Back to the 1980s or Not? The Drivers of Inflation and Real Risks in Treasury Bonds[*]

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Abstract

What is the informational content of bond risks for the economic drivers in a New Keynesian model of monetary policy? In my model, habit formation preferences generate endogenously time-varying risk premia, explain the volatility and predictability of bonds and stocks, and turn bond-stock betas into forward-looking indicators. Positive nominal bond-stock betas as in the 1980s arise in the model from the interaction of supply shocks with a systematic monetary policy that has high inflation weight and little inertia. Conversely, a counterfactual with 1980s-style shocks but 2000s-style monetary policy predicts negative nominal but increasing real bond-stock betas, similar to post-pandemic data.

Keywords: Bond betas, stagflation, soft landing, supply shocks, demand shocks, monetary policy, New Keynesian, time-varying risk premia
JEL Classifications: E43, E52, E58

1 Introduction

What does data from nominal and real Treasury bond risks tell us about supply shocks and stagflation or, conversely, the Fed's ability to engineer a "soft landing"? This classic question is newly relevant as supply shocks leave economists, policy makers, and investors wondering whether we will face a repeat of the tumultuous macroeconomy and bond markets of the 1980s. Nominal Treasury bond yields rise with expected inflation and stocks are linked to the economy, so it is appealing to look towards the comovement of bonds and stocks as a real-time indicator of supply vs. demand shocks. Common intuition suggests that if nominal bond yields rise with the stock market, this should reflect demand shocks moving inflation and output together along a Phillips curve. Conversely, if nominal bond yields move higher as the stock market falls, this is often thought to indicate supply shocks moving inflation and output in opposite directions.[1] However, this basic intuition does not account for the role of monetary policy nor changes in risk attitudes, and therefore a model is needed.

This paper provides a model of the demand, supply, monetary policy drivers of bond-stock betas when risk premia in bonds and stocks are also time-varying (Shiller (1981)). I find that beyond the two cases with dominant supply vs. demand shocks there is an interesting and relevant third case with distinct implications for bond-stock betas. This third case combines supply shocks with a "soft landing", where monetary policy manages to buffer the recession that would otherwise ensue. In this third case, the nominal component of bond yields may have little correlation with stocks, but the correlation between real (inflation-indexed) bond prices and stocks is predicted to turn positive, in line with US data 2021-2022.

Figure 1 shows empirical nominal and inflation-indexed bond-stock return betas from the 1980s through the post-pandemic inflation surge.[2] Because bond prices move inversely with yields, these bond-stock betas have the opposite sign as bond yield-stock comovements. During the 1980s nominal bond betas were positive and significantly larger than inflation-indexed bond betas, as intuition suggests when inflation is driven by volatile supply shocks. Nominal bond betas changed sign and the gap between nominal and inflation-indexed bond

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[1]Recent policy discussions appeal to bond-stock correlations as indicators of supply- vs. demand-driven inflation. See e.g the Economic Report of the President (March 2023, https://www.whitehouse.gov/wp-content/uploads/2023/03/ERP-2023.pdf) and ECB board member Isabel Schnabel's speech ("Inflation in the euro area and the US - causes, persistence, outlook", April 20, 2023).

[2]Panel A regresses quarterly bond excess returns onto quarterly stock returns over five-year rolling windows. Panel B regresses daily bond returns onto daily stock returns post-2018 using six-month rolling windows. I compute bond returns from zero-coupon nominal and inflation-indexed yields, so the bond duration is held constant at ten years. I use UK inflation-linked bond yields prior to 1999 and yields on US Treasury Inflation Protected Securities (TIPS) after 1999, when TIPS data becomes available. I end the sample in 30/06/2022, when the conduct of monetary policy clearly changed. Campbell, Shiller and Viceira (2009) find similar changes in US and UK nominal and inflation-indexed bond-stock betas.

Figure 1: Rolling Treasury Bond-Stock Betas

Panel A: 1979.Q4-2022.Q3   **Panel B:** January 2018 - June 2022
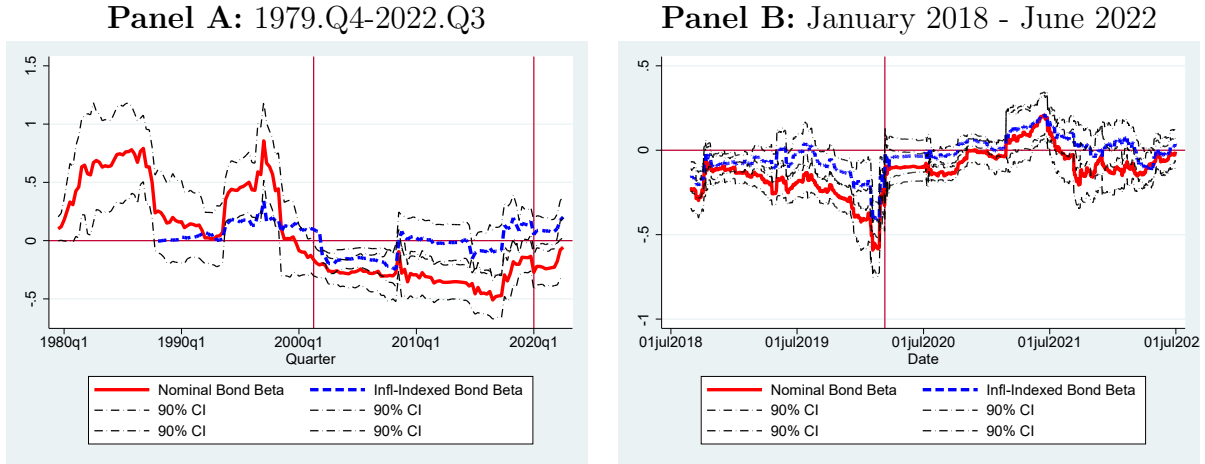
Note: Panel A shows betas from regressing quarterly ten-year Treasury bond excess returns onto quarterly US equity excess returns over five-year rolling windows for the period 1979.Q4-2022.Q3. Quarterly excess returns are in excess of three-month T-bills. Prior to 1999, I replace US Treasury Inflation Protected (TIPS) returns with UK ten-year linker returns. Bond excess returns are computed from changes in yields. Zero-coupon yield curves from Gürkaynak, Sack and Wright (2006, 2008) and the Bank of England. Vertical lines indicate 2001.Q2 and the start of the pandemic 2020.Q1. Panel B shows betas from regressing daily ten-year Treasury bond log returns onto quarterly US equity log returns over 120-trading day backward-looking rolling windows for the sample 01/01/2018 through 30/06/2022. A vertical line indicates March 11, 2020 (Covid). 90% confidence intervals based on heteroskedasticity robust standard errors are shown in dashed.

betas narrowed during the 2000s, as intuition would suggest when inflation is mostly demand driven and less volatile. Maybe surprisingly, the post-pandemic picture looks different from either the 1980s or the 2000s, suggesting a third type of equilibrium. While this was a period of high inflation, different from the 1980s real bond betas increased and nominal betas remained negative.[3]

The model builds on the New Keynesian asset pricing model of Campbell, Pflueger and Viceira (2020) and Pflueger and Rinaldi (2022), which integrates log-linear macroeconomic dynamics with highly nonlinear risk premia via habit formation preferences, but either assumed reduced-form inflation dynamics or allowed only for monetary policy shocks. Different from this prior work, I model supply and demand shocks and focus on how these economic shocks interact with monetary policy to drive bond risks. Asset pricing habit formation preferences are advantageous because they explain several asset pricing puzzles in the data, such as the high volatility of stock relative to fundamentals (Shiller (1981)), the predictabil-

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[3]He, Nagel and Song (2022) document a brief episode of positive bond-stock comovements in March 2020, which they attribute to short-term constraints on intermediaries.

ity of stock excess returns (Campbell and Cochrane (1999)), and the risk premium effect of high-frequency monetary policy surprises (Bernanke and Kuttner (2005), Pflueger and Rinaldi (2022)). Bond risks in the model are hence based on plausible countercyclical risk premia and an empirically reasonable risk premium effect of monetary policy.

In the model, investors price bonds and stocks with the stochastic discount factor arising from consumption utility, subject to a bond preference shock. The bond preference shock is needed to generate the demand shock in the macro Euler equation, and to explain negative real bond-stock betas during the pre-pandemic 2000s. It can be microfounded from time-varying intermediation capacity, similar to a safety shock in the international finance literature (Bianchi and Lorenzoni (2021)) or a credit spread shock (Gilchrist and Zakrajšek (2012)).[4] Alternatively, the bond preference shock can be microfounded as a growth or optimism shock (e.g. Beaudry and Portier (2006), Chahrour and Jurado (2018)). The supply side of the model features partially adaptive wage-setter inflation expectations and sticky wages in the manner of Rotemberg (1982), so a supply shock to the wage Phillips curve corresponds to a wage markup shock. Monetary policy is described by a Taylor (1993)-type rule for the short-term interest rate with an inertia coefficient on the lagged policy rate. Stocks represent a levered claim to firm profits or equivalently a levered claim to consumption (Abel (1990)) and investors are assumed to have rational inflation expectations. Risk premia are driven by a separate state variable, the surplus consumption ratio, which is driven by the same fundamental economic shocks as the macroeconomy but is highly nonlinear.

I calibrate the model to macroeconomic data from the 1980s vs. 2000s, thereby using the well-understood changes in the macroeconomy over these decades as a laboratory for my model of bond-stock betas. The model matches the changing bond-stock betas from the 1980s to the 2000s with a change from a supply-shock driven economy in the 1980s to a demand-shock driven one in the 2000s, and a change from a quick-acting and inflation-focused monetary policy rule in the 1980s to an inertial and more output-focused monetary policy rule in the 2000s.[5] I use a break date of 2001.Q2 as in Campbell, Pflueger and Viceira (2020) when the correlation between inflation and the output gap turned from negative

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[4]See e.g. Krishnamurthy and Vissing-Jorgensen (2012), Du, Tepper and Verdelhan (2018b), Jiang, Krishnamurthy and Lustig (2020), Jiang, Krishnamurthy and Lustig (2021), Itskhoki and Mukhin (2021), Fukui, Nakamura and Steinsson (2023), Gorton and Ordoñez (2022), Brunnermeier, Merkel and Sannikov (2022), Choi, Kirpalani and Perez (2023), Berger, Bocola and Dovis (2023) for evidence and theory on safety shocks. Pflueger, Siriwardane and Sunderam (2020) provide US evidence that preference for safety not immediately driven by aggregate risk aversion can forecast business cycle variables.

[5]The change to a more inertial monetary policy rule with relatively greater weight on output is in line with anecdotal evidence, as in recent decades central bankers have tended to move in incremental policy steps that are expected to be followed by more steps in the same direction, and have shown substantial concern for output. See Cieslak and Vissing-Jorgensen (2021), Bauer and Swanson (2023), and Bauer, Pflueger and Sunderam (2022) for direct empirical evidence of the Fed's output concern after the mid-1990s.

