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

Carolin Pflueger

University of Chicago, Harris School of Public Policy, NBER, and CEPR

First Version: July 12, 2022
This Version: July 8, 2023

Abstract

This paper analyzes the informational content of nominal and real bond risks for the economic drivers in a New Keynesian model of monetary policy. Endogenously time-varying risk premia fit standard asset pricing moments for bonds and stocks, and link model nominal bond-stock betas to the shocks prevalent in equilibrium, rather than realized shocks. Counterfactual analyses show that positive nominal bond-stock betas as in the 1980s arise from the combination of supply shocks and a reactive monetary policy rule, but not if supply shocks are accompanied by a more inertial output-focused monetary policy response.

Keywords: Bond betas, stagflation, supply shocks, demand shocks, monetary policy, New Keynesian, habit formation preferences
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 from 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 inflation expectations and nominal bond yields move higher as the stock market falls one might imagine that this indicates supply shocks.[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 formally models the demand, supply, monetary policy drivers of bond-stock betas when risk premia 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—as intuition suggests with supply shocks—but changed sign and became negative during the 2000s—as intuition suggests with demand shocks. The beta of inflation-indexed bonds also changed but was substantially smaller during the 1980s, indicating that inflation expectations played a role for nominal bonds. Maybe

---

[1]Recent policy applications of this intuition include 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
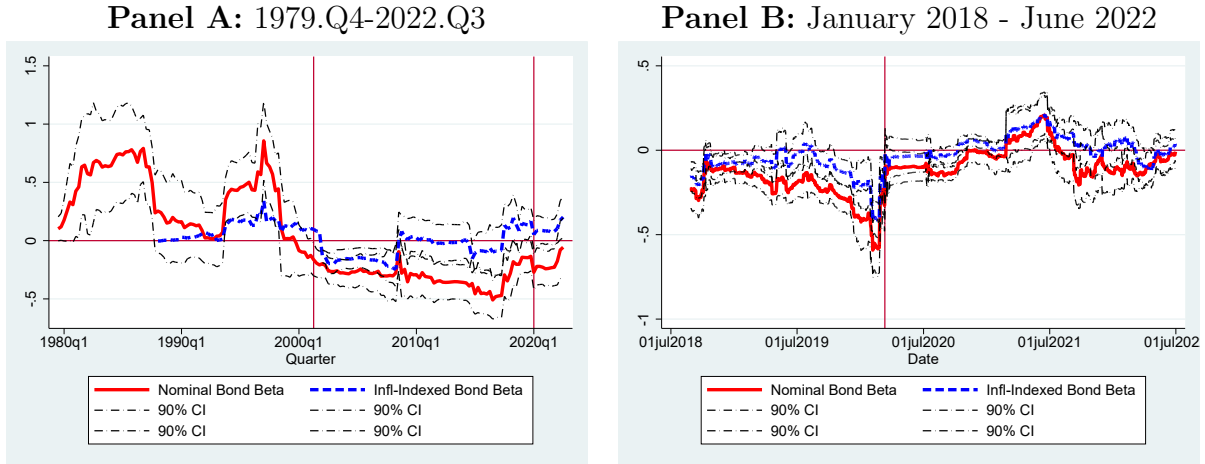
Note: Panel A shows betas from regressing quarterly ten-year Treasury bond excess returns onto quarterly US equity excess returns over five-year rolling windows for the period 1979.Q4-2022.Q3. Quarterly excess returns are in excess of three-month T-bills. Prior to 1999, I replace US Treasury Inflation 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.

surprisingly, the post-pandemic picture looks different from either the 1980s or the 2000s. In contrast to the 1980s, real bond betas increased this time and nominal betas remained negative even as inflation surged through mid-2022.

My model integrates a small-scale New Keynesian framework (e.g. Galí (2008)), with an asset pricing model that captures salient features in stocks and bonds, such as the high volatility of stock relative to fundamentals (Shiller (1981)) and the risk premium effects of monetary policy (Bernanke and Kuttner (2005), Pflueger and Rinaldi (2022)). I use the habit formation preferences of Campbell, Pflueger and Viceira (2020) to derive an exactly log-linear macro Euler equation, and price stocks and bonds. These preferences imply that risk bearing capacity falls following an adverse output surprise and thereby generate endogenously time-varying risk premia. Different from this prior work, the model in this paper features supply and demand shocks and partially adaptive inflation expectations in the economy, which allows me to analyze how different shocks interact with monetary policy and inflation expectations to drive bond risks.

The demand shock in the Euler equation arises from a preference shock for bonds, just

like a safety shock in the international finance literature or a credit spread shock (Gilchrist and Zakrajšek (2012)).[3] Alternatively, the demand shock can be interpreted as a shock to growth expectations that leads to business cycle fluctuations (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 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 start by calibrating 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.[4] 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 (i.e. "stagflations") to positive. Preference parameters are as in Pflueger and Rinaldi (2022) and the slope of the Phillips curve is set to the value estimated by Hazell, Herreno, Nakamura and Steinsson (2022). 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). The model matches equity market moments, such as the equity Sharpe ratio, the persistent price-dividend ratio,

---

[3]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). Pflueger, Siriwardane and Sunderam (2020) provide US evidence that preference for safety not immediately driven by aggregate risk aversion can forecast business cycle variables.

[4]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) and Bauer, Pflueger and Sunderam (2022) for direct empirical evidence of the Fed's output concern after the mid-1990s.

and stock excess return predictability from the price-dividend ratio equally well as Campbell and Cochrane (1999) or Campbell, Pflueger and Viceira (2020), so bond risks in the model are based on a plausible description of countercyclical risk premia in the aggregate economy.

I next use the calibrated model for a series of counterfactual analyses to disentangle the economic drivers of bond-stock betas. The first counterfactual varies the monetary policy rule vs. the volatilities of shocks. The key result is that combining 1980s-style shocks with 2000s-style monetary policy implies negative nominal bond betas, whereas real bond-stock betas rise. Intuitively, when monetary policy allows the real rate to fall in response to an inflationary supply shock, the recession is mitigated. Stocks benefit even more than the real economy, as investors' consumption remains further from habit, increasing their willingness to pay for risky stocks. Because there is little "stagflation" risk in equilibrium, nominal bond betas do not turn positive in this counterfactual. Real bonds in this third case counterfactual mostly load on monetary policy shocks, which tend to increase output and stock prices just as the real rate declines, and raise the correlation between real bond prices and stock prices, just as in the post-pandemic data in Figure 1.

The second counterfactual shows that the role of prevalent shocks is crucial, whereas the changing nature of realized shocks has only a minor effect on bond-stock betas. Concretely, the model implies that nominal bond-stock betas remain positive as long as 1980s-style shocks are perceived to be prevalent and 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 it is 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 hence reflect investors' views about prevalent rather than past realized shocks and should be interpreted as forward-looking indicators.

The third counterfactual separates the long-term monetary policy weights on inflation and output vs. monetary policy inertia. In the model, a "slow-and-steady" approach to monetary policy with greater weight on lagged interest rates can protect nominal bond-stock betas from turning positive (and hence risky in a CAPM sense) in the face of supply shocks, as can 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 in New Keynesian models (Clarida, Gali and Gertler (2000)). The intuition is that either monetary policy inertia or a low long-term inflation weight are sufficient to drive down the short-term real rate in response to an inflationary supply shock, mitigating the

fallout on output and consumption. Because in my model real rate surprises have strong effects on stock risk premia (Bernanke and Kuttner (2005)), stock prices fall less or even rise as bond prices fall. Despite their macroeconomic differences, either type of monetary policy rule hence keep nominal bond-stock betas negative in the presence of volatile supply shocks. Overall, observing negative nominal bond betas in the face of supply shocks need not imply that investors think the central bank has a low inflation weight, but may instead be consistent with a "slow-and-steady" monetary policy response.

The fourth counterfactual turns to the adaptiveness of inflation expectations by wage-setting agents. While bond-stock betas in my model do not depend strongly on the backward-lookingness of the Phillips curve, the predictability of bond excess returns as in Campbell and Shiller (1991) does. In the 1980s calibration, adaptive wage-setter inflation expectations lead to a persistent inflation process (Fuhrer (1997)), so the expectations hypothesis component roughly cancels from the spread between long- and short-term nominal interest rates. The yield spread therefore loads onto time-varying risk premia and predicts future bond excess returns, explaining the long-standing evidence of Campbell and Shiller (1991). For the 2000s, the model generates no predictability in nominal bond excess returns, consistent with the data for this subperiod. Bond risks in this model therefore contribute to the literature on forward- vs. backward-looking Phillips curves (Fuhrer (1997)).

This paper contributes to the broad 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.[5] More recently, several authors have argued that the reemergence of inflation can at least be partly attributed to supply-type shocks (e.g. Rubbo (2022), Harding, Lindé and Trabandt (2022), Di Giovanni et al. (2022)). I contribute to this literature by studying the asset pricing implications and showing that bond risks are a forward-looking indicator.

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.[6] This distinguishes my model from monetary policy-asset pricing models with constant risk premia. While my model builds on habit formation preferences, the findings should be regarded

---

[5]See e.g. Stock and Watson (2002), Sims and Zha (2006), Primiceri (2006), Justiniano and Primiceri (2008), Clarida, Gali and Gertler (2000), Lubik and Schorfheide (2004), Bernanke, Gertler and Watson (1997).

[6]Some research, including Uhlig (2007), Dew-Becker (2014), and Rudebusch and Swanson (2008) has used simplified habit formation preferences, and discusses some of the challenges in integrating asset pricing habit formation preferences into New Keynesian models. Verdelhan (2010) and Wachter (2006) show that similar finance habit preferences combined with more reduced-form models of the macroeconomy can explain risk premia in foreign exchange and bond markets, respectively.

more broadly as the result of 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 (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 wide range of classic macroeconomic and asset pricing puzzles.

