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Pierlauro Lopez, Francisco Vázquez-Grande and David López-Salido

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Pierlauro Lopez [**]

FEDERAL RESERVE BANK OF CLEVELAND

Francisco Vázquez-Grande [***]

FEDERAL RESERVE BOARD

David López-Salido [****]

BANCO DE ESPAÑA

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(**) pierlaurolopez@gmail.com
(***) francisco.vazquez-grande@frb.gov
(****) david.lopez-salido@bde.es

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Abstract

A simple production economy with nominal price rigidities explains several key asset pricing facts, including the average slopes and cyclicality of equity and interest rate term structures. Nominal rigidities amplify the procyclicality of dividends after negative productivity shocks and generate countercyclical inflation, as sluggish price adjustment leads to a gradual dividend recovery. Consequently, short-duration equities (bonds) have more (less) procyclical payoffs than their long-duration counterparts. Slow-moving consumption habits produce large, countercyclical risk prices, yielding realistic asset valuations. Extending Campbell-Cochrane preferences with both market and home consumption habits allows them to operate in production economies while preserving realistic macroeconomic dynamics.

Keywords: equity and bond yields, Campbell-Cochrane habits, nominal rigidities, macro- inance separation, New Keynesian model.

JEL classification: E43, E44, G12.

Resumen

Una economía de producción sencilla con rigideces nominales de los precios explica varios hechos fundamentales observados en la valoración de los activos financieros, entre ellos las pendientes medias y el comportamiento cíclico de las estructuras temporales de los rendimientos de las acciones y de los tipos de interés. Las rigideces nominales amplifican el carácter procíclico de los dividendos tras perturbaciones negativas de la productividad y generan una inflación contracíclica, ya que el ajuste lento de los precios provoca una recuperación gradual de los dividendos. Como consecuencia, las acciones de corta duración (y, de forma análoga, los bonos de corta duración) presentan flujos de pago más procíclicos que sus equivalentes de larga duración. Los hábitos de consumo de los inversiores, que evolucionan lentamente, generan primas de riesgo elevadas y contracíclicas, lo que permite obtener valoraciones de activos realistas. Además, la ampliación de las preferencias de Campbell-Cochrane para incluir hábitos tanto de consumo de mercado como de consumo en el hogar permite que estas preferencias funcionen en las economías de producción sin perder la capacidad de reproducir dinámicas macroeconómicas realistas.

Palabras clave: rendimientos de acciones y bonos, hábitos de Campbell-Cochrane, rigideces nominales, separación entre macroeconomía y finanzas, modelo neokeynesiano.

Códigos JEL: E43, E44, G12.

1. Introduction

Recent evidence shows that discount rates of financial claims differ across maturities and across asset classes. In particular, the maturity structure and time variation of equity and bond risk premia contain rich information to understand investors' marginal utility of wealth and their expectations about future macroeconomic variables. The empirical literature has documented that the returns of nominal and real bonds increase with maturity on average, while claims to short-term dividends have high average excess returns, comparable in size to the aggregate equity premium (Binsbergen et al., 2012; Binsbergen and Koijen, 2017). During stock market downturns, the slope of the term structure of equity yields decreases (Binsbergen et al., 2013), while the aggregate equity premium increases by more than short-duration equity premia (Gormsen, 2021); thus, equity yield spreads are procyclical, and equity term premia are countercyclical. Finally, at the bottom of stock market downturns, the term structures of bond yields—both real and nominal—become steeper, as they predict higher future growth and rates (an observation that goes back to at least Estrella and Hardouvelis, 1991).

Our main contribution is to offer a quantitative and parsimonious general-equilibrium explanation of the macroeconomic forces that drive this set of empirical features in equity and bond markets. This paper offers a structural story that captures several of the empirical properties of equity and bond prices that so far only the reduced-form, no-arbitrage models of Lettau and Wachter (2011) and Gormsen (2021) have tried to capture. Specifically, we present a New Keynesian model with habit formation that relies on *two ingredients*. The first ingredient, a textbook *sticky-price production economy* driven by productivity shocks, provides a familiar model of output and inflation that matches standard macroeconomic data and rationalizes the payoffs of nominal bonds (inverse inflation) and dividends as a levered version of consumption. The second ingredient, *slow-moving habits* in consumption as in Campbell and Cochrane (1999) generate realistically large and time-varying discount rates.

A key theme of our contribution is how to unite nonlinear consumption habits and a production economy without compromising the model's ability to fit macroeconomic variables—a challenge documented by Lettau and Uhlig (2000) and Rudebusch and Swanson (2008). We avoid that difficulty by including a *second* habit in effective leisure, or home consumption. Intuitively, after a bad productivity shock, both market and home consumption drop close to their habit levels, with offsetting effects on the labor choice, thereby neutralizing the undesirable effect of persistent consumption habits on production. In fact, we show how one can preserve the model of quantities derived under CRRA preferences, in spite of nonlinear habits that preserve the Campbell and Cochrane (1999) pricing kernel and produce realistic asset prices. This *macro-finance separation* (MFS) result—whereby the states that drive variation in discount rates beyond the usual CRRA preferences do not drive consumption, hours, and inflation—implies that habits do not affect the well-known properties of quantities in the macro model, and hence extends to the habit formation setting a result analogous to the one that Tallarini (2000) described in a setting with Epstein-Zin preferences. MFS also implies that we can effectively inspect the mechanism by considering in isolation the role of the two ingredients.

We first strip down our mechanism to the essential ingredients; we match most asset pricing facts in a simple model without capital accumulation and with only productivity shocks. Our first ingredient, the production economy with sticky prices, provides a macroeconomic model

that matches the observed volatility and autocorrelation of the key cash flows (consumption growth, dividend growth, and inflation). Thanks to the macro-finance separation, the model's quantity and inflation implications and responses to a productivity shock are standard. The central mechanism relies on nominal rigidities that produce countercyclical labor shares after a productivity shock, which imply procyclical corporate profits and countercyclical inflation. Therefore, because of this *cash flow effect*, dividend claims and nominal bonds pay off badly in a downturn and are therefore risky investments. Then, as more and more firms are able to adjust their prices to mark them up over marginal costs, corporate profits recover and the price level increases. Thus, the payoff of long-duration dividend strips is less procyclical and the payoff of long-duration nominal bonds is more procyclical.

Our second ingredient, slow-moving external habit formation, then magnifies these cash flow risks into large and countercyclical risk premia. Moreover, in the model, the discount rate also makes all long-term claims inherently risky. Specifically, during a downturn, the prices of longer-duration claims drop more than those of shorter ones. This happens because consumers in the model will get accustomed to the lower consumption level, so they are less willing to defer consumption. As a result, they demand more compensation for shifting resources into the future. Because of this *habit effect*, the model produces an average term structure of the equity premium that is U-shaped—with a negative slope in the short to medium run, driven by the cash flow effect, and a positive slope for longer maturities, driven by the habit effect. By the same habit effect, our model produces a positively sloped term structure of real rates, thereby avoiding a real bond premium puzzle (Backus et al., 1989), while the cyclicality of inflation implies a positive inflation risk premium at all horizons and a positively sloped nominal term structure.

The nonlinear habits also generate the cyclicality of the term structures observed in the data. In bad times, as consumption falls close to habits and dividends drop, risk premia increase and future dividends are expected to recover. Thus, the slope of equity yields for the observable maturities becomes more negative, but risk premia also increase for longer horizons by the habit effect. Consequently, in the model market equity premia turn out to increase by more than short-run equity premia. At the same time, inflation is expected to increase sluggishly, and hence the slope of bond yields becomes more positive.

In the background of these results, our framework preserves the main achievements of Campbell and Cochrane (1999), including a solution to the average equity premium and the risk-free rate puzzles, long-horizon predictability of excess stock returns, and the countercyclical variation of stock market returns and volatility.

We then depart from MFS by extending our model to incorporate realistic capital accumulation. We find that it preserves the desirable asset pricing implications of the baseline model, while helping match more facts about quantities. In particular, the extended model has similar implications for the average slope and cyclicality of the term structures of equity and bond returns.

The choice of external habits to explain the term structure evidence may seem surprising at first, as Binsbergen et al. (2012) and Gormsen (2021) document the challenges of the habit framework in producing negative and procyclical equity yield spreads, even though they are naturally consistent with the countercyclicality of equity term premia due to the habit effect at very long horizons. Those results, however, are typically derived in endowment economies with exogenous random-walk dividend streams. Indeed, the endogenous mean-reverting dividend dynamics implied by our production economy avoid the counterfactual result. In

particular, by using the model to make the properties of cash flows match their volatility and autocorrelation in the data, we are able to naturally generate a downward and procyclical slope at the observable end of the term structure of equity yields while preserving the property of habits that generates countercyclical equity term premia.

Furthermore, the countercyclicality of equity term premia documented in Gormsen (2021), which is naturally generated in our model by the habit effect just described, challenges the use of Epstein-Zin preferences to model jointly the term structures of equities and bonds. Indeed, Gormsen shows how recent examples in Hasler and Marfè (2016) and Ai et al. (2018), who are able to generate a downward-sloping equity term structure by changing the cash flow process, display as a consequence the wrong cyclicality of the term structure of equity premia. Therefore, the use of Epstein-Zin preferences faces a tension between matching the cyclicality of equity term premia and the slope and cyclicality of equity spreads. Moreover, economies with Epstein-Zin preferences tend to produce real term structures that are downward sloping, as shown by Rudebusch and Swanson (2012) and Li and Palomino (2014), rather than upward sloping as in the data.

Finally, we inspect how our quantitative results depend on the key ingredients of the baseline model—namely, the two habits and nominal price rigidities. When we deactivate the habit in effective leisure, we confirm the dramatic distortions to the model's properties that arise when the effect of habits on the consumption-labor tradeoff is left unchecked, echoing Lettau and Uhlig (2000). As we turn down the nominal rigidities, the desirable cyclical properties of cash flows vanish—as we introduce realistic capital accumulation in the flexible-price version of the two-habit model, we even obtain counterfactually countercyclical dividends, echoing Kaltenbrunner and Lochstoer (2010). Indeed, as we increase the degree of nominal rigidity starting from the flexible-price model, the slope of the equity term structure turns negative while the bond term structure steepens, as the stronger countercyclicality of the labor share generates procyclical and mean-reverting dividends alongside countercyclical and sluggish inflation.

