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

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First Version: July 12, 2022
This Version: February 22, 2024

Abstract

This paper shows that the interaction of economic shocks with the monetary policy rule drives bond-stock betas in a New Keynesian asset pricing model with habit formation preferences. In my model, nominal bond betas change sign with the monetary policy inflation weight, but only if supply shocks are dominant. The betas of real bonds are closely linked to the nature of economic shocks. In the model, endogenously time-varying risk premia explain the volatility and predictability of bond and stock excess returns in the data, and imply that bond-stock betas price the expected equilibrium mix of shocks rather than realized shocks. The model explains the change from positive nominal and real bond-stock betas in the 1980s to negative nominal and real bond-stock betas in the 2000s through a change from dominant supply shocks and an inflation-focused monetary policy rule, to demand shocks in the 2000s. The model can be used to infer financial market concerns about inflation producing a severe recession, and provides a framework to assess the dominance of supply vs. demand shocks and the inflation-focus of monetary policy priced in financial markets.

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

*Email cpflueger@uchicago.edu. I thank Adrien Auclert, Francesco Bianchi, Luigi Bocola, Stefania D'Amico, John Campbell, Anna Cieslak, Wioletta Dziuda, Mark Gertler, Simon Gilchrist, Joshua Gottlieb, Francois Gourio, Emi Nakamura, Anil Kashyap, Moritz Lenel, Martin Lettau, Sydney Ludvigson, Xiaoji Lin, Dongho Song, Harald Uhlig, Rosen Valchev, Luis Viceira, Min Wei, Gianluca Rinaldi, Jón Steinsson, and seminar participants at the University of Chicago, Princeton, Harvard, Notre Dame University, NYU, Cornell, the Bank of Canada, the San Francisco Fed Macroeconomics and Monetary Policy Conference, NBER Summer Institute Monetary Economics 2023, NBER DSGE Workshop, and the Minnesota Macro-Finance conference for valuable comments, and Valeria Morales and Luis Yépez for excellent research assistance. Funding from the National Science Foundation (NSF 2149193) "Monetary Policy as a Driver of Financial Markets" is gratefully acknowledged.

1 Introduction

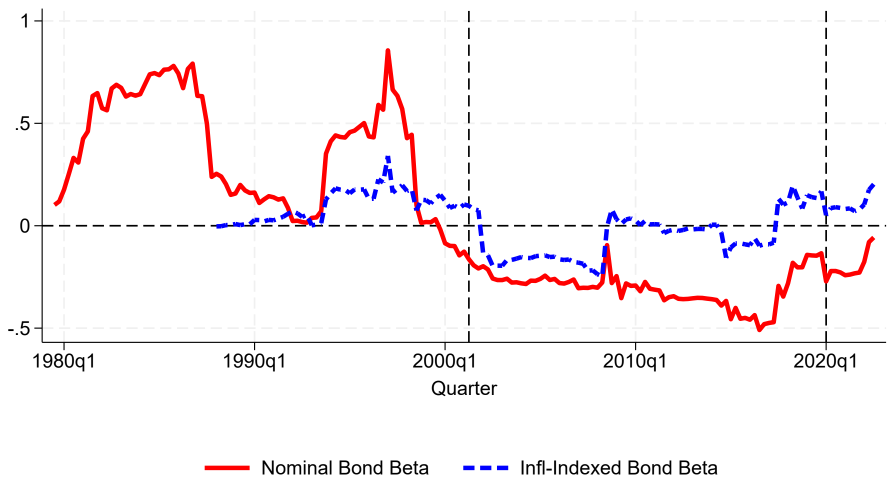
What do nominal and real Treasury bond risks tell us about supply shocks and stagflation or, conversely, the Fed's ability to engineer a "soft landing"? Figure 1 shows rolling nominal and inflation-indexed bond-stock return betas from the 1980s through 2022.[1] Nominal and inflation-indexed bonds have different inflation exposures, so nominal bond betas are intuitively informative about inflation dynamics, whereas inflation-indexed bond betas are informative about the drivers of real interest rates. During the 1980s nominal bond betas were positive and significantly larger than inflation-indexed bond betas, as one would expect if inflation expectations rise during stagflationary recessions. Nominal bond betas changed sign and the gap between nominal and inflation-indexed bond betas narrowed during the 2000s, as one would expect when inflation is relatively stable and tends to rise in expansions. While the level of inflation changed dramatically post-pandemic, nominal bond-stock betas remained, perhaps surprisingly, stable through 2022.

Using a model that integrates volatile and business-cycle driven risk premia with a standard New Keynesian model, this paper demonstrates that the *interaction* of economic shocks and monetary policy is priced in bond-stock comovements. The model shows that the changing bond-stock betas from the 1980s to the 2000s are explained by a change from dominant supply shocks to dominant demand shocks, and from a fast and inflation-focused monetary policy rule to a more inertial and output-centric one. Counterfactual combinations reveal that real bond betas are closely linked to which shock is dominant, being positive with supply and monetary policy shocks but negative with demand shocks. Nominal bond betas in the model strongly increase with the monetary policy inflation weight, particularly when supply shocks are dominant. Combining supply shocks with a "soft landing," where monetary policy manages to buffer the recession that would otherwise ensue following an adverse supply shock, implies negative nominal but positive real bond-stock betas in my model, similar to empirical bond-stock betas during the initial inflation surge of 2021-2022. Hence, while economists may have been surprised that bond-stock betas remained stable during the recent inflation surge, and worried about a recession that never came, my model, combined with my empirical analysis, suggests that these observations should not be surprising, if financial markets correctly anticipated a more inertial and output-focused monetary policy response to supply shocks than in the 1980s.

A growing literature has focused on modeling the interaction between monetary policy, fundamental shocks, and financial markets (e.g. Kekre and Lenel (2020), Caballero and

[1] 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. Campbell, Shiller and Viceira (2009) find similar changes in US and UK nominal and inflation-indexed bond-stock betas.

Figure 1: Rolling Nominal and Real Bond-Stock Betas



Note: This figure 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.

Simsek (2022), Bianchi, Lettau and Ludvigson (2022a), Bianchi, Ludvigson and Ma (2022c)). This paper contributes to this body of work by studying how different types of fundamental shocks interact with the monetary policy rule to determine the risks of nominal and real bonds when risk premia are volatile and responsive to the state of the economy. Building on Campbell, Pflueger and Viceira (2020) but different from this prior work, I require the inflation and interest rate equilibrium equations to take the form of a Phillips curve and Taylor-type monetary policy rule. While the different leading asset pricing frameworks can be useful in different contexts,[2] the debate is sufficiently open that it is important to understand the implications of the monetary policy rule when asset prices are modeled via habit formation preferences. The asset pricing habit formation preferences used here are known to capture a wide range of asset pricing moments, including the high volatility of stock returns, their high Sharpe ratio, the predictability of stock excess returns (Campbell and Cochrane (1999)), and the risk premium effect of high-frequency monetary policy surprises (Bernanke and Kuttner (2005), Pflueger and Rinaldi (2022)).

[2]See e.g. Ai and Bansal (2018), Ai, Bansal and Han (2021) and Wachter and Zhu (2020) for recent applications of recursive preferences and rare disasters around news announcements.

In the model, investors price bonds and stocks with the stochastic discount factor from consumption utility, subject to a bond preference shock similar to the safety shock that has been increasingly successful in the international finance literature (Bianchi and Lorenzoni (2021), Kekre and Lenel (2021), Jiang, Krishnamurthy and Lustig (2021)). The supply side of the model features partially adaptive wage-setter inflation expectations and sticky wages in the manner of Rotemberg (1982), so a supply shock to the wage Phillips curve corresponds to a wage markup shock. Monetary policy is described by a Taylor (1993)-type rule for the short-term interest rate with an inertia coefficient on the lagged policy rate. In the tradition of structural economic shocks, the demand, supply, and monetary policy shocks are assumed to be uncorrelated.[3] 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 separately to macroeconomic data from the 1980s and 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, when the correlation between inflation and the output gap turned from negative (i.e. stagflations) to positive (Campbell et al. (2020)). The volatilities of shocks and monetary policy parameters for each subperiod target 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 results by Campbell and Shiller (1991). When inflation follows a highly persistent process, the yield spread between long- and shorter-term bonds mostly reflects time-varying risk premia and predicts future bond excess returns. Bond risks therefore contribute to the understanding of forward- vs. backward-

[3]While Campbell, Pflueger and Viceira (2020) allow for an equilibrium relationship (21) that looks similar to a Taylor rule, that equation cannot be interpreted as structural because its shocks are correlated with other economic shocks and its coefficients are negative.

[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), Bauer and Swanson (2023), and Bauer, Pflueger and Sunderam (2022) for direct empirical evidence of the Fed's output concern after the mid-1990s.

looking Phillips curves (Fuhrer (1997)) and expectations in New Keynesian models (Gabaix (2020)).

I next use the calibrated model for a series of counterfactual analyses. The first counterfactual shows that combining 1980s-style shocks with 2000s-style systematic monetary policy implies negative nominal bond betas but positive real bond-stock betas. Intuitively, when the systematic component of monetary policy allows the real rate to fall substantially in response to an inflationary supply shock, the recession is mitigated and a "soft landing" ensues. Stocks benefit even more since investors' consumption remains further from habit, increasing the willingness to pay for risky stocks just as real rates fall. Because the stock market and nominal bonds experience negatively correlated real cash flows, nominal bonds are hedges. This implies that investors are willing to pay more for nominal bonds when risk aversion increases, leading to a negative nominal bond-stock beta. Nominal bond-stock betas do not depend strongly on the adaptiveness of wage-setters' inflation expectations.

