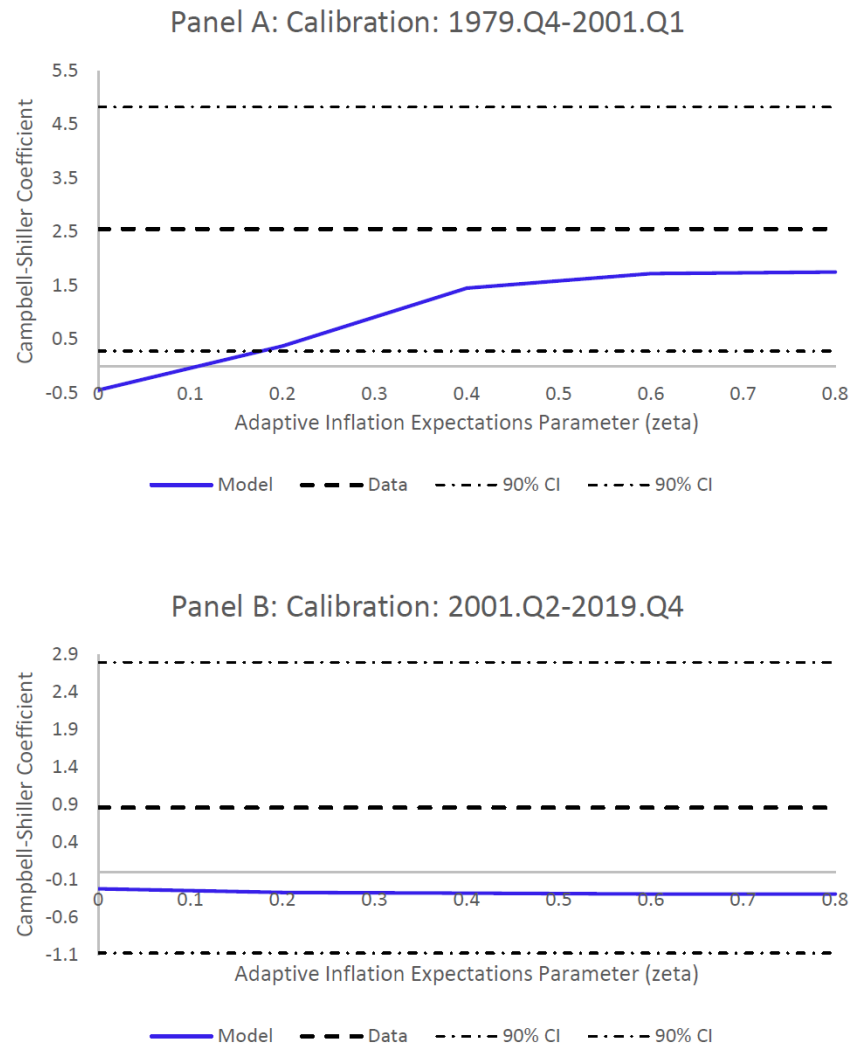
This figure shows the model Campbell-Shiller bond return predictability regression coefficient as in Table 3 against the parameter determining the adaptiveness of inflation expectations, ζ. All other parameters are held constant at their values listed in Table 1. The corresponding data moment is shown in black. Data 90% confidence intervals based on Newey-West standard errors with 4 lags are shown in black dashed. The top panel shows data and model moments for the 1979.Q4-2001.Q calibration. The bottom panel shows model and data moments for the 2001.Q2-2019.Q4 calibration.