Relationship to the literature

Our paper subscribes to a recent literature that focuses on risk pricing across maturities (see, for example, Lettau and Wachter, 2007, 2011; Binsbergen et al., 2012, 2013; Borovicka and Hansen, 2014; Belo et al., 2015; Hasler and Marfè, 2016; Marfè, 2017; Ai et al., 2018; Lopez, 2018b; Weber, 2018; Kogan et al., 2020; Bansal et al., 2021; Gormsen, 2021; Zeng and Zhao, 2022; Li and Xu, 2024). While the search for a structural explanation of the positive slope and cyclicality of the term structure of interest rates has a rather long history, the search for a structural explanation for the negative slope of the term structure of equity has only recently received attention (see Binsbergen and Koijen, 2017, for a survey). While a relatively small sample and potential liquidity issues introduce some controversy as to the sign of the average slope, as argued by Bansal et al. (2021), the cyclical properties of the term structure of equity are so far less controversial. These more recent facts add to the more classic facts documenting a large and countercyclical equity premium and a low and stable risk-free rate.

Our simple story captures these empirical regularities, which so far only the reduced-form

models in Lettau and Wachter (2011) and Gormsen (2021) have tried to capture, although outside a general-equilibrium context that spells out preferences and production choices. An alternative view, such as Zeng and Zhao (2022) and Li and Xu (2024), focuses on departures from standard assumptions in business-cycle analysis, including behavioral expectations and intermediary-based asset pricing, to capture properties of the term structures of equity, thereby offering a complementary view to ours. We focus instead on explaining asset pricing facts through a business-cycle model in a standard production economy without exotic ingredients.

We likewise contribute to a growing literature that explores the asset pricing implications of New Keynesian models, including Rudebusch and Swanson (2008, 2012); Bekaert et al. (2010); Li and Palomino (2014); Weber (2014); Kung (2015); Campbell et al. (2020); Gourio and Ngo (2022); Pflueger and Rinaldi (2022). None of these studies, however, focuses on the joint properties of the term structures of equity and interest rates. Within this literature, Campbell et al. (2020) and Pflueger and Rinaldi (2022) also study the effects of Campbell-Cochrane-type habits in the presence of sticky prices, highlighting how countercyclical risk premia generated by habits interact with inflation and monetary policy. Their analysis, however, relies on a reduced-form specification of the production side of the economy that abstract from labor supply and capital accumulation decisions, and hence sidesteps the difficulties in reconciling business cycle facts with habit formation in production economies documented by Lettau and Uhlig (2000).

In this context, we show how Campbell-Cochrane habits can be incorporated into a full-fledged production economy in a way that avoids these difficulties. By doing so, we not only respond to the critique by Lettau and Uhlig (2000) and Rudebusch and Swanson (2008)—and echoed by Jermann (1998), Uhlig (2007), or Jaccard (2014)—but also show how the additional structure that comes from the production side of the economy jointly delivers realistic properties of the three term structures.

2. Habits in a Real Business Cycle Model

When habit formation is combined with a production economy, their interaction can generate counterfactual implications, as noted by Lettau and Uhlig (2000) and Rudebusch and Swanson (2008). To address these issues, this section begins by diagnosing them within a simple real business cycle framework. Specifically, in production economies, slow-moving habits distort the marginal rates of substitution between consumption and saving, labor, and investment. Consequently, equilibrium quantities depend on a state variable that drives discount rates, which must be highly volatile to match observed asset prices. These *spillovers of habits onto quantities* can severely affect the business-cycle properties of the model; with a habit in consumption, consumers dislike so much consumption fluctuations that they absorb macroeconomic shocks through adjustments in labor supply and investment. It follows that either the resulting consumption process becomes so smooth that it suppresses most discount-rate volatility, undermining the model's ability to match asset pricing facts, or other macroeconomic quantities become excessively volatile or exhibit counterfactual comovement, giving rise to what we call a *quantity puzzle*.

This section shows analytically how these spillovers come about in a simple real business cycle model and, importantly, how to control them. Specifically, to avoid the quantity puzzle, we introduce a second habit in effective leisure—or, more precisely, nonlinear habits in two consumption goods, one purchased in the market and the other produced at home—and in the spirit of Campbell and Cochrane (1999), we engineer restrictions on the habit dynamics to control the intertemporal and static spillovers of habits onto macroeconomic quantities. In standard production economies, we show that three parameters—the average market and home surplus consumption ratios and the curvature of investment adjustment costs—control the effect of habits on the consumption-saving, consumption-labor, and consumption-investment tradoffs, and hence on equilibrium quantities. Such *spillover parameters* can be even set so that habits preserve the business-cycle implications of a model with CRRA utility. Thus, in such a model habits can be introduced to produce more realistic asset price fluctuations while leaving the model's implications for macroeconomic quantities unaffected—an instance of macro-finance separation that reminds of the result that Tallarini (2000) documented in a production economy with Epstein-Zin preferences. Therefore, when carefully designed, slow-moving habits à la Campbell and Cochrane (1999) can be reconciled with business-cycle facts.

2.1. Households

As in Greenwood and Hercowitz (1991), identical households derive utility from two sources: nondurable goods purchased in the market and goods produced at home. Our households get used to an accustomed standard of living as represented by some particular level of consumption of the market-purchased and the home-produced goods. Accordingly they have preferences

$$U_0(j) = E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{[C_t(j) - X_t^c]^{1-\gamma} - 1}{1-\gamma} + \chi \frac{[H_t(j) - X_t^h]^{1-\gamma} - 1}{1-\gamma} \right) \tag{1}$$

where $C_t(j)$ is real consumption purchased in the market by household $j \in (0,1)$ and $H_t(j)$ denotes the consumption produced at home. As described later, X_t^c and X_t^h represent external habit levels that are nonlinear functions of contemporaneous and past aggregate consumption. The parameter β is the subjective discount rate and χ controls the steady-state value of hours, while the curvature γ of the utility function in market and home consumption is the same, as discussed below. The home consumption good is produced by households with technology

$$H_t(j) = A_t[1 - N_t(j)]$$

where $N_t(j)$ is the amount of time spent working outside the home, the total time endowment is normalized to 1, and A_t is the productivity in home-produced goods.

As in Campbell and Cochrane (1999), we ensure well-behaved marginal utilities in this context of additive habits by assuming that the law of motion of habits is specified indirectly through processes for log surplus market consumption ratio $s_t = \ln(S_t)$ and log surplus home

consumption ratio $z_t = \ln(Z_t)$, defined as

$$S_t \equiv \frac{C_t - X_t^c}{C_t}, \quad Z_t \equiv \frac{H_t - X_t^h}{H_t}$$

Their laws of motion are driven by aggregate market and home consumption, $C_t \equiv \int C_t(j)dj$ and $H_t \equiv \int H_t(j)dj$; since each individual agent has zero mass, she takes the habit levels as external to her consumption decisions. The dynamics for the logarithms of aggregate surplus ratios are

$$\begin{aligned} s_{t+1} &= s + \rho_s(s_t - s) + \Lambda_{c,t}(c_{t+1} - E_t c_{t+1}) \\ z_{t+1} &= z + \rho_s(z_t - z) + \Lambda_{h,t}(h_{t+1} - E_t h_{t+1}) \end{aligned} \tag{2}$$

We specify below the parametric shape of the sensitivity functions (Λ_c and Λ_h) and values for the steady-state levels of the surplus variables that ensure a sensible notion of habit, as discussed in Section 2.3.

When consumers maximize utility by choosing consumption, savings in a risk-free bond with real rate $r_{f,t}$, and labor supply at the real wage rate W_t, optimality implies

$$r_{f,t} = -\ln E_t M_{t+1}, \qquad M_{t+1} = \frac{\partial U_t/\partial C_{t+1}}{\partial U_t/\partial C_t} = \beta \left(\frac{C_{t+1}S_{t+1}}{C_t S_t}\right)^{-\gamma} \tag{3}$$

$$W_t = -\frac{\partial U_t/\partial N_t}{\partial U_t/\partial C_t}, \qquad -\frac{\partial U_t/\partial N_t}{\partial U_t/\partial C_t} = \chi A_t \left(\frac{C_t S_t}{H_t Z_t}\right)^{\gamma} \tag{4}$$

where M_{t+1} denotes the stochastic discount factor. Habits in market and home consumption affect marginal utilities in different ways. A shock that brings market consumption closer to its habit level alters the intertemporal rate of substitution—and hence incentives to save—and increases the marginal rate of substitution between labor and consumption—raising incentives to work. By contrast, a shock that brings home consumption closer to its habit level reduces the marginal rate of substitution between labor and consumption, thereby weakening incentives to work.

Note that there are at least two reasons we focus on home consumption rather than standard leisure. First, once it is accepted that consumers get used to an accustomed market consumption level, it is only natural to assume that they also develop a habit in home consumption. Second, because home consumption is scaled by productivity, utility (1) can be separable in consumption and labor while remaining consistent with balanced growth for any value of γ, as the marginal rate of substitution between labor and consumption (4) makes apparent. Therefore, we can preserve the form in Campbell and Cochrane (1999) for the stochastic discount factor in (3).

2.2. Firms

Firms operate the production technology

$$Y_t = A_t(e^{\mu t}N_t)^{1-\alpha}K_t^{\alpha}$$

where Y_t is real output, N_t is the labor input, K_t is the capital stock, and $e^{\mu t}$ is a labor-augmenting deterministic trend that grows at rate μ. The logarithm of productivity $a_t = \ln(A_t)$ follows the stationary AR(1) process

$$a_{t+1} = \rho_a a_t + \sigma \varepsilon_{t+1}$$

where ε_t is i.i.d. normally distributed with mean 0 and variance 1.

Firms discount the future using the household's stochastic discount factor, and maximize profits by hiring labor at real wage rate W_t and by accumulating capital according to the law of motion

$$K_{t+1} = (1-\delta)K_t + \Phi\Big(\frac{I_t}{K_t}\Big)K_t \tag{5}$$

where δ is the depreciation rate and capital is costly adjusted according to the function

$$\Phi\Big(\frac{I_t}{K_t}\Big) = a_1 + \frac{a_2}{1-\frac{1}{\xi_3}}\left(\frac{I_t}{K_t}\right)^{1-\frac{1}{\xi_3}}$$

where $\xi_3 \geq 0$. The parametric form of capital adjustment costs is standard (e.g., Jermann, 1998) and a_1 and a_2 are calibrated to imply the steady-state relations $I/K = \bar{\iota}$, $\Phi(I/K) = I/K$, and $\Phi'(I/K) = 1$, so there are no adjustment costs locally around the steady state.[2]

Each period, total firm profits minus investment expenditures are paid out as dividends $D_t = Y_t - W_t N_t - I_t$ to consumers—who own the firms. Optimal labor demand is such that $W_t = \alpha Y_t/N_t$ and it implies that dividends are $D_t = \alpha Y_t - I_t$. Optimality of the investment and capital choices imply the conditions

$$\frac{I_t}{K_t} = \delta Q_t^{\xi_3}, \qquad\qquad Q_t = E_t M_{t+1}\left(\frac{D_{t+1}}{K_{t+1}} + Q_{t+1}\frac{K_{t+2}}{K_{t+1}}\right) \tag{6}$$

Through the adjustment cost curvature, ξ_3, investment is determined by Tobin's Q, which in our frictionless setting equals the expected discounted value of future market dividends, and hence, through the discounting in (3) depends on surplus consumption. Thus, higher discount rates reduce Q_t, and hence investment.