The second counterfactual shows the crucial role of the expected mix of shocks priced in equilibrium, whereas realized shocks matter little for bond-stock betas. Since time-varying risk premia dominate the volatilities of asset prices in the model, risk premia are crucial for the responses of bonds and stocks to shocks. The equilibrium – including the equilibrium shock volatilities – matters for bond-stock comovements by determining whether bonds benefit or suffer from "flight-to-safety." Concretely, I show that model nominal bond-stock betas remain positive as long as the 1980s calibration is priced in equilibrium, even if the realized shocks are drawn from the 2000s distribution. Intuitively, in the 1980s equilibrium nominal bonds are priced as risky assets because they are expected to pay out in low marginal utility states. An increase in risk aversion – whether ultimately caused by realized demand, supply, or monetary policy shocks – leads investors to require a higher risk discount on these risky nominal bonds and tends to drive down nominal bond and stock prices simultaneously.

The third counterfactual varies the monetary policy inflation weight for three separate shock configurations: a) dominant supply shocks as in the 1980s calibration; b) dominant demand shocks as in the 2000s calibration; and c) dominant monetary policy shocks. This counterfactual shows that the sign of real bond betas is closely linked to the expected combination of shocks. On the other hand, monetary policy hawkishness is important for the magnitude of nominal bond betas, particularly when supply shocks are dominant. Demand shocks generate negative real bond-stock betas, while supply and monetary policy shocks generate positive real bond-stock betas. This is because supply shocks and monetary policy shocks move consumption along a stable Euler equation, lowering consumption and dividends in response to higher real rates. Conversely, demand shocks or bond preference shocks drive a wedge in the Euler equation, leading to a recession just as real rates are falling. Since the monetary policy response determines whether or not a supply shock leads to a "soft landing," nominal bond betas increase with the monetary policy inflation weight and even flip sign when supply shocks are dominant. By contrast, when demand shocks are dominant, model-implied nominal bond betas are negative and slightly lower than real bond betas, since inflation moves up and down a stable Phillips curve. When monetary policy shocks are dominant, model-implied nominal bond betas are positive, again somewhat lower than real bond betas, and increase with the monetary policy inflation weight. Overall, nominal and real bond-stock betas are jointly informative about the dominant shock and the monetary policy inflation weight.

Finally, I invert the relationship between real and nominal bond-stock betas and the priced dominant shocks and the monetary policy rule for a select number of target betas. Even though only bond-stock betas and no macroeconomic moments are used for this exercise, the implied dominant shocks and monetary policy rule are intuitive and in line with the macroeconomic calibration for the 1980s and 2000s. The negative nominal and positive real bond betas over the period 2020-2022 imply dominant supply shocks and a moderate monetary policy inflation weight, similar to the counterfactual combination of 1980s style shocks with 2000s-style monetary policy rule. In the last half of 2023, nominal and real bond-stock betas experienced a pronounced spike, which the model attributes to dominant supply shocks and an increase in the monetary policy inflation coefficient. When interpreting these higher-frequency fluctuations in bond betas it is important to keep in mind the role of time-varying risk premia, which imply that bond-stock betas can price an equilibrium with dominant supply shocks even if no supply shocks have occurred over a short period. Taken together, this application shows how nominal and real bond-stock betas can serve as informative moments for the nature of macroeconomic shocks and the monetary inflation stance.

This paper contributes broadly to research seeking to understand the nexus between asset prices, monetary policy, and the macroeconomy. The insight that monetary policy has short- to medium-term effects and impacts risk premia makes it attractive to use an asset pricing model that prices business cycle fluctuations. In that sense, this paper is closely related to reduced-form models of the economy, where time-varying risk premia are driven by habit formation preferences (Wachter (2006), Verdelhan (2010)). Prior work has emphasized the challenges of integrating asset pricing habit preferences with production and monetary policy (Jermann (1998), Lettau and Uhlig (2000)). While my model builds on habit formation preferences, the mechanism more broadly relies on countercyclical risk premia, whether they are generated from the price of risk as here, from the quantity of risk as in Jurado, Ludvigson and Ng (2015), or from heterogeneous agents with different risk aversion (Chan and Kogan

(2002), Kekre and Lenel (2020), Caballero and Simsek (2020), Drechsler, Savov and Schnabl (2018)). The relatively parsimonious habits model used here is known to unify a wide range of asset pricing puzzles, such as the evidence on equity volatility, stock return predictability, and the stock response to monetary policy surprises. In contrast to Bauer, Pflueger and Sunderam (2022) the asset moments in this paper are informative about both monetary policy and economic shocks, priced over the lifetime of the assets. Bond-stock comovements also matter separately, for example for portfolio allocation and Treasury debt issuance.

This paper also contributes to the growing literature on changing bond risks, showing how the interaction between economic shocks and monetary policy determines real and nominal bond-stock betas. It is complementary to more reduced-form approaches. Notably, Piazzesi and Schneider (2006) found that over the second half of the 20th century, high inflation tended to predict lower future consumption and nominal bonds were hence risky assets for investors.[5] 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 patterns in nominal and real bond risks pre-2000, which allows me to analyze the contributions of fundamental shocks and monetary policy. By emphasizing how monetary policy interacts with supply, demand and monetary policy shocks, this paper differs from and complements prior work studying the implications of changing monetary policy with a constant distribution of shocks.[6] A separate set of papers has used recursive preferences and long-run risks to understand unconditional asset pricing moments in New Keynesian models (Kung (2015), Rudebusch and Swanson (2012), Swanson (2021)). In work building on this paper, Seo (2023) studies bond-stock correlations when supply-type shocks are microfounded via price dispersion.

Finally, this paper disciplines the macroeconomic understanding on the sources of stagflations using asset prices, and offers a new framework to interpret the informational content in financial markets. Within the discussion on the role of shocks vs. policy, a prominent literature has argued that stagflations are not the result of fundamental economic shocks or the monetary policy rule in isolation, but instead require the interaction between them to create a "perfect storm."[7] I show that historical variation in bond-stock betas and their sign-flip

[5]See also Baele, Bekaert and Inghelbrecht (2010), David and Veronesi (2013), Song (2017), Campbell, Sunderam, Viceira et al. (2017).

[6]Bianchi, Lettau and Ludvigson (2022a), Bianchi, Ludvigson and Ma (2022c), Gourio and Ngo (2020), Li, Zha, Zhang and Zhou (2022), Gourio and Ngo (2022). Feldman and King (2024) and focus on monetary policy shocks as the source of uncertainty, and different from here do not speak to supply or demand shocks.

[7]See, e.g. Stock and Watson (2002), Sims and Zha (2006), Primiceri (2006), Lubik and Schorfheide

between the 1980s and 2000s supports this interpretation. Further, in my model positive nominal bond-stock betas are indicative, as they arise if investors anticipate volatile supply shocks and a reactive monetary policy rule in equilibrium, but not if the monetary policy rule is inertial and more output-focused. Post-Covid, the model indicates that bond-stock betas priced volatile supply shocks and an initially moderate but increasing monetary policy weight on inflation, corroborating macroeconomic research on the recent rise in inflation (e.g. Reis (2022), Gagliardone and Gertler (2023), Rubbo (2022)).

2 Model

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

2.1 Preferences

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

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

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:

$$S_t = \frac{C_t - H_t}{C_t}. \quad (2)$$

Risk aversion therefore increases 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:

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

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

(2004), Bernanke, Gertler and Watson (1997).

Here, x_t equals the log output gap, defined as log real output minus log potential real output at perfectly flexible prices and wages. In Section 2.4, potential depends on a moving average of past output and there is no real investment, yielding a useful expression linking the output gap and consumption (up to a constant):

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

Here, ϕ is a smoothing parameter. Expression (5) implies that log consumption growth is stationary – as is standard in asset pricing – but the output gap is stationary in levels, as is standard in macroeconomics. It is also consistent with the smoothing embedded in typical empirical proxies of potential. Provided that the parameter ϕ is close to one, asset price dynamics are relatively insensitive to its precise value.

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

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

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

This function is decreasing in log surplus consumption, so marginal utility becomes more sensitive to consumption surprises when surplus consumption is already low, as would be the case after a sequence of bad shocks. Here, σ_c denotes the standard deviation of the consumption surprise $\varepsilon_{c,t+1}$ and $\bar{s}$ is the steady-state value for log surplus consumption. Both consumption and the output gap are equilibrium objects that depend on fundamental shocks, and in equilibrium they are conditionally homoskedastic and lognormal. As shown in Campbell, Pflueger and Viceira (2020), implied log habit follows approximately a weighted average of lagged consumption and lagged consumption expectations.

2.2 Asset Pricing Equations and Bond Preference Shock

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

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

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

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

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

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

At time t, the aggregate levered firm buys P^c_t and sells equity worth δP^c_t, with the remainder of the firm's position financed by one-period risk-free debt worth $(1-\delta)P^c_t$, so the price of the levered equity claim equals $P^\delta_t = \delta P^c_t$.

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

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

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

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

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

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

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

where all expectations are rational. Because all bonds are priced with the preference shock ξ_t, the expectations hypothesis holds when investors are risk-neutral. Log zero coupon yields are defined by $y_{n,t} = -\log P_{n,t}$ and $y^\$_{n,t} = -\log P^\$_{n,t}$, and log excess returns in excess of the corresponding 1-quarter rate from t to $t+h$ are denoted by $xr^\$_{n,t\to t+h}$ and $xr_{n,t\to t+h}$.