Finally, this paper also contributes to the growing literature on changing bond risks. This paper is complementary to the perspectives of Rudebusch and Swanson (2012), Bianchi, Lettau and Ludvigson (2022a), Bianchi, Ludvigson and Ma (2022b), Gourio and Ngo (2020), and Li, Zha, Zhang and Zhou (2022), who model changing bond risk premia or bond risks within New Keynesian models, but focus on the role of monetary policy with constant shock volatilities and constant risk aversion. Gourio and Ngo (2022) study the complementary channel of downward-price rigidity in a model with Epstein-Zin preferences. Caballero and Simsek (2022) provide a highly stylized model of optimal monetary policy when asset prices matter for the economy. Several papers have also studied changing bond risks in more reduced-form models (e.g. Piazzesi and Schneider (2006), Baele, Bekaert and Inghelbrecht (2010), Viceira (2012), David and Veronesi (2013), Song (2017)). 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, and do not model supply shocks, demand shocks or their interaction with monetary policy. 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. On the empirical side, 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. Laarits (2022) and Bok, Mertens and Williams (2022) provide empirical evidence of a changing bond-VIX comovement, in line with the endogenous risk premium channel in my model.

The rest of the paper proceeds as follows. Section 2 describes the model. Section 3 describes the calibration procedure and model properties. Section 4 presents the counterfactual exercises. Finally, Section 5 concludes.

2 Model

The model combines a small-scale log-linearized New Keynesian model with supply and demand shocks and a model of habit-formation preferences for asset prices. I use lower-case letters to denote logs, 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:

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

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)

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

$$\bar{S} = \sigma_c\sqrt{\frac{\gamma}{1 - \theta_0}}, \tag{7}$$

$$\bar{s} = \log(\bar{S}), \tag{8}$$

$$s_{max} = \bar{s} + 0.5(1 - \bar{S}^2). \tag{9}$$

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), the specification for log surplus consumption (3) implies that log market habit follows approximately a weighted average of lagged consumption and lagged consumption expectations.

2.2 Asset Pricing Equations and Bond Preference Shock

Investors price bonds and stocks with the stochastic discount factor arising from consumption utility (1). The stochastic discount factor (SDF) for consumption claims M_{t+1} in this economy equals:

$$M_{t+1} = \beta\frac{\frac{\partial U_{t+1}}{\partial C}}{\frac{\partial U_t}{\partial C}} = \beta\exp\left(-\gamma(\Delta s_{t+1} + \Delta c_{t+1})\right). \tag{10}$$

The bond asset pricing recursions are subject to a preference shock ξ_t, akin to the safety shock that has been found successful at reconciling several empirical puzzles in international finance.[7] 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

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

---

[7]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).

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. The assumption that all bonds are priced with the preference shock ξ_t ensures that in the absence of uncertainty the expectations hypothesis holds for nominal and real bonds.

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

$$\frac{P_{n,t}^c}{C_t} = E_t\left[M_{t+1}\frac{C_{t+1}}{C_t}\frac{P_{n-1,t+1}^c}{C_{t+1}}\right]. \tag{15}$$

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

$$\frac{P_t^c}{C_t} = \sum_{n=1}^{\infty}\frac{P_{n,t}}{C_t}. \tag{16}$$

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 preference shock ξ_t allows for several interpretations, corresponding to two classes of asset price-related demand shocks proposed in the literature (Bernanke and Gertler (2001), Gilchrist and Leahy (2002)). First, and most simply, an increase in ξ_t may reflect that households do not have direct access to the fed funds 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 an increase in intermediaries' ability to intermediate the private loan market (Gilchrist and Zakrajšek (2012), Bianchi and Lorenzoni (2021)). Second, ξ_t can be interpreted as a shock to expected (but not necessarily realized) potential output growth, decreasing the valuations of bonds relative to stocks at any given level of current consumption. Such an interpretation is similar to expectations-based demand shocks proposed by Beaudry and Portier (2006), Angeletos and La'O (2013), De La'O and Myers (2021), Bordalo, Gennaioli, LaPorta and Shleifer (2022) and the "traditional financial forces" shock

in Caballero and Simsek (2022).[8] My results do not depend on the specific interpretation of ξ_t within these broad categories. The next Section shows that a negative bond preference shock gives rise to a positive demand shock in the macroeconomic Euler equation.

2.3 Macroeconomic Euler Equation from Preferences

The macroeconomic Euler equation is simply the asset pricing equation for a one-period risk-free bond (11). Substituting for the SDF and surplus consumption dynamics gives (up to a constant):

$$
\begin{aligned}
r_t &= \gamma E_t \Delta c_{t+1} + \gamma E_t \Delta s_{t+1} - \frac{\gamma^2}{2} \left(1 + \lambda(s_t)\right)^2 \sigma_c^2 + \xi_t, \tag{17} \\
&= \gamma E_t \Delta c_{t+1} + \gamma \theta_1 x_t + \gamma \theta_2 x_{t-1} + \underbrace{\gamma(\theta_0 - 1)s_t - \frac{\gamma^2}{2} \left(1 + \lambda(s_t)\right)^2 \sigma_c^2}_{=0} + \xi_t. \tag{18}
\end{aligned}
$$

The sensitivity function (6) through (9) 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**:

$$
x_t = f^x E_t x_{t+1} + \rho^x x_{t-1} - \psi r_t + v_{x,t}. \tag{19}
$$

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

$$
\rho^x = \frac{\theta_2}{\phi - \theta_1}, f^x = \frac{1}{\phi - \theta_1}, \psi = \frac{1}{\gamma(\phi - \theta_1)}, \theta_2 = \phi - 1 - \theta_1. \tag{20}
$$

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

$$
v_{x,t} = \psi \xi_t. \tag{21}
$$

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

---

[8]Details of these two sets of microfoundations are presented in Appendix C. I model demand shocks as arising from a preference shock for bonds rather than from a shock to the discount factor β shared by bonds and stocks (Albuquerque, Eichenbaum, Luo and Rebelo (2016)), because a shock to the discount factor β would generate strongly positive bond-stock correlations, in stark contrast to the post-2000 data.

denoted by σ_x. 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 a decline in expected potential output growth.

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. Because the supply side is largely standard, I only provide an overview and relegate details to the Appendix. There is no real investment, and the aggregate resource constraint simply states that aggregate consumption equals aggregate output:

$$C_t = Y_t. \tag{22}$$

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 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**:

$$\pi_t^w = f^\pi E_t \pi_{t+1}^w + \rho^\pi \pi_{t-1}^w + \kappa x_t + v_{\pi,t}, \tag{23}$$

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.[9]

---

[9]While I do not model fiscal sources of inflation, under certain conditions a shock to inflation expectations

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

$$\tilde{E}_t \pi_{t+1}^w = (1 - \zeta)E_t \pi_{t+1}^w + \zeta \pi_{t-1}^w, \tag{24}$$

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). The case $\zeta = 0$ corresponds to rational forward-looking inflation expectations, while $\zeta > 0$ reflects partially adaptive inflation expectations. 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)).[10] If $\rho^{\pi,0}$ is the backward-looking component obtained under rational inflation expectations ($\zeta = 0$), the backward- and forward-looking Phillips curve parameters equal:

$$\rho^\pi = \rho^{\pi,0} + \zeta - \rho^{\pi,0}\zeta, \ f^\pi = 1 - \rho^\pi. \tag{25}$$

Ten-year survey inflation expectations are modeled similarly to wage-setters' expectations 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:

$$\pi_t = \pi_t^w - (1 - \phi)x_{t-1}. \tag{26}$$

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.[11]

---

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 would also be 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 actual output gap and x_t the output gap perceived by consumers and the central bank.

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

[11]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 ensure that a claim to firm profits behaves similarly to a claim to

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):

$$i_t = \rho^i i_{t-1} + \left(1 - \rho^i\right)\left(\gamma^x x_t + \gamma^\pi \pi_t\right) + v_{i,t}, \tag{27}$$

$$v_t \sim N\left(0, \sigma_i^2\right). \tag{28}$$

Here, $\gamma^x x_t + \gamma^\pi \pi_t$ denotes the central bank's interest rate target, to which it adjusts slowly.[12] 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 interest rate above and beyond the rule, which then mean-reverts at rate ρ^i.

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

$$Y_t = [x_t, \pi_t^w, i_t]'. \tag{29}$$

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

$$v_t = [v_{x,t}, v_{\pi,t}, v_{i,t}], \tag{30}$$

according to the consumption Euler equation (19), the Phillips curve (23), the monetary policy rule (27), and the wage-price inflation link (26). I solve for a minimum state variable

---

consumption in an asset pricing sense. Appendix D shows that model's results are robust to setting wage and price inflation equal.

[12]I do not model the zero lower bound here, 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.

equilibrium of the form

$$Y_t = BY_{t-1} + \Sigma v_t, \tag{31}$$

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 (31) 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 (31) 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 specific asset and 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:

$$E_t \left[r_{1,t+1}^{c,\alpha} - r_t \right] + \frac{1}{2} Var \left(r_{1,t+1}^{c,\alpha} \right) = \text{Cov}_t \left(-m_{t+1}, x_{t+1} \right) = \alpha \gamma \left(1 + \lambda \left(s_t \right) \right) \sigma_c^2. \tag{32}$$

This expression shows that assets with risky real cash flows ($\alpha > 0$) require positive risk premia. Since $\lambda(s_t)$ is downward-sloping, it also illustrates that 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. How nominal bond risk premia respond to a consumption surprise is therefore endogenous to the macroeconomic equilibrium.

Because full asset prices are not one-period claims, I use numerical value function iteration to solve the recursions (13) through (16) while accounting for the new demand shock and the link between wage and price inflation (26). 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 at the end of the paper. However, because the pandemic period represents a small portion of the sample, little would change if I folded it into the post-2001.Q2 sample period. I do not account for the possibility that agents might have anticipated a change in regime.[13] 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.

3.2 Invariant Parameters

The calibration proceeds in three steps. First, I set some parameters to values following the literature. Those invariant parameter values are held constant across both subperiods and are listed 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 basically flat over a range of values (*correlation* = 76% at $\phi = 0.93$ vs. *correlation* = 73% at $\phi = 0.99$), and a larger value for ϕ minimizes the gap between price and wage inflation and therefore simplifies the model.

---

[13]Cogley and Sargent (2008) have shown 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 for parameters shown in parentheses are computed after the second calibration/estimation step, minimization of the objective function (33). Standard errors are computed using the delta method with details given in Appendix E.