(i.e. stagflations) to positive. The volatilities of shocks and monetary policy parameters are calibrated for each subperiod to target Jordà (2005)-type local projections of the inflation-output gap, fed funds rate-output gap, and inflation-fed funds rate relationships, as well as the volatilities of consumption growth, long-term inflation expectations, and the fed funds rate. I set the adaptiveness of wage-setters' inflation expectations to match the well-known predictability of bond excess returns of Campbell and Shiller (1991).

I next use the calibrated model for a series of counterfactual analyses. The first counterfactual shows that combining 1980s-style shocks with 2000s-style systematic monetary policy implies negative nominal bond betas but increasing real bond-stock betas, explaining the post-pandemic evidence in Figure 1, Panel B. Intuitively, when the systematic component of monetary policy allows the real rate to fall in response to an inflationary supply shock, the recession is mitigated. Stocks benefit even more as investors' consumption remains further from habit, increasing their willingness to pay for risky stocks. Real bond bond betas increase in this counterfactual, since both monetary policy and supply shocks tend to move output and the real rate in opposite directions along the Euler equation.

The second counterfactual shows that the role of prevalent shocks is crucial, whereas changing realized shocks have little effect on bond-stock betas. I show that model nominal bond-stock betas remain positive as long as the 1980s calibration is priced in equilibrium, even if the realized shocks are drawn from the 2000s distribution. The mechanism relies on endogenously time-varying risk premia. Intuitively, in the 1980s equilibrium nominal bonds are priced as risky assets because they are expected to pay out in low marginal utility states. An increase in risk aversion—whether ultimately caused by realized demand, supply, or monetary policy shocks—leads investors to require a higher risk discount on these risky nominal bonds and drives down nominal bond and stock prices simultaneously. Bond betas in the model should hence be interpreted as forward-looking indicators about the equilibrium.

The third counterfactual shows that observing negative nominal bond betas in the face of supply shocks need not imply that the central bank has a low inflation weight, but may instead be consistent with a "slow-and-steady" monetary policy response. In the model, an inertial monetary policy rule keeps nominal bond betas negative in the face of supply shocks, as does a lower long-term inflation weight. This finding may be surprising because a low long-term inflation weight and monetary inertia are known to have different macroeconomic implications (Clarida, Gali and Gertler (2000)). The intuition is that either monetary policy inertia or a low long-term inflation weight is sufficient to drive down the short-term real rate in response to an inflationary supply shock, mitigating the fallout on output, consumption, and stock risk premia.

The fourth counterfactual shows that model nominal bond-stock betas do not depend

strongly on the adaptiveness of wage-setters' inflation expectations, but the predictability of bond excess returns as in Campbell and Shiller (1991) does. Intuitively, in the 1980s calibration, adaptive wage-setter inflation expectations lead to a persistent inflation process, so the expectations hypothesis component roughly cancels from the spread between long- and short-term nominal interest rates. The yield spread hence loads onto time-varying risk premia and predicts future bond excess returns. For the 2000s, the model generates no predictability in nominal bond excess returns, consistent with the data for this subperiod. Bond risks therefore contribute to the understanding of forward- vs. backward-looking Phillips curves (Fuhrer (1997)) and expectations in New Keynesian models (Gabaix (2020)).

This paper contributes to the literatures understanding the sources of stagflations, the link between monetary policy and asset prices, and changing bond-stock comovements. The literature seeking to explain the extraordinary inflation dynamics of the 1980s has a long tradition of disentangling changes in shocks vs. monetary policy.[6] More recently, several authors have argued that the reemergence of inflation can at least be partly attributed to supply-type shocks or non-linear deviations from the linearized Phillips curve,[7] and that the economic effects of such shocks depend on the systematic component of monetary policy (Miyamoto, Nguyen and Sergeyev (2023)). I contribute to this literature by showing that the interaction of supply shocks with systematic monetary policy is priced in bond risks.

The insight that monetary policy has short- to medium-term effects and impacts risk premia necessitates a model of time-varying risk premia, such as the one used here.[8] This distinguishes this paper from a separate literature that has focused on explaining unconditional moments in bond and stock markets within New Keynesian models (Kung (2015), Swanson (2021)). While my model builds on habit formation preferences, the mechanism more broadly relies on countercyclical risk premia, whether they are generated from the price of risk as here, the quantity of risk as in Jurado, Ludvigson and Ng (2015), or heterogeneous agents with different risk aversion that have been used as a microfoundation habit formation (Chan and Kogan (2002), Kekre and Lenel (2022), Caballero and Simsek (2022)). The advantage of the habits model is that it is parsimonious and unifies a wider range of classic and monetary-policy related asset pricing puzzles.

Finally, this paper also contributes to the growing literature on changing bond risks. This

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[6]See e.g. Stock and Watson (2002), Sims and Zha (2006), Primiceri (2006), Justiniano and Primiceri (2008), Lubik and Schorfheide (2004), Bernanke, Gertler and Watson (1997).

[7]Reis (2022), Rubbo (2022), Di Giovanni, Kalemli-Özcan, Silva and Yildirim (2022), Comin, Johnson and Jones (2023), Gagliardone and Gertler (2023), Benigno and Eggertsson (2023).

[8]Uhlig (2007), Dew-Becker (2014), and Rudebusch and Swanson (2008) use simplified habit formation preferences and discuss some of the challenges in integrating asset pricing habit formation preferences into New Keynesian models. Verdelhan (2010) and Wachter (2006) show that finance habit preferences combined with reduced-form models of the macroeconomy can explain risk premia in foreign exchange and bonds.

paper focuses on the interaction of changing shocks vs. changing monetary policy and hence is complementary to prior work that has studied the risk premium implications of changing monetary policy with a constant distribution of shocks and constant risk aversion.[9] Gourio and Ngo (2022) study the complementary channel of downward-price rigidity in a model with Epstein-Zin preferences. Caballero and Simsek (2022) model optimal monetary policy in a more stylized setup when asset prices matter for the economy. Several papers have also studied changing bond risks and market-based inflation expectations in more reduced-form models.[10] Campbell, Sunderam and Viceira (2017) discuss the basic intuition of supply vs. demand shocks as drivers of bond-stock betas, but do not provide a structural model. Campbell, Pflueger and Viceira (2020) embed finance habit preferences within a New Keynesian Euler equation, but rely on reduced-form inflation dynamics. This paper also complements the more reduced-form approach of Chernov, Lochstoer and Song (2021), who use rolling correlations rather than betas to argue that the time-varying bond-stock comovements are 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, correlations may not reveal the separate roles of inflation and real rate risks. My focus on betas reveals distinct differences between nominal and real bond risks pre-2000, which allows me to analyze the contributions of fundamental shocks and monetary policy.

2 Model

I use lower-case letters to denote logs throughout, π_t to denote log price inflation, and π_t^w to denote log wage inflation. I refer to price inflation and inflation interchangeably.

2.1 Preferences

As in Campbell and Cochrane (1999), a representative agent derives utility from real consumption C_t relative to a slowly moving habit level H_t:

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

[9]Rudebusch and Swanson (2012), Bianchi, Lettau and Ludvigson (2022a), Bianchi, Ludvigson and Ma (2022c), Gourio and Ngo (2020), Li, Zha, Zhang and Zhou (2022).

[10]Piazzesi and Schneider (2006), Baele, Bekaert and Inghelbrecht (2010), David and Veronesi (2013), Song (2017). For papers on inflation markets, see D'Amico, Kim and Wei (2018), Haubrich, Pennacchi and Ritchken (2012), Hilscher, Raviv and Reis (2021), Bahaj, Czech, Ding and Reis (2023)).

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 consumption available to generate utility:

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

Risk aversion therefore declines when consumption has fallen close to habit. As equation (2) makes clear, a model for market habit implies a model for surplus consumption and vice versa. As in Campbell, Pflueger and Viceira (2020), I model market consumption habit implicitly by assuming that log surplus consumption, s_t, satisfies:

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

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

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

$$x_t = c_t - (1 - \phi)\sum_{j=0}^{\infty} \phi^j c_{t-1-j}, \tag{5}$$

where ϕ is a smoothing parameter. For the microfoundations in Section 2.4, x_t equals the log output gap, or the difference between log output and log potential output under flexible prices and wages, and I refer to it as the output gap for short.

The sensitivity function $\lambda(s_t)$ takes the form as in Campbell and Cochrane (1999)

$$\lambda(s_t) = \begin{cases} \frac{1}{\bar{S}}\sqrt{1 - 2(s_t - \bar{s})} - 1 & s_t \leq s_{max} \\ 0 & s_t > s_{max} \end{cases}, \tag{6}$$

$$\bar{S} = \sigma_c\sqrt{\frac{\gamma}{1 - \theta_0}}, \ \bar{s} = \log(\bar{S}), \ s_{max} = \bar{s} + 0.5(1 - \bar{S}^2). \tag{7}$$

This function is decreasing in log surplus consumption, so marginal utility becomes more sensitive to consumption surprises when surplus consumption is already low, as would be the case after a sequence of bad shocks. 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. Both consumption and the output gap are equilibrium objects that depend on fundamental shocks, and in equilibrium they are conditionally homoskedastic and lognormal. As shown in Campbell, Pflueger and Viceira (2020), implied log habit follows approximately a weighted average of lagged consumption and lagged consumption expectations.

2.2 Asset Pricing Equations and Bond Preference Shock

The stochastic discount factor (SDF) M_{t+1} is derived from (1):

$$M_{t+1} = \beta \frac{\frac{\partial U_{t+1}}{\partial C}}{\frac{\partial U_t}{\partial C}} = \beta \exp\left(-\gamma(\Delta s_{t+1} + \Delta c_{t+1})\right). \tag{8}$$

I model stocks as a levered claim on consumption or equivalently firm profits, while preserving the cointegration of consumption and dividends. The asset pricing recursion for a claim paying consumption at time $t + n$ and zero otherwise takes the following form

$$\frac{P_{n,t}^c}{C_t} = E_t\left[M_{t+1}\frac{C_{t+1}}{C_t}\frac{P_{n-1,t+1}^c}{C_{t+1}}\right]. \tag{9}$$

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

$$\frac{P_t^c}{C_t} = \sum_{n=1}^{\infty}\frac{P_{n,t}}{C_t}. \tag{10}$$

At time t the aggregate levered 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 $(1-\delta)P_t^c$, so the price of the levered equity claim equals $P_t^\delta = \delta P_t^c$.

The bond asset pricing recursions are subject to a bond preference shock ξ_t. The Euler equation for the one-period risk-free rate is given by:

$$1 = E_t\left[M_{t+1}exp\left(r_t - \xi_t\right)\right], \tag{11}$$

and one-period real and nominal interest rates are linked via the Fisher equation

$$i_t = E_t\pi_{t+1} + r_t. \tag{12}$$

Equation (12) is an approximation, effectively assuming that the inflation risk premium in one-period nominal bonds is zero. Longer-term bond prices do not use this approximation and are given by the recursions:

$$P_{1,t}^\$ = exp(-i_t), \ P_{1,t} = exp(-r_t), \tag{13}$$

$$P_{n,t}^\$ = exp(-\xi_t)E_t\left[M_{t+1}exp(-\pi_{t+1})P_{n-1,t+1}^\$\right], \ P_{n,t} = exp(-\xi_t)E_t\left[M_{t+1}P_{n-1,t+1}\right], \tag{14}$$

where all expectations are rational. Because all bonds are priced with the preference shock ξ_t, the expectations hypothesis holds when investors are risk-neutral.