2.3. Sources of habit spillovers and microfoundation of the two habits

In a production economy, habits affect intertemporal and static decisions by their effect on the marginal utilities of market and home consumption. Intertemporally, the *consumption-saving tradeoff* is described by equation (3), which implies a potential dependence of the real risk-free rate on surplus consumption, while the *consumption-investment tradeoff* is

[2]Specifically, $a_1 = e^{\mu} - 1 + \delta - \bar{\iota}/(1-1/\xi_3)$ and $a_2 = \bar{\iota}^{\xi_3}$ achieve the conditions. Typically, $\bar{\iota} = e^{\mu} - 1 + \delta$, but other values are possible; for example, $\bar{\iota} = (e^{\mu} - 1 + \delta)/(1 + 1/\xi_3)$ implies a target investment-capital ratio that goes to zero with ξ_3, converging to an economy with zero investment as capital adjustment costs become infinitely large.

described by equation (6), which implies a potential dependence of Tobin's Q on surplus consumption. Intratemporally, equation (4) shows how the surplus consumption processes have an effect on the *consumption-labor tradeoff* that makes the real wage depend on the ratio of the surplus processes. Surplus consumption drives risk prices and is very volatile; therefore, the spillover of this state variable on real variables by these two channels can induce counterfactual business cycle properties.

2.3.1. Spillover on the consumption-saving tradeoff

To handle the intertemporal spillover in (3), we follow Campbell and Cochrane (1999) and choose the market consumption sensitivity function to satisfy the following conditions: (i) the market consumption habit does not produce a risk-free rate puzzle; (ii) the habit is approximately a moving average of past market consumption that adjusts slowly to unanticipated movements in market consumption; and (iii) the habit is locally predetermined and moves nonnegatively with consumption near the steady state. The first condition describes how habits must be engineered for intertemporal neutrality, and it implies breaking the equivalence between the inverse elasticity of intertemporal substitution (EIS) and the risk aversion coefficient. The remaining conditions represent a minimal microfoundation to guarantee a sensible notion of habit.

To achieve these objectives, we parameterize the surplus consumption dynamics so that the surplus market consumption sensitivity function Λ_c and steady-state level S are:

$$\Lambda_{c,t} = \begin{cases} \sqrt{\frac{var(\varepsilon^c)}{var_t(\varepsilon^c_{t+1})}}\frac{1}{S}\sqrt{1-2\hat{s}_t} - 1, & \hat{s}_t \leq \frac{1}{2}(1-S^2) \\ 0 & \hat{s}_t > \frac{1}{2}(1-S^2) \end{cases}, \qquad S = \sqrt{\frac{\gamma\ var(\varepsilon^c)}{1-\rho_s-\xi_1/\gamma}} \tag{7}$$

for a free parameter $\xi_1 < \gamma(1-\rho_s)$, where $\varepsilon^x_t \equiv (E_t - E_{t-1})x_t$ denotes innovations in variable x and a hatted variable $\hat{x}$ represents the deviation of variable $x \equiv \ln(X)$ from its steady state. Appendix A proves the desired properties (i)-(iii) of the implied market consumption habits.

The motivation for the choices of sensitivity function and of the value of S follows Campbell and Cochrane (1999), and they are made to control the direct spillover of state s_t on the risk-free rate. The choice keeps such a spillover as close as possible to $\xi_1\hat{s}_t$ in a mean-squared sense, and exactly equal to it when consumption innovations are conditionally Gaussian. Indeed, in that case specification (7) and the lognormality of consumption imply that equation (3) can be rewritten as

$$\begin{aligned} r_{f,t} &= -\ln(\beta) + \gamma E_t\Delta c_{t+1} + \gamma E_t\Delta s_{t+1} - \frac{1}{2}\gamma^2(1+\Lambda_{c,t})^2 var_t(\varepsilon^c_{t+1}) \\ &= -\ln(\beta) - \frac{\gamma(1-\rho_s-\xi_1/\gamma)}{2} + \gamma E_t\Delta c_{t+1} - \xi_1\hat{s}_t \end{aligned} \tag{8}$$

Intuitively, surplus consumption affects the risk-free rate through two motives: an intertemporal substitution effect—captured by the term $\gamma E_t\Delta s_{t+1}$—and a precautionary saving effect—captured by the variance term in (8). A low surplus consumption today signals lower marginal utility tomorrow, which reduces the willingness to save and thereby pushes

the real rate up. At the same time, it implies greater uncertainty about future marginal utility, which increases the precautionary motive to save and thus lowers the risk-free rate. The net effect is governed by parameter ξ_1, which determines which of the two motives dominates.

Here it is important to note that the value of S in (7) should not be interpreted as endogenously depending on the consumption process. Instead, it serves as a convenient device to map a given S into another parameter, ξ_1, which—as we show below—governs the elasticity of the risk-free rate with respect to the surplus consumption ratio. In this sense, S is simply a parameter, and its expression in (7) merely provides a way to pin down its value so as to generate the desired properties of the risk-free rate.

2.3.2. Spillover on the consumption-labor tradeoff

By analogous logic, we choose the home consumption sensitivity function to handle the intratemporal spillover in (4) as follows: (i) the home consumption habit does not produce a quantity puzzle by having the habit-related effects of shocks on the marginal utility of market and home consumption offset each other; (ii) the habit is approximately a moving average of past home consumption that adjusts slowly to unanticipated movements in home consumption; and (iii) the habit is locally predetermined and moves nonnegatively with home consumption near the steady state. As in the case of market consumption habits, the first condition describes how habits must be engineered for intratemporal neutrality and the last two conditions are their microfoundation.

We specify the surplus home consumption sensitivity function Λ_h and steady-state level Z as

$$\Lambda_{h,t} = \frac{S}{1-S}\frac{1-Z}{Z}\frac{cov_t(\varepsilon^c_{t+1}, \varepsilon^h_{t+1})/var_t(\varepsilon^h_{t+1})}{cov(\varepsilon^c, \varepsilon^h)/var(\varepsilon^h)}\Lambda_{c,t}, \quad Z = \left(1 + \frac{1-S}{S}(1+\xi_2)\frac{cov(\varepsilon^c, \varepsilon^h)}{var(\varepsilon^h)}\right)^{-1} \tag{9}$$

for a free parameter ξ_2.[3] Appendix A proves the desired properties (ii)-(iii) of the implied home consumption habits.

The choice of Z is made to control the direct spillover of surplus consumption on the marginal rate of substitution between consumption and labor. Namely, since our choice of Z is such that

$$Z = \arg\min var_t[\Lambda_{h,t}\varepsilon^h_{t+1} - (1+\xi_2)\Lambda_{c,t}\varepsilon^c_{t+1}] \tag{10}$$

it follows that the term $\hat{s}_t - \hat{z}_t$ in (13) is as close as possible to $-\xi_2\hat{s}_t$ in a mean-squared sense, and exactly equal to it when, in equilibrium, market and home consumption innovations are conditionally linear in the productivity shocks. Indeed, in such a case, specification (9)

[3] Lettau and Uhlig (2000) also consider two habits and yet do not find macro-finance separation. There are at least two reasons for our different results. First, note that their second habit is in leisure rather than in home consumption, which would not be balanced-growth compatible. Second, and more importantly, they set $Z = S$. Equation (9) shows that Z must differ generically from S for a small intratemporal spillover.

implies that

$$z_t - z = (1 + \xi_2)(s_t - s)$$

and therefore the parameter ξ_2 can be used to control the effect that the surplus consumption processes has on the consumption-labor tradeoff (4). It follows that the case $\xi_2 = 0$ implies $Z_t/Z = S_t/S$, and hence a consumption-labor tradeoff (4) equivalent to the one in a model without habits.

Intuitively, in the presence of a negative market consumption shock, the home consumption habit makes the substitution effect toward home consumption dominate the income effect, making households choose not to absorb the movement in consumption by significantly increasing their labor effort. With home consumption habits, the Frisch labor supply elasticity scales by Z_t and hence it scales down by a factor $Z \in (0, 1)$ relative to the case without habits, and it drops in a recession; households become particularly sensitive to fluctuations in *both* market and home consumption during a downturn.[4]

Here as well, note that the expression for Z in (9) is convenient to map a given Z into another parameter, ξ_2, which governs the elasticity of the marginal rate of substitution between consumption and labor with respect to the surplus consumption ratio. In particular, Z should not be interpreted as endogenously depending on the consumption processes, but simply as a parameter.

2.3.3. Spillover on the consumption-investment tradeoff

Finally, parameter ξ_3 controls the intertemporal spillover in (6) on consumption-investment decisions, which operates via Tobin's Q as $I_t = \bar{\iota} Q_t^{\xi_3} K_t$. Investment is high when the present value of the stream of profits it generates is high.

The absence of this type of spillover, $\xi_3 = 0$, implies $I_t = \bar{\iota} K_t$, as the elasticity of the investment-capital ratio to Tobin's Q becomes zero. Accordingly, investment becomes independent of stock price movements, which are driven by habits through their effects on discount rates.

2.4. Macro-finance separation by force of habit

To summarize, we have gained a handle on the three habit spillovers through the choices of the surplus consumption levels S and Z—or, equivalently, through the choice of the free parameters ξ_1 and ξ_2—and of the elasticity ξ_3 of the investment-capital ratio to Tobin's Q. The spillover of the time-varying risk aversion on quantities is now controlled by parameter $\xi = [\xi_1; \xi_2; \xi_3]$.

In fact, there exists a parameterization of the spillover parameter that preserves the desirable implications for observed macroeconomic quantities of a real business cycle model with CRRA preferences—namely, when $\xi_1 = \xi_2 = \xi_3 = 0$. We call such a property of a model, macro-finance separation (MFS), which we define as follows:

[4] Alternative modeling strategies directly limit households' ability to absorb shocks through labor supply. For example, Kehoe et al. (2023) use a search-and-matching framework in which employment dynamics arise from costly job search and vacancy posting rather than from the marginal rate of substitution between consumption and labor. In their model, a bad technology shock raises discount rates, thereby lowering the value of a new hire, so employment falls in recessions by a different mechanism than the one emphasized here.

Definition. The competitive equilibrium is *macro-financially separate* if the equilibrium allocation $\{c_t, h_t, n_t\}$ and the price system $\{w_t - p_t, r_{f,t}\}$ are the same as in the model with CRRA utility such that $X_t^c = X_t^h = 0$ at all dates.