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 the monetary policy rule and Phillips curve parameters, I effectively match habit preferences to the output response to an identified monetary policy shock in the data. 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 A2 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

In a second step, I set period-specific monetary policy parameters and shock volatilities through a Simulated Methods of Moments step. 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:

$$\left\| \frac{\hat{\Psi} - \Psi(\sigma_x, \sigma_\pi, \sigma_i, \gamma^x, \gamma^\pi, \rho^i; \zeta = 0)}{SE(\hat{\Psi})} \right\|^2. \tag{33}$$

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, inflation-fed funds rate lead-lag relationships at three different horizons.[14]
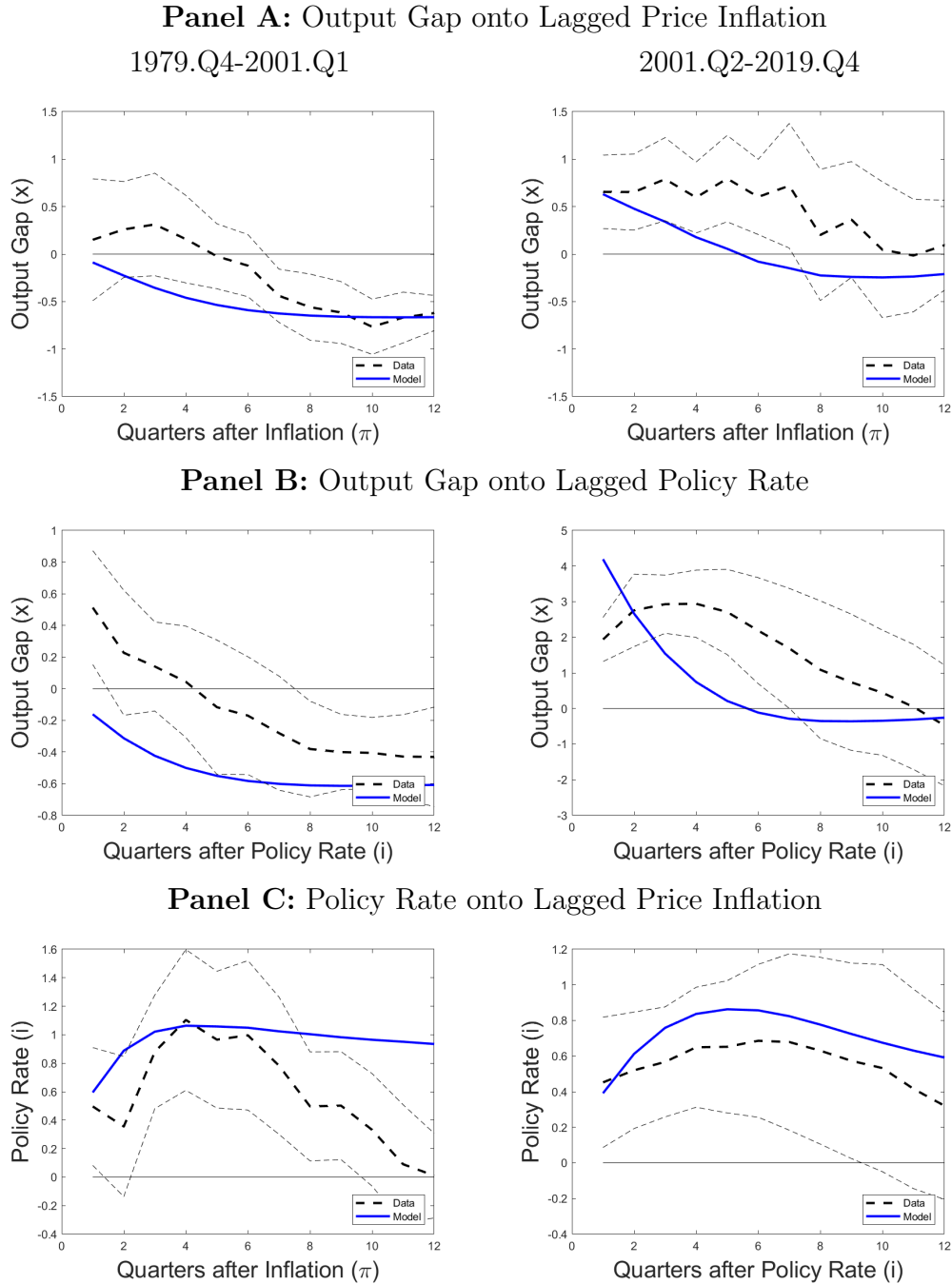
The targeted inflation-output, policy rate-output, and policy rate-inflation comovements are regression coefficients $a_{1,h}$ at horizons one, three, and seven quarters, and are shown in Figure 2:

$$z_{t+h} = a_{0,h} + a_{1,h} y_t + a_{2,h} y_{t-1} + \varepsilon_{t+h}. \tag{34}$$

I consider the variable combinations $(z_t, y_t) = (x_t, \pi_t)$, $(z_t, y_t) = (x_t, i_t)$, and $(z_t, y_t) = (\pi_t, i_t)$. For the second calibration period when wage inflation data is easily available, I also estimate

---

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

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.

the specification $(z_t, y_t) = (x_t, \pi_t^w)$ and include the difference $a_{1,h}^{x,\pi} - a_{1,h}^{x,\pi^w}$ in the vector of target moments $\hat{\Psi}$. The regressions (34) are run analogously on actual and model-simulated data and control for lagged values of the right-hand-side variable in the manner of Jordà (2005). 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 for the standard deviations of macroeconomic annual changes and with Newey-West standard errors with h lags.

I match many more empirical moments than I have parameters, so this is a demanding calibration objective.[15] The rationale for including several lags is that, for example, the negative inflation-output gap relationship ("stagflation") in the left plot in Panel A 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 necessarily at every lag.

The model successfully matches the salient changes in inflation-output-policy rate relationships between the 1980s vs. the 2000s. Figure 2, Panel A shows that model matches the negative inflation-output gap relationship ("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 high standard deviation of demand shocks for the 2000s calibration. While the model inflation-output gap relationship for the 2000s calibration is not quite as positive in the data, the key upward-shift in the inflation-output relationship from the first to the second period is well replicated in the model.

---

[15]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.

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.

Panel B turns to the relationship between the output gap and the fed funds rate. The model matches the left plot by setting a high volatility of monetary policy shocks for the 1980s calibration, which tend to lead to a recession after an increase in the policy rate in the model. The model matches the right plot by setting a high volatility of demand shocks combined with a strong monetary policy response to output (γ^x) for the 2000s calibration.[16]

The lead-lag relationship between inflation and the fed funds rate in Panel C mostly pins down the monetary policy rule parameters. In particular, while the calibrated inflation weights γ^π in Table 1 are greater than one for both subperiods, the 1980s calibration features a higher inflation weight γ^π, a lower output gap weight γ_x, and a lower inertia parameter ρ^i, while the 2000s calibration features a lower inflation weight γ^π, a higher output gap weight γ_x, and a higher inertia parameter ρ^i.

The bottom panel of Table 2 shows the macroeconomic volatilities targeted in this calibration step. 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.

Delta method standard errors indicate that model parameters are generally well-identified.[17] 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. Combined with the long-standing literature that has found a change in the nature of shocks from the 1980s to the 2000s (e.g. Sims and Zha (2006)), and external evidence of a more inertial and more output-focused monetary policy rule after 2000 (e.g. Bauer, Pflueger and Sunderam (2022)), the calibration therefore generates a reasonable picture of changes in the macroeconomy from the 1980s to the 2000s.

---

[16]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).

[17]Delta method standard errors are computed from simulated derivatives of the objective function, holding all other parameters constant. Details for the standard errors are provided in Appendix E.

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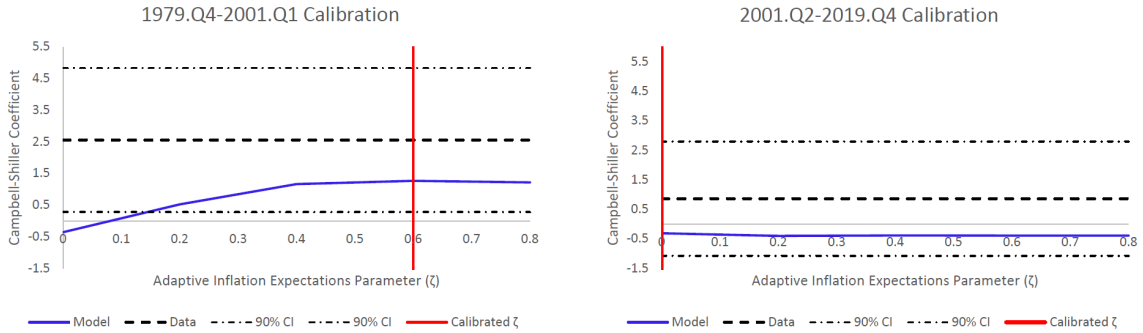
This figure shows the model Campbell-Shiller bond excess return predictability regression coefficient as in Table 2 against the parameter determining the adaptiveness of inflation expectations, ζ. All other parameters are as in Table 1. The data coefficient is shown in black dashed with 90% confidence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

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 (33) plus the squared standardized difference between the model and data Campbell-Shiller bond return predictability coefficient with a weight of 100.[18]

Figure 3 shows the predictability of bond excess returns from the yield spread at different values for the inflation expectations parameter, ζ. Even though the linearized delta method standard errors shown in Table 1 do not quite indicate statistical significance, the nonlinear model-implied Campbell-Shiller coefficients in Figure 3 indicate that we can reject fully rational inflation expectations for the 1980s subperiod. Of course, the fit to the macroeconomic dynamics is affected by varying ζ in this separate step. However, I am not concerned about this loss in fit because it mostly means that the policy rate response in the left plot of Panel C is more persistent in the model than in my relatively simple data moment.[19] A long-standing econometric literature on the persistence of inflation dynamics has found a strong persistent component in inflation during the 1980s (Stock and Watson

---

[18]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 A1).

[19]Appendix Figure A1 compares the model fit with $\zeta = 0$ vs. $\zeta = 0.6$.

((2007)), supportive of the persistent model response for the 1980s calibration with $\zeta = 0.6$ depicted in the left plot in Panel C.

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

Having already discussed the targeted macroeconomic moments, I now turn to the asset pricing moments shown in the top panels of Table 2. The model generates a quantitatively plausible match for time-varying risk premia in stocks, matching 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). The model's success for equity moments shows that incorporating these preferences into a model with supply and demand shocks does not hurt its performance along these dimensions, and that implications for bond risks are based on a plausible description of countercyclical risk premia.