The bond preference shock ξ_t can be derived from two classes of standard microfoundations, see Appendix C. First, and most simply, it may reflect that households do not have direct access to the government bond market. A positive shock ξ_t therefore acts like a decline in Treasury bond convenience (Krishnamurthy and Vissing-Jorgensen (2012), Du, Im and Schreger (2018a)) or a decrease in intermediary frictions (Bernanke and Gertler (2001), Gilchrist and Zakrajšek (2012), Bianchi and Lorenzoni (2021), Gabaix and Maggiori (2015)), analogously to the safety shock that has been successful at reconciling several empirical puzzles in international finance.[11] Second, the bond preference shock ξ_t can be microfounded as an optimism or growth shock, similar to expectations-based demand shocks in Beaudry and Portier (2006), Angeletos and La'O (2013), De La'O and Myers (2021), Bordalo, Gennaioli, LaPorta and Shleifer (2022) and Caballero and Simsek (2022)'s "traditional financial forces" shock. My results do not depend on the specific interpretation of ξ_t within these broad categories.

2.3   Macroeconomic Euler Equation from Preferences

This Section shows that the bond preference shock is necessary to generate a demand shock in the macroeconomic Euler equation. Starting from the asset pricing equation for a one-period risk-free bond (11), and substituting for the SDF and surplus consumption dynamics gives (up to a constant):

$$
r_t \;=\; \gamma \mathrm{E}_t \Delta c_{t+1} + \gamma \mathrm{E}_t \Delta s_{t+1} - \frac{\gamma^2}{2} \left(1 + \lambda(s_t)\right)^2 \sigma_c^2 + \xi_t, \tag{15}
$$

$$
\;=\; \gamma \mathrm{E}_t \Delta c_{t+1} + \gamma \theta_1 x_t + \gamma \theta_2 x_{t-1} + \underbrace{\gamma(\theta_0 - 1)s_t - \frac{\gamma^2}{2} \left(1 + \lambda(s_t)\right)^2 \sigma_c^2}_{=0} + \xi_t. \tag{16}
$$

The sensitivity function (6) through (7) has the advantageous property that the two bracketed terms drop out, and the real risk-free rate has the familiar log-linear form, and much lower volatility than the stock market. Substituting (5) then gives the exactly loglinear macroeconomic **Euler equation**:

$$
x_t = f^x E_t x_{t+1} + \rho^x x_{t-1} - \psi r_t + v_{x,t}. \tag{17}
$$

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[11]See e.g. Jiang, Krishnamurthy and Lustig (2021), Itskhoki and Mukhin (2021), Kekre and Lenel (2022), Fukui, Nakamura and Steinsson (2023), Engel and Wu (2023).

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

$$\rho^x \;\; = \;\; \frac{\theta_2}{\phi - \theta_1}, f^x = \frac{1}{\phi - \theta_1}, \psi = \frac{1}{\gamma(\phi - \theta_1)}, \theta_2 = \phi - 1 - \theta_1. \tag{18}$$

Non-zero values for the habit parameters, θ_1 and θ_2, are therefore needed to generate the standard New Keynesian block with forward- and backward-looking coefficients. The demand shock in the Euler equation equals

$$v_{x,t} \;\; = \;\; \psi\xi_t. \tag{19}$$

The demand shock $v_{x,t}$ is conditionally homoskedastic, serially uncorrelated and uncorrelated with supply and monetary policy shocks because ξ_t is. I denote its standard deviation by σ_x.

Equation (17) shows that the bond preference shock is important for the sign of the real bond-output gap comovement, with implications for model real bond-stock betas.[12] In the absence of bond preference shocks, a higher real rate is associated with a lower output gap through (17), so real bond prices and the output gap are positively correlated. On the other hand, a preference shift towards bonds (a decrease in ξ_t) leads to a reduction in consumption and a more negative output gap as if households face a loan rate above the government bond rate or perceive lower expected potential output growth. By driving down the output gap and the real risk-free rate at the same time, the bond preference shock is the only shock in the model that induces a negative correlation between real bond prices and the output gap.

2.4 Supply Side

I keep the supply side as simple as possible to generate a standard log-linearized Phillips curve describing inflation dynamics, and the link between consumption and the output gap. Details are provided in the Appendix. There is no real investment, and the aggregate resource constraint simply states that aggregate consumption equals aggregate output, i.e. $C_t = Y_t$. Following Lucas (1988) I assume that productivity depends on past economic activity. Potential output is defined as the level of real output that would obtain with flexible prices and wages taking current productivity as given. The log output gap is the difference between

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[12]While a shock to the discount factor shared by bonds and stocks (Albuquerque, Eichenbaum, Luo and Rebelo (2016)) also generates a demand shock in the Euler equation, a joint discount rate shock moves bonds and stocks in the same direction unless the endogenous cash flow effect is very strong. Different from a bond preference shock, a joint discount rate shock hence cannot explain the negative real bond-stock beta observed during the pre-pandemic 2000s.

log real output and log potential output and in equilibrium satisfies (5).

I consider the simplified case where wage unions charge sticky wages but firms' product prices are flexible. Specifically, I 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, Eichenbaum and Evans (2005). I assume that households experience disutility of working outside the home due to the opportunity cost of home production as in Greenwood, Hercowitz and Huffman (1988), with external home production habit defined so that home production drops out of the intertemporal consumption decision and the asset pricing stochastic discount factor. Log-linearizing the intratemporal first-order condition of wage-setting unions gives the **Phillips curve**:

$$\pi_t^w = f^\pi E_t \pi_{t+1}^w + \rho^\pi \pi_{t-1}^w + \kappa x_t + v_{\pi,t}, \tag{20}$$

for constants ρ^π, f^π, and κ. The parameter κ is a wage-flexibility parameter. The supply or Phillips curve shock $v_{\pi,t}$ is assumed to be conditionally homoskedastic with standard deviation $\sigma_{\pi,t}$, 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.[13]

I allow wage-setters to have partially adaptive subjective inflation expectations

$$\tilde{E}_t \pi_{t+1}^w = (1 - \zeta) E_t \pi_{t+1}^w + \zeta \pi_{t-1}^w, \tag{21}$$

where E_t denotes the rational expectation conditional on state variables at the end of period t. Hence, while financial assets are priced with rational inflation expectations, wage-setters' expectations are more sluggish, capturing the idea that markets are more sophisticated and attentive to macroeconomic dynamics than individual wage-setters. A similar assumption has been used by Bianchi, Lettau and Ludvigson (2022a). A long-standing Phillips curve literature has found that adaptive inflation expectations and a strongly backward-looking Phillips curve are needed to capture the empirical persistence of inflation (Fuhrer and Moore (1995), Fuhrer (1997)).[14] If $\rho^{\pi,0}$ is the backward-looking component under rational inflation

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[13]While I do not model fiscal sources of inflation, under certain conditions a shock to inflation expectations due to fiscal policy can act similarly to a shift to the Phillips curve (Hazell, Herreno, Nakamura and Steinsson (2022), Bianchi, Faccini and Melosi (2023)). Up to the distinction between wage and price inflation, supply shocks are also isomorphic to shifts to potential output unrecognized by the central bank, in which case x_t is the output gap perceived by consumers and the central bank, and the actual output gap is $x_t + \frac{1}{\kappa} v_{\pi,t}$.

[14]Consistent with this older literature, a quickly growing literature has documented deviations from rationality (Coibion and Gorodnichenko (2015), Bianchi, Ludvigson and Ma (2022b)) and excess dependence of expectations on lagged inflation (Malmendier and Nagel (2016)).

expectations ($\zeta = 0$), the backward- and forward-looking Phillips curve parameters equal:

$$\rho^\pi = \rho^{\pi,0} + \zeta - \rho^{\pi,0}\zeta, \ f^\pi = 1 - \rho^\pi. \tag{22}$$

Ten-year survey inflation expectations are modeled similarly as a weighted average of a moving average of inflation over the past ten years and the rational forecast, with the weight on past inflation given by ζ.

Equilibrium price inflation equals wage inflation minus productivity growth, which depends on the output gap:

$$\pi_t = \pi_t^w - (1 - \phi)x_{t-1}. \tag{23}$$

In the calibrated model, ϕ is close to one, and price and wage inflation are very similar. The reason to assume sticky wages rather than sticky prices is simply that with these assumptions a consumption claim (Abel (1990)) is identical to a claim to firm profits.[15]

2.5 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):

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

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

Here, $\gamma^x x_t + \gamma^\pi \pi_t$ denotes the central bank's interest rate target, to which it adjusts slowly.[16] The parameters γ^x and γ^π represent monetary policy's long-term output gap and inflation weights. The inertia parameter ρ^i governs how quickly monetary policy adjusts towards this long-term target. 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 policy rate, which then mean-reverts at rate ρ^i.

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[15]It is also in line with Christiano, Eichenbaum and Evans (1999) who find that sticky wages are more important for aggregate inflation dynamics than sticky prices. See also Favilukis and Lin (2016) who find that wage-setting frictions are important to ensure that a claim to firm profits behaves similarly to a claim to consumption in an asset pricing sense. Appendix D shows that model implications are robust to setting wage and price inflation equal.

[16]I do not model the zero lower bound, because I am 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, as emphasized by Gourio and Ngo (2020), and I leave this to future research.

2.6   Model Solution

The solution proceeds in two steps. First, I solve for log-linear macroeconomic dynamics. Second, I use numerical methods to solve for highly non-linear asset prices. This is aided by the particular tractability of the surplus consumption dynamics, which imply that the surplus consumption ratio is a state variable for asset prices but not for macroeconomic dynamics. I solve for the dynamics of the log-linear state vector

$$Y_t = [x_t, \pi_t^w, i_t]'. \tag{26}$$

The dynamics of these equilibrium objects are driven by the vector of exogenous shocks

$$v_t = [v_{x,t}, v_{\pi,t}, v_{i,t}], \tag{27}$$

according to the consumption Euler equation (17), the Phillips curve (20), the monetary policy rule (24), and the wage-price inflation link (23). I solve for a minimum state variable equilibrium of the form

$$Y_t = BY_{t-1} + \Sigma v_t, \tag{28}$$

where B and Σ are $[3 \times 3]$ and $[3 \times 3]$ matrices, and v_t is the vector of structural shocks. I solve for the matrix B using Uhlig (1999)'s formulation of the Blanchard and Kahn (1980) method. In both calibrations, there exists a unique equilibrium of the form (28) with non-explosive eigenvalues. I 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 the scope of this paper. Note that equation (28) implies that macroeconomic dynamics are conditionally lognormal. The output gap-consumption link (5) therefore implies that equilibrium consumption surprises $\varepsilon_{c,t+1}$ are conditionally lognormal, as previously conjectured.