Fundamentally, the shock ξ_t corresponds to a disconnect between the bond and the stock markets, like the one that occurred in March 2020, as documented empirically by He, Nagel and Song (2022). A positive shock ξ_t acts like a decline in Treasury bond convenience – analogous to the time-varying intermediation capacity that has been successful at reconciling several empirical puzzles in international finance – and may reflect that households do not have direct access to the government bond market.[8] Alternatively, the shock ξ_t can be microfounded as an optimism or growth shock, similar to expectations-based demand shocks in Beaudry and Portier (2006), Bordalo, Gennaioli, LaPorta and Shleifer (2022) and Caballero and Simsek (2022)'s "traditional financial forces" shock. For microfoundations see Appendix C.

2.3 Macroeconomic Euler Equation from Preferences

I next show that the bond preference shock enters equilibrium macroeconomic dynamics just like a demand shock in the Euler equation. Starting from the asset pricing equation for a one-period risk-free bond (11), and substituting for the SDF and surplus consumption dynamics gives (up to a constant):

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

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

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

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

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

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

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

[8] See e.g. Krishnamurthy and Vissing-Jorgensen (2012), Du, Im and Schreger (2018), Bernanke and Gertler (2001), Gilchrist and Zakrajšek (2012), Bianchi and Lorenzoni (2021), Gabaix and Maggiori (2015), Jiang, Krishnamurthy and Lustig (2021), Jiang, Krishnamurthy and Lustig (2021), Itskhoki and Mukhin (2021), Kekre and Lenel (2021), Fukui, Nakamura and Steinsson (2023), Engel and Wu (2023). Pflueger, Siriwardane and Sunderam (2020) provide US evidence that preference for safety that is not immediately driven by aggregate risk aversion can forecast business cycle variables.

shock in the Euler equation equals:

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

Because consumption is endogenous, a decrease in the preference for government bonds ($\xi_t \uparrow$) tends to raise both consumption and the real rate through (17). Higher consumption, in turn, raises dividends and lowers risk aversion. The preference shock ξ_t is hence expected to raise stock prices, even though it does not appear directly in the Euler equation for consumption claims. Because ξ_t is conditionally homoskedastic, serially uncorrelated and uncorrelated with supply and monetary policy shocks, the demand shock $v_{x,t}$ is as well. The standard deviation of $v_{x,t}$ is denoted by σ_x.[9]

2.4 Supply Side

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

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

Phillips curve:

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

for constants ρ^π, f^π, and κ. The parameter κ is a wage-flexibility parameter. The supply or Phillips curve shock $v_{\pi,t}$ is assumed to be conditionally homoskedastic with standard deviation $\sigma_{\pi,t}$, serially uncorrelated, and uncorrelated with other shocks. This supply shock can arise from a variety of sources, such as variation in optimal wage markups charged by unions or shocks to the marginal utility of leisure.[10]

Following Fuhrer (1997) I allow wage-setters to have partially adaptive subjective inflation expectations:

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

where E_t denotes the rational expectation conditional on state variables at the end of period t. Hence, while financial assets are priced with rational inflation expectations, wage-setters' expectations are more sluggish, capturing the idea that markets are more sophisticated and attentive to macroeconomic dynamics than individual wage-setters. A similar assumption has been used by Bianchi, Lettau and Ludvigson (2022a). A long-standing Phillips curve literature has found that adaptive inflation expectations and a strongly backward-looking Phillips curve are needed to capture the empirical persistence of inflation (Fuhrer and Moore (1995), Fuhrer (1997)).[11] If $\rho^{\pi,0}$ is the backward-looking component under rational inflation expectations ($\zeta = 0$), the backward- and forward-looking Phillips curve parameters equal:

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

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

Equilibrium price inflation equals wage inflation minus productivity growth, which de-

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

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

pends on the output gap:

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

In the calibrated model, ϕ is close to one and price and wage inflation are very similar. The reason to assume sticky wages rather than sticky prices is simply that with these assumptions a consumption claim (Abel (1990)) is identical to a claim to firm profits.[12]

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):

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

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

Here, $\gamma^x x_t + \gamma^\pi \pi_t$ denotes the central bank's interest rate target, to which it adjusts slowly.[13] 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 uncorrelated with supply and demand shocks, serially uncorrelated, and conditionally homoskedastic. A positive monetary policy shock represents a surprise tightening of the short-term nominal policy rate, which mean-reverts at rate ρ^i.

2.6 Model Solution

The solution proceeds in two steps, extending the solution method of Campbell et al. (2020). 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

[12] It is also in line with Christiano, Eichenbaum and Evans (1999), who find that sticky wages are more important for aggregate inflation dynamics than sticky prices. See also Favilukis and Lin (2016), who find that wage-setting frictions are important to ensure that a claim to firm profits behaves similarly to a claim to consumption in an asset pricing sense. Appendix D.4 shows that model implications are robust to setting wage and price inflation equal through $\phi = 1$.

[13] I do not model the zero lower bound, because I am interested in longer-term regimes, and a substantial portion of the zero lower bound period appears to have been governed by expectations of a swift return to normal (Swanson and Williams (2014)). The zero-lower-bound may however be important for more cyclical changes in bond-stock betas, as emphasized by Gourio and Ngo (2020), and I leave this to future research.

the log-linear state vector:

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

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

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

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

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

where B and Σ are $[3 \times 3]$ and $[3 \times 3]$ matrices, and v_t is the vector of structural shocks. I solve for the matrix B using Uhlig (1999)'s formulation of the Blanchard and Kahn (1980) method. In both calibrations, there exists a unique equilibrium of the form (28) with non-explosive eigenvalues. I acknowledge that, as in most New Keynesian models, there may be further equilibria with additional state variables or sunspots (Cochrane (2011)), but resolving these issues is beyond the scope of this paper. Note that equation (28) implies that macroeconomic dynamics are conditionally lognormal. The output gap-consumption link (5) therefore implies that equilibrium consumption surprises $\varepsilon_{c,t+1}$ are conditionally lognormal, as previously conjectured.

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

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

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

Because full asset prices are not one-period claims, I use numerical value function iteration to solve the recursions (9) through (14) while accounting for the new demand shock and the link between wage and price inflation (23). Asset prices have five state variables: the three state variables included in Y_t, the lagged output gap x_{t-1}, and the surplus consumption ratio s_t. Different from Campbell et al. (2020), I need x_{t-1} as an additional state variable because it enters the the surplus consumption ratio dynamics (3), and the new demand shock breaks the link between x_{t-1} and the state vector Y_t.

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 date was chosen by testing for a break in the inflation-output gap relationship without using asset prices. I start the sample in 1979.Q4, when Paul Volcker was appointed as Fed chairman. I end the sample in 2019.Q4, prior to the pandemic, leaving the analysis of how shocks changed during the pandemic period for a separate discussion. I do not account for the possibility that agents might have anticipated a change in regime.[14] 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 invariant values following the literature, shown in Panel B of Table 1. The expected consumption growth rate, utility curvature, the risk-free rate, and the persistence of the surplus consumption ratio (θ_0) are from Campbell and Cochrane (1999), who found that a utility curvature of $\gamma = 2$ gives an empirically reasonable equity Sharpe ratio and set θ_0 to match the quarterly

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

Table 1: Calibration Parameters

Panel A: Period-Specific Parameters		1979.Q4-2001.Q1	2001.Q2-2022.Q2
MP Inflation Coefficient	γ^{π}	1.35	1.10
		(0.53)	(0.06)
MP Output Coefficient	γ^{x}	0.50	1.00
		(0.74)	(0.30)
MP Inertia	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	δ	0.50	0.66

Panel B: Invariant Parameters		
Consumption Growth	g	1.89
Utility Curvature	γ	2
Risk-Free Rate	$\bar{r}$	0.94
Persistence Surplus Cons.	θ_0	0.87
Backward-Looking Habit	θ_1	-0.84
PC slope	κ	0.0062
Consumption-output gap	ϕ	0.99

Consumption growth and the real risk-free rate are in annualized percent. The standard deviation σ_x is in percent, and the standard deviations σ_π and σ_i are in annualized percent. The Phillips curve slope κ and the monetary policy parameters γ^{π}, γ^{x} and ρ^{i} are in units corresponding to the output gap in percent, and inflation and interest rates in annualized percent. Standard errors are computed using the delta method with details given in Appendix E.

persistence of the equity price-dividend ratio in the data. The output gap-consumption link parameter $\phi = 0.99$ is chosen to maximize the empirical correlation between stochastically detrended real GDP and the output gap from the Bureau of Economic Analysis. I choose a slightly higher value because the correlation between the output gap and stochastically detrended real GDP is flat over a range of values ($corr = 76\%$ at $\phi = 0.93$ vs. $corr = 73\%$ at $\phi = 0.99$), and higher ϕ minimizes the gap between price and wage inflation and hence simplifies the model. I calibrate $\theta_1 - \phi$ and hence the Euler equation exactly as in Pflueger and Rinaldi (2022), where the habit parameters θ_1 and θ_2 were chosen to replicate the hump-shaped response of output to an identified monetary policy shock in the data. The second habit parameter, θ_2 is implied and set to ensure that the backward- and forward-looking components in the Euler equation sum up to one. Because the model impulse responses to a monetary policy shock are invariant to the shock volatilities and vary little with monetary policy and Phillips curve parameters, I effectively match habit preferences to the output response to an identified monetary policy shock. I set the slope of the Phillips curve to $\kappa = 0.0062$ based on Hazell, Herreno, Nakamura and Steinsson (2022), who also find it to be stable over time. Appendix Table A4 shows that asset pricing implications are robust to choosing a different utility curvature γ, consumption-output gap link ϕ, and Phillips curve slope κ.