The middle panel in Table 2 shows that the model replicates the motivating evidence in Figure 1, even though bond-stock betas were not explicitly targeted in the calibration. The model-implied nominal bond beta switches from strongly positive in the 1980s calibration to negative in the 2000s calibration, similarly to the data. The model-implied real bond-stock beta is small and positive in the 1980s calibration and negative and slightly smaller than the nominal bond beta in the 2000s calibration, matching both the sign-change and the ordering relative to nominal bond-stock betas in the data.[20] The volatility of model nominal bond excess returns is also similar to the data for both subperiods. Model-implied nominal Treasury bond excess returns are volatile in the 1980s calibration and much less volatile in the 2000s calibration.[21] I compare the steady-state model bond excess return to subjective expected bond excess return in the data (Piazzesi, Salomao and Schneider (2015), Nagel

---

[20]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 parsimony and 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.

[21]My model is consistent with Duffee (2022)'s 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.

and Xu (2022)) for both subperiods, and find that they line up. I prefer a measure of the subjective expected bond excess return in the data because it is a less noisy measure than ex-post realized returns or the slope of the term structure, which in finite samples mixes steady-state risk premia with the expected path of interest rates and inflation.

The model also generates empirically-plausible excess return predictability for nominal bonds in the manner of Campbell and Shiller (1991). 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 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 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 even 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. Panel A starts from the 1980s calibration and shows model-implied nominal and real bond betas as individual parameter groups are changed to the average of the 1980s and 2000s calibrations. Panel B conducts the converse exercise, starting from the 2000s calibration and changing individual parameter groups halfway towards their 1980s values, effectively asking which parameter group has the potential to turn nominal bonds risky again.[22]

Panel A shows that starting from the 1980s calibration changing either the volatility of shocks or the monetary policy rule flips nominal bonds from risky (i.e. a positive nom-

---

[22]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 halfway between the 1980s and 2000s calibrations.

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
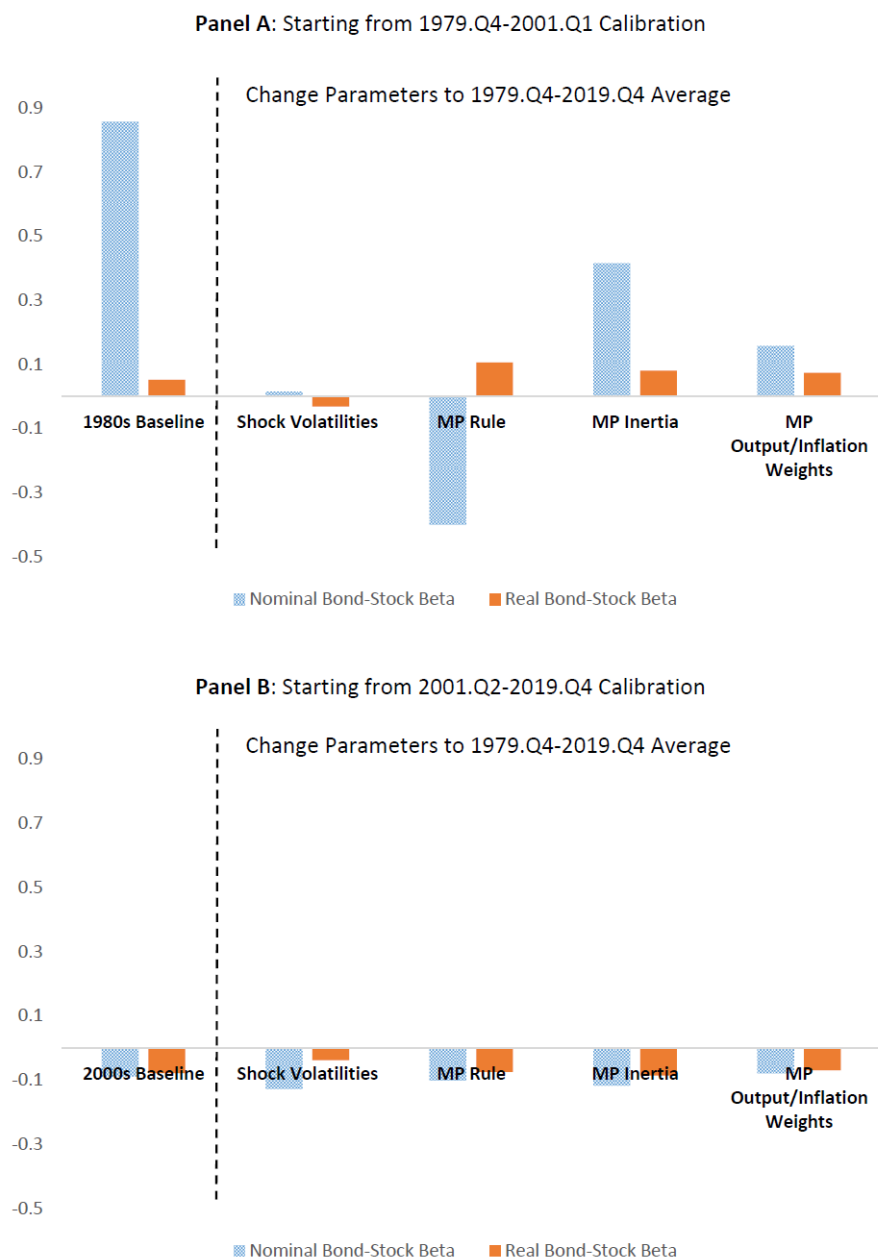
This figure shows model-implied nominal and real bond betas while changing parameter groups one at a time. Panel A sets all parameter values to the 1979.Q4-2001.Q1 calibration unless stated otherwise. It then reports the beta while setting the following parameters to the average of the 1979.Q4-2001.Q1 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.

inal bond beta) to safe (i.e. a zero or negative nominal bond beta). 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. While changing either the shock volatilities or the monetary policy rule in Panel A eliminates positive nominal bond-stock betas, the implications for real bond-stock betas differ. The real bond-stock betas in the "MP Rule" counterfactual in Panel A turn positive, depicting a third case with different bond-stock beta implications than either the 1980s or the 2000s calibrations. This happens because the monetary policy rule in this counterfactual mutes the stock and real rate responses to supply shocks. Monetary policy shocks, which lower real bond and stock prices simultaneously, therefore dominate the real bond-stock beta and turn it positive. The next two columns in Panel A take a look at the components of the monetary policy rule, showing 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.

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. Similar to the "third case" in Panel A, real bond-stock betas increase for this counterfactual, which combines volatile supply shocks with a weak initial monetary policy response. The counterfactuals in Panel B therefore reiterate that the monetary policy rule can protect nominal bonds from turning risky even in the face of 1980s-style shocks.

The counterfactual of a 2000s-style monetary policy rule with volatile supply shocks as in the 1980s ("Shock Volatilities" in Panel B) lines up well with the post-pandemic experience of positive real bond betas and negative nominal bond betas, shown in Figure 1. The model can therefore qualitatively account for the recent empirical evidence, if the post-pandemic economy experienced elevated supply shock volatility but, unlike in the 1980s, the conduct of monetary policy was more inertial and more output-focused. 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 mon-

etary 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. Impulse responses to shocks can therefore be separated from the volatilities of shocks, which merely scale up all responses proportionately.

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 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 that the 1980s and 2000s calibrations imply different responses to an inflationary supply shock, due to their different monetary policy rules. 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 that the real rate falls initially after the shock, 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)). While inflation and the output gap comove similarly after monetary policy and demand shocks, a monetary policy shock has a more pronounced effect on the policy rate, which pins down the relative volatilities of monetary policy and demand shocks in the calibration in Section 3.1. In contrast to the supply shock, the responses to a monetary policy shock are similar across the 1980s and 2000s calibrations, despite their different monetary policy rules and Phillips curve inertia.

Taken together, the macroeconomic impulse responses show that a reactive monetary policy rule and volatile supply shocks are needed to generate a "stagflation", and a negative inflation-output gap comovement. By contrast, inflation and the output gap comove little 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 discusses how these macroeconomic dynamics translate into asset prices with time-varying risk premia.

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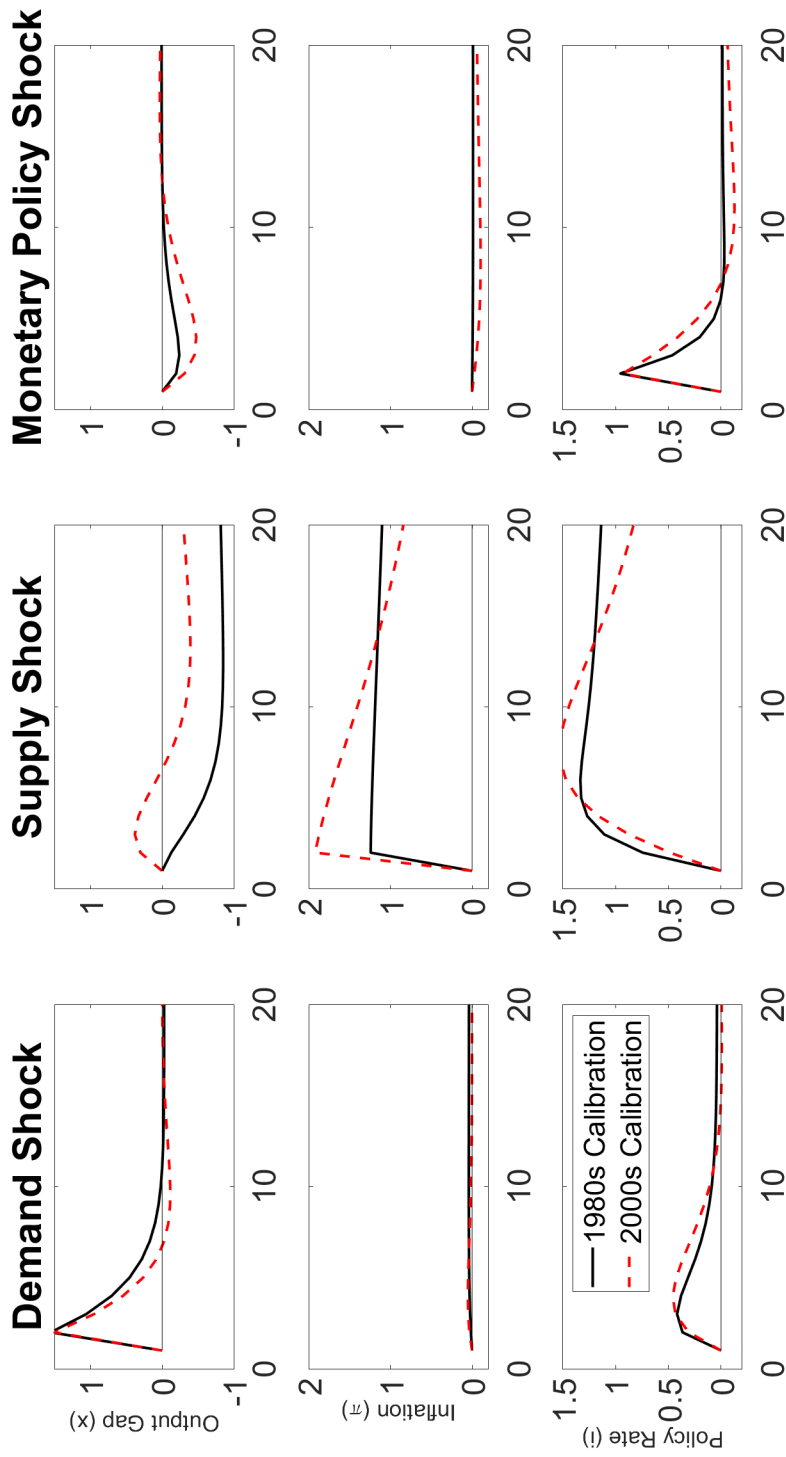
This figure shows model impulse responses for the output gap (%, top row), inflation (ann %, middle row), and nominal policy rate (ann. %, bottom row). The impulse in the left column is a one-percentage-point demand shock, in the middle column is a one-percentage-point cost-push or supply shock, and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