The key properties of endogenously time-varying risk premia can be illustrated with a simple analytic expression. Consider a one-period claim with log real payoff αc_t. For illustrative purposes consider α to be an exogenous constant, though in the full model it depends on the macroeconomic equilibrium. Denoting the log return on the one-period claim by $r_{1,t+1}^{c,\alpha}$, the risk premium—adjusted for a standard Jensen's inequality term—equals the conditional covariance between the negative log SDF and the log real asset payoff:

$$E_t\left[r_{1,t+1}^{c,\alpha} - r_t\right] + \frac{1}{2}Var\left(r_{1,t+1}^{c,\alpha}\right) = \mathrm{Cov}_t\left(-m_{t+1}, x_{t+1}\right) = \alpha\gamma\left(1 + \lambda\left(s_t\right)\right)\sigma_c^2. \tag{29}$$

13

This expression shows that assets with risky real cash flows ($\alpha > 0$) require positive risk premia. Since $\lambda(s_t)$ is downward-sloping, risk premia on risky assets increase further after a series of bad consumption surprises. Conversely, assets with safe real cash flows ($\alpha < 0$) require negative risk premia that decrease after a series of bad consumption surprises. Because real cash flows on nominal bonds are inversely related to inflation, nominal bonds resemble a risky asset ($\alpha > 0$) if inflation is countercyclical (i.e. stagflations) but a safe asset ($\alpha < 0$) if inflation falls in bad times.

Because full asset prices are not one-period claims, I use numerical value function iteration to solve the recursions (13) through (10) while accounting for the new demand shock and the link between wage and price inflation (23). 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. I need x_{t-1} as an additional state variable because the expected surplus consumption ratio depends on it through the dynamics (3).

3   Empirical Analysis and Calibration Strategy

Table 1 lists the parameters for the calibrations and how they vary across subperiods.

3.1   Calibration Strategy

I calibrate the model separately for two subperiods, where I choose the 2001.Q2 break date from Campbell, Pflueger and Viceira (2020). This break date was chosen by testing for a break date in the inflation-output gap relationship and did not use asset prices. I start the sample in 1979.Q4, when Paul Volcker was appointed as Fed chairman. I end the sample in 2019.Q4 prior to the pandemic, leaving the analysis of how shocks changed during the pandemic period for a separate discussion. I do not account for the possibility that agents might have anticipated a change in regime.[17] The model is calibrated to macroeconomic moments, with only the inflation expectations parameter set to match Campbell and Shiller (1991)-type bond return predictability. I do not match bond-stock betas directly but use them as additional moments, because the solution for macroeconomic dynamics is much faster than the solution for asset prices.

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

Table 1: Calibration Parameters

Panel A: Period-specific parameters

		1979.Q4-2001.Q1	2001.Q2-2022.Q2
MP inflation coefficient	γ^π	1.35	1.10
		(0.53)	(0.06)
MP output coefficient	γ^x	0.50	1.00
		(0.74)	(0.30)
MP persistence	ρ^i	0.54	0.80
		(0.18)	(0.04)
Vol. demand shock	σ_x	0.01	0.59
		(0.32)	(0.02)
Vol. PC shock	σ_π	0.58	0.07
		(0.04)	(0.00)
Vol. MP shock	σ_i	0.55	0.07
		(0.14)	(0.06)
Adaptive Inflation Expectations	ζ	0.6	0.0
		(0.51)	(2.67)
Leverage parameter	δ	0.50	0.66

Panel B: Invariant parameters

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

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. Standard errors are computed using the delta method with details given in Appendix E.

3.2 Invariant Parameters

The calibration proceeds in three steps. First, I set some parameters to invariant values following the literature, shown in Panel B 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 output gap-consumption link parameter $\phi = 0.99$ is chosen similarly to Campbell, Pflueger and Viceira (2020) to maximize the empirical correlation between stochastically detrended real GDP and the output gap from the Bureau of Economic Analysis. I choose a slightly higher value because the correlation between the output gap and stochastically detrended real GDP is flat over a range of values ($corr = 76\%$ at $\phi = 0.93$ vs. $corr = 73\%$ at $\phi = 0.99$), and higher ϕ minimizes the gap between price and wage inflation and hence simplifies the model. I calibrate $\theta_1 - \phi$ and hence the Euler equation exactly as in Pflueger and Rinaldi (2022), where the habit parameters θ_1 and θ_2 were chosen to replicate the hump-shaped response of output to an identified monetary policy shock in the data. 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. Because the model impulse responses to a monetary policy shock are invariant to the shock volatilities and vary little with monetary policy and Phillips curve parameters, I effectively match habit preferences to the output response to an identified monetary policy shock. I set the slope of the Phillips curve to $\kappa = 0.0062$ based on Hazell, Herreno, Nakamura and Steinsson (2022), who also find little variation in this parameter over time. Appendix Table A4 shows that model implications are robust to choosing a different utility curvature γ, consumption-output gap link ϕ, and Phillips curve slope κ.

3.3 Period-Specific Shock Volatilities and Monetary Policy

The second step chooses period-specific monetary policy parameters and shock volatilities through Simulated Methods of Moments. Let $\hat{\Psi}$ denote the vector of twelve (13 for the second subperiod) empirical target moments, and $\Psi(\sigma_x, \sigma_\pi, \sigma_i, \gamma^x, \gamma^\pi, \rho^i; \zeta)$ the vector of model moments computed analogously on model-simulated data. I choose subperiod-specific monetary policy parameters γ^x, γ^π, and ρ^i and shock volatilities σ_x, σ_π, and σ_i while holding the inflation expectations parameter constant at $\zeta = 0$ to minimize the objective function:

$$\left\| \frac{\hat{\Psi} - \Psi(\sigma_x, \sigma_\pi, \sigma_i, \gamma^x, \gamma^\pi, \rho^i; \zeta = 0)}{SE(\hat{\Psi})} \right\|^2. \tag{30}$$

The vector of target moments $\hat{\Psi}$ includes the standard deviations of annual real consumption growth, the annual change in the fed funds rate, and the annual change in survey ten-year inflation expectations, as well as the output gap-inflation, output gap-fed funds rate, and inflation-fed funds rate lead-lag relationships at three different horizons.[18]

I also target coefficients $a_{1,h}$ from Jordà (2005)-type regressions of the form:

$$z_{t+h} = a_{0,h} + a_{1,h}y_t + a_{2,h}y_{t-1} + \varepsilon_{t+h}. \tag{31}$$

I consider the variable combinations $(z_t, y_t) = (x_t, \pi_t)$, $(z_t, y_t) = (x_t, i_t)$, and $(z_t, y_t) = (\pi_t, i_t)$ and horizons of one, three and seven quarters. For the second calibration period when wage inflation data is easily available, I also estimate the specification $(z_t, y_t) = (x_t, \pi_t^w)$ and target the difference $a_{1,h}^{x,\pi} - a_{1,h}^{x,\pi^w}$. While these regressions do not estimate identified shocks, including lags tends to result in a right-hand-side that is highly correlated with structural shocks in model-simulated data. The vector of empirical standard errors $SE(\hat{\Psi})$ is computed via the delta method and Newey-West standard errors with h lags.
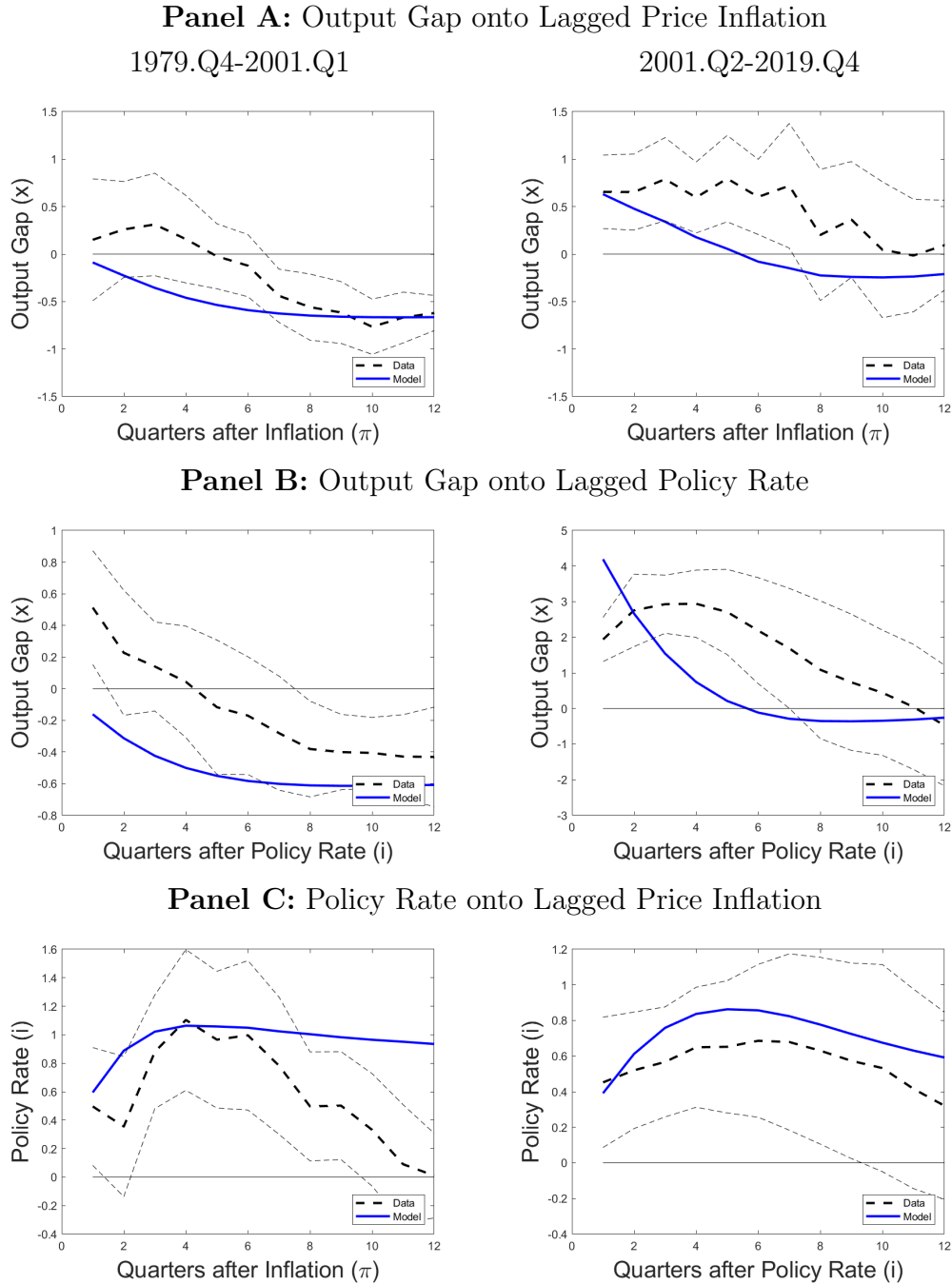
I match many more empirical moments than I have parameters, so this is a demanding calibration objective.[19] The rationale for including several lags is that, for example, the negative inflation-output gap relationship (i.e. stagflation) is clearest at a 6-8 quarter lag horizon. Rather than picking different lags for different variables I include all lags for all variables, effectively averaging across different lead and lag horizons. Because the model is relatively parsimonious, the model cross-correlations should be expected to be matched on average but not at every lag.