In focusing on this case we are taking to its logical extreme the critique of DSGE models with habit formation in the spirit of Campbell and Cochrane (1999) made by Lettau and Uhlig (2000). Our strategy implies that we can preserve a macroeconomist's preferred model of quantities, with the associated well-tested empirical properties for quantities. While we are not denying the possibility that a spillover from a volatile discount factor onto quantities better fits quantity dynamics,[5] we argue that the first step of the modeling exercise of incorporating volatile discount factors into a macro model should be to keep the spillovers on quantities under control. Indeed, in Section 6 we show that *uncontrolled* spillovers generate quantitative departures from MFS that dramatically worsen the quantity and asset pricing implications of the model.

Therefore, we choose to work under MFS in our baseline model, to ensure a structure with standard implications for quantities and inflation. As we will show, such a model goes a long way in explaining asset pricing facts and is particularly transparent, as separation implies that we can effectively inspect the mechanism by considering in isolation the role of habits and the role of nominal rigidities. We will later depart from MFS when we introduce nontrivial capital accumulation. Notably, our parameterization of the sensitivity functions and average surplus consumption levels will ensure limited spillovers, and hence well-behaved quantities, also in such a setup.

2.5. A missing ingredient: Nominal price rigidities

The real model laid out in this section has shortcomings that limit its empirical relevance to model equity prices. In particular, the growth rate of the model's dividend payouts coincides with consumption growth under MFS, and under nontrivial capital accumulation it exhibits counterfactual cyclicality, as emphasized by Kaltenbrunner and Lochstoer (2010) and shown quantitatively in Section 6. Moreover, the real model cannot speak directly to the properties of nominal yields we are interested in.

For these reasons, the quantitative model we bring to the data incorporates nominal price rigidities under a standard monetary-policy rule. When added to the real business cycle structure laid out in this section, they endogenize both inflation and dividend dynamics in a way that better aligns with the data. Namely, price stickiness generates procyclical dividend dynamics and countercyclical inflation, which, when combined with realistic discount rates, goes a long way in capturing the observed properties of quantities and asset prices.

3. Habits in a Sticky Price Model

Our baseline specification is a textbook model with nominal rigidities, augmented with nonlinear habits in market and home consumption. As defined in the previous section, and

[5] For example, such a spillover generates hump-shaped dynamics in Boldrin et al. (2001), and is essential to generate realistic unemployment fluctuations in Kehoe et al. (2023).

to isolate the role of our key ingredients, we impose MFS in the baseline economy, which also implies abstracting from the dynamic effects of capital accumulation.[6] In Section 5, we relax this assumption and allow for nontrivial capital accumulation, thereby departing from MFS. In Section 6, we separately examine the roles of habits—which amplify the household's risk aversion—and nominal rigidities—which assign the correct degree of riskiness to cash flows.

Moreover, because the term structures depend on the degree of mean reversion in cash flows, it is crucial that the driving process exhibits a realistic level of persistence. Thus, while the previous section introduced a simple AR(1) specification for didactic purposes, here we adopt a more flexible process for productivity that nests both random-walk and AR(1) dynamics. We then estimate this process from the properties of observed cash flows to ensure the model captures the empirically observed serial correlation.

3.1. Households

Households have the preferences described in Section 2. They trade in complete financial markets and choose market and home consumption to maximize the intertemporal objective (1) subject to the present-value budget constraint

$$E_0 \sum_{t=0}^{\infty} M_{0,t} C_t(j) = \frac{B_{-1}(j)}{P_0} + E_0 \sum_{t=0}^{\infty} M_{0,t} \left(\frac{W_t}{P_t} N_t(j) + D_t \right)$$

with t-period real contingent claims prices $M_{0,t}$, where W_t is the nominal wage rate, P_t is the price index, D_t is the dividend consumers receive from owning the aggregate firm, and B_t denotes their nominal holdings of one-period nominal government bonds with unit price $\exp(-i_t)$. The budget constraint implicitly includes other arbitrary claims in zero net supply, which we can therefore price by relying on no-arbitrage relations, including one-period noncontingent claims with unit price $\exp(-r_{f,t}) = E_t M_{t+1}$.

Optimality implies that consumers equalize intertemporal rates of substitution and contingent claims price ratios, and hence the t-period stochastic real discount factor

$$M_{0,t} = \beta^t \left(\frac{C_t S_t}{C_0 S_0} \right)^{-\gamma}, \tag{11}$$

that their bond holdings satisfy the Euler equation

$$i_t = -\ln E_t(\beta e^{-\gamma \Delta c_{t+1} - \gamma \Delta s_{t+1} - \pi_{t+1}}), \tag{12}$$

where $\pi_t \equiv \ln(P_t/P_{t-1})$ defines the inflation rate, and that the rate of substitution between

[6] In this context, note that, while the MFS result holds exactly in the flexible-price economy covered in Section 2, in the case of our sticky-price model, consumption shocks are not lognormal and homoskedastic, and the spillovers cannot be completely eliminated. In practice, we calibrate $\xi \equiv [\xi_1; \xi_2; \xi_3]$ so that the model is macro-financially separate to a first-order approximation around the risky steady state, as defined for example in Lopez et al. (2016). Using a global solution, we later confirm that the quantitative implications of the model are nearly identical to those of the model without habits.

labor and consumption equals the wage rate

$$w_t - p_t = \ln(\chi) + a_t + \gamma(c_t - h_t + s_t - z_t) \tag{13}$$

As we discussed in Section 2, equation (11) shows how, through the process s_t, habits generate additional discount-rate variation relative to a CRRA specification of preferences. But habits also affect the consumption-saving tradeoff in (12) as well as the consumption-labor tradeoff in (13), with a spillover controlled by the process $s_t - z_t$.

3.2. Firms

The production side of the economy is characterized by a unit mass of monopolistically competitive firms indexed by $i \in [0, 1]$. They discount future profits by the households' stochastic discount factor $M_{0,t}$ and choose nominal prices $\{P_t^*(i)\}$ and labor demand $\{N_t(i)\}$ to maximize the intertemporal objective

$$E_0 \sum_{t=0}^{\infty} M_{0,t} D_t(i), \qquad D_t(i) = \frac{P_t(i)}{P_t} Y_t(i) - (1-\tau)\frac{W_t}{P_t} N_t(i) - T_t$$

subject to Calvo nominal price rigidities

$$P_t(i) = \begin{cases} P_t^*(i), & \text{with probability } 1-\eta \\ e^{\pi^*} P_{t-1}(i), & \text{with probability } \eta \end{cases}$$

where the ith good sells for the nominal price $P_t(i)$ and $P_t \equiv [\int_0^1 P_t(i)^{1-\varepsilon} di]^{1/(1-\varepsilon)}$ is the price index. We allow for indexation to a positive steady-state inflation rate π^* to produce a realistic level of the nominal yield curve. Firms operate with production technology

$$Y_t(i) = [e^{\mu t} \widetilde{A}_t N_t(i)]^{1-\alpha} K_t(i)^{\alpha}$$

where Y_t is real output, N_t is the labor input, $e^{\mu t}\widetilde{A}_t$ denotes the exogenous labor-augmenting productivity level, and $K_t = e^{\mu t}$ is the deterministic capital stock, which grows at rate μ on a balanced-growth path. (In Section 5 we allow for nontrivial capital accumulation.) In the model we define market equity as the value of the aggregate firm, which pays out to households per-period equilibrium profits $D_t(i)$ as dividends.

Owing to the price stickiness, each firm i can reset prices at any given time only with probability $1-\eta$ and faces the demand curve for the good it produces $C_t(i) = [P_t(i)/P_t]^{-\varepsilon} C_t$, which arises as the cost-minimizing plan of individual consumers who bundle the continuum of goods via a Dixit-Stiglitz aggregator with constant elasticity of substitution between goods, ε. To single out the role of nominal rigidities, we assume that the government levies lump-sum taxes T_t on each firm to finance an employment subsidy, τ, which reduces the unit nominal cost of labor and is in place to offset any steady-state distortions caused by monopolistic competition.

In this context, a firm's optimal labor demand schedule implies real marginal costs

$$mc_t(i) = w_t - p_t + \ln(1-\tau) - \ln(1-\alpha) - y_t(i) + n_t(i) \tag{14}$$

while a nonlinear New Keynesian Phillips curve describes the optimal price-setting behavior of a firm that reset prices at time t as the condition linking inflation and marginal costs,

$$\left(\frac{1-\eta e^{(\varepsilon-1)(\pi_t-\pi^*)}}{1-\eta}\right)^{\frac{1}{1-\varepsilon}} = \frac{E_t \sum_{j=0}^{\infty}(\beta\eta)^j e^{y_{t+j}-\gamma c_{t+j}-\gamma\hat{s}_{t+j}+\varepsilon\sum_{h=1}^{j}(\pi_{t+h}-\pi^*)+mc^*_{t+j}-\ln((\varepsilon-1)/\varepsilon)}}{E_t \sum_{j=0}^{\infty}(\beta\eta)^j e^{y_{t+j}-\gamma c_{t+j}-\gamma\hat{s}_{t+j}+(\varepsilon-1)\sum_{h=1}^{j}(\pi_{t+h}-\pi^*)}} \tag{15}$$

where the real marginal cost at date $t+j$ for a firm that last reset prices at date t is, in equilibrium,

$$mc^*_{t+j} = mc_{t+j} - \frac{\alpha\varepsilon}{(1-\alpha)(1-\varepsilon)}\ln\left(\frac{1-\eta e^{(\varepsilon-1)(\pi_t-\pi^*)}}{1-\eta}\right) + \frac{\alpha\varepsilon}{1-\alpha}\sum_{h=1}^{j}(\pi_{t+h}-\pi^*) - \Delta_{t+j} \tag{16}$$

where we used optimality condition (14) and the market clearing condition described below. Note how each resetting firm faces the same problem, so we dropped the i index from equation (15). The aggregate marginal cost in equation (16) integrates equation (14) over i.

3.3. Government

Monetary policy is described by a simple Taylor rule for the nominal interest rate that reacts to inflation and the output gap relative to its stochastic trend, $\bar{y}_t$, described below,

$$i_t = i^* + \phi_\pi(\pi_t - \pi^*) + \phi_y(y_t - \bar{y}_t) \tag{17}$$

for an interest rate level i^* consistent with the positive steady-state inflation rate π^*.

Fiscal policy runs a balanced budget in that $P_tT_t = \tau W_tN_t$.