## 4.3 Model Asset Price Impulse Responses

How do supply and demand shocks affect asset prices and risk premia under different monetary policy rules? 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 also 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, and therefore stock prices rise and stock dividend yields fall whenever a shock raises the output gap in Figure 5. Stocks fall with an adverse output shock more strongly than the present discounted value of dividends, as consumption falls towards habit and investors become more risk-averse.

Comparing the bond and stock responses to a supply shock in the middle column shows that the different macroeconomic responses to an inflationary supply shock translate into different nominal bond-stock betas across the 1980s and 2000s calibrations. The reason for this is the difference in macroeconomic dynamics in Figure 5. 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 are known to replicate the large 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. As a result, supply shocks 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 in the leftmost column. The risk-neutral nominal bond yield behaves as expected from the macroeconomic dynamics, rising slightly as inflation expectations and the policy rate increase, and looking very similar across the 1980s and 2000s calibrations. However, the overall nominal bond yield responses in the bottom panel are substantially larger and even switch sign across the two calibrations. This potentially surprising result arises from endogenously time-varying risk premia in the

Figure 6: Model Asset Price Impulse Responses
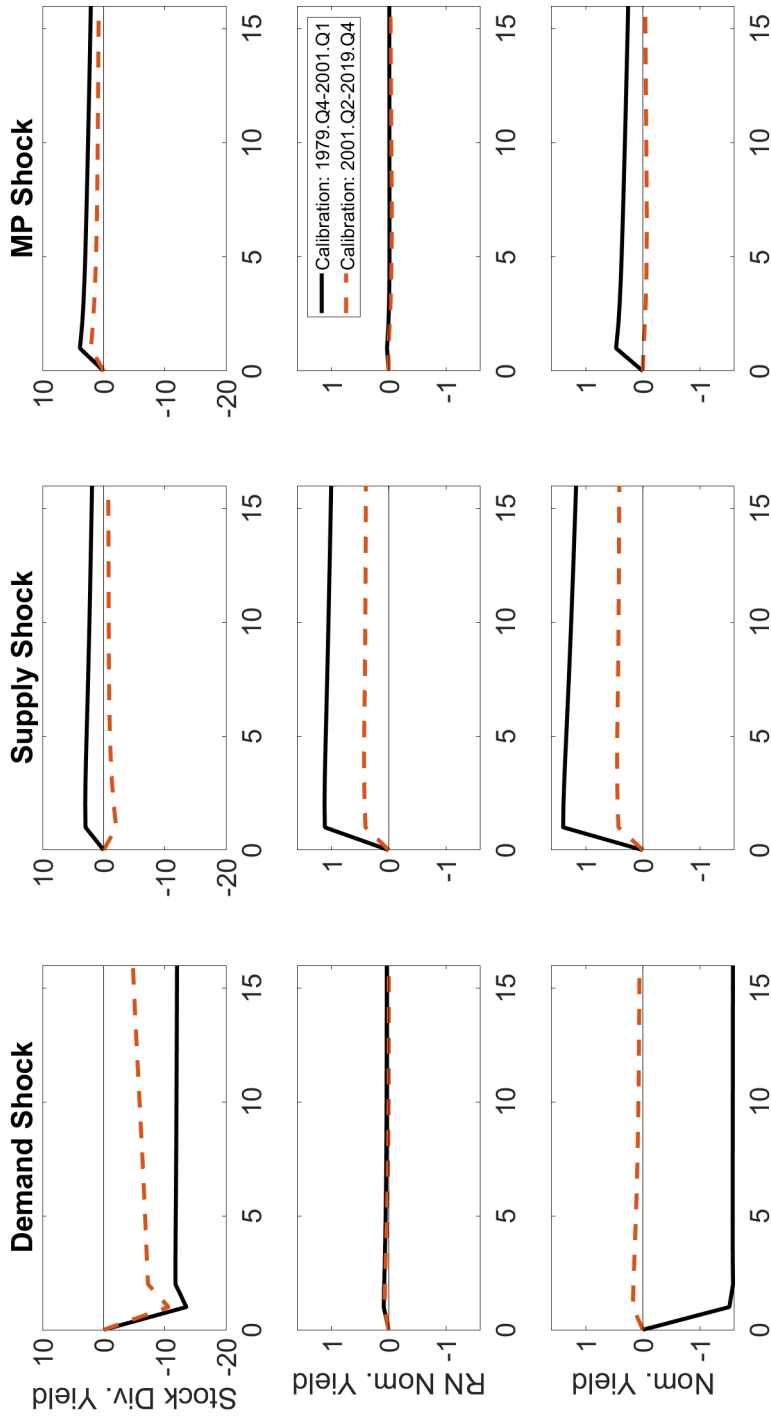
This figure shows model impulse responses for the stock dividend yield, and bond yields for zero-coupon nominal Treasury bonds (all in ann. %) in response to structural shocks. Stock prices move inversely with the stock dividend yield and bond prices move inversely with the ten-year nominal bond yield. 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.

30

model. 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 (32). A positive demand shock is good news for output and consumption, raising consumption relative to habit and lowering risk aversion through the surplus consumption ratio s_t. In the 1980s calibration, this leads investors to require a lower return to hold risky nominal bonds, and nominal bond yields fall. This insight can potentially rationalize the empirical observation that even though supply shocks were subsiding during the 1990s, nominal Treasury bond-stock betas remained elevated, potentially because 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. Importantly, this reversal of the role of time-varying risk premia is an endogenous outcome of the different macroeconomic equilibria in the model.

4.4 Counterfactual Prevalent vs. Realized Shocks

Endogenously time-varying risk premia in the model imply that prevalent shocks priced in equilibrium vs. realized shocks have distinct implications for bond-stock betas. Figure 7 shifts the distributions of prevalent vs. realized shocks separately to the 2000s calibration while holding all other parameters constant at the 1980s calibration. As previously seen, moving the distributions of both prevalent and realized shocks towards the demand-shock dominated 2000s calibration eliminates the positive nominal bond beta of the 1980s calibration. By contrast, the model nominal bond beta remains positive if realized shocks follow the 2000s calibration as long as long as assets are priced as if 1980s shocks are prevalent. In the counterfactual with 2000s realized shocks and 1980s prevalent shocks, asset prices are solved as if shocks follow the 1980s distribution, but the model is then simulated as if investors are repeatedly surprised by shocks from the 2000s distribution. As indicated by the dashed bar, the risk-neutral bond-stock beta does turn negative in this case, highlighting the role of time-varying risk premia. The mechanism goes back to the bottom-left panel of Figure 6. When supply shocks are prevalent, nominal bonds are understood to be risky, and the overall nominal bond yield response to a demand shock flips sign. Endogenously time-varying risk premia therefore turn nominal bond-stock betas into a forward-looking indicator that depends on prevalent rather than realized shocks.