Figure 2, Panel A shows that model matches the negative inflation-output gap relationship, or stagflations, in the earlier period. The model achieves this fit by setting a high volatility of supply shocks for the 1980s calibration. The right plot in Panel A shows that in the 2000s an increase in inflation tended to be followed by an increase in the output gap, akin to moving up and down a Phillips curve, and the model replicates this relationship by setting a small supply shock volatility in the 2000s calibration. While the model inflation-

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[18]Empirical ten-year CPI inflation expectations are from the Survey of Professional Forecasters after 1990 and from Blue Chip before that, available from the Philadelphia Fed research website.

[19]Because I match three cross-relationships (output-inflation, output-fed funds, inflation-fed funds) at three different horizons (one, three and seven quarters) and three volatilities, this step of the calibration procedure effectively chooses six parameters to fit $3 \times 3 + 3 = 12$ (13 for the second subperiod) moments. I include only one moment for wage inflation to avoid over-weighting inflation moments by including many nearly identical moments. The grid search procedure is relatively simple and draws 50 random values for $(\gamma^x, \gamma^\pi, \rho^i, \sigma_x, \sigma_\pi, \sigma_i)$ and picks the combination with the lowest objective function. I repeat this algorithm until convergence, meaning that the grid search result no longer changes starting from the calibrated values for each subperiod calibration. The only parameter value that reaches the externally set upper bound is $\gamma^x = 1$ for the 2000s calibration. I regard this as a plausible upper bound based on economic priors.

Figure 2: Local Projections for Inflation, Output Gap, and Fed Funds Rate

Panel A: Output Gap onto Lagged Price Inflation

1979.Q4-2001.Q1   2001.Q2-2019.Q4

Panel B: Output Gap onto Lagged Policy Rate

Panel C: Policy Rate onto Lagged Price Inflation

This figure shows 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 the fed funds rate on the right-hand side, i.e. $z_t = x_t$ and $y_t = i_t$. Panel C 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.

output gap relationship for the 2000s calibration is not quite as positive in the data, the upward-shift from the first to the second period is well replicated by the model.

Figure 2, Panel B shows that the model matches the negative fed funds-output gap relationship in the 1980s, and the positive fed funds-output gap relationship in the 2000s. The model achieves this setting a high volatility of monetary policy shocks for the 1980s calibration, but a volatile demand or bond preference shock in the 2000s calibration.[20]

The lead-lag relationship between inflation and the fed funds rate in Figure 2, Panel C mostly pins down the monetary policy rule parameters in the model. The 1980s calibration features a higher inflation weight, γ^π, a lower output gap weight, γ_x, and lower inertia, ρ^i, while the 2000s calibration features a lower inflation weight, γ^π, a higher output gap weight, γ_x, and higher inertia, ρ^i. While the standard errors for γ^x and γ^π appear to be somewhat high for the 1980s calibration, the joint hypothesis that γ^x and γ^π are the same as in the 2000s calibration can be rejected at any conventional significance level.

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[20]Whether one interprets the demand shock as an increase in financial frictions or as an expected growth shock, it is empirically plausible that its volatility increased from the first subperiod to the second subperiod. The standard deviation of the Gilchrist and Zakrajšek (2012) credit spread, which is known to predict recessions empirically, doubled between the first and the second subperiods in the data (0.54% vs. 1.06%). The standard deviation of expectations of one-year earnings growth similarly increased from 0.14 in the first subperiod to 0.37 in the second subperiod. Quarter-end credit spread data from https://www.federalreserve.gov/econres/notes/feds-notes/updating-the-recession-risk-and-the-excess-bond-premium-20161006.html. Quarterly data on one-year earnings growth expectations from De La'O and Myers (2021) ends in 2015.Q3 and was obtained from https://www.ricardodelao.com/data (accessed 12/12/2022).

Table 2: Quarterly Asset Prices and Macro Volatilities

	1979.Q4-2001.Q1		2001.Q2-2019.Q4	
	Model	Data	Model	Data
Asset Prices: Stocks				
Equity Premium	7.33	7.96	9.15	7.64
Equity Vol	14.95	16.42	19.29	16.80
Equity SR	0.49	0.48	0.47	0.45
AR(1) pd	0.96	1.00	0.93	0.84
1 YR Excess Returns on pd	-0.38	-0.01	-0.38	-0.50
1 YR Excess Returns on pd (R^2)	0.06	0.00	0.14	0.28
Asset Prices: Bonds				
Expected Bond Exc. Return	4.26	2.46	-0.84	-2.07
Return Vol.	15.82	14.81	2.12	9.28
Nominal Bond-Stock Beta	0.86	0.24	-0.09	-0.31
Real Bond-Stock Beta	0.05	0.08	-0.08	-0.06
1 YR Excess Return on Yield Spread*	1.26	2.55	-0.31	0.86
1 YR Excess Return on Yield Spread (R^2)	0.01	0.07	0.01	0.02
Macroeconomic Volatilities				
Std. Annual Cons. Growth*	0.76	1.15	1.59	1.15
Std Annual Change Fed Funds Rate*	1.64	2.26	0.65	1.40
Std. Annual Change 10-Year Subj. Infl. Forecast*	0.62	0.47	0.12	0.12

Ten-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 ten-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. Moments that were explicitly targeted in the calibration procedure are noted with an asterisk. The expected bond excess return in the data starts in 1985 and is defined as the one-year subjective expected return on an 11-year par bond relative to the four-quarter forecast of the 10-year nominal bond yield with no Jensen's inequality adjustment using Blue Chip financial forecasters bond yield forecasts following Piazzesi, Salomao and Schneider (2015) and Nagel and Xu (2022). The model bond excess return is the steady-state excess return for a zero-coupon ten-year bond.

Figure 3: Model Campbell-Shiller Predictability by Inflation Expectations
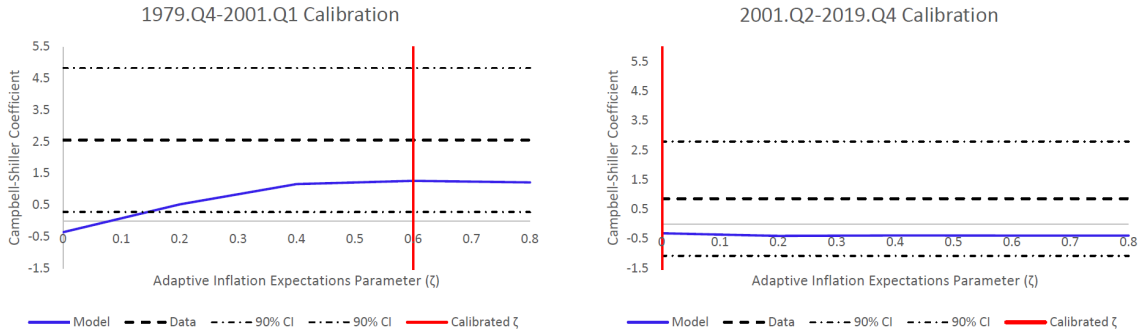
This figure shows the model Campbell-Shiller bond excess return predictability regression coefficient as in Table 2 against the parameter determining the adaptiveness of inflation expectations, ζ. All other parameters are as in Table 1. The data coefficient is shown in as a black dashed line with 90% confidence intervals based on Newey-West standard errors with 4 lags.

The bottom panel of Table 2 shows the targeted macroeconomic volatilities. The decline in the volatility of long-term inflation expectations from the 1980s to the 2000s in the data is well-matched, and the consumption growth and fed funds rate volatilities are roughly in line with the data. The model somewhat undershoots the volatility of changes in the fed funds rate in both periods, potentially due to monetary policy timing decisions about the very short-term policy rate that the model does not aim to capture and that are empirically less important for asset prices (Bernanke and Kuttner (2005)). Overall, the calibration captures intuitive macroeconomic changes from the 1980s to the 2000s.

3.4   Adaptiveness of Inflation Expectations and Leverage

I choose the adaptive inflation expectations parameter $\zeta \in \{0, 0.6\}$ to match the empirical evidence on bond excess return predictability for each subperiod, while holding all other parameters constant at their values chosen in the second step. This step is kept separate because solving for asset prices is orders of magnitudes slower than solving for macroeconomic dynamics. The objective function minimized in this step is equation (30) plus the squared standardized difference between the model and data Campbell-Shiller bond return predictability coefficient with a weight of 100.[21]

Figure 3 shows the predictability of bond excess returns from the yield spread at different

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[21]Inflation forecast error regressions along the lines of Coibion and Gorodnichenko (2015) further support partially adaptive inflation expectations in the 1980s and rational inflation expectations in the 2000s (see Appendix Table A3).

values for the inflation expectations parameter, ζ. The model-implied Campbell-Shiller coefficients in Figure 3 indicate that we can reject fully rational inflation expectations for the 1980s subperiod. Of course, the distance to the macroeconomic dynamics is affected by varying ζ in this separate step. However, viewed more broadly within the econometric literature on inflation dynamics the macroeconomic fit actually improves, as setting $\zeta = 0.6$ in the 1980s calibration makes the policy rate response in the left plot of Panel C more persistent, in line with empirical evidence of a strong persistent inflation component during the 1980s (Stock and Watson (2007)). Appendix Figure A2 compares the model fit with $\zeta = 0$ vs. $\zeta = 0.6$.

The leverage parameter effectively scales up stock returns, but leaves all other model implications unchanged. I set it to roughly match the volatility of equity returns in the data. The model does not require high leverage, with $\delta = 0.5$ for the 1980s calibration corresponding to a debt-to-assets ratio of 50%, and $\delta = 0.66$ for the 2000s calibration corresponding to a debt-to-assets ratio of 33%.

3.5   Asset Pricing Implications

The top panels of Table 2 show that asset pricing habit preferences generate quantitatively plausible time-varying risk premia and volatilities in stocks and bonds. The model matches a high equity Sharpe ratio, equity volatility, stock excess return predictability, and the persistence of price-dividend ratios just like Campbell and Cochrane (1999) and Campbell, Pflueger and Viceira (2020), which would not be possible in a model with constant risk aversion (Mehra and Prescott (1985)). Appendix Tables A1 and A2 show that time-varying risk premia are responsible for the vast majority of model stock and bond returns, and drive about 90% of bond-stock covariances.