Figure 5: Model Bond Risk Premium Impulse Responses
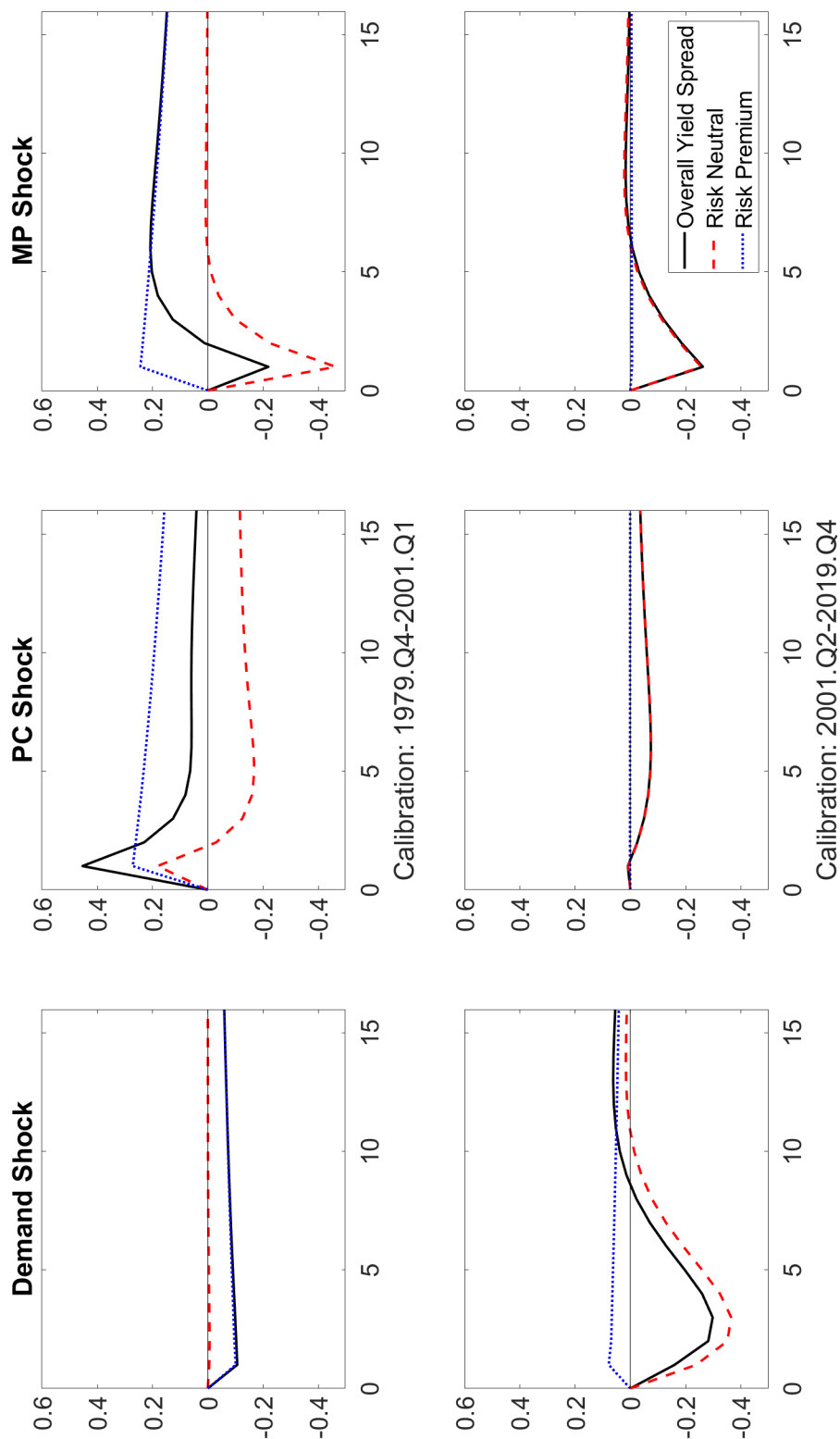
This figure shows model impulse responses for the yield spread, decomposed into a risk-neutral and risk premium component. The risk neutral yield spread is computed under the expectations hypothesis. The risk premium is the difference between the overall yield spread and the risk-neutral yield spread. The top row shows impulse responses for the 1979.Q4-2001.Q1 calibration and the bottom row shows impulse responses for the 2001.Q2-2019.Q4 calibration. The impulse in the left column is a one-standard deviation demand shock, in the middle column is a one-standard deviation Phillips curve or supply shock, and in the right column is a one-standard deviation monetary policy shock.

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Figure 6: Counterfactuals for Nominal and Real Bond-Stock Betas

Panel A: Starting from 1979.Q4-2001.Q1 Calibration

Change Parameters to 2001.Q2-2019.Q4

Baseline · MP: Persistence · MP Output and Inflation Weights · Inflation Expectations · Shock Volatilities

■ Nominal Bond-Stock Beta   ■ Real Bond-Stock Beta

Panel B: Starting from 2001.Q2-2019.Q4 Calibration

Change Parameters to 1979.Q4-2001.Q1

Baseline · MP: Persistence · MP Output and Inflation Weights · Inflation Expectations · Shock Volatilities

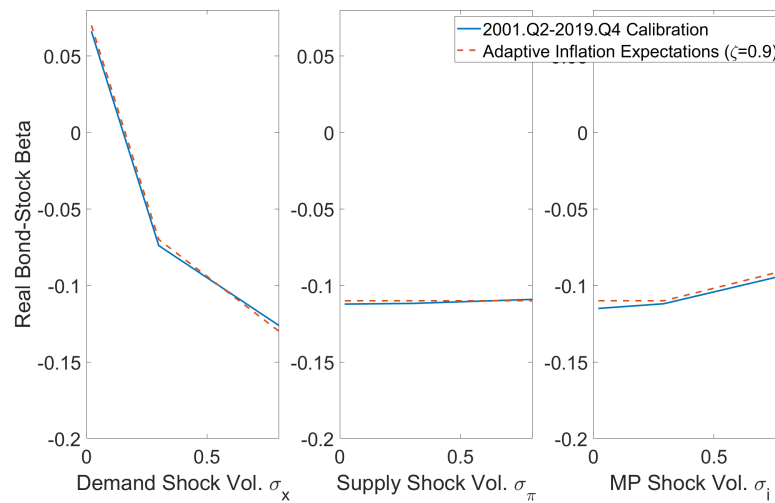■ Nominal Bond-Stock Beta   ■ Real Bond-Stock Beta

This figure shows model-implied nominal and real bond betas while changing parameter groups one-at-a-time. Panel A sets all parameter values to the 1979.Q4-2001.Q1 calibration unless stated otherwise. It then changes one at a time the following parameters to their 2001.Q2-2019.Q4 values: "MP: Persistence" (ρ^i), "MP: Output and Inflation Weights" (γ^x and γ^π), "Inflation Expectations" (ζ), and "Shock volatilities" (σ_x, σ_π, and σ_i). Panel B does the reverse exercise, holding all parameter values constant at their 2001.Q2-2019.Q4 and changing individual parameter groups to the values of the 1979.Q4-2001.Q1 calibration.