3.4. Technology

As in Campbell and Ludvigson (2001), we assume that the same productivity process governs both the household's and the firm's production functions to ensure a balanced-growth path, so the relationship between productivity in market- and home-produced goods is $A_t = e^{\mu t}\widetilde{A}_t^{1-\alpha}$. Note that the productivities of market and home technologies need not be identical, as we could add a stationary exogenous component to either production technologies and still have balanced growth, but it is a parsimonious benchmark that does not add an additional state variable to the problem; more importantly, the model can capture key quantities and asset prices without needing such additional components.

The logarithm of the growth rate of productivity evolves by the process

$$\begin{aligned} \Delta a_{t+1} &= \mu + u_t + \sigma\varepsilon_{t+1} \\ u_{t+1} &= \rho_u u_t - \phi\sigma\varepsilon_{t+1} \end{aligned} \tag{18}$$

where ε_t is i.i.d. normally distributed with mean 0 and variance 1. This structure nests both random-walk ($\phi = 0$) and AR(1) specifications ($\phi = 1 - \rho_u$) with drift μ. Our estimation strategy will pin down the exact dynamics to correctly capture the volatility and autocorrelation of consumption, dividends, and the CPI and hence of the cash flow processes we are interested in pricing.

Note that the Beveridge-Nelson trend $\bar{a}_t$ in productivity evolves as $\Delta\bar{a}_{t+1} = \mu + [1 - \phi/(1-\rho_u)]\sigma\varepsilon_{t+1}$, and hence the stochastic trend of output that enters (17) can be written as

$$\bar{y}_t = y + \bar{a}_t$$

3.5. Competitive equilibrium

Market clearing for each good i implies market clearing at the aggregate level, $y_t = c_t$. Market clearing in the labor market $N_t = \int_0^1 N_t(i)di$ implies

$$y_t = a_t + (1-\alpha)(n_t - \Delta_t)$$

where cross-sectional price dispersion $\Delta_t \equiv \ln \int_0^1 [P_t(i)/P_t]^{-\varepsilon/(1-\alpha)} di$ evolves according to

$$e^{\Delta_t} = \eta e^{\frac{\varepsilon}{1-\alpha}(\pi_t - \pi^*) + \Delta_{t-1}} + (1-\eta)\left(\frac{1-\eta e^{(\varepsilon-1)(\pi_t-\pi^*)}}{1-\eta}\right)^{\frac{\varepsilon}{(1-\alpha)(\varepsilon-1)}} \tag{19}$$

Substituting the aggregate market production function in the aggregate home production function yields

$$e^{h_t} = e^{a_t}\left(1 - e^{\frac{1}{1-\alpha}(y_t - a_t) + \Delta_t}\right) \tag{20}$$

and the aggregate dividend

$$D_t = \int_0^1 D_t(i)di = \int_0^1 \left[\frac{P_t(i)}{P_t} Y_t(i) - (1-\tau)\frac{W_t}{P_t} N_t(i) - T_t\right] di = C_t - \frac{W_t}{P_t} N_t \tag{21}$$

or, using the equilibrium condition for labor demand,

$$d_t = c_t + \ln[1 - (1-\alpha)e^{mc_t - mc^*}] \tag{22}$$

We are thus ready to define the competitive equilibrium allocation of this economy:

Definition (Competitive equilibrium). For endogenous state vector $\{s_t, z_t, \Delta_t\}_{t=0}^{\infty}$ and exogenous state vector $\{a_t, u_t\}_{t=0}^{\infty}$, the competitive equilibrium is an allocation $\{c_t, h_t, n_t\}_{t=0}^{\infty}$ and a price system $\{w_t - p_t, \pi_t, r_{f,t}, i_t\}_{t=0}^{\infty}$ such that for each date t, *(a)* the choice of prices and labor demand solves the individual firm's problem, *(b)* the choice of market and home consumption solves the individual consumer's problem, *(c)* the goods and labor markets clear, *(d)* market and home consumption habits evolve according to (2), *(e)* price dispersion evolves according to (19), *(f)* the nominal rate follows rule (17), and *(g)* the fiscal authority

runs a balanced budget.[7]

In this context, the definition of MFS extends to cover the inflation and nominal interest rates.

Definition. The competitive equilibrium is *macro-financially separate* if the equilibrium allocation $\{c_t, h_t, n_t\}$ and the price system $\{w_t - p_t, \pi_t, i_t, r_{f,t}\}$ are the same as in the model with CRRA utility such that $X_t^c = X_t^h = 0$ at all dates.

4. Quantitative Results

This section studies the quantitative predictions of the model. We adopt standard values for all parameters except the habit spillover parameters—which are set to achieve approximate MFS—and the productivity process—which we estimate by a generalized method of moments (GMM) that matches the observed volatility at different horizons, and hence the serial correlation, of the cash flows of equities and bonds. We start by examining the model's implications for quantities and cash flows, and then study the implications for stock and bond markets. Note that our model's implications for the term structures of asset prices represent information that was not used in the parameterization step. In this sense, we show that the model naturally reproduces key empirical regularities of interest in equity and bond markets.

The nonlinearity of habits calls for an accurate nonlinear solution method. Namely, we solve the model numerically using a collocation method over a tensor grid to project the global solution of our model onto the subspace spanned by a basis of Chebyshev polynomials of up to degree 15. We consider large boundaries for the grid, especially in the endogenous habit state, motivated by Wachter (2005), who shows how the best practice in solving models with Campbell-Cochrane preferences is to consider a large and fine grid that places many grid points close to zero in the space of surplus market consumption, which mostly drives the stochastic discount factor.

4.1. Parameterization

Table 1 lists all deep parameters in the model and their values. To calibrate our model we focus on data since the 1980s to focus on a historical period that can be appropriately described by a New Keynesian model with determinate dynamics (Clarida et al., 2000). Namely, we consider data over the 1982-2019 period, right after the 1981-82 recession when the abnormal inflation readings of the previous decade subsided.

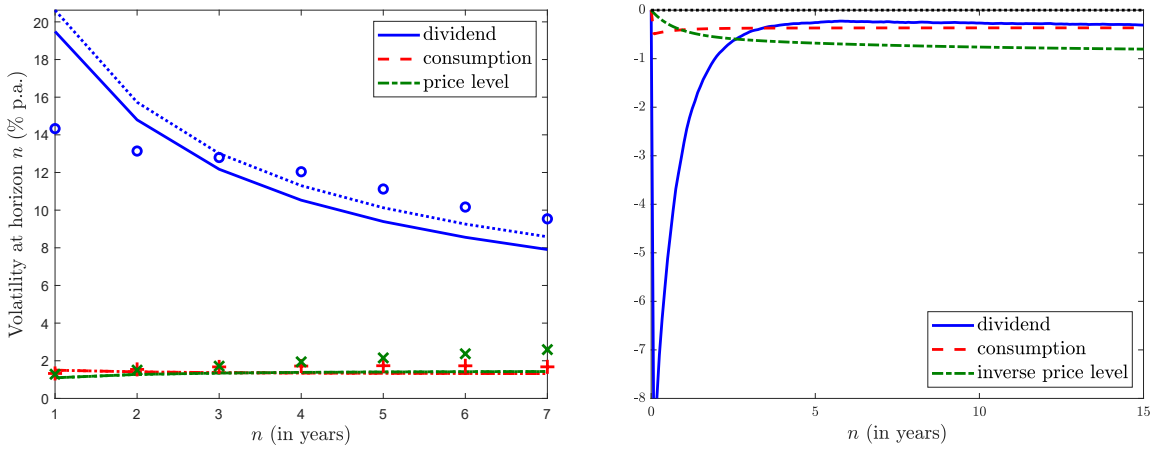
We calibrate the parameters of the production side of the economy according to a standard New Keynesian model. We pick values from Galí (2008): the average duration of prices is $(1-\eta)^{-1} = 9$ months; the elasticity of substitution in the CES aggregator is $\varepsilon = 6$; the Taylor rule coefficients attached to inflation and the output gap are 1.5 and 0.5/12; and we assume steady-state hours $N = 1/2$, so the Frisch elasticity of labor supply equals the

[7] We choose the textbook equilibrium selection strategy under a Taylor rule, and hence focus on the unique locally bounded solution (see Cochrane, 2011, for a critical discussion).

	Parameter		Value	Method
New Keynesian block	$1/(1-\eta)$	Average price duration (in months)	9	Galí (2008)
	ε	Elasticity of substitution in CES aggregator	6	Galí (2008)
	ϕ_π	Policy response coefficient to inflation	1.5	Galí (2008)
	ϕ_y	Policy response coefficient to output	0.5/12	Galí (2008)
	$1-\alpha$	Labor share in value added	.86	Cal.
	π^*	Average inflation rate (%)	2.7/12	Cal.
Preference block	β	Subjective discount factor	0.994	Cal.
	$1/\gamma$	Elasticity of intertemporal substitution (EIS)	1/2	Cal.
	ρ_s	Habit persistence	0.992	Cal.
	ξ_1	Intertemporal financial spillover	0.0001	MFS
	ξ_2	Static financial spillover	−0.0057	MFS
Exogenous block	μ	Mean productivity growth rate (%)	1.7/12	Cal.
	ρ_u	Persistence of conditional mean growth rates	0.859	GMM
	σ	Conditional volatility of productivity	0.75	GMM
	ϕ	Relative volatility of predictable productivity	0.072	GMM

Cal.: steady-state calibration.
MFS: value chosen to ensure approximate macro-finance separation.
GMM: estimated by a generalized method of moments to match realized 1- to 5-year horizon volatility of per capita real consumption growth, real dividend growth, and inflation.

Table 1: Deep parameters and their calibration (monthly frequency).



(a) *Fit to the GMM objective; markers are moments in the data, curves are moments in the model. Dotted lines are the implications of the model under CRRA preferences.*

(b) *Generalized impulse response to −1 standard deviation productivity shock, starting from the ergodic mean of the states; percentage changes in cash flows over a given horizon.*

Figure 1: Dynamic properties of cash flows.

EIS. The steady-state inflation rate is calibrated to the sample's average inflation rate of 2.7 percent p.a. over the 1982-2019 period.

We set the parameter α to match the ratio between labor income and consumption in the 1982-2019 data of .86. Here note that in the baseline model consumption equals output and that the model implies the relationship (21), or $D_t = C_t - L_t$, between dividends, consumption, and labor income $L_t \equiv W_t N_t / P_t$. This key economic relation is robust to our extension with capital, in which case $D_t = Y_t - L_t - I_t = C_t - L_t$, in that output will equal the sum of consumption and investment. Fluctuations in dividends must correspond with either consumption or labor income changes, so versions of the model in which consumption equals output must match the ratio between labor income and consumption to achieve realistic dividend properties. Later, in our extension with capital, a value of $\alpha = .4$ will be able to match simultaneously the ratio between labor income and consumption and between consumption and output (.86 and .69 over the 1982-2019 period, respectively), to achieve a standard ratio of labor income and output of around .6.