The middle panel in Table 2 shows that the model explains the motivating evidence in Figure 1, Panel A, even though bond-stock betas were not explicitly targeted in the calibration. The model-implied nominal bond beta is strongly positive and much larger than the real bond beta in the 1980s calibration, but negative and close to the real bond beta in the 2000s calibration, similar to the data. Model-implied nominal Treasury bond excess returns are volatile in the 1980s calibration and much less volatile in the 2000s calibration, again similar to the data.[22]   Steady-state expected bond excess returns in the model are

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[22]Nominal bond betas in the model are somewhat less negative in the 2000s calibration than in the model. This could be fixed by making demand shocks serially correlated, which would make demand shocks more powerful and also make the relationships more persistent in the right plots of Figure 2 Panels A and B, similar to the data. However, there is a trade-off between clarity and introducing additional parameters to the model, especially when additional state variables would not change the basic mechanism in the model, and I therefore do not pursue this additional state variable. My model is consistent with Duffee (2011)'s

closely related to betas, and switch sign from positive in the 1980s calibration to negative in the 2000s calibration. This pattern is consistent with empirical subjective expected bond excess returns, constructed by subtracting the survey expected interest rate path (Piazzesi, Salomao and Schneider (2015), Nagel and Xu (2022)). Subjective expected bond excess returns may be a better measure of ex-ante expected risk premia in the model, if ex-post realized returns in the 2000s were biased upwards as investors were repeatedly surprised by lower-than-expected interest rates (Cieslak (2018), Farmer, Nakamura and Steinsson (2021)).

The 1980s calibration generates a positive regression coefficient of ten-year nominal bond excess returns with respect to the lagged slope of the yield curve, as in the data and targeted in the calibration. On the other hand, the 2000s calibration does not generate any such bond excess return predictability, which is also in line with a much weaker and statistically insignificant relationship in the data. In unreported results, I find that the model does not generate 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 predictability in nominal than real bond excess returns after adjusting for time-varying liquidity.

4 Counterfactual Analysis and Economic Mechanism

What would it take for bonds to become similarly risky as in the stagflationary 1980s, and what would this tell us about the economy? In this Section, I show how nominal and real bond betas change in the model as I vary the economy's exposure to fundamental shocks, the monetary policy rule, and the adaptiveness of wage-setters' inflation expectations.

4.1 Counterfactual Monetary Policy vs. Shock Volatilities

Figure 4 shows that nominal bond betas remain negative but real bond betas increase in the presence of shock volatilities similar to the 1980s, provided that the monetary policy framework is more output-focused, less inflation-focused and more inertial than during the 1980s. The model therefore provides a simple account for the recent empirical evidence in Figure 1, Panel B, which shows negative nominal bond-stock betas but increasing real bond-stock betas.

Panel A starts from the 1980s calibration and shows that changing either the shock volatilities or the monetary policy rule towards the 2000s calibration flips nominal bonds from risky (i.e. positive nominal bond beta) to safe (i.e. zero or negative nominal bond

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evidence of low volatility of inflation expectations relative to bond yields ("inflation variance ratios"), as he also finds that habit models give reasonable implications due to their volatile risk premia. Inflation variance ratios in my model range between $1/3$ to $1/2$.

Figure 4: Bond Betas by Shock Volatilities vs. Monetary Policy

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

Panel B: Starting from 2001.Q2-2019.Q4 Calibration
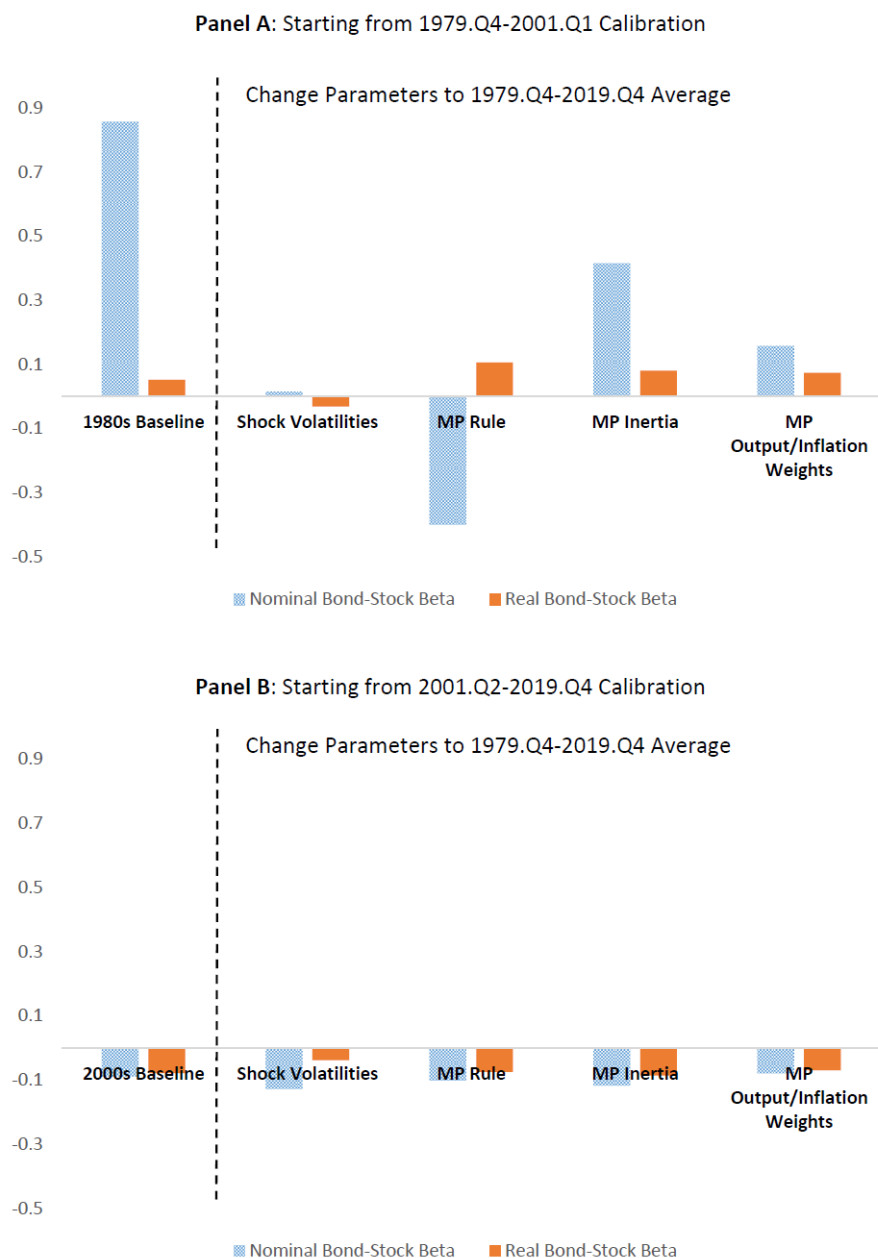
This figure shows model-implied nominal and real bond betas while changing parameter groups one at a time. Panel A sets all parameter values to the 1979.Q4-2001.Q1 calibration unless stated otherwise. It then reports the beta while setting the following parameters to the average of the 1979.Q4-2001.Q1 and 2001.Q2-2019.Q4 values: "Shock Volatilities" (σ_x, σ_π, and σ_i), "MP Rule" (ρ^i, γ^x and γ^π), "MP Inertia" (ρ^i), and "MP Output/Inflation Weights" (γ^x and γ^π). Panel B does the reverse exercise, holding all parameter values constant at the 2001.Q2-2019.Q4 baseline.

beta).[23] Said differently, the model does not imply positive nominal bond-stock betas unless it has both: 1980s-style shock volatilities and a 1980s-style monetary policy rule. However, the implications for real bond-stock betas differ. The real bond-stock beta in the "MP Rule" counterfactual in Panel A turns positive, depicting a "third case" with distinct bond-stock beta implications different from either the 1980s or the 2000s calibrations. The real bond-stock beta in this counterfactual is positive because supply and monetary policy shocks dominate, moving the output gap inversely to the real rate along the Euler equation (17). The next two columns in Panel A show that monetary policy inertia (ρ^i) and the long-term inflation and output weights (γ^x, γ^π) both matter, but are not individually sufficient to eliminate positive nominal bond betas. Figure A1 in the Appendix decomposes the "Shock Volatilities" column, and shows that the lower counterfactual nominal bond beta is driven by both the lower volatility of supply shocks and higher volatility of demand shocks in the 2000s calibration, while the negative counterfactual real bond beta is a function of the higher demand shock volatility in the 2000s calibration.

Panel B of Figure 4 shows the central result, namely that starting from the 2000s calibration none of the changes to individual parameter groups have the power to flip the sign of nominal bond betas. Most tellingly, the "Shock Volatilities" column implies that even if the shock volatilities were to resemble the 1980s, an inertial and more output-focused monetary policy rule as in the 2000s would keep nominal bond-stock betas negative. The counterfactual real bond beta increases, even though it does not quite turn positive. This is similar to the "MP Rule" column in Panel A, which also combines 1980s-style shocks with a 2000s-style monetary policy rule. Overall, these counterfactuals indicate that positive nominal bond-stock betas and stagflations are not the result of fundamental economic shocks or monetary policy in isolation, but instead require the interaction to create a "perfect storm".

4.2 Model Macroeconomic Impulse Responses

Figure 5 illustrates the mechanism through model impulse responses for the output gap, nominal policy rate, and wage inflation to one-percentage-point demand, supply, and monetary policy shocks. Because of the structure of the model, the macroeconomic impulse responses preserve the intuition of a standard log-linearized three-equation New Keynesian model for given parameter values, but parameter values are partly chosen to match evidence on bond excess return predictability.

The first column in Figure 5 shows that demand shocks move the output gap, the policy rate, and inflation in the same direction, as if the economy moves along a stable Phillips

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[23]In some cases, the equilibrium may not exist if I move a parameter group all the way to the other calibration, so for comparability I move all parameter groups to the average of the 1980s and 2000s calibrations.

Figure 5: Model Macroeconomic Impulse Responses
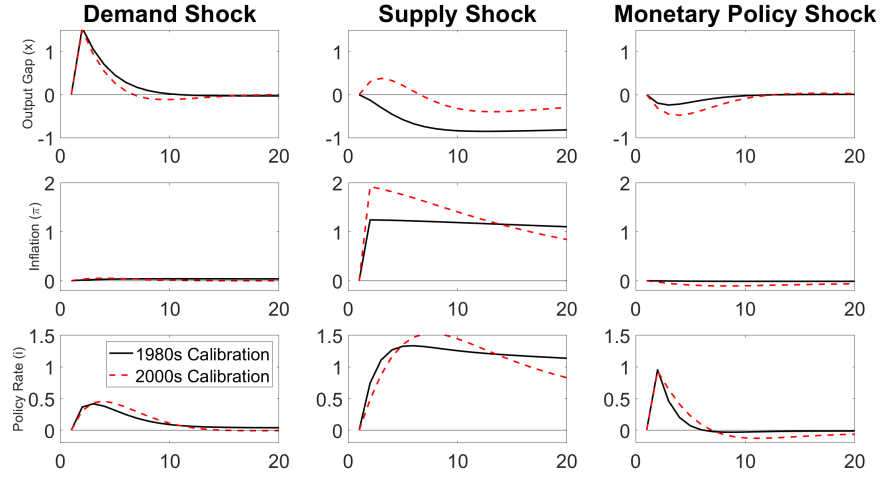
This figure shows model impulse responses for the output gap (%, top row), inflation (ann %, middle row), and nominal policy rate (ann. %, bottom row). The impulse in the left column is a one-percentage-point demand shock, in the middle column is a one-percentage-point cost-push or supply shock, and in the right column is a one-percentage-point 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 red dashed.

curve. The responses are similar for the 1980s and 2000s calibrations, though of course the volatility of demand shocks is much higher in the 2000s calibration.