Figure 7: Varying the Volatilities of Individual Shocks

Panel A: Model Nominal Bond Beta
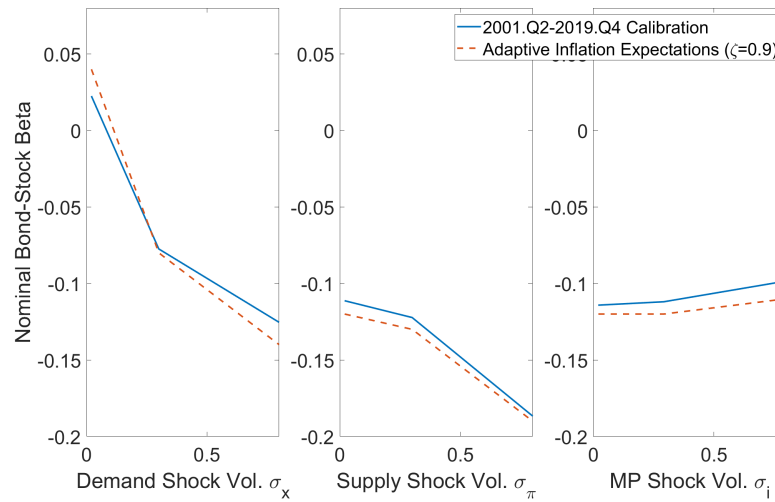
Panel B: Model Real Bond Beta

This figure shows shows model-implied 10-year nominal bond-stock betas (Panel A) and 10-year real bond-stock betas (Panel B) against the volatilities of demand shocks, supply shocks, and monetary policy shocks. The solid blue line shows comparative statics starting from the 2001.Q2-2019.Q4 calibration. The red dashed line sets the adaptive inflation expectations parameter to $\zeta = 0.9$ and the shock volatilities to the values shown on the x-axis, but all other parameter values as listed in Table 1 for the 2001.Q2-2019.Q4 calibration.

Figure 8: Model Nominal Bond Beta at Different Monetary Policy Rules
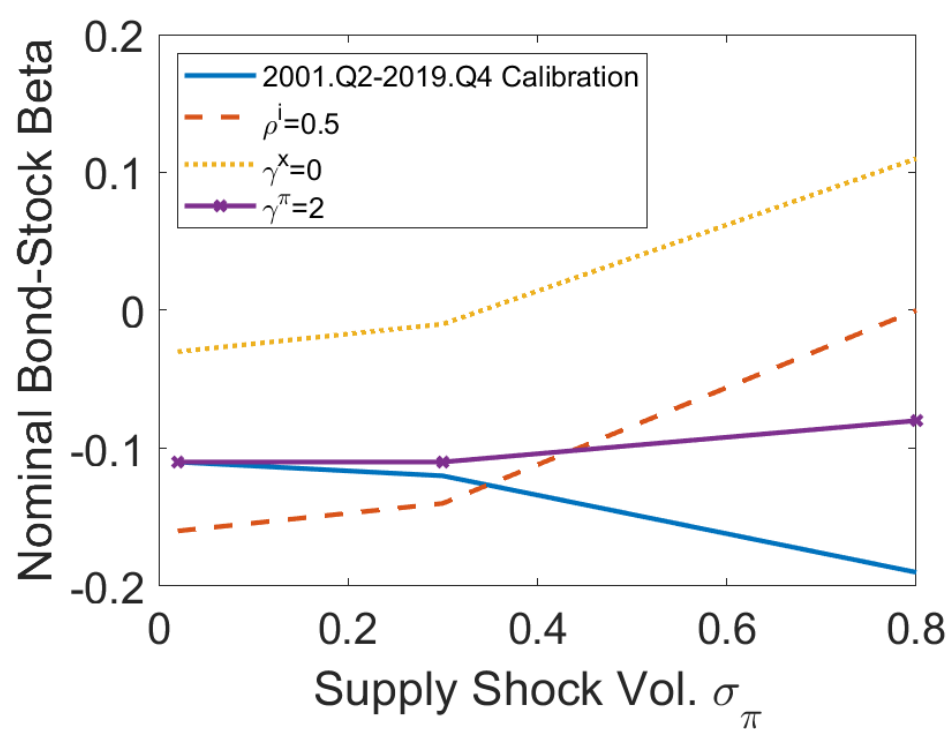
This figure shows shows model-implied 10-year nominal bond-stock betas against the standard deviation of supply shocks for different monetary policy rules. Unless otherwise labeled all parameter values are set to the 2001.Q2-2019.Q4 calibration.