We set all parameters related to preferences, and hence to the pricing kernel, following the same calibration strategy used by Campbell and Cochrane (1999). Namely, we set a value for the EIS of .5 for a maximum Sharpe ratio of .42 on an annual basis; habit persistence matches an annual autocorrelation coefficient of the S&P 500 price-dividend ratio of .90; the subjective discount factor matches an annualized average real risk-free rate of 1.04 percent. The spillover parameters ξ_1 and ξ_2 are set to ensure approximate MFS as discussed in the previous section.

To pin down the exogenous process that drives the model's dynamics, we use a GMM strategy to estimate the parameter values that capture the volatility at different horizons of the cash flows we are interested in pricing—consumption and dividend growth and inflation. (The online appendix provides more details.) Note that our process for productivity allows for flexible dynamics encompassing in particular both random-walk and AR(1) processes. We therefore estimate the degree of mean reversion in productivity, which will be a key factor behind the slopes of the term structures at the short end, to capture the serial correlation in the data. Namely, we rely on monthly data over the period 1982-2019 on personal consumption expenditure on nondurable goods and services from the BEA and on dividend payouts on the S&P 500, the index for which dividend term structure data is available. We rely on annual BLS data on the CPI as our preferred measure of the price level.

4.2. Results: Quantities

Table 2 and Figure 1a show that our simple production economy under MFS generates realistic cash-flow dynamics: consumption is nearly a random walk, dividends are much more volatile and mean-reverting, and inflation is autocorrelated. The dotted lines in Figure 1a show that a CRRA version of the model delivers nearly identical cash flows, confirming that MFS neutralizes the effect of habits on quantities.

Figure 1b illustrates the response of the cash flows of consumption and dividend claims and of nominal bonds to a negative productivity shock. All cash flows drop during a downturn. The negative productivity shock depresses output but signals higher future growth because the process is partially mean reverting. Consumption drops on impact and then recovers,

although to a limited extent, reflecting an estimated productivity process with a sizable permanent component. Dividends drop by a multiple of consumption, rebound quickly, and share its long-run decline by their cointegration. The price level increases sluggishly, reducing the payoff of nominal bonds.

These dynamics reflect an *operating leverage* mechanism: dividends, defined as $D_t = C_t - L_t$, are smaller in level than consumption, so a given percentage movement in C_t can translate into a larger percentage movement in D_t, unless labor income is exactly proportional to consumption. Under flexible prices, $D_t = \alpha C_t$, so $\Delta d_t = \Delta c_t$ and no amplification arises, but with sticky prices equation (22) implies that lower output combined with higher marginal costs makes dividends doubly hit.[8]

In the New Keynesian framework, sticky prices endogenously create a wedge between dividend and consumption growth mediated by marginal costs, while also endogenizing inflation. Intuitively, corporate profits are low when marginal costs are high, while inflation is high when firms expect high marginal costs, in which case resetting firms choose a price above the index to realign their markup to the desired level. Higher nominal rigidities exacerbate these effects, as inflation takes longer to manifest when rigidities are stronger, and hence profits must absorb a larger share of the shocks that hit the economy, with a stronger contractionary effect on dividends. Thus, nominal rigidities not only generate inflation dynamics but also strengthen operating leverage, making dividends more volatile and risky than consumption, as in the data.

Finally, because we impose MFS, surplus consumption does not spill over onto quantities, so the model retains standard properties along untargeted dimensions. Wages and labor income display realistic volatility, the correlation between consumption growth and inflation is in line with the data, and while output equals consumption in the baseline (thus missing some relative volatilities), the extension with capital accumulation improves the fit while preserving the asset-pricing implications.

4.3. Results: Asset prices

The model reproduces a rich set of empirical regularities of equity prices and real and nominal bond prices. We begin by looking at the model's implications for the risk-free rate $r_{f,t}$ and for the excess equity return $r_{e,m,t} \equiv r_{m,t} - r_{f,t}$ and the log dividend-price ratio $dp_t \equiv d_t - p_t$ on the aggregate stock market, whose log price $p_t = \ln(\sum_{n=1}^{\infty} E_t M_{t,t+n} D_{t+n})$ is the expected discounted value of all future dividend payments. We then look at the model's term structure implications for yields and holding-period returns on dividend claims and nominal and real bonds. Specifically, we denote the price of a claim to cash flow g that will be realized in n periods as $P_{g,t}^{(n)} = E_t(M_{t,t+n} G_{t+n})$, and consider the associated one-period log return $r_{g,t+1}^{(n)} = p_{g,t+1}^{(n-1)} - p_{g,t}^{(n)}$ and yield $y_{g,t}^{(n)} = -(p_{g,t}^{(n)} - g_t)/n$, where, as usual, lower case letters denote logarithms.

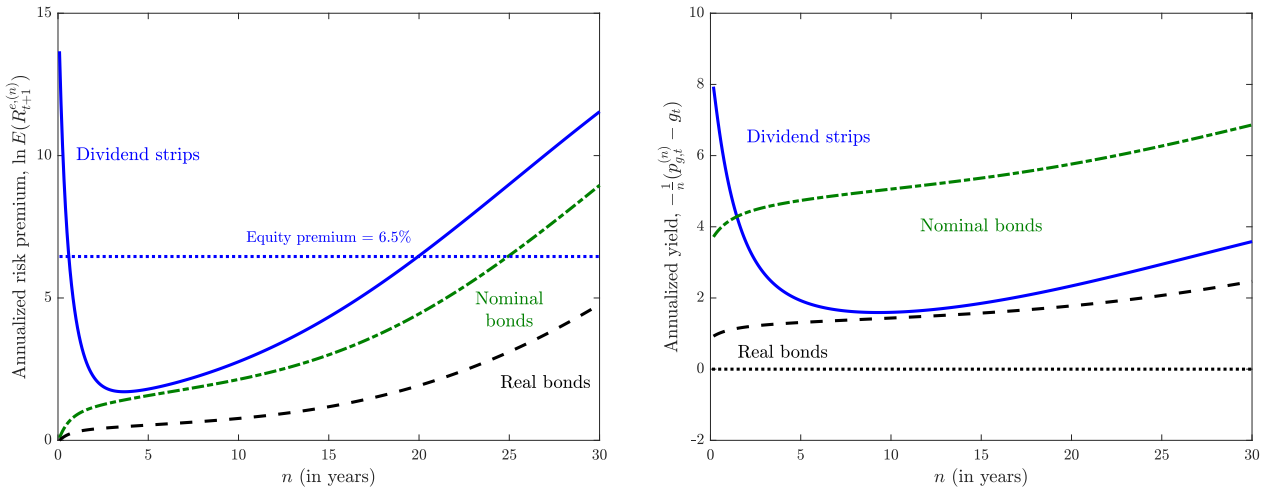
[8] A similar amplification would arise with wage rigidities, which also break the one-for-one relation between labor income and consumption. We focus on price rigidities because they directly link to inflation dynamics.

Volatility $\sqrt{\frac{1}{n}var(g_{t+n} - g_t)}$		Horizon (years)				
		1	2	3	5	7
Consumption $g = c$	Data:	1.3	1.5	1.7	1.7	1.7
	Model:	1.4	1.4	1.4	1.3	1.3
Dividends $g = d$	Data:	14.3	13.2	12.8	11.1	9.5
	Model:	19.5	14.8	12.2	9.4	7.9
Inverse CPI $g = -p$	Data:	1.3	1.5	1.7	2.1	2.6
	Model:	1.1	1.3	1.4	1.4	1.4

Table 2: Standard deviations of simulated and historical cash flow data at different horizons. Data for consumption growth and inflation use data over the period 1982-2019 for personal consumption expenditure on nondurables and services and the CPI; dividend growth uses dividend payouts (aggregated within the month without reinvestment) of the end-of-month S&P 500. Weighting matrices for the two-stage GMM estimates are the identity matrix (first step) and the spectral density at frequency zero (second step) constructed as the Newey-West HAC estimator with a Bartlett kernel and an automatic bandwidth selection criterion.

	Data	Model			
		Pop.	5%	50%	95%
Consumption volatility, $std(\Delta c_{t+1y})$ (%)	1.3	1.4	1.3	1.4	1.5
Dividend relative volatility, $\frac{std(\Delta d_{t+1y})}{std(\Delta c_{t+1y})}$	10.6	14.1	11.0	14.3	16.5
Inflation relative volatility, $\frac{std(\pi_{t+1y})}{std(\Delta c_{t+1y})}$	1.0	0.8	0.7	0.8	0.9
Wage relative volatility, $\frac{std(\Delta w_{t+1y})}{std(\Delta c_{t+1y})}$	1.2	0.9	0.8	0.9	1.0
Labor income relative volatility, $\frac{std(\Delta \ell_{t+1y})}{std(\Delta c_{t+1y})}$	2.0	1.3	1.2	1.3	1.4
Output relative volatility, $\frac{std(\Delta y_{t+1y})}{std(\Delta c_{t+1y})}$	1.5	1.0	1.0	1.0	1.0
$corr(\pi_t, \Delta c_t)$	-0.33	-0.44	-0.46	-0.44	-0.43
Labor income to consumption ratio, $E[L_t/C_t]$	0.86	0.86	0.85	0.86	0.86
Consumption to output ratio, $E[C_t/Y_t]$	0.69	1.0	1.0	1.0	1.0

Table 3: Results of the baseline model: Quantities. Moments of historical data over 1982-2019 and of the model. Model moments are reported in population and their distribution over 10,000 simulated samples with the same length as the historical data.



(a) *Term structures of one-period returns* (b) *Term structures of yields*

Figure 2: Average term structures of equity and interest rates. Different lines are associated with term structures of different cash flow claims: real bonds (dashed), nominal bonds (dash-dotted), and market equity (solid line).

	Data		Model	
	Mean	S.d.	Mean	S.d.
Risk-free rate, r_f (% p.a.)	1.0*	1.8	1.0	0.8
Excess stock market return, $r_{e,m}$ (% p.a.)	6.5	15.3	5.6	12.7
Log dividend-price ratio, dp (annualized)	-3.78	0.36	-3.26	0.23

	Lag (in years)				
	1	2	3	5	7
Autocorrelation of dp, data	0.90*	0.82	0.75	0.53	0.34
Autocorrelation of dp, model	0.90	0.87	0.77	0.62	0.49
Long-run return regressions, 10 × coefficient	1.2	2.3	3.2	5.0	6.5
Long-run return regressions, R^2	4.9%	9.2%	13.2%	20.1%	26.1%

Table 4: Results of the baseline model: Risk-free rate and aggregate stock market. Moments of simulated and historical data over 1982-2019. $r_{e,m}$ and dp denote the excess stock market return and the dividend-price ratio of the aggregate stock market portfolio, measured in the data using the CRSP value-weighted index; returns are in excess of the the CRSP 1-month Treasury bill rate; r_f is the real risk-free rate, measured in the data as the 1-month real risk-free rate from Haubrich et al. (2012). The long-run return regressions run the predictive regression $\sum_{j=1}^{h} r_{m,t+j} - r_{f,t+j} = b_0 + b_1 dp_t + e_{t+j}$. An asterisk denotes a moment that was matched during our estimation using the approximate solution.