3.3 Period-Specific Shock Volatilities and Monetary Policy

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

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

The vector of target moments $\hat{\Psi}$ includes the standard deviations of annual real consumption growth, the annual change in the fed funds rate, and the annual change in survey ten-year inflation expectations, as well as the output gap-inflation, output gap-fed funds rate, and inflation-fed funds rate lead-lag relationships at three different horizons.[15]

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

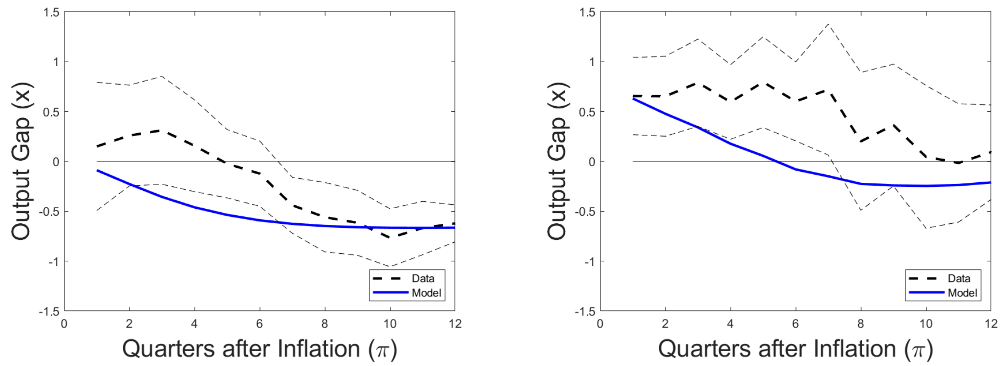
$$z_{t+h} = a_{0,h} + a_{1,h} y_t + a_{2,h} y_{t-1} + \varepsilon_{t+h}. \tag{31}$$

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

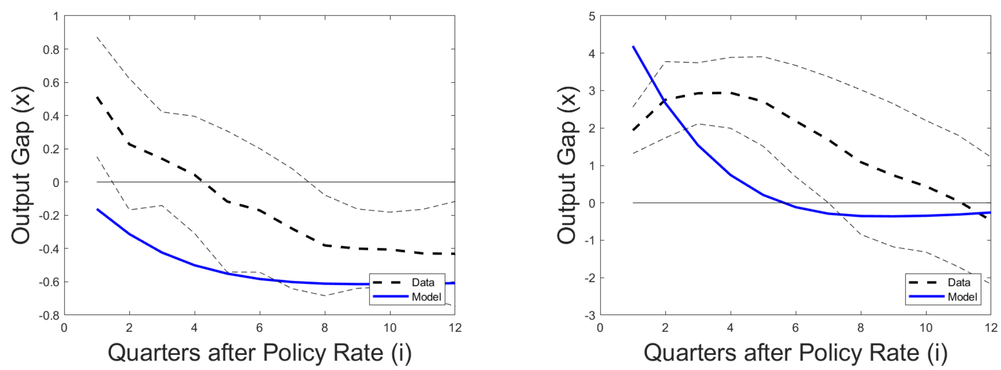
Figure 2: Local Projections for Inflation, Output Gap, and Fed Funds Rate

Panel A: Output Gap onto Lagged Price Inflation

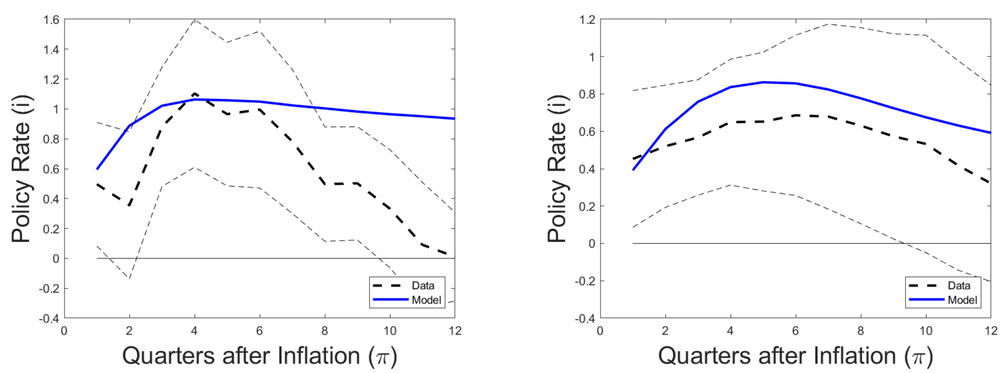
1979.Q4-2001.Q1 2001.Q2-2019.Q4



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.

I consider the variable combinations $(z_t, y_t) = (x_t, \pi_t)$, $(z_t, y_t) = (x_t, i_t)$, and $(z_t, y_t) = (\pi_t, i_t)$ and horizons of one, three, and seven quarters. For the second calibration period, when wage inflation data is easily available, I also estimate the specification $(z_t, y_t) = (x_t, \pi_t^w)$ and target the difference $a_{1,h}^{x,\pi} - a_{1,h}^{x,\pi^w}$. While these regressions do not estimate identified shocks, including lags tends to result in a right-hand-side that is highly correlated with structural shocks in model-simulated data. The vector of empirical standard errors $SE(\hat{\Psi})$ is computed via the delta method and Newey-West standard errors with h lags.

I match many more empirical moments than I have parameters, so this is a demanding calibration objective.[16] The rationale for including several lags is that, for example, the negative inflation-output gap relationship (i.e. stagflation) is clearest at a 6-8 quarter lag horizon. Rather than picking different lags for different variables, I include all lags for all variables – effectively averaging across different lead and lag horizons. Because the model is relatively parsimonious, the model cross-correlations should be expected to be matched on average but not at every lag.

Figure 2, Panel A shows that the model matches the negative inflation-output gap relationship, or stagflations, in the earlier period. The model achieves this fit by setting a high volatility of supply shocks for the 1980s calibration. The right plot in Panel A shows that in the 2000s an increase in inflation tended to be followed by an increase in the output gap, akin to moving up and down a Phillips curve, and the model replicates this relationship by setting a small supply shock volatility in the 2000s calibration. While the model inflation-output gap relationship for the 2000s calibration is not quite as positive in the data, the upward-shift from the first to the second period is well replicated by the model.

Figure 2, Panel B shows that the model matches the negative fed funds-output gap relationship in the 1980s, and the positive fed funds-output gap relationship in the 2000s. The model achieves this by setting a high volatility of monetary policy shocks for the 1980s calibration, but a volatile demand or bond preference shock in the 2000s calibration.[17]

[16] 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 (γ^x, γ^π, ρ^i, σ_x, σ_π, σ_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.

[17] Whether one interprets the demand shock as an increase in financial frictions or as an expected growth shock, it is plausible that its volatility increased from the first subperiod to the second subperiod. The standard deviation of the Gilchrist and Zakrajšek (2012) credit spread 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

The lead-lag relationship between inflation and the fed funds rate in Figure 2, Panel C pins down the monetary policy rule parameters in the model. The 1980s calibration features a higher inflation weight, γ^{π}, a lower output gap weight, γ^{x}, and lower inertia, ρ^{i}, while the 2000s calibration features a lower inflation weight, γ^{π}, a higher output gap weight, γ^{x}, and higher inertia, ρ^{i}. While the standard errors for γ^{x} and γ^{π} appear to be 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.

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

3.4 Adaptiveness of Inflation Expectations and Leverage

I choose the adaptive inflation expectations parameter $\zeta \in \{0, 0.6\}$ to match the empirical evidence on bond excess return predictability for each subperiod, while holding all other parameters constant at their values chosen in the second step. This step is kept separate because solving for asset prices is orders of magnitudes slower than solving for macroeconomic dynamics. The objective function minimized in this step is equation (30) plus the squared standardized difference between the model and data Campbell-Shiller bond return predictability coefficient with a weight of 100.[18]

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).

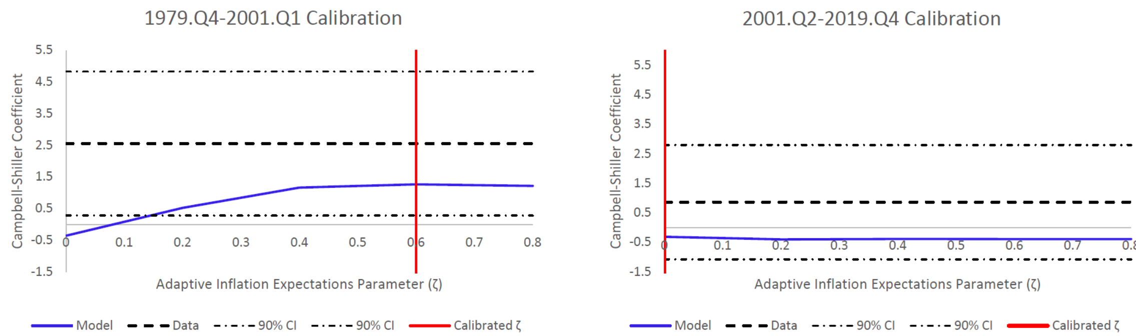
[18]Inflation forecast error regressions along the lines of Coibion and Gorodnichenko (2015) further support partially adaptive inflation expectations in the 1980s and rational inflation expectations in the 2000s (see Appendix Table A3).

Table 2: Quarterly Asset Prices and Macro Volatilities

	1979.Q4-2001.Q1		2001.Q2-2019.Q4	
Asset Prices: Stocks	Model	Data	Model	Data
Equity Premium	7.33	7.96	9.15	7.64
Equity Vol	14.95	16.42	19.29	16.80
Equity Sharpe Ratio	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

Moments that are 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. 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.