The middle column shows the interaction between supply shocks and systematic monetary policy. For the 1980s calibration a positive supply shock leads to an immediate and persistent jump in inflation, a rapid increase in the policy rate, and a large and persistent decline in the output gap—a stagflation. By contrast, for the 2000s calibration, a monetary policy rule that prescribes very little immediate tightening in response to such a shock implies an initial drop in the real rate, and the output gap follows a much more moderate s-shaped path—a "soft landing". The inflation response for the 2000s calibration is also initially larger but less persistent, due to the less backward-looking Phillips curve in this calibration.

Finally, the third column in Figure 5 shows intuitive responses to monetary policy shocks. A positive monetary policy shock tends to lower the output gap in a hump-shaped fashion and leads to a small and delayed fall in inflation, in line with the empirical evidence from identified monetary policy shocks (Ramey (2016)). The responses to a monetary policy shock are similar across the 1980s and 2000s calibrations.

Taken together, the macroeconomic impulse responses show that a reactive monetary policy rule and volatile supply shocks are needed to generate a stagflation and negative inflation-output gap comovement. By contrast, inflation and the output gap comove little

Figure 6: Model Asset Price Impulse Responses
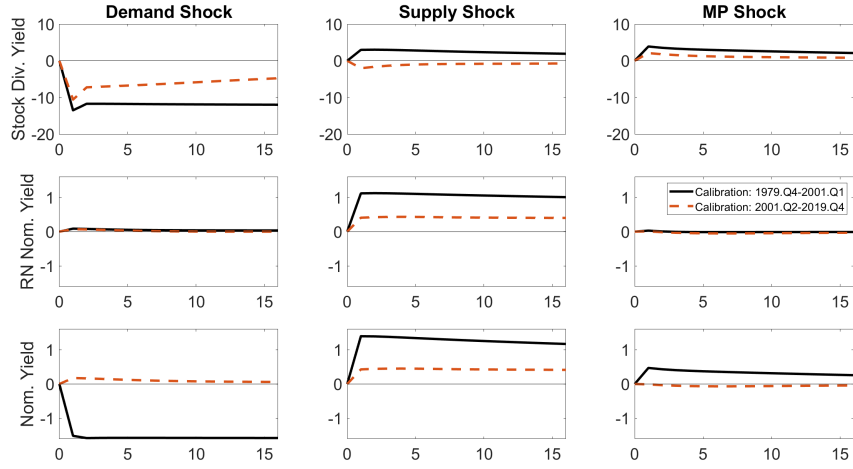
This figure shows model impulse responses for the stock dividend yield, and bond yields for zero-coupon nominal Treasury bonds (all in ann. %) in response to structural shocks. The middle row shows responses for the risk-neutral (or expectations hypothesis) component of ten-year nominal bond yields. The bottom row shows responses for the overall ten-year nominal bond yield. The 1979.Q4-2001.Q1 calibration is shown with black solid lines and the 2001.Q2-2019.Q4 calibration is shown with red dashed lines. The impulse in the left column is a one-percentage-point demand shock, in the middle column is a one-percentage-point cost-push or supply shock, and in the right column is a one-percentage-point monetary policy shock.

if monetary policy engineers a "soft landing" after an inflationary supply shock. Positive inflation-output gap comovement results after demand or monetary policy shocks. The next Section shows how these macroeconomic dynamics translate into asset prices with time-varying risk premia.

4.3 Model Asset Price Impulse Responses

Figure 6 shows impulse responses for the dividend yield of levered stocks (top row), risk-neutral ten-year nominal bond yields (middle row), and the overall ten-year nominal bond yields (bottom row). Risk-neutral nominal bond yields equal the expected average policy rate over the lifetime of the bond, whereas full nominal bond yields include time-varying risk premia. Because dividend yields are inversely related to stock prices and bond yields are inversely related to bond prices, a shock that moves stock dividend yields and bond yields in the same direction tends to induce a positive nominal bond-stock beta and vice versa.

The stock dividend yield response is always dominated by the countercyclical risk premium component, so stock prices rise and stock dividend yields fall whenever a shock raises the output gap in Figure 5. Stocks fall more with an adverse output shock than the present

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discounted value of dividends, as consumption falls towards habit and investors become more risk-averse.

The middle column of Figure 6 shows that the different macroeconomic responses to an inflationary supply shock translate into different nominal bond-stock betas across the 1980s and 2000s calibrations. In both calibrations, both risk-neutral and overall nominal bond yields rise to reflect the heightened inflation expectations after an inflationary supply shock. But only in the 1980s calibration does the stock dividend yield rise as stocks fall, and a deep recession ensues. In the 2000s calibration the stock dividend yield is flat or even falls slightly, as the economy experiences a "soft landing". Because the model uses preferences that replicate the stock risk premium response to policy rate innovations in the data (Bernanke and Kuttner (2005), Pflueger and Rinaldi (2022)), the initial drop in the real rate boosts stock prices beyond its effect on risk-neutral discounted dividends. Supply shocks hence induce a positive nominal bond-stock beta in the 1980s calibration, but not in the 2000s calibration.

The asset price impulse responses to demand and monetary policy shocks in Figure 6 show the significant role of endogenously time-varying risk premia. To understand the intuition, consider the nominal bond yield response to a demand shock for the 1980s calibration. The risk-neutral nominal bond yield behaves as expected from the macroeconomic dynamics and looks very similar across the 1980s and 2000s calibrations, rising slightly as inflation expectations and the policy rate increase. However, the overall nominal bond yield responses in the bottom panel are substantially larger and even switch sign for the 1980s calibration.[24] Dominant supply shocks and a reactive monetary policy rule in the 1980s calibration imply that nominal Treasury bonds have risky cash flows in equilibrium, similar to positive α in equation (29). A positive demand shock is good news for output and consumption, raising consumption relative to habit and leading investors require a lower return to hold risky nominal bonds. This insight can potentially rationalize why nominal Treasury bond-stock betas remained elevated during the 1990s even as supply shocks were subsiding, if investors were concerned that supply shocks remained a prevalent source of volatility in equilibrium. The role of time-varying risk premia reverses for the 2000s calibration, where bond risk premia are smaller and negatively correlated with stock risk premia.

4.4 Counterfactual Prevalent vs. Realized Shocks

Figure 7 shifts the distributions of prevalent vs. realized shocks separately to the demand-shock dominated 2000s calibration, while holding all other parameters constant at the 1980s

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[24]Laarits (2022) and Bok, Mertens and Williams (2022) provide empirical evidence of a changing bond-VIX comovement around 2000, in line with this endogenous risk premium channel.
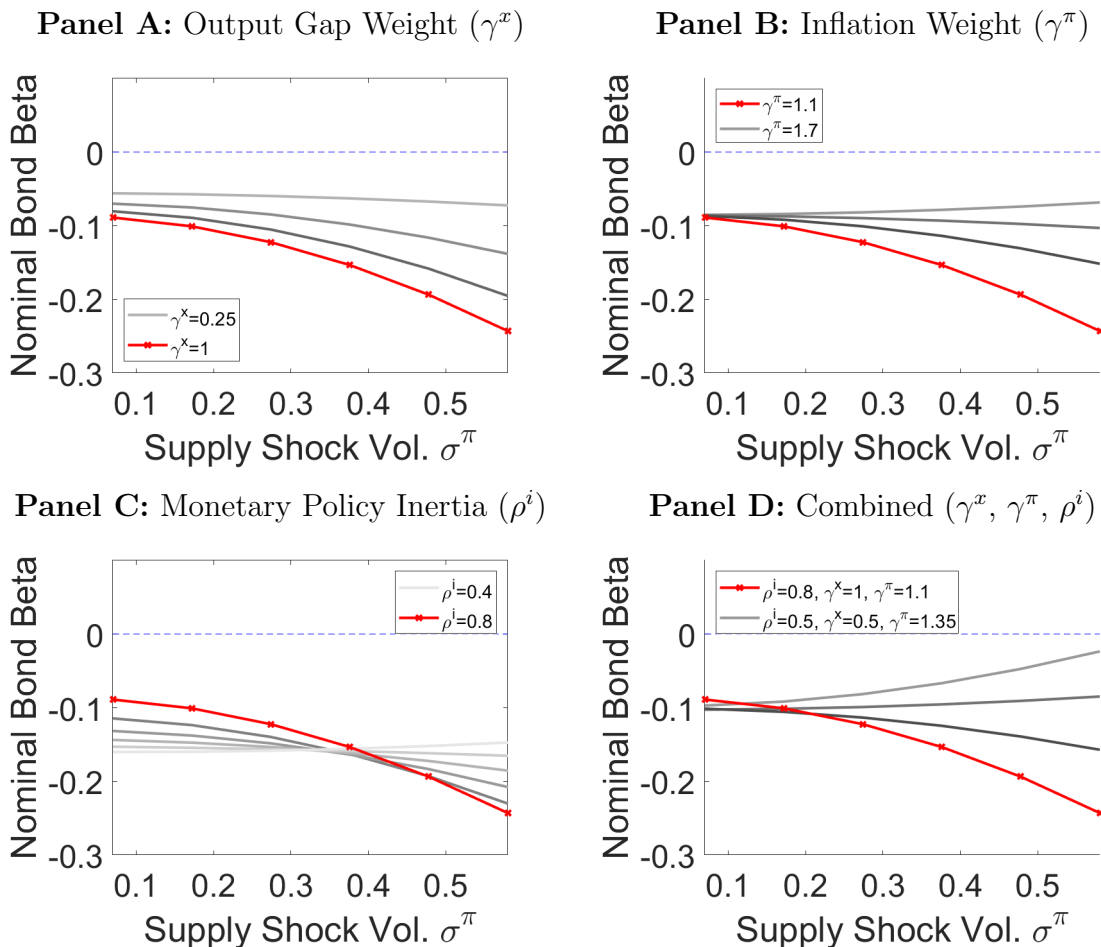
calibration. As previously seen, moving the distributions of both prevalent and realized shocks towards the 2000s calibration eliminates positive nominal bond-stock betas. However, the picture looks different when only realized shocks are drawn from the 2000s distribution and prevalent shocks still follow the 1980s distribution, i.e. equilibrium asset prices are not recomputed. In this case, the full nominal bond-stock beta is positive and only the risk-neutral nominal bond-stock beta turns negative. The mechanism goes back to the bottom-left panel of Figure 6, where full nominal bond yields and dividend yields comove positively after a demand shock in the 1980s calibration, but risk-neutral bond yields and stock dividend yields comove negatively. Countercyclical risk-bearing capacity and time-varying risk premia therefore matter, implying that model bond-stock betas are forward-looking and reflect investors' views of prevalent rather than realized shocks.