4.3.1. Risk-free rate, equity premium, and dividend-price ratios

Table 4 reports key moments of the risk-free rate, the excess equity return, and the dividend-price ratio on the aggregate stock market. Overall, we reproduce the main appealing properties of Campbell and Cochrane (1999), including countercyclical financial market volatility and risk premia, as well as the long-horizon predictability of excess stock returns.

Low and stable risk-free rate. The model matches the level of the real 1-month risk-free rate, measured at an annualized 1.04 percent in the 1982-2019 data, and is able to produce a stable risk-free rate thanks to the parameterization that implies MFS, with even less volatility than in the data because of the discipline imposed by MFS. Note that we match the level of both the real and the nominal bond term structures because we parameterized the model to match not only the average risk-free rate but also the average inflation rate of 2.7 percent.

Large and countercyclical aggregate equity premium. The model produces an average annualized premium on the market portfolio of 5.6 percent, close to the 6.5 percent in the data. The volatility of these returns is similar as in the data, and much more volatile than the risk-free rate. Similar to Campbell and Cochrane, aggregate dividend-price ratios have a mean similar to that in the data, have around two-thirds of the observed variance, and predict future aggregate stock market returns. Namely, the equity premium is countercyclical, as high dividend-price ratios predict high future stock market returns.

Overall, we preserve the successes of Campbell and Cochrane in modeling aggregate price-dividend ratios. In this sense, while the model of cash flows plays an important role in driving the equity term structure at the short end of the term structure, as shown below, the model of cash flows plays a minor role in driving the behavior of the aggregate stock market.

4.3.2. Term structures of the equity premium

Table 5 and Figure 2 report the quantitative implications of the model for the term structure of the equity premium. We follow Binsbergen et al. (2012), Lopez (2018b), and Gormsen (2021) in using option-implied dividend prices. Namely, we exploit no-arbitrage relations to replicate synthetic single market dividend payments from put and call European options on the S&P 500 index. The sample is the 2003-2019 period to line up with the longest possible sample for short-term dividend claims used in Gormsen (2021).

A caveat in the comparison between the model and the data is that the empirical evidence refers to claims on dividends, whereas the model counterpart is defined as firm profits net of investment expenditure, thereby abstracting from other aspects of firms' financing and payout policies, such as the role of corporate debt.

Large short-run equity returns. As shown by Table 5, the model produces large short-duration equity yields and equity risk premia similar in size to the aggregate equity premium. In this sense, the model produces downward-sloping equity term structures. The one-year dividend strip commands a risk premium of 6.5 percent in the model on average that is similar to the 5.5 percent value in the data, a value that is easily reproduced by the model when accounting for dispersion in simulations. The model is likewise able to reproduce the negative average 2- minus 1-year yield spread of -0.2 percent in the data.

	Data	Model			
		Pop.	5%	50%	95%
Dividend claims					
$E[r_{m,t} - r_{f,t}]$	6.5	5.6	3.8	5.6	7.8
$std(r_{m,t} - r_{f,t})$	15.3	12.7	9.4	12.6	15.5
$E[r^{(1y)}_{d,t+1y}] = E[y^{(1y)}_{d,t} + \Delta d_{t+1y}]$	5.5	6.9	4.6	6.9	10.0
$E[y^{(2y)}_{d,t} - y^{(1y)}_{d,t}]$	-0.2	-1.2	-2.3	-1.2	-0.1
$E[r_{m,t+1y} - r^{(1y)}_{d,t+1y}]$	-1.3	0.0	-1.4	0.0	1.3
$corr(dp_t, y^{(2y)}_{d,t} - y^{(1y)}_{d,t})$	-38.7	-44.6	-91.2	-61.4	-34.2
$corr(dp_t, r_{m,t+1y} - r^{(1y)}_{d,t+1y})$	29.6	22.9	10.0	25.9	40.9
Nominal bonds					
$E[i_t] = E[y^{(1m)}_{-p,t}]$	3.8	3.8	2.9	3.7	4.5
$std(i_t) = std(y^{(1m)}_{-p,t})$	3.0	2.1	1.8	2.1	2.4
$E[y^{(1y)}_{-p,t} - \pi_{t+1y}] = E[r^{(1y)}_{-p,t+1y}]$	1.6	1.6	1.2	1.6	2.0
$E[y^{(2y)}_{-p,t} - y^{(1y)}_{-p,t}]$	0.3	0.2	0.1	0.2	0.3
$E[y^{(10y)}_{-p,t} - y^{(1y)}_{-p,t}]$	1.6	0.8	0.7	0.8	0.9
$corr(dp_t, y^{(2y)}_{-p,t} - y^{(1y)}_{-p,t})$	30.8	43.2	31.8	60.1	88.2
$corr(dp_t, y^{(10y)}_{-p,t} - y^{(1y)}_{-p,t})$	4.5	38.4	28.6	56.6	86.8
$corr(dp_t, r^{(2y)}_{-p,t+1y} - r^{(1y)}_{-p,t+1y})$	27.1	11.7	-12.1	12.3	32.9
$corr(dp_t, r^{(10y)}_{-p,t+1y} - r^{(1y)}_{-p,t+1y})$	17.7	13.6	-11.9	13.8	34.7
Real bonds					
$E[r_{f,t}] = E[y^{(1m)}_{0,t}]$	1.0	1.0	0.7	0.9	1.2
$std(r_{f,t}) = std(y^{(1m)}_{0,t})$	1.8	0.8	0.7	0.8	0.9
$E[y^{(1y)}_{0,t}] = E[r^{(1y)}_{0,t+1y}]$	1.5	1.1	0.9	1.1	1.4
$E[y^{(2y)}_{0,t} - y^{(1y)}_{0,t}]$	0.1	0.1	0.0	0.1	0.1
$E[y^{(10y)}_{0,t} - y^{(1y)}_{0,t}]$	1.0	0.3	0.3	0.3	0.4
$corr(dp_t, y^{(2y)}_{0,t} - y^{(1y)}_{0,t})$	14.8	44.8	35.2	61.1	88.5
$corr(dp_t, y^{(10y)}_{0,t} - y^{(1y)}_{0,t})$	1.5	50.6	43.5	64.2	88.2
$corr(dp_t, r^{(2y)}_{0,t+1y} - r^{(1y)}_{0,t+1y})$	26.8	12.9	-11.6	13.0	33.7
$corr(dp_t, r^{(10y)}_{0,t+1y} - r^{(1y)}_{0,t+1y})$	11.6	19.5	-10.8	16.5	38.3

Table 5: Results of the baseline model: Term structures. Moments of historical data over 1982-2019 (2003-2019 for dividend strips—Gormsen's (2021) longest available sample) and of the model. Model moments are reported in population and their distribution over 10,000 simulated samples with the same length as the historical data. Moments are expressed in percent and annualized.

Finally, the model generates equity term premia, defined as the average one-year dividend strip return minus the aggregate equity return, that easily switch sign. Here note that, consistent with the evidence in Binsbergen and Koijen (2017), Bansal et al. (2021), or Gormsen (2021), there is some controversy as to the sign of such a slope of the dividend term structure as the evidence about it is limited to a small sample and has potential liquidity issues. Interestingly, the model reflects such ambiguity, easily producing both negative and positive signs to the slope over small samples.

Figure 2a shows that the premium commanded by short-term equities can reach up to 13 percent on average, higher than the annualized premium on the market portfolio. At the longer end, beyond the maximum horizon for which we have dividend strip data, the average equity term structures display an important nonmonotonicity, and become upward sloping. The term structure of equity is therefore U-shaped, with premia that start to increase beyond 5 or so years, and become especially large in the long run. Our model therefore reflects the familiar property of habit models of implying large risk premia for long-duration claims. This U-shape is driven by the dependence of yields on the two states, namely, expected productivity growth u_t, which mainly accounts for the downward slope at the short end of the curve, and the surplus consumption ratio s_t, which mainly accounts for the upward slope at the long end. Since aggregate dividend-price ratios are mostly driven by the state s_t, such a U-shape is key to capture the countercyclicality of equity term premia, as we discuss below.

Procyclical equity yield spreads. Consistent with the procyclicality of equity yield spreads documented by Binsbergen et al. (2013), the term structure of equity yields is more downward sloping in downturns and becomes upward sloping in normal times. As shown in Table 5, the model is able to produce the negative correlation of -38.7 percent between dividend-price ratios and equity yield spreads.

Figure 3b further depicts the cyclicality of yields in the model. Bad times, as indicated by low values of price-dividend ratios, scale up the level and slope of the term structures. The term structure of equity yields becomes more downward sloping in bad times.

While the cyclical properties of the term structure of equity seem so far less controversial, it should be here again noted that the evidence is based on a narrow sample—specifically, the 2003-2019 period spans only one NBER recession.

Countercyclical equity term premia. Consistent with the countercyclicality of equity term premia documented by Gormsen (2021), long-term one-period returns are more correlated than short-term returns with movements in the aggregate price-dividend ratio. As shown in Table 5, the model is able to produce the positive correlation of 29.6 percent between dividend-price ratios and equity term premia.

Furthermore, Figure 3a shows a version of Gormsen's Figure 1 by regressing simulated one-period returns of a short-maturity claim, $\frac{1}{N}\sum_{n=1}^{N} r_{t,t+12}^{(n)}$ for a yearly value of $N = 4$, and of the market portfolio on a constant and log dividend-price ratios, and by plotting averages and the first and fifth quintiles of the fitted values of the two regressions. In the model, the market portfolio is more elastic than short-maturity claims and the term structure of one-period equity returns becomes more downward sloping in good times.

4.3.3. Term structures of nominal and real interest rates

Table 5 reports key moments of the term structures of real and nominal bonds. The sample is the 1982-2019 period for aggregate dividend-price ratios and real and nominal bonds, the sample sample used above for quantities, aggregate market returns, and the risk-free rate. We measure real bond yields over 1982-2019 using the series constructed by Haubrich et al. (2012), who employ a no-arbitrage affine term structure model that combines Treasury yield curves, inflation-linked derivatives, and survey expectations of inflation and interest rates, and available from the Cleveland Fed website. This approach provides a longer history than TIPS, while also alleviating the liquidity distortions that affect TIPS yields.