Figure 3: Model Campbell-Shiller Predictability by Inflation Expectations



This figure shows the model Campbell-Shiller bond excess return predictability regression coefficient b from a regression of the form $xr^{\$}_{n,t\to t+4} = a + b\left(y^{\$}_{n,t} - y^{\$}_{1,t}\right) + \varepsilon_t$ using quarterly overlapping observations and $n = 40$ quarters (10 years) in the model and in the data. On the y-axis is the parameter determining the adaptiveness of inflation expectations, ζ, which determines the backward-looking component of the PC through (22) in the model. All other parameters are as in Table 1. The data coefficient is shown as a black dashed line with 90% confidence intervals based on Newey-West standard errors with 4 lags.

Figure 3 shows the predictability of bond excess returns from the yield spread at different values for the inflation expectations parameter, ζ. The model-implied Campbell-Shiller coefficients in Figure 3 indicate that we can reject fully rational inflation expectations for the 1980s subperiod. Of course, the distance to the macroeconomic dynamics is affected by varying ζ in this separate step. However, viewed more broadly within the econometric literature on inflation dynamics, the macroeconomic fit actually improves, as setting $\zeta = 0.6$ in the 1980s calibration makes the policy rate response in the left plot of Panel C more persistent, in line with empirical evidence of a strong persistent inflation component during the 1980s (Stock and Watson (2007)). Intuitively, when inflation is highly persistent, the expectations hypothesis term in the yield spread cancels, the yield spread predicts future bond excess returns, and the Campbell-Shiller coefficient is positive. Appendix Figure A5 illustrates the mechanism. Appendix Figure A2 compares the model fit with $\zeta = 0$ vs. $\zeta = 0.6$. The link between bond excess return predictability and the persistence of inflation is reminiscent of an older empirical literature that has documented that the expectations hypothesis holds in time periods and countries where interest rates are less persistent (Mankiw, Miron and Weil (1987), Hardouvelis (1994)). It is also consistent with Cieslak and Povala (2015)'s evidence that removing trend inflation uncovers time-varying risk premia in the yield curve.

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

3.5 Asset Pricing Implications

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

The middle panel in Table 2 shows that the model explains the motivating evidence in Figure 1, Panel A, even though bond-stock betas were not explicitly targeted in the calibration. The model-implied nominal bond beta is strongly positive and much larger than the real bond beta in the 1980s calibration, but negative and close to the real bond beta in the 2000s calibration, similar to the data. Model-implied nominal Treasury bond excess returns are volatile in the 1980s calibration and much less volatile in the 2000s calibration, again similar to the data.[19] Steady-state expected bond excess returns in the model are closely related to betas, and switch sign from positive in the 1980s calibration to negative in the 2000s calibration. This pattern is consistent with empirical subjective expected bond excess returns, constructed by subtracting the survey expected interest rate path (Piazzesi, Salomao and Schneider (2015), Nagel and Xu (2022)). Subjective expected bond excess returns may be a better measure of ex-ante expected risk premia in the model if ex-post realized returns are biased upwards, as investors were repeatedly surprised by lower-than-expected interest rates (Cieslak (2018), Farmer, Nakamura and Steinsson (2021)).

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

[19]The model nominal bond-stock beta for the 1980s calibration is even more positive here than in the data. Table 3 fits the monetary policy rule and shocks to bond-stock betas, and finds that bond betas can be matched closely with a qualitatively similar monetary policy rule. My model is consistent with Duffee (2011)'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 from 1/3 to 1/2.

the empirical findings of Pflueger and Viceira (2016), which finds 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 as risky as they were 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 and the monetary policy rule, while the adaptiveness of wage-setters' inflation expectations is found to matter little for bond-stock betas.

4.1 Counterfactual Betas 1980s vs. 2000s

Figure 4 shows that nominal bond betas remain negative but real bond betas increase in the presence of shock volatilities similar to the 1980s, provided that the monetary policy framework is more output-focused, less inflation-focused, and more inertial than during the 1980s.

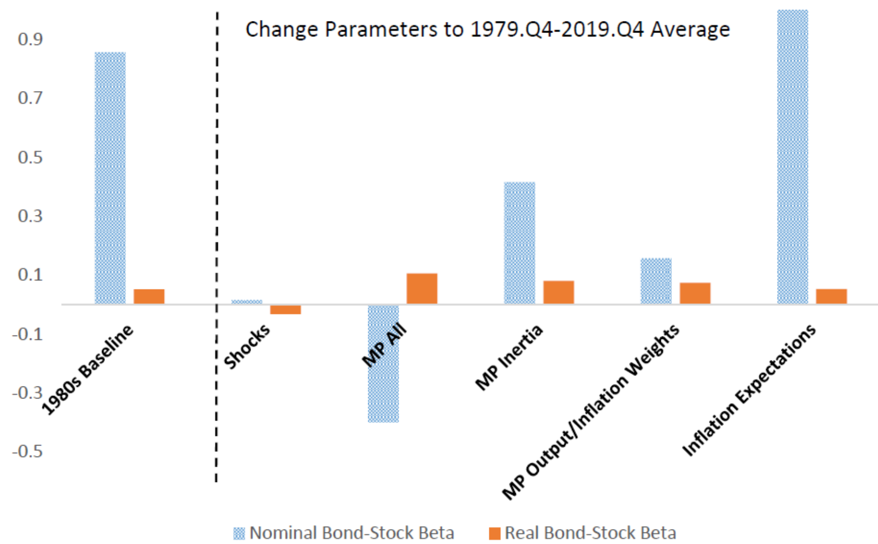
Panel A starts from the 1980s calibration and shows that changing either the shock volatilities or the monetary policy rule towards the 2000s calibration flips nominal bonds from risky (i.e. positive nominal bond beta) to safe (i.e. zero or negative nominal bond beta).[20] Put another way, the model does not imply positive nominal bond-stock betas unless it has both: 1980s-style shock volatilities and a 1980s-style monetary policy rule. However, unlike the 2000s calibration, the real bond-stock beta in the "MP Rule" counterfactual in Panel A is positive. This is because supply and monetary policy shocks dominate, moving the output gap inversely to the real rate along the Euler equation (17). The next two columns in Panel A show that changes in monetary policy inertia (ρ^i) and the long-term inflation and output weights (γ^x, γ^π) both act in the same direction, but that the output and inflation weights are more important quantitatively. The last column shows that the adaptiveness of wage-setters' inflation expectations, i.e. whether wage setters have perfectly rational inflation expectations or partially index them to past inflation, has little effect on bond-stock 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

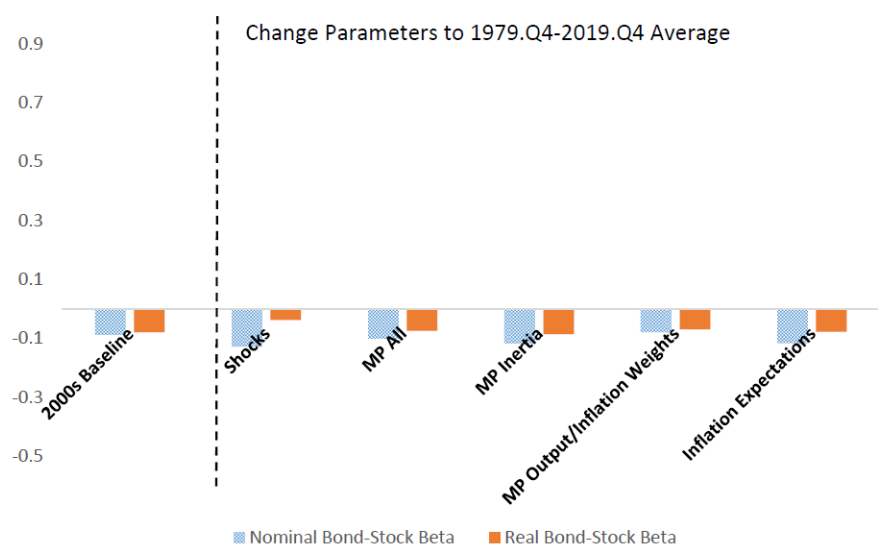
[20]In some cases, the equilibrium may not exist if I move a parameter group all the way to the other calibration, so for comparability I move all parameter groups to the average of the 1980s and 2000s calibrations.

Figure 4: Counterfactual Bond-Stock Betas

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 bond betas 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 All" (ρ^i, γ^x and γ^π), "MP Inertia" (ρ^i), "MP Output/Inflation Weights" (γ^x and γ^π), and "Inflation Expectations" (ζ). Panel B does the reverse exercise, holding all parameter values constant at the 2001.Q2-2019.Q4 baseline.

of nominal bond betas. Most tellingly, the "Shock Volatilities" column implies that even if the shock volatilities were to resemble the 1980s, an inertial and more output-focused monetary policy rule as in the 2000s would keep nominal bond-stock betas negative. The counterfactual real bond beta increases, even though it does not quite turn positive. This is similar to the "MP Rule" column in Panel A, which also combines 1980s-style shocks with a 2000s-style monetary policy rule. Overall, these counterfactuals indicate that positive nominal bond-stock betas and stagflations are not the result of fundamental economic shocks or monetary policy in isolation, but instead require the interaction between them to create a "perfect storm." This interpretation is reminiscent of the macroeconomics literature (Bernanke, Gertler and Watson (1997), Primiceri (2006)), though this prior literature did not consider bond-stock betas. The last column in Panel B again shows that the adaptiveness of wage-setters' inflation expectations is not priced in bond-stock betas, demonstrating that this insensitivity is a robust feature across different calibrations.

4.2 Mechanism

I now illustrate the mechanism through impulse response functions for the macroeconomy and asset prices.