Figure 7: Nominal Bond Betas by Prevalent vs. Realized Shocks
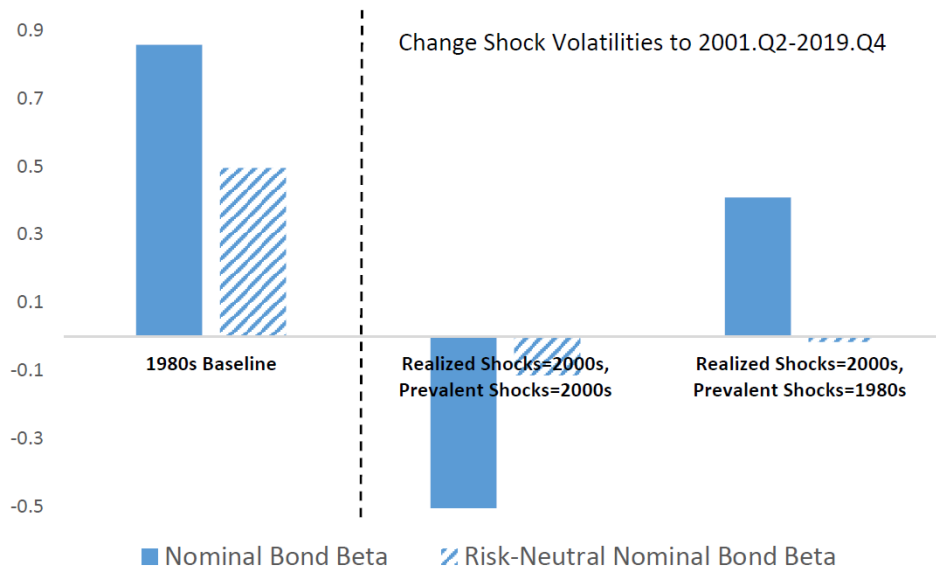
This figure shows model-implied nominal bond betas (solid) and the betas of risk-neutral nominal bond returns with respect to the stock market (dashed) across prevalent and realized shock distributions. The leftmost bars set all parameter values to the 1979.Q4-2001.Q1 calibration. The middle bars change the both the realized and prevalent shock volatilities to the 2001.Q2-2019.Q4 values, i.e. the equilibrium is recomputed at the 2001.Q2-2019.Q4 shock volatilities. The rightmost bars change only the realized but not the prevalent shock volatilities to their 2001.Q2-2019.Q4 values, i.e. equilibrium asset prices are not recomputed and only the simulated shocks drawn from the 2001.Q2-2019.Q4 distribution.

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Figure 8: Nominal Bond Betas by Inflation-Output Weights vs. Monetary Policy Inertia

Panel A: Output Gap Weight (γ^x)

Panel B: Inflation Weight (γ^π)

Panel C: Monetary Policy Inertia (ρ^i)

Panel D: Combined (γ^x, γ^π, ρ^i)

This figure shows model-implied ten-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. Panel A shows different values of γ^x, Panel B shows different values of γ^π, and Panel C shows different values of ρ^i. Panel D moves all three monetary policy parameters in constant increments from the 2000s calibration ($\rho^i = 0.8, \gamma^x = 1, \gamma^\pi = 1.1$) to the 1980s calibration ($\rho^i = 0.5, \gamma^x = 0.5, \gamma^\pi = 1.35$). The 2001.Q2-2019.Q4 calibration monetary policy parameter values are highlighted with red asterisks.

4.5   Counterfactual Monetary Policy Weights vs. Inertia

Figure 8 shows that two types of monetary policy rules keep model nominal bond betas negative even when supply shocks are volatile. First, a monetary policy rule with a lower long-term inflation weight; Second, a monetary policy rule with greater inertia.[25] Comparing

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[25]Panel A varies the long-term output gap weight, γ^x, Panel B varies the long-term inflation weight, γ^π, and Panel C varies monetary policy inertia, ρ^i. Panel D moves all three monetary policy parameters in constant increments from the 2000s calibration to the 1980s calibration. The x-axis moves the volatility

Panels A and B shows that a higher long-term inflation weight acts equivalently to a lower long-term output weight for nominal bond-stock betas as the volatility of supply shocks increases. This makes sense, since the monetary policy authority's relative weight on inflation vs. output-stabilization determines its response to supply shocks. Panel C shows that when the economy is dominated by supply shocks, as on the right part of the x-axis, greater monetary policy inertia also lowers the nominal bond-stock beta. The mechanism in the model is that an inertial monetary policy response softens the blow to investor surplus consumption and risk aversion from an adverse supply shock, thereby preventing stocks and bonds from falling simultaneously.

Finally, Panel D combines the changes in the monetary policy rule from the 1980s calibration to the 2000s calibration, and shows that these changes complement each other. This result suggests that a monetary policy rule in-between the 1980s and 2000s calibrations may give the most plausible explanation for why nominal bond betas remained negative as supply shocks reemerged during the post-pandemic inflation surge 2021-2022.

These results are complementary to Rudebusch and Swanson (2012)'s steady-state comparative statics in a long-run risk model, where nominal term premia are generally positive and largest for a monetary policy rule with weak price level targeting. While resolving the debate between leading asset pricing models is beyond this paper, a perspective based on cyclical risk bearing capacity via habits seems useful for this application, as monetary policy has strong and immediate risk premium implications in the data (Bernanke and Kuttner (2005)).

4.6 Counterfactual Inflation Expectations

The adaptiveness of wage-setters' inflation expectations drives how long inflation remains high after an adverse supply shock. It is therefore relevant to understand how this parameter is reflected in bond risks. Figure 9 shows that nominal bond betas change little with the adaptiveness of wage-setters' inflation expectations. Intuitively, more adaptive wage-setter inflation expectations imply a smaller initial but more persistent inflation response to a supply shock. The expectation of more persistent inflation amplifies the fall in nominal bond prices, but monetary policy also raises rates more slowly, with offsetting effects on bond-stock comovements in the model. Macroeconomic impulse responses at different ζ are depicted in Appendix Figure A3.

However, the adaptiveness of wage-setters' inflation expectations does have important implications for Campbell-Shiller bond excess return predictability in the model, as shown

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of (prevalent and realized) supply shocks. The baseline monetary policy rule from the 2000s calibration is highlighted with red asterisks. All other parameters are held constant at the 2000s calibration.

Figure 9: Nominal Bond Betas by Adaptiveness of Inflation Expectations
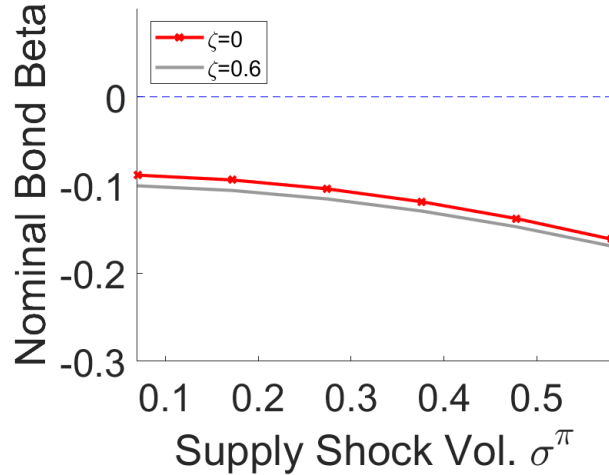
This figure shows model-implied ten-year nominal bond-stock betas against the standard deviation of supply shocks for rational ($\zeta = 0$) and partially adaptive ($\zeta = 0.6$) wage-setter inflation expectations. Unless otherwise labeled all parameter values are set to the 2001.Q2-2019.Q4 calibration. The 2001.Q2-2019.Q4 calibration monetary policy parameter values are highlighted with red asterisks.

in Figure 3. Intuitively, when inflation is highly persistent the expectations hypothesis term in the yield spread cancels, the yield spread predicts future bond excess returns, and the Campbell-Shiller coefficient is positive. Appendix Figure A5 illustrates the mechanism by decomposing the impulse responses for the yield spread into its risk premium and risk neutral components. The link between bond excess return predictability and the persistence of inflation is reminiscent of an older empirical literature that has documented that the expectations hypothesis holds in time periods and countries where interest rates are less persistent (Mankiw, Miron and Weil (1987), Hardouvelis (1994)). It is also consistent with Cieslak and Povala (2015)'s evidence that removing trend inflation uncovers time-varying risk premia in the yield curve. Wage-setters' inflation expectations in this model change the Phillips curve, so this result should be viewed more broadly as a link between the predictability of bond excess returns and the backward-lookingness of the Phillips curve.

5   Conclusion

This paper shows in a New Keynesian asset pricing model with countercyclical risk-bearing capacity that the interaction between volatile supply shocks and monetary policy is priced in positive nominal bond-stock betas, as observed during the stagflationary 1980s. Conversely, a combination of 1980s-style shocks with a more output-focused and inertial monetary policy

rule leads to a "soft landing" in the output gap, negative nominal bond-stock betas, and positive real bond-stock betas, in line with evidence on post-pandemic bond-stock betas.

The mechanism works through the monetary policy trade-off between inflation and output after a supply shock and endogenously time-varying risk premia. An adverse supply shock in the model generally moves inflation expectations up and output down, which leads to simultaneous falls in nominal bond and stock prices. However, monetary policy can alter these implications if the central bank keeps nominal rates sufficiently steady that the short-term real rate falls, mitigating the recession and the impact on investors' willingness to pay for risky stocks. Either a more output-focused monetary policy rule or a "slow-and-steady" monetary policy rule can mitigate the positive bond-stock comovement that would otherwise result from supply shocks. By contrast, demand shocks move output and inflation up and down together relatively independently of monetary policy, and imply negative nominal and real bond-stock betas, as observed during the pre-pandemic 2000s.

Time-varying risk premia generate predictability in stocks and bonds, and imply that bond-stock betas price the distribution of prevalent shocks in equilibrium rather than past realized shocks. When investors are surprised by realizations of volatile demand shocks but bonds and stocks are priced as if 1980s shocks are prevalent, the model nominal bond-stock beta is similarly positive to the 1980s calibration. Intuitively, bond and stock returns are dominated by time-varying risk premia, and in a 1980s-type equilibrium where nominal bonds are stock-like risk premia in bonds and stocks move together. The predictability of bond excess returns is explained in the model if the Phillips curve strongly backward-looking, so the expectations hypothesis component in the yield spread roughly cancels.

Overall, this paper provides a framework to interpret the macroeconomic informational content of bond risks. In particular, when the economy is driven by volatile supply shocks, nominal bond stock betas in the model emerge as a forward-looking indicator of "soft landings". This analysis suggest that further research on financial market comovements as forward-looking indicators is likely to be fruitful.

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