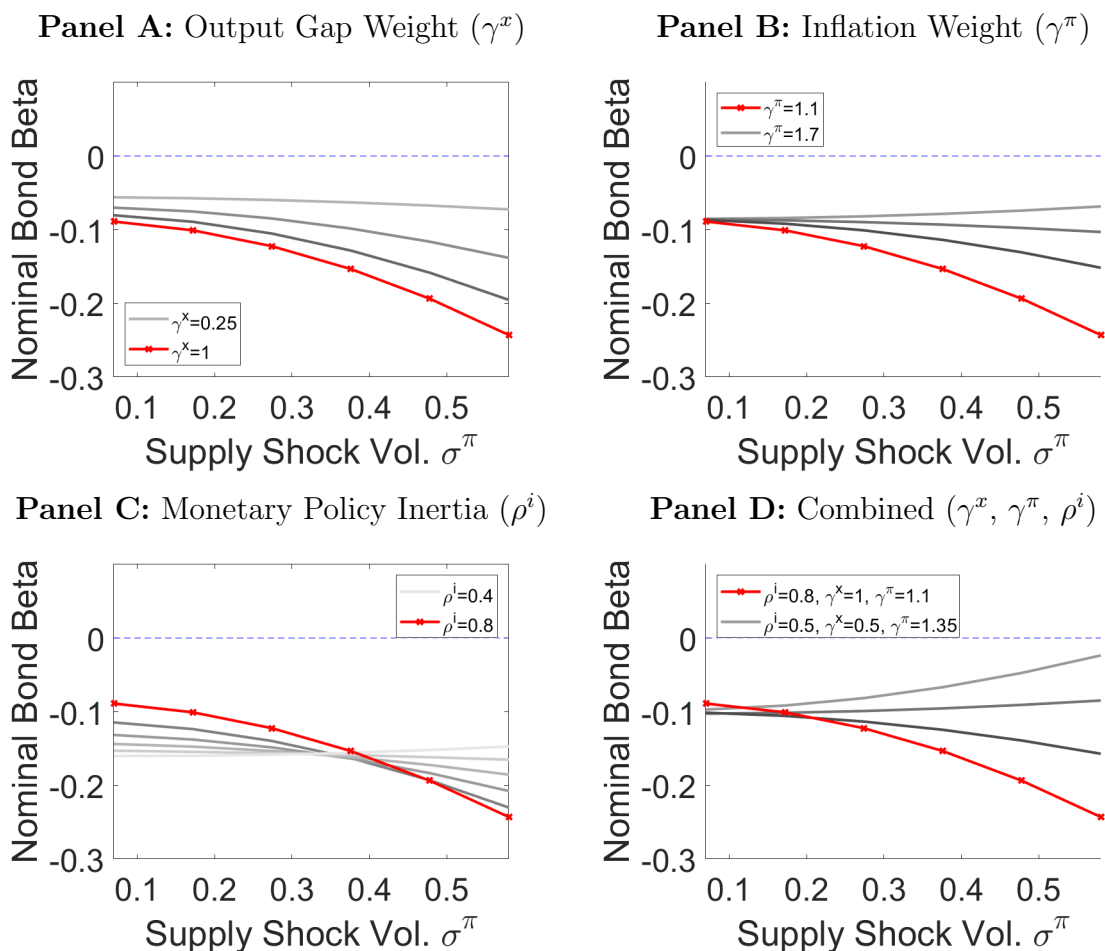Figure 7: Nominal Bond Betas by Prevalent vs. Realized Shocks
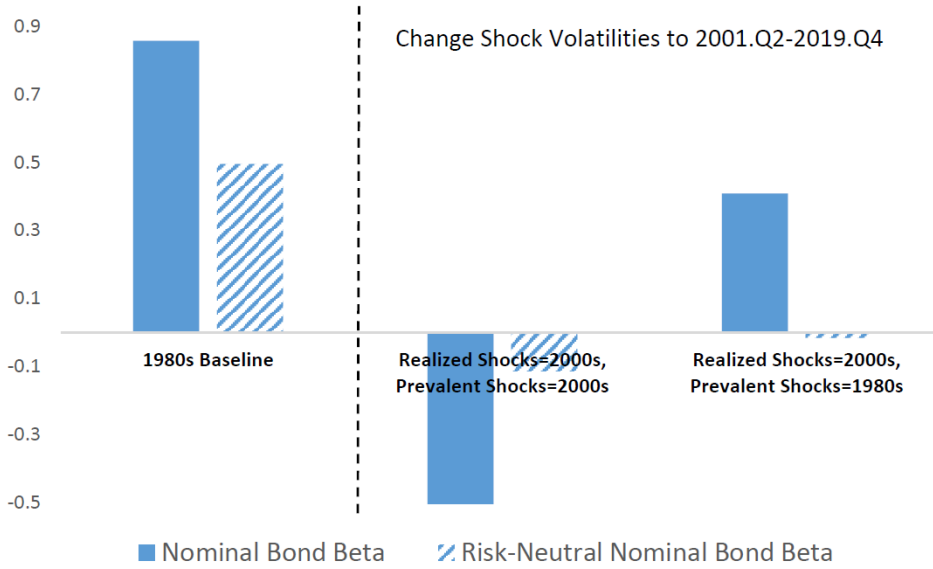
This figure shows model-implied nominal bond betas (solid) and the betas of risk-neutral nominal bond returns with respect to the stock market (dashed) across prevalent and realized shock distributions. The leftmost bars set all parameter values to the 1979.Q4-2001.Q1 calibration. The middle bars change 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.

4.5 Counterfactual Monetary Policy Inertia vs. Long-Term Inflation/Output Weights

Decomposing the monetary policy rule shows that there are two types of monetary policy rules that keep nominal bond betas negative even when supply shocks are volatile. First, a monetary policy rule with a high output weight and a low inflation weight; second, a monetary policy rule with a high inflation weight but a more gradual and inertial response to inflation. This result contrasts with Rudebusch and Swanson (2012)'s model, where a monetary policy rule that focuses on long-term inflation fluctuations is needed to lower the nominal bond term premium. The difference arises because preferences in my model generate volatile risk premia and plausible risk premium effects of monetary policy, whereas Rudebusch and Swanson (2012) use a long-run risk model with constant volatility and constant risk premia, showing the importance of accounting for the risk premium effect of monetary policy.

Figure 8, 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 their 2000s calibration values to their 1980s calibration values. The x-axis moves the volatility 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 their 2000s calibration values.

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 $(\gamma^x, \gamma^\pi, \rho^i)$

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.

Comparing Panels A and B shows that a higher long-term inflation weight acts equiv-

alently to a lower long-term output weight on nominal bond-stock betas as the volatility of supply shocks increases. This makes sense, as the monetary policy authority's relative weights on inflation vs. output-stabilization determine 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 lowers the nominal bond-stock beta, similarly to a lower inflation weight or a higher output weight. The mechanism in the model is that greater monetary policy inertia ρ^i weakens the immediate monetary policy response to a supply shock while leaving the long-term response unchanged (see equation (27)), and thereby facilitates a "soft landing" similar to the red dashed impulse response in the top middle panel of Figure 5. Intuitively, an inertial monetary policy response softens the blow to investor surplus consumption and risk aversion from an adverse supply shock, thereby avoiding stocks and bonds from falling simultaneously.

Panel D shows that when moving from a rule with high monetary policy inertia, high output weight, and low inflation weight as in the 2000s calibration towards a rule with low inertia, low output weight, and high inflation weight as in the 1980s calibration, nominal bond betas go from downward-sloping all the way to upward-sloping in the volatility of supply shocks. These results suggest that a monetary policy rule in-between the 1980s and 2000s calibrations may give the closest explanation for why nominal bond betas remained flat as supply shocks reemerged during the post-pandemic inflation surge 2021-2022. Overall, negative nominal bond-stock betas in the presence of supply shocks therefore can arise from a lower long-term inflation weight in the monetary policy rule, a higher long-term inflation weight or greater monetary policy inertia, or a combination of all three.

4.6   Counterfactual Inflation Expectations

The adaptiveness of wage-setters' inflation expectations is important for the persistence of inflation (Fuhrer (1997)), so it is relevant to understand how it is reflected in bond risks. Figure 9 plots nominal bond-stock betas at different values for the adaptiveness of inflation expectations, ζ, against the volatility of supply shocks on the x-axis, holding all other parameters constant at their 2000s values. In contrast to the monetary policy decomposition in Figure 8, this figure shows that the lines for different ζ are almost on top of each other, so nominal bond betas change little with the adaptiveness of wage-setters' inflation expectations. Intuitively, more adaptive wage-setter inflation expectations lead to greater inflation persistence through (25), and 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

34

bond-stock betas in the model. Macroeconomic impulse responses at different values for ζ are depicted in Appendix Figure A2.

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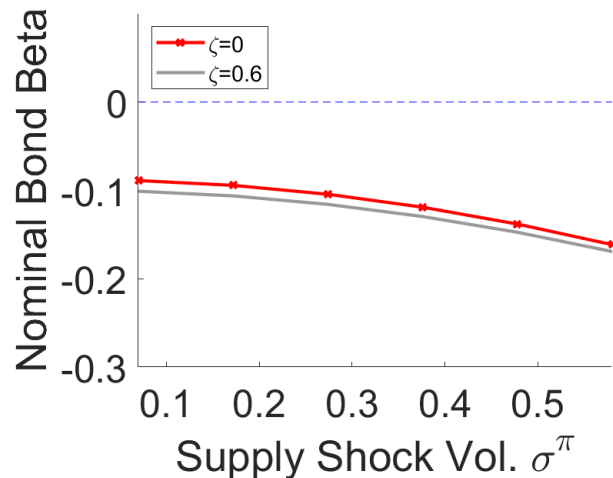
This figure shows model-implied ten-year nominal bond-stock betas against the standard deviation of supply shocks for rational ($\zeta = 0$) and partially adaptive ($\zeta = 0.6$) wage-setter inflation expectations. Unless otherwise labeled all parameter values are set to the 2001.Q2-2019.Q4 calibration.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

At the same time, the adaptiveness of wage-setters' inflation expectations does have important implications for Campbell-Shiller bond excess return predictability in the model, as shown in Figure 3. Figure 10 illustrates the mechanism by decomposing the impulse responses for the yield spread between long-term and short-term nominal bond yields into its risk premium and risk neutral components. The top three panels show that when the Phillips curve is strongly backward-looking, as in the 1980s calibration, yield spread responses to supply and demand shocks are dominated by risk premia. 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. 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 is a better description of the term structure of interest rates in time periods and countries where interest rates are less persistent (Mankiw, Miron and Weil (1987), Hardouvelis (1994)), and 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 as a new link between the predictability of bond excess returns and the backward-lookingness of the Phillips curve more broadly.