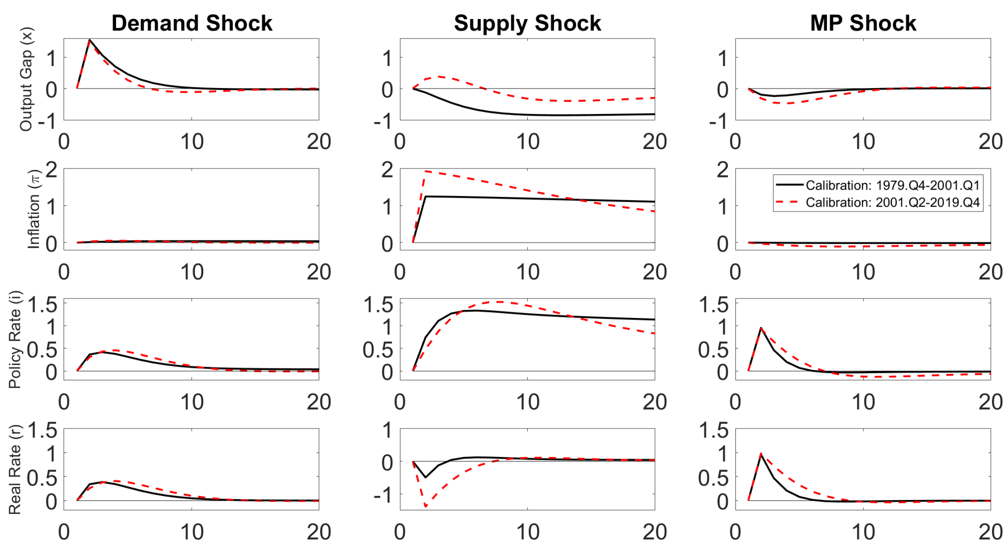
4.2.1 Macroeconomic Impulse Responses

Figure 5 shows model impulse responses for the output gap, nominal policy rate, and wage inflation to one-percentage-point demand, supply, and monetary policy shocks. Because of the structure of the model, the macroeconomic impulse responses preserve the intuition of a standard log-linearized three-equation New Keynesian model for given parameter values, but parameter values are partly chosen to match evidence on bond excess return predictability. Responses to one-standard deviation shocks, which give a visual variance decomposition, are shown in Appendix Figure A6.

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 demand shocks are more important in the 2000s calibration.

The middle column shows the interaction between supply shocks and systematic monetary policy. For the 1980s calibration, a positive supply shock leads to an immediate and persistent jump in inflation, a rapid increase in the nominal 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 little immediate tightening in response to such a shock

Figure 5: Model Macroeconomic Impulse Responses



This figure shows model impulse responses for the output gap (%,), inflation (ann. %), nominal policy rate (ann. %), and real one-quarter interest rate (ann. %). The impulse in the left column is a one-percentage-point demand shock, in the middle column is a one-percentage-point Phillips curve 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 lines.

implies a real rate substantially below steady-state for several quarters. As a result, the output gap follows a much more moderate s-shaped path – a "soft landing." The inflation response for the 2000s calibration is also initially larger but less persistent, due to the less backward-looking Phillips curve in this calibration.

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

Taken together, the macroeconomic impulse responses show that a reactive monetary policy rule and volatile supply shocks are needed to generate a stagflation and negative inflation-output gap comovement. By contrast, inflation and the output gap comove little if monetary policy engineers a "soft landing" after an inflationary supply shock. Positive inflation-output gap comovement results after demand or monetary policy shocks. I next show how these macroeconomic dynamics shape bonds and stocks with endogenously time-varying risk premia.

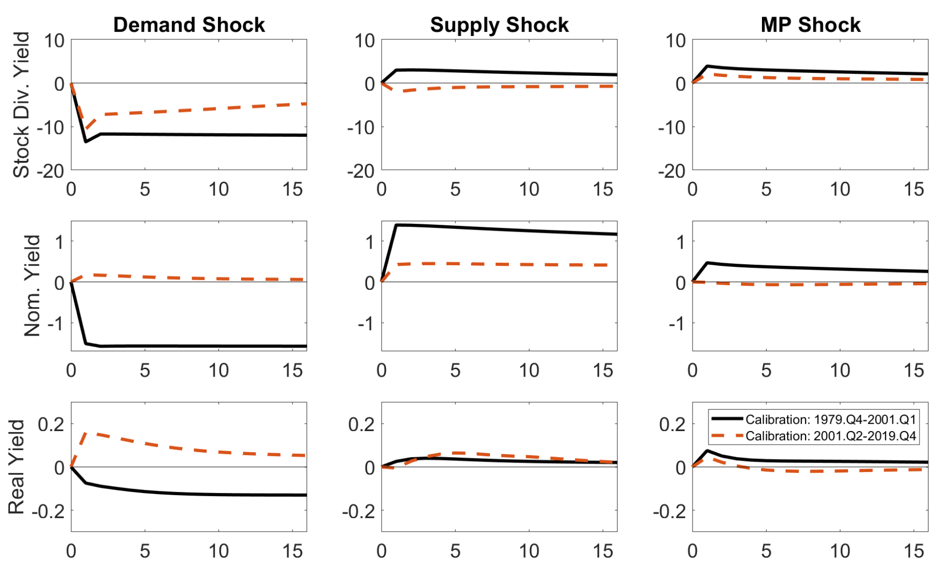
4.2.2 Asset Price Impulse Responses

Since time-varying risk premia dominate the volatilities of asset prices, risk premia are crucial for the responses of bonds and stocks to shocks. As a result, while demand, supply, and monetary policy shocks tend to affect output-interest rate comovements differently, different shocks affect bond-stock comovements similarly within each equilibrium. The equilibrium – including the equilibrium shock volatilities – matters for bond-stock comovements by determining whether bonds benefit or suffer from "flight-to-safety."

Figure 6 shows impulse responses for the dividend yield of levered stocks (top row), ten-year nominal bond yield (middle row), and ten-year real bond yield (bottom row). 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 bond-stock beta and vice versa.

The stock dividend yield responds in the opposite direction as the output gap in the top row of Figure 5. Adverse output gap and consumption news lower expected dividends and the surplus consumption ratio, raising risk aversion. The dividend yield hence rises, and stock prices fall more than the expected discounted value of future dividends. The top-middle panel shows that the dividend yield falls and stock prices rise in response to an adverse supply shock in the 2000s calibration, mirroring the initial output gap increase when monetary policy generates a "soft landing" after an adverse supply shock. This sign change

Figure 6: Model Asset Price Impulse Responses



This figure shows model impulse responses for the stock dividend yield, 10-year zero-coupon nominal bond yield, and 10-year zero-coupon real bond yield (all in ann. %). 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 Phillips curve or supply shock, and in the right column is a one-percentage-point monetary policy shock.

in the stock response is consistent with the well-documented empirical fact that "good news" for the economy was often "bad news" for the stock market (Boyd, Hu and Jagannathan (2005), Elenev, Law, Song and Yaron (2024)).

The responses of long-term nominal and real bond yields differ substantially from their short-term counterparts in Figure 5 due to the endogenous nature of time-varying risk premia, which change the sign of bond-stock comovements not just after supply but also after demand shocks. The left column in Figure 6 shows that long-term nominal bond yields decrease in the 1980s calibration but increase in the 2000s calibration following a positive demand shock. Long-term real bond yield responses to a demand shock similarly flip sign, though the magnitudes are smaller. These sign flips occur because the mix of shocks and monetary policy lead nominal, and to a certain degree real bonds, to resemble positive-α assets in equation (29) in the 1980s calibration, but negative α assets in the 2000s calibration. A positive demand shock lowers risk aversion, leading risky nominal bonds to rise in the 1980s calibration. However, nominal bonds have hedging value in the 2000s calibration, leading their prices to fall when risk aversion falls, as after a positive demand shock.[21]

The reason why nominal bonds change from risky in the 1980s calibration to safe in the 2000s calibration is due to the changing comovement of their real cash flows with the output gap and the stock market. On the one hand, the dominance of demand shocks in the 2000s calibration implies that inflation and nominal short-term rates tend to rise with the output gap, while nominal bonds' real cash flows tend to fall. On the other hand, the change in the monetary policy rule means that supply shocks are less recessionary, also leading to a more negative comovement between nominal bonds' real cash flows and the output gap. The counterfactuals in Figure 4 show that the change in the mix of shocks and the change in monetary policy reinforced each other, and either alone would have been sufficient to change the betas of nominal bonds.

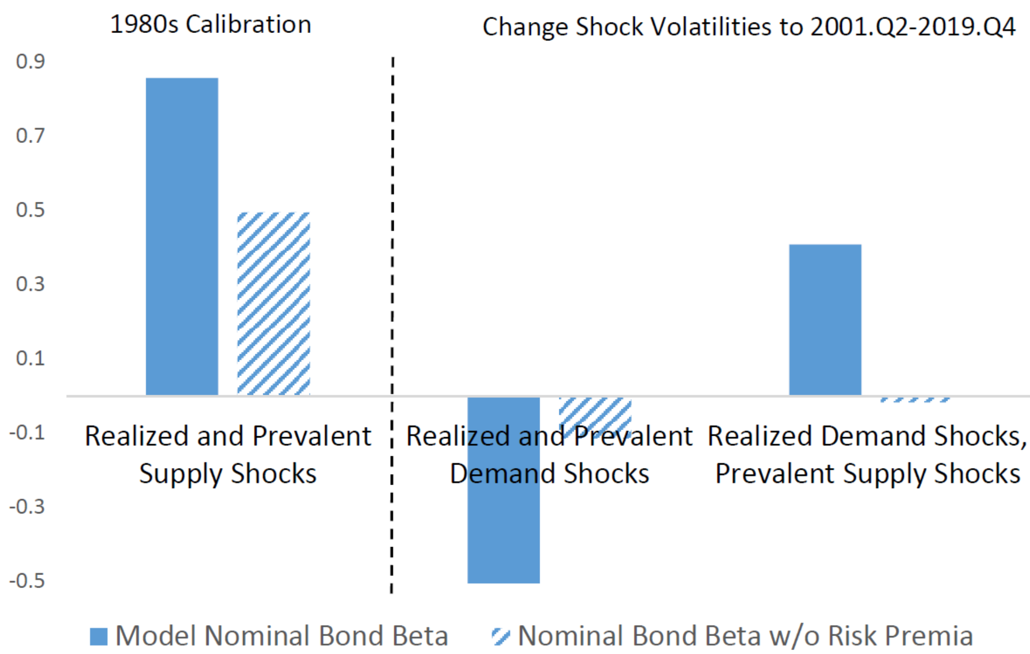
4.3 Counterfactual Bond Betas Prevalent vs. Realized Shocks