Figure 10: Model Yield Spread Impulse Responses
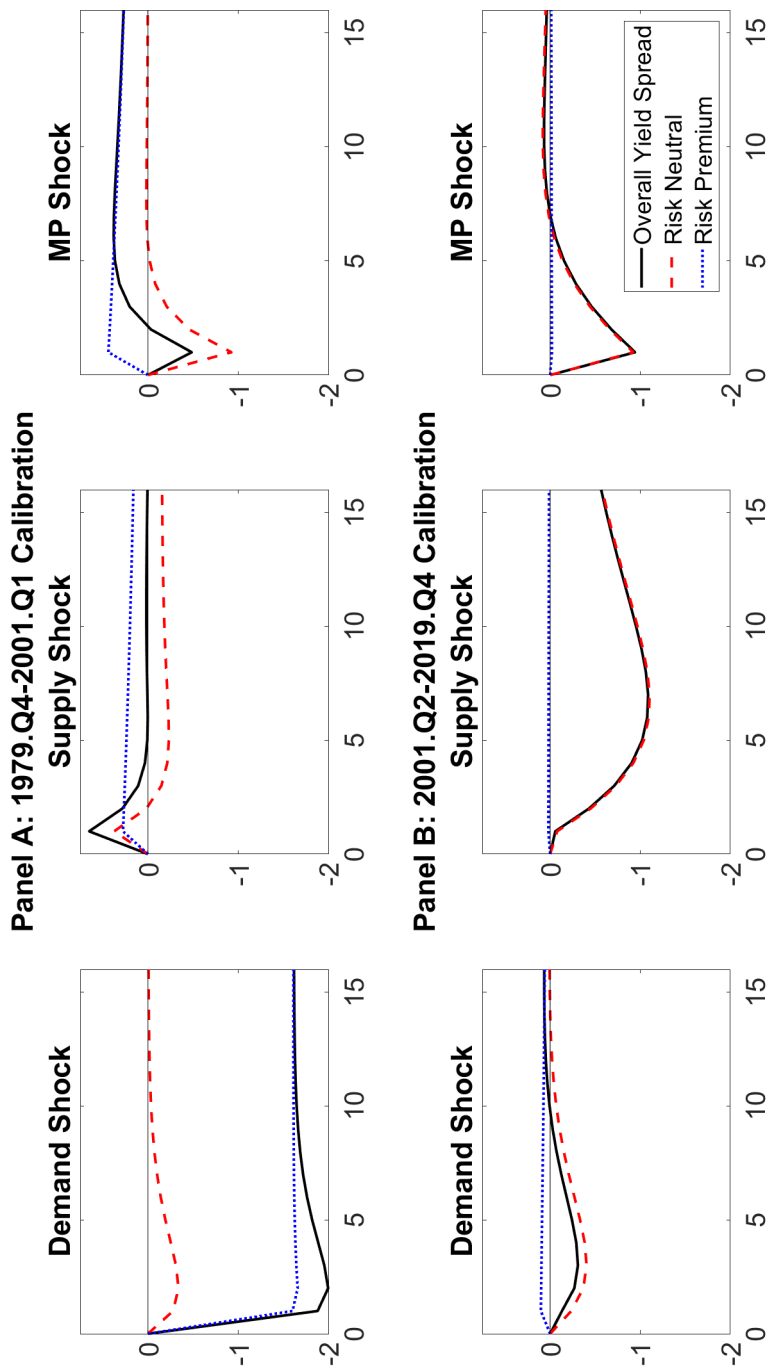
This figure shows model impulse responses for the yield spread, i.e. the right-hand-side of the Campbell-Shiller regressions in Table 2. The yield spread is defined as the ten-year nominal zero-coupon Treasury bond yield minus the nominal risk-free rate. It is decomposed into risk-neutral (expectations hypothesis) and risk premium components, see also Figure 6. 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-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.

5 Conclusion

This paper links the risks of nominal and real bonds to how monetary policy acts on supply and demand shocks, time-varying risk premia, and the formation of inflation expectations in the economy. Bond and stock prices in the model feature time-varying risk premia from consumption habits in the manner of Campbell, Pflueger and Viceira (2020), but different from this prior work arise from supply and demand shocks, and their interaction with monetary policy. Based on this model, I show that the interaction between volatile supply shocks and monetary policy is crucial for generating positive nominal bond-stock betas, as observed during the stagflationary 1980s. Conversely, a more inertial or more output-focused monetary policy rule can explain why nominal bond betas remained negative during the post-pandemic inflation surge through mid-2022.

I fit the model to macroeconomic and bond excess return predictability data separately for the 1980s and the 2000s and show that it yields an intuitive link between the changes in the economy and bond risks across these decades. The paper highlights three different cases with distinct implications for bond-stock betas: first, volatile supply shocks and a reactive monetary policy rule generate "stagflation" and positive nominal bond-stock betas as in the 1980s; second, volatile demand shocks generate low inflation recessions and negative nominal bond-stock betas as in the 2000s; third, a counterfactual of volatile supply 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 post-pandemic bond-stock betas in the data.

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 therefore 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 therefore imply negative nominal bond-stock betas.

Time-varying risk premia offer distinct implications for how realized vs. prevalent shocks affect bond-stock betas. 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, a positive demand shock raises consumption relative to habit and makes households more willing to bear risk, raising the prices of both stocks and (in the 1980s equilibrium) risky bonds relative to their expected discounted real cash flows. Endogenously time-varying risk premia in the model therefore turn nominal bond-stock betas into a forward-looking measure that reflects shocks prevalent in equilibrium rather than realized shocks.

Partly backward-looking inflation expectations in the economy drive the predictability of model bond excess returns, but leave bond-stock betas relatively unchanged. When backward-looking inflation expectations lead to a highly persistent inflation process as in the 1980s, the level of inflation drops out from the yield spread between long- and short-term interest rates, which are hence dominated by time-varying risk premia. When supply shocks are volatile and the Phillips curve strongly backward-looking, the model yield spread predicts nominal bond excess returns, explaining the empirical evidence by Campbell and Shiller (1991).

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 into how financial market comovements can serve as forward-looking indicators for the nature of macroeconomic shocks is likely to be fruitful.

References

Abel, Andrew B (1990) "Asset prices under habit formation and catching up with the Joneses," *American Economic Review*, 80, 38–42.

Albuquerque, Rui, Martin Eichenbaum, Victor Xi Luo, and Sergio Rebelo (2016) "Valuation risk and asset pricing," *Journal of Finance*, 71 (6), 2861–2904.

Angeletos, George-Marios and Jennifer La'O (2013) "Sentiments," *Econometrica*, 81 (2), 739–779.

Baele, Lieven, Geert Bekaert, and Koen Inghelbrecht (2010) "The determinants of stock and bond return comovements," *Review of Financial Studies*, 23 (6), 2374–2428.

Bauer, Michael D, Carolin Pflueger, and Adi Sunderam (2022) "Perceptions about monetary policy," National Bureau of Economic Research, working paper wp 30480.

Beaudry, Paul and Franck Portier (2006) "Stock prices, news, and economic fluctuations," *American Economic Review*, 96 (4), 1293–1307.

Bernanke, Ben S and Mark Gertler (2001) "Should central banks respond to movements in asset prices?" *American Economic Review: Papers and Proceedings*, 91 (2), 253–257.

Bernanke, Ben S, Mark Gertler, and Mark Watson (1997) "Systematic monetary policy and the effects of oil price shocks," *Brookings Papers on Economic Activity*, 1997 (1), 91–157.

Bernanke, Ben S and Kenneth N Kuttner (2005) "What Explains the Stock Market's Reaction to Federal Reserve Policy?" *Journal of Finance*, 60 (3), 1221–1257.

Bianchi, Francesco, Renato Faccini, and Leonardo Melosi (2023) "A fiscal theory of trend inflation," *Quarterly Journal of Economics, forthcoming.*

Bianchi, Francesco, Martin Lettau, and Sydney C Ludvigson (2022a) "Monetary policy and asset valuation," *Journal of Finance*, 77 (2), 967–1017.

Bianchi, Francesco, Sydney C Ludvigson, and Sai Ma (2022b) "Belief distortions and macroeconomic fluctuations," *American Economic Review*, 112 (7), 2269–2315.

Bianchi, Javier and Guido Lorenzoni (2021) "The prudential use of capital controls and foreign currency reserves," *Handbook of International Economics Vol. V.*

Blanchard, Olivier Jean and Charles M Kahn (1980) "The solution of linear difference models under rational expectations," *Econometrica*, 1305–1311.

Bok, Brandyn, Thomas M Mertens, and John C Williams (2022) "Macroeconomic Drivers and the Pricing of Uncertainty, Inflation, and Bonds," *FRB of New York Staff Report* (1011).

Bordalo, Pedro, Nicola Gennaioli, Rafael LaPorta, and Andrei Shleifer (2022) "Belief overreaction and stock market puzzles," Working paper, Oxford, Bocconi, Brown University, and Harvard University.

Caballero, Ricardo J and Alp Simsek (2022) "A monetary policy asset pricing model."

Campbell, John Y and John H Cochrane (1999) "By force of habit: A consumption-based explanation of aggregate stock market behavior," *Journal of Political Economy*, 107, 205–251.

Campbell, John Y, Carolin Pflueger, and Luis M Viceira (2020) "Macroeconomic drivers of bond and equity risks," *Journal of Political Economy*, 128 (8), 3148–3185.

Campbell, John Y and Robert J Shiller (1991) "Yield spreads and interest rate movements: A bird's eye view," *Review of Economic Studies*, 58 (3), 495–514.

Campbell, John Y, Robert J Shiller, and Luis M Viceira (2009) "Understanding Inflation-Indexed Bond Markets.," *Brookings Papers on Economic Activity*, 79–138.

Campbell, John Y, Adi Sunderam, and Luis M Viceira (2017) "Inflation Bets or Deflation Hedges? The Changing Risks of Nominal Bonds," *Critical Finance Review*, 6 (2), 263–301.

Chahrour, Ryan and Kyle Jurado (2018) "News or noise? The missing link," *American Economic Review*, 108 (7), 1702–36.

Chan, Yeung Lewis and Leonid Kogan (2002) "Catching Up with the Joneses: Heterogeneous Preferences and the Dynamics of Asset Prices," *Journal of Political Economy*, 110 (6), 1255–1285.

Chernov, Mikhail, Lars A Lochstoer, and Dongho Song (2021) "The real explanation of nominal bond-stock puzzles," National Bureau of Economic Research Working Paper, wp 29085.

Christiano, Lawrence H, Martin Eichenbaum, and Charles L Evans (2005) "Nominal rigidities and the dynamic effects of a shock to monetary policy," *Journal of Political Economy*, 113 (1), 1–45.

Christiano, Lawrence J, Martin Eichenbaum, and Charles L Evans (1999) "Monetary policy shocks: What have we learned and to what end?" *Handbook of Macroeconomics*, 1, 65–148.

Cieslak, Anna and Pavol Povala (2015) "Expected returns in Treasury bonds," *Review of Financial Studies*, 28 (10), 2859–2901.

Cieslak, Anna and Annette Vissing-Jorgensen (2021) "The economics of the Fed put," *Review of Financial Studies*, 34 (9), 4045–4089.

Clarida, Richard, Jordi Gali, and Mark Gertler (2000) "Monetary policy rules and macroeconomic stability: Evidence and some theory," *Quarterly Journal of Economics*, 115 (1), 147–180.

Cochrane, John H (2011) "Determinacy and identification with Taylor rules," *Journal of Political Economy*, 119 (3), 565–615.