Figure 7 focuses on the equilibrium distribution of shocks, holding monetary policy and realized shocks constant. It shifts the distributions of the equilibrium mix of shocks – or prevalent shocks – vs. realized shocks separately to the demand-shock dominated 2000s calibration. All other parameters are held constant at the 1980s calibration. Moving the distributions of both prevalent and realized shocks towards the 2000s calibration eliminates positive nominal bond-stock betas. However, the picture looks different when only realized

[21] This insight can potentially rationalize why nominal Treasury bond-stock betas remained elevated during the 1990s even as supply shocks were subsiding, if investors were concerned that supply shocks remained a prevalent source of volatility in equilibrium.

shocks are drawn from the 2000s distribution and the equilibrium is still priced as if shocks follow the 1980s distribution. In this case, the nominal bond-stock beta is positive even though the risk-neutral nominal bond beta (i.e. the beta with constant risk premia) is slightly negative. The mechanism draws on the left column of Figure 6, where nominal bond yields and dividend yields comove positively after a surprise demand shock in the 1980s calibration. Endogenously time-varying risk premia therefore matter and imply that the macroeconomic equilibrium is priced in bond-stock betas.

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 both the realized distribution of shocks and the prevalent (equilibrium) mix of shocks 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 are drawn from the 2001.Q2-2019.Q4 distribution.

4.4 Counterfactual Bond Betas by Monetary Policy × Economic Shocks

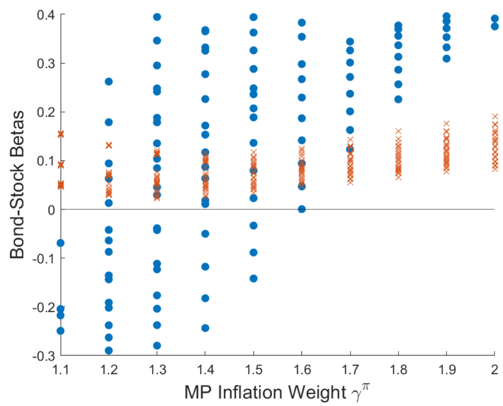
Having seen that the interaction between the economic shocks and the monetary policy rule matters for bond betas, I next show this interaction more systematically for all three shocks and with an emphasis on the important inflation weight in the monetary policy rule.

Figure 8 shows that the sign of real bond betas is pinned down by which type of shock is dominant. Monetary policy hawkishness modulates the magnitude of nominal bond betas holding fixed the equilibrium combination of shocks, and can even change the sign when supply shocks are dominant. The pictures are generated from computing model-implied bond betas on a grid for all three monetary policy parameters and then making a scatter plot against the important monetary policy inflation parameter, γ^π. Each marker corresponds to a different combination of the monetary policy rule parameters $(\gamma^\pi, \gamma^x, \rho^i)$. The shock volatilities in Panels A and B are set as in the 1979.Q4-2001.Q1 and 2001.Q2-2019.Q4 calibrations in Table 1, i.e. supply shocks are dominant in Panel A and demand shocks are assumed to be dominant in Panel B. To isolate the role of monetary policy shocks, Panel C sets a mix of shocks dominated by monetary policy shocks, and zero volatilities for demand and supply shocks.[22]

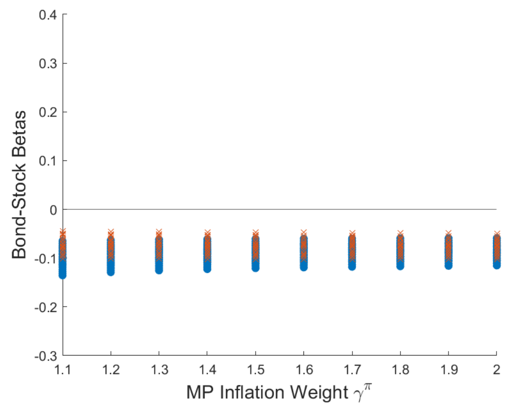
[22]The magnitude of the monetary policy shock in Panel C is set to 1.19%, which generates a volatility of annual real consumption growth of 1.6% at monetary policy parameters $\gamma^\pi = 1.5$, $\gamma^x = 0.5$ and $\rho^i = 0.8$. However, because betas are ratios of a covariance and a variance, the scaling of shocks matters less for bond betas than their relative volatilities.

Figure 8: Scatter Bond Betas by Shocks and Monetary Policy

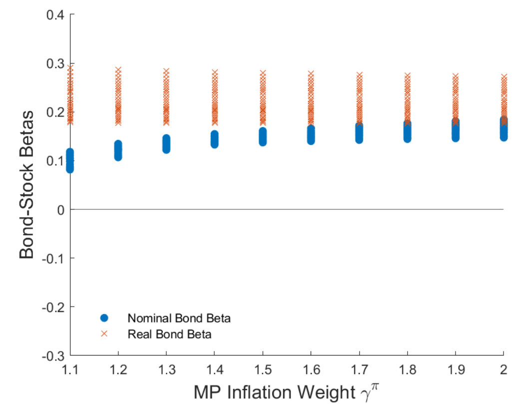
Panel A: Supply Shocks



Panel B: Demand Shocks



Panel C: MP Shocks



This figure shows scatter plots of counterfactual ten-year nominal bond-stock betas (blue circles) and real bond betas (red asterisks) against the monetary policy inflation weight, γ^{π} on the x-axis. Panel A sets the volatilities of shocks to the 1980s column of Table 1, where supply shocks are dominant $(\sigma_x, \sigma_\pi, \sigma_i) = (0.01, 0.58, 0.55)$. Panel B sets the shock volatilities to the 2000s column in Table 1, where demand shocks are dominant $(\sigma_x, \sigma_\pi, \sigma_i) = (0.59, 0.07, 0.07)$. Panel C sets the shock volatilities to a calibration where monetary policy surprises are dominant $(\sigma_x, \sigma_\pi, \sigma_i) = (0.00, 0.00, 1.19)$. Each marker corresponds to a different combination of monetary policy parameters, taken from a grid on $\gamma^x \in [0.4, 1.1]$, $\gamma^{\pi} \in [1.1, 2]$, $\rho^i \in [0.5, 0.9]$. The inflation expectations parameter is set to zero $\zeta = 0$.

This figure shows that real bond betas are positive when supply shocks are dominant, negative when demand shocks are dominant, and again positive when monetary policy shocks are dominant. This finding is intuitive, as both supply shocks and monetary policy shocks allow the real rate and consumption to move along a stable Euler equation (17). In the absence of demand shocks this means that higher real rates tend to lead to lower consumption and dividends, raising risk aversion. As a result, the real expected payoffs of long-term real bonds decline with the stock market, turning real bonds into risky assets whose risk premia increase at the same time as stock risk premia. Conversely, demand shocks introduce a wedge in the Euler equation (17). For example, a negative demand shock lowers the real risk-free rate. Because consumption is endogenous, this shock also leads to lower consumption. When demand shocks are dominant, the real discounted payoff of long-term real bonds hence rises as the output gap falls and marginal utility is high. These risk-neutral dynamics turn real bonds into hedges whose risk premia are negatively correlated with the risk premium on the stock market.

Comparing Panels A and C shows that supply and monetary policy shocks differ substantially in their implications for nominal bond betas, even though their implications for real bond betas are not too different. When monetary policy shocks are dominant, as in Panel C, nominal bond betas are positive and lower than real bond betas, and the gap between nominal and real bond betas is small. This is because a positive monetary policy shock tends to reduce demand and lowers inflation along the Phillips curve. A positive monetary policy shock hence raises nominal and real bond yields, but raises nominal yields less. As a result nominal bond betas tend to look similar to real bond betas but are less pronounced when monetary policy shocks are dominant. By contrast, when supply shocks are dominant, as in Panel A, nominal bond betas can differ substantially from real bond betas and can be either positive or negative.

Looking along the x-axis, it is clear that a higher inflation weight in the monetary policy rule, γ^{π}, raises nominal bond betas and can even switch their sign when supply shocks are dominant. Panel A shows that in the presence of supply shocks, nominal bond betas are positive when monetary policy reacts strongly to inflation (γ^{π} high), but negative when monetary policy reacts relatively weakly to inflation (γ^{π} close to one). The mechanism goes back to monetary policy's ability to generate a "soft landing," as shown in the macroeconomic impulse responses in Figure 5. A stronger immediate response in the nominal policy rate to inflation leads the central bank to raise real rates, which is bad for the economy. Because the stock market and nominal bonds experience negative expected real cash flow shocks at the same time, nominal bonds are risky. When the central bank has a high inflation coefficient, nominal bond risk premia are highly correlated with stocks and the nominal bond beta is positive. The cloud around the upward-sloping relationship arises because the other monetary policy parameters, γ^x and ρ^i, also influence how strongly and quickly the central bank raises the nominal policy rate. But, overall, the relationship with the inflation weight γ^π is the clearest and that is why it is depicted here.