Cogley, Timothy and Thomas J Sargent (2008) "Anticipated utility and rational expectations as approximations of Bayesian decision making," *International Economic Review*, 49 (1), 185–221.

Coibion, Olivier and Yuriy Gorodnichenko (2015) "Information rigidity and the expectations formation process: A simple framework and new facts," *American Economic Review*, 105 (8), 2644–2678.

David, Alexander and Pietro Veronesi (2013) "What ties return volatilities to fundamentals and price valuations?" *Journal of Political Economy*, 121, 682–746.

De La'O, Ricardo and Sean Myers (2021) "Subjective cash flow and discount rate expectations," *Journal of Finance*, 76 (3), 1339–1387.

Dew-Becker, Ian (2014) "Bond Pricing with a Time-Varying Price of Risk in an Estimated Medium-Scale Bayesian DSGE Model," *Journal of Money, Credit and Banking*, 46 (5), 837–888.

Di Giovanni, Julian, Sebnem Kalemli-Özcan, Alvaro Silva, and Muhammed A Yildirim (2022) "Global supply chain pressures, international trade, and inflation," National Bureau of Economic Research Working Paper, wp30240.

Du, Wenxin, Joanne Im, and Jesse Schreger (2018a) "The US Treasury premium," *Journal of International Economics*, 112, 167–181.

Du, Wenxin, Alexander Tepper, and Adrien Verdelhan (2018b) "Deviations from covered interest rate parity," *Journal of Finance*, 73 (3), 915–957.

Duffee, Greg (2022) "Macroeconomic news and stock-bond comovement," Working paper, Johns Hopkins University.

Engel, Charles and Steve Pak Yeung Wu (2023) "Liquidity and Exchange Rates: An Empirical Investigation," *Review of Economic Studies, forthcoming.*

Favilukis, Jack and Xiaoji Lin (2016) "Wage rigidity: A quantitative solution to several asset pricing puzzles," *Review of Financial Studies*, 29 (1), 148–192.

Fuhrer, Jeff and George Moore (1995) "Inflation persistence," *Quarterly Journal of Economics*, 110 (1), 127–159.

Fuhrer, Jeffrey C (1997) "The (un) importance of forward-looking behavior in price specifications," *Journal of Money, Credit, and Banking*, 29, 338–350.

Fukui, Masao, Emi Nakamura, and Jón Steinsson (2023) "The Macroeconomic Consequences of Exchange Rate Depreciations," National Bureau of Economic Research working paper wp 31279.

Galí, Jordi (2008) *Monetary Policy, Inflation, and the Business Cycle*: Princeton University Press.

Gilchrist, Simon and John V Leahy (2002) "Monetary policy and asset prices," *Journal of Monetary Economics*, 49 (1), 75–97.

Gilchrist, Simon and Egon Zakrajšek (2012) "Credit spreads and business cycle fluctuations," *American Economic Review*, 102 (4), 1692–1720.

Gourio, François and Phuong Ngo (2020) "Risk premia at the ZLB: A macroeconomic interpretation," Working Paper, Federal Reserve Bank of Chicago.

——— (2022) "Downward Nominal Rigidities and Term Premia Preliminary," Working Paper, Chicago Federal Reserve and Cleveland State University.

Greenwood, Jeremy, Zvi Hercowitz, and Gregory W Huffman (1988) "Investment, capacity utilization, and the real business cycle," *American Economic Review*, 402–417.

Harding, Martín, Jesper Lindé, and Mathias Trabandt (2022) "Resolving the missing deflation puzzle."

Hardouvelis, Gikas A (1994) "The term structure spread and future changes in long and short rates in the G7 countries: Is there a puzzle?" *Journal of Monetary Economics*, 33 (2), 255–283.

Hazell, Jonathon, Juan Herreno, Emi Nakamura, and Jón Steinsson (2022) "The slope of the Phillips curve: Evidence from US states," *Quarterly Journal of Economics*, 137, 1299–1344.

He, Zhiguo, Stefan Nagel, and Zhaogang Song (2022) "Treasury inconvenience yields during the COVID-19 crisis," *Journal of Financial Economics*, 143 (1), 57–79.

Itskhoki, Oleg and Dmitry Mukhin (2021) "Exchange rate disconnect in general equilibrium," *Journal of Political Economy*, 129 (8), 2183–2232.

Jiang, Zhengyang, Arvind Krishnamurthy, and Hanno Lustig (2020) "Dollar safety and the global financial cycle."

——— (2021) "Foreign safe asset demand and the dollar exchange rate," *Journal of Finance*, 76 (3), 1049–1089.

Jordà, Òscar (2005) "Estimation and inference of impulse responses by local projections," *American Economic Review*, 95 (1), 161–182.

Jurado, Kyle, Sydney C Ludvigson, and Serena Ng (2015) "Measuring uncertainty," *American Economic Review*, 105 (3), 1177–1216.

Justiniano, Alejandro and Giorgio E Primiceri (2008) "The time-varying volatility of macroeconomic fluctuations," *American Economic Review*, 98 (3), 604–641.

Kekre, Rohan and Moritz Lenel (2022) "Monetary policy, redistribution, and risk premia," *Econometrica*, 90 (5), 2249–2282.

Krishnamurthy, Arvind and Annette Vissing-Jorgensen (2012) "The aggregate demand for Treasury debt," *Journal of Political Economy*, 120 (2), 233–267.

Laarits, Toomas (2022) "Precautionary savings and the stock-bond covariance," Working Paper, NYU Stern School of Business.

Li, Erica XN, Tao Zha, Ji Zhang, and Hao Zhou (2022) "Does fiscal policy matter for stock-bond return correlation?" *Journal of Monetary Economics*, 128, 20–34.

Lubik, Thomas A and Frank Schorfheide (2004) "Testing for indeterminacy: An application to US monetary policy," *American Economic Review*, 94 (1), 190–217.

Lucas, Robert E. Jr. (1988) "On the Mechanics of Economic Development," *Journal of Monetary Economics*, 22, 3–42.

Malmendier, Ulrike and Stefan Nagel (2016) "Learning from inflation experiences," *Quarterly Journal of Economics*, 131 (1), 53–87.

Mankiw, N Gregory, Jeffrey A Miron, and David N Weil (1987) "The adjustment of expectations to a change in regime: A study of the founding of the Federal Reserve," *American Economic Review*, 77, 358–374.

Nagel, Stefan and Zhengyang Xu (2022) "Dynamics of subjective risk premia," National Bureau of Economic Research working paper wp29803.

Pflueger, Carolin E and Luis M Viceira (2016) "Return predictability in the Treasury market: Real rates, inflation, and liquidity," in Veronesi, Pietro ed. *Handbook in Fixed-Income Securities*: Wiley, New Jersey.

Pflueger, Carolin and Gianluca Rinaldi (2022) "Why does the Fed move markets so much? A model of monetary policy and time-varying risk aversion," *Journal of Financial Economics*, 146, 71–68.

Pflueger, Carolin, Emil Siriwardane, and Adi Sunderam (2020) "Financial market risk perceptions and the macroeconomy," *Quarterly Journal of Economics*, 135 (3), 1443–1491.

Piazzesi, Monika, Juliana Salomao, and Martin Schneider (2015) "Trend and Cycle in Bond Premia," Working Paper, Stanford University and University of Minnesota.

Piazzesi, Monika and Martin Schneider (2006) "Equilibrium yield curves," *NBER Macroeconomics Annual*, 21, 389–472.

Primiceri, Giorgio E (2006) "Why inflation rose and fell: Policy-makers' beliefs and US postwar stabilization policy," *Quarterly Journal of Economics*, 121 (3), 867–901.

Ramey, Valerie A (2016) "Macroeconomic shocks and their propagation," *Handbook of Macroeconomics*, 2, 71–162.

Rotemberg, Julio J (1982) "Monopolistic price adjustment and aggregate output," *Review of Economic Studies*, 49 (4), 517–531.

Rubbo, Elisa (2022) "Networks, Phillips curves, and monetary policy," Working Paper, University of Chicago.

Rudebusch, Glenn D and Eric T Swanson (2008) "Examining the bond premium puzzle with a DSGE model," *Journal of Monetary Economics*, 55, S111–S126.

——— (2012) "The bond premium in a DSGE model with long-run real and nominal risks," *American Economic Journal: Macroeconomics*, 4 (1), 105–43.

Shiller, Robert J (1981) "Do Stock Prices Move Too Much to be Justified by Subsequent Changes in Dividends?" *American Economic Review*, 71 (3), 421–436.

Sims, Christopher A and Tao Zha (2006) "Were there regime switches in US monetary policy?" *American Economic Review*, 96 (1), 54–81.

Smets, Frank and Rafael Wouters (2007) "Shocks and frictions in US business cycles: A Bayesian DSGE approach," *American Economic Review*, 97, 586–606.

Song, Dongho (2017) "Bond market exposures to macroeconomic and monetary policy risks," *Review of Financial Studies*, 30 (8), 2761–2817.

Stock, James H and Mark W Watson (2002) "Has the business cycle changed and why?" *NBER Macroeconomics Annual*, 17, 159–218.

——— (2007) "Why has US inflation become harder to forecast?" *Journal of Money, Credit and Banking*, 39, 3–33.

Swanson, Eric T and John C Williams (2014) "Measuring the effect of the zero lower bound on medium-and longer-term interest rates," *American Economic Review*, 104 (10), 3154–85.

Taylor, John B (1993) "Discretion versus policy rules in practice," *Carnegie-Rochester Conference Series on Public Policy*, 39, 195–214.

Uhlig, Harald (1999) "A toolkit for analysing nonlinear dynamic stochastic models easily," in Marimon, Ramon and Andrew Scott eds. *Computational Methods for the Study of Dynamic Economics*, 30–61: Oxford University Press.

——— (2007) "Explaining asset prices with external habits and wage rigidities in a DSGE model," *American Economic Review*, 97 (2), 239–243.

Verdelhan, Adrien (2010) "A habit-based explanation of the exchange rate risk premium," *The Journal of Finance*, 65 (1), 123–146.

Viceira, Luis M (2012) "Bond risk, bond return volatility, and the term structure of interest rates," *International Journal of Forecasting*, 28 (1), 97–117.

Wachter, Jessica A (2006) "A consumption-based model of the term structure of interest rates," *Journal of Financial Economics*, 79 (2), 365–399.