The strongly increasing relationship between the monetary policy inflation weight and nominal bond betas in Panel A is central to my model's ability to reconcile the risky nominal bonds of the 1980s with the strong anti-inflationary monetary policy stance of the post-Volcker Fed. It also distinguishes my model from Rudebusch and Swanson (2012), who focus on steady-state term premia in a long-run risks model. In contrast to here, in their model nominal term premia tend to be positive, rarely switch sign, and are smallest (i.e. nominal bonds are least risky) when monetary policy price level targeting is strong. The different implications arise because in my habits model risk aversion is countercyclical, and cyclical fluctuations have strong effects on stocks and bonds, whereas in their long-run risks model, fluctuations in the long-run inflation target are important. While resolving the debate between leading asset pricing models is beyond this paper, a perspective based on cyclical risk bearing capacity seems useful, as monetary policy appears to have strong and immediate risk premium implications in the data (Bernanke and Kuttner (2005), Boyd, Hu and Jagannathan (2005)).

In Panel C, a higher weight on inflation in the monetary policy rule, γ^π, tends to raise nominal bond betas towards real bond betas when monetary policy shocks are dominant. This makes sense, as a higher γ^π means that the central bank stabilizes inflation more, closing the gap between nominal and real bonds in response to a monetary policy shock. Similarly, a higher monetary policy inflation weight raises nominal bond betas in Panel B when demand shocks are present, though the magnitudes are small.

Overall, model nominal and real bond betas vary with the mix of shocks and the inflation weight of the monetary policy rule. Whether real bond betas are smaller or greater than zero, and smaller or greater than nominal bond betas, is closely related to economic shocks. Nominal bond betas increase with the monetary policy inflation weight, particularly when supply shocks or monetary policy shocks are dominant. I next show how these relationships can be inverted in a simple application.

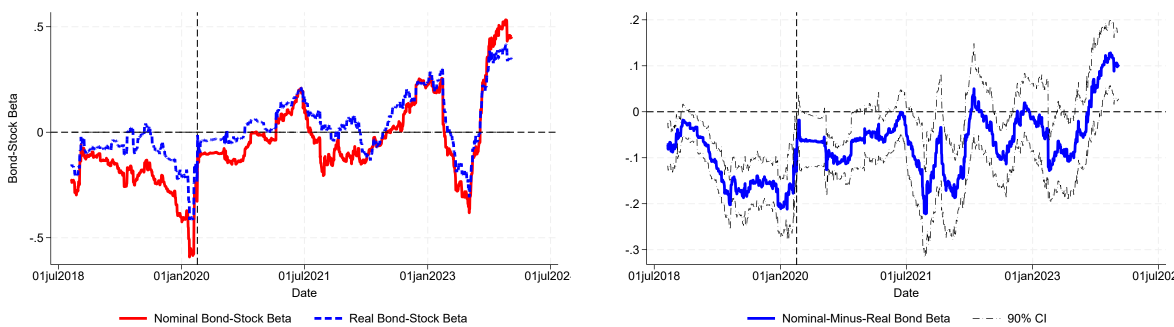
4.5 Application: Bond Beta-Implied Shocks and Monetary Policy

Having seen how nominal and real bond betas depend on shocks and the monetary policy rule, I now invert this relationship in a few simple cases and show that I obtain intuitive results.

Figure 9 displays nominal and real bond-stock betas using daily data over 120-day rolling windows starting in 2018. Panel A shows the regression coefficients of daily nominal bond log returns (red) and daily inflation-indexed log returns (blue) with respect to the stock market. Panel B on the right zooms in on the difference between nominal and inflation-indexed bond beta, the breakeven beta, with 90% confidence intervals. The estimates in Panel A are roughly consistent with the lower-frequency estimates in Figure 1, though of course betas from daily data are more volatile. Nominal bond betas remained negative through mid-2022 – the peak of US inflation – while real bond betas turned slightly positive. Breakeven betas remained negative and mostly significantly so through mid-2022. Subsequently, the daily data reveal a spike in nominal and real bond betas starting in October 2023, as daily breakeven betas in Panel B turned significantly positive for the first time since 2018.

Figure 9: Rolling Treasury Bond-Stock Betas: Daily Data

Panel A: Real and Nominal Bond Betas **Panel B:** Breakeven Beta



Note: Panel A shows betas from regressing daily ten-year nominal Treasury (TIPS) bond log returns onto daily US equity log returns over 120-trading day backward-looking rolling windows for the sample 01/01/2018 through 31/12/2023. Zero-coupon yield curves from Gürkaynak, Sack and Wright (2006, 2008). A vertical line indicates March 11, 2020 (Covid). Panel B shows the difference between the nominal and real (TIPS) bond-stock beta with 90% confidence intervals.

Table 3 computes beta-implied monetary policy and shocks for a few selected target values of nominal and real bond betas. I invert the counterfactual bond betas in Figure 8, selecting the shock regime ("Supply," "Demand," or "MP") and the monetary policy inflation weight, γ^π, that best match the target moments. The advantage of focusing on the monetary policy inflation weight γ^π is that it can be interpreted as monetary policy "hawkishess," and the different monetary policy parameters are not necessarily separately identified from betas. The other monetary policy parameters are held constant at conventional values, $\gamma^x = 0.5$ and $\rho^i = 0.8$, and inflation expectations are set to rational $\zeta = 0$, though as shown in Figure 4, ζ matters mainly for the predictability of bond excess returns and little

Table 3: Beta-Implied Monetary Policy and Shocks

Target		1979.Q4-2001.Q1	2001.Q2-2019.Q4	2020.Q1-2022.Q3	12/29/2023
Nominal Bond Beta		0.24	-0.31	-0.06	0.45
Real Bond Beta		0.08	-0.06	0.22	0.35
Model					
Nominal Bond Beta		0.24	-0.12	-0.05	0.42
Real Bond Beta		0.09	-0.06	0.21	0.16
MP Inflation Coeff.	γ^{π}	1.7	1.1	1.4	2.0
Shock Regime		Supply	Demand	Supply	Supply

This table shows the model-implied nominal and real bond betas, and parameter values that provide the best fit for each pair of nominal and real bond betas, while holding constant $\zeta = 0$, $\gamma^x = 0.5$, and $\rho^i = 0.8$. All other parameter values are as Table 1. Nominal and real bond betas for 1979.Q4-2001.Q1, 2001.Q2-2019.Q4, and 2020.Q1-2022.Q3 are estimated using quarterly bond and stock excess returns. Nominal and real bond betas for 12/29/2023 correspond to a rolling 120-day window of daily log bond and stock returns, as in Figure 9.

for bond-stock betas. The objective function is the sum of the absolute distances between target and model betas, requiring that the signs of the model betas match the signs of the targets. Limiting consideration to only three different sets of realistic combinations of shock volatilities significantly helps with computational speed.

For the first two periods, 1979.Q4-2001.Q1 and 2001.Q2-2019.Q4, the model matches the target betas well and implies an intuitive change from supply to demand shocks, as well as a decrease in monetary hawkishness as captured by γ^{π}. Because the target moments are different than in Table 1, the implied parameters are also different, but the overall message is remarkably consistent. For the periods 2020.Q1-2022.Q3 and the six-month period ending 12/29/2023, the model fits the observed bond betas with an initially moderate increase in the monetary policy inflation weight to $\gamma^{\pi} = 1.4$ for the 2020.Q1-2022.Q3 period, and finally a sharp increase to $\gamma^{\pi} = 2$ at the end of December 2023. For both the 2020.Q1-2022.Q3 and December 2023 target bond betas, the model favors dominant supply shocks, since only dominant supply shocks can generate positive real bond betas and either negative or highly positive nominal bond betas in the model. When interpreting these results it is important to keep in mind that bond-stock betas price the expected mix of shocks in equilibrium rather than realized shocks, due to the role of time-varying risk premia. The increases in bond betas and the implied monetary policy inflation weight at the end of 2023 hence do not mean that a supply shock has occurred, or that stagflation is necessarily predicted for the near future. The most natural explanation is that, should another adverse supply shock occur, financial markets anticipate a stronger monetary policy response and correspondingly a deeper recession. Overall, despite no macroeconomic moments being used in this exercise, changing bond betas imply intuitive changes in monetary policy and dominant economic shocks.

5 Conclusion

A New Keynesian asset pricing model with countercyclical risk-bearing capacity shows that the interaction between supply shocks and inflation-focused monetary policy leads to positive nominal bond-stock betas, as observed during the stagflationary 1980s. Conversely, a combination of 1980s-style shocks with a more output-focused and inertial monetary policy rule leads to a "soft landing," which is priced in negative nominal bond-stock betas, and positive real bond-stock betas. However, bond-stock betas do not necessarily price realized shocks in this model, but instead the expected equilibrium mix of shocks going forward.

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 and engineer a "soft landing" if the central bank keeps nominal rates sufficiently steady and allows the real rate to fall. A less inflation-focused or inertial monetary policy rule mitigates the positive bond-stock comovement that would otherwise result from supply shocks. By contrast, demand shocks move output and inflation up and down together relatively independently of monetary policy, and imply negative nominal and real bond-stock betas, as observed during the pre-pandemic 2000s.

Time-varying risk premia generate predictability in stocks and bonds, and imply that bond-stock betas price the distribution of shocks in equilibrium rather than past realized shocks. When investors are surprised by realized demand shocks but bonds and stocks are priced as if 1980s shocks are prevalent in equilibrium the model implies a positive nominal bond-stock beta, in contrast to the negative model nominal bond-stock beta when demand shocks are both realized and priced in equilibrium. Intuitively, bond and stock returns are dominated by time-varying risk premia, and in a 1980s-type equilibrium nominal bonds are stock-like, so risk premia in nominal bonds and stocks move together.

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

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