Upward-sloping average term structure of nominal bond premia and yields. The model produces upward-sloping average term structures of nominal bond premia, with a positive difference relative to real bond premia, reflecting an inflation risk premium that is positive at all maturities, of around 50 basis points per year. Figures 2a and 2b, and Table 5 show that, while it matches the level of nominal interest rates, the model reproduces the upward-sloping average term structures of nominal bond yields in the data.

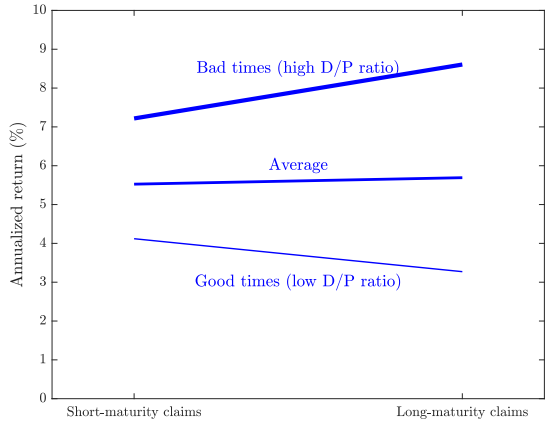
Upward-sloping average term structure of real bond premia and yields. The model has a similar prediction of an upward-sloping average term structure of real bond premia and yields, which is close to the data shown in Table 5, both in the level and the slope, with the exception of a relatively small real yield spread at a ten-year horizon.

Countercyclical nominal bond term premia and yield spreads. Consistent with evidence that goes back at least to Estrella and Hardouvelis (1991), the model reproduces the countercyclicality of the slope of nominal interest rates, as indicated by the correlation of the slopes at short and long horizons of bond yields with dividend-price ratios. Indeed, the model successfully reproduces the countercyclicality of nominal term premia, which have a correlation with aggregate dividend-price ratios of 27.1 and 17.7 at the short- and long-end of the curve, respectively. Still, the amount of countercyclicality in bond yield spreads is slightly overstated by the model, especially at long horizons.

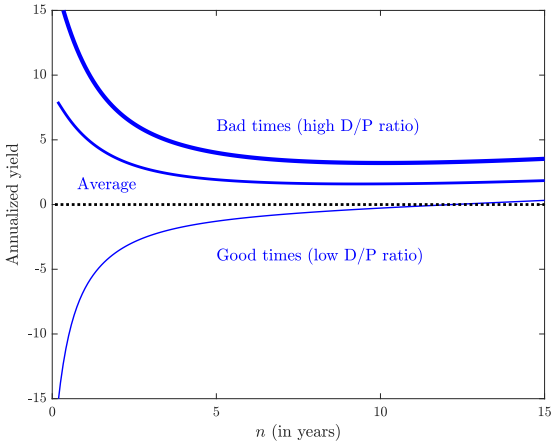
Furthermore, Figure 3c depicts the cyclicality of nominal bond yields in the model; the model predicts a term structure of bond yields that becomes more upward sloping in times of high aggregate dividend-price ratios, which are associated with increasing expected future interest and inflation rates, and high term and inflation risk premia. The term structure of bond yields inverts in good times by the opposite logic.

Countercyclical real bond term premia and yield spreads. The model successfully reproduces the countercyclicality of the slope of real bond term premia and yield spreads, with an overstatement of the countercyclicality of real yield spreads similar as for nominal yield spreads.

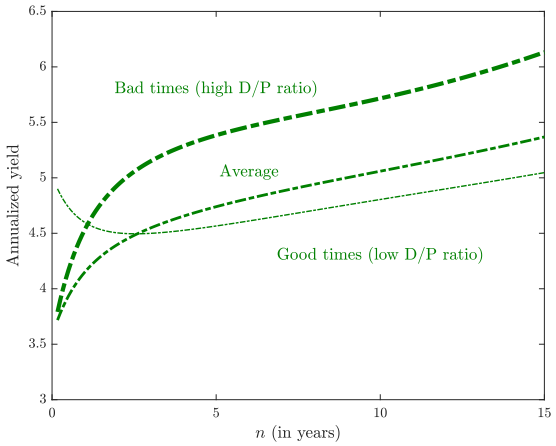
In bad times, real term premia and yield spreads increase, as depicted in Figure 3d; the real bond term structure becomes more upward sloping in times of high aggregate dividend-price ratios, which are associated with high expected real rates, future growth rates, and risk premia, and even inverts in good times.



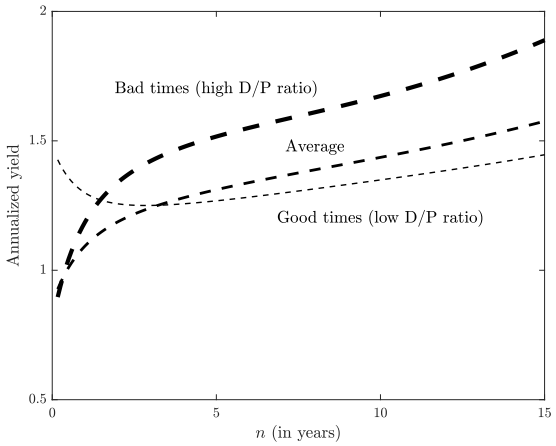
(a) *One-period returns: The short-maturity return is the average return to dividend strips of up to 4-year maturity; the long-maturity return is the aggregate stock market return.*



(b) *Yields: Dividend strips*



(c) *Yields: Nominal bonds*



(d) *Yields: Real bonds*

Figure 3: Time variation of the term structures of one-period returns and yields. Bad (good) times are periods in which the aggregate price-dividend ratio is below (above) its bottom (top) quartile.

5. Extension to a Model with Capital

We now extend the model to allow for realistic capital accumulation, thereby departing from MFS. Our results remain robust once realistic investment dynamics are included, while the model becomes able to match more business-cycle facts. Overall, the asset pricing implications remain similar to those of the baseline model. We conclude that relaxing the assumption of MFS to match investment data does not alter our main results. Rather, we view such local departures from MFS a particularly promising avenue for improving the joint fit of macroeconomic and financial data.[9]

Specifically, production is now described by a continuum of monopolistically competitive retailers that buy undifferentiated goods from intermediate goods producers, and that transform them into a differentiated good that is sold to final goods producers subject to nominal price rigidities. Final goods producers bundle these differentiated goods via a Dixit-Stiglitz aggregator. Competitive intermediate goods producers make an undifferentiated good using labor and accumulate capital by purchasing final goods according to (5), following the specification in Section 2.[10] As discussed there, the adjustment cost curvature parameter, ξ_3, equals the elasticity of the investment-capital ratio to Tobin's Q, which controls the spillover of surplus consumption onto the optimal investment choice, along with the other intertemporal spillover parameter, ξ_1, which controls the spillover of surplus consumption onto asset prices, including Tobin's Q itself. As before, parameter ξ_2 controls the spillover on the consumption-labor tradeoff.

Note that aggregate dividends in this context can still be written as

$$D_t = Y_t - \frac{W_t}{P_t} N_t - I_t = C_t - \frac{W_t}{P_t} N_t \tag{23}$$

using the equilibrium condition that output equals the sum of consumption and investment. Therefore, the relation (21) between dividends, consumption, and labor income is unchanged by the presence of investment relative to our baseline model. Fluctuations in dividends must still correspond with either consumption or labor income changes.

We adopt the following parameterization of the model. The steady-state investment-capital ratio, $I/K = e^{\mu} - 1 + \delta$, is set with a standard target value of 8 percent per year, which implies a depreciation rate δ of 6.3 percent per year. The capital share parameter is fixed at $\alpha = .4$ to match the ratio between labor income and output of .6 over the 1982-2019 period. The adjustment cost curvature is set to $\xi_3 = .33$, following the estimate in Lopez (2018a), to match the empirical relationship between investment-capital ratios and measures of Tobin's Q. The intertemporal habit spillover parameter, $\xi_1 = .003$, which affects Tobin's Q, is then chosen to match the relative volatilities of investment growth and output growth. In doing so, because ξ_1 controls the elasticity of the risk-free rate with respect to s_t, as discussed at length above, we verify that the implied volatility of the risk-free rate remains

[9] In the online appendix, we additionally study extensions that incorporate wage rigidities, demand shocks, and a zero lower bound on the interest rate.

[10] The online appendix fleshes out the full model.

moderate—indeed, it remains if anything less volatile than the data. The subjective discount factor, β, and the variance of productivity shocks, σ, are re-calibrated to continue matching the volatility of consumption growth and the average risk-free rate. All other values are the same as in the baseline model, including the intratemporal habit spillover parameter, ξ_2.

Table 6 reports the implications of this version of the model for quantities and asset prices. The model is now able to match the relative volatility of output growth and the average output-to-consumption ratio, as output and consumption no longer coincide—but its implications for equity claims, bonds, and their cash flows remain close to those of the baseline. Furthermore, the mechanism closely mirrors that of the baseline: the response of the main cash flows to a productivity shock, shown in Figure 4a, is very similar to the baseline case in Figure 1b.

6. Role of Habits and Nominal Rigidities

This section examines how our quantitative results depend on the key ingredients of the baseline model—namely, the two habits and nominal price rigidities. We turn off nominal rigidities and begin by comparing outcomes across three cases: when both habits are absent, when only the habit in market consumption is present, and when both habits are active so as to preserve MFS. As we show, the habit in effective leisure is essential for allowing consumption habits to generate realistic discount rates while avoiding counterfactual implications.

We then depart from MFS by introducing nontrivial capital accumulation in the flexible-price version of the two-habit model. As we show, however, capital accumulation alone fails to produce the correct cyclicality of dividends, for reasons that go back to Kaltenbrunner and Lochstoer (2010).

Finally, we examine how the degree of nominal rigidity shapes the term-structure properties. Specifically, we ask what the term structure would look like in a model with MFS but a lower degree of price stickiness.

6.1. The role of habits

Table 7 reports the quantitative results from the real versions of our baseline model that isolate the roles of the two habits. In all versions, parameters are fixed at their baseline values, except for the subjective discount factor, β, the variance of productivity shocks, σ, and the habit spillover parameters, ξ_1 and ξ_2. The first two parameters, β and σ, are re-calibrated so the real model without habits continues matching the volatility of consumption growth (1.3 percent p.a.) and the average risk-free rate (1.0 percent p.a.), as in the baseline. When habits are introduced, the spillover parameters are instead set to reflect MFS, $\xi_1 = \xi_2 = 0$, with the caveat that in the one-habit case such separation is not feasible, as discussed in Section 2.

In the real version with nontrivial capital accumulation, we likewise adjust parameters β and σ to continue matching the volatility of consumption growth and the average risk-free rate, and set all other parameters as in our extension with capital presented in Section 5, except for the intratemporal spillover parameter, which is set to $\xi_2 = 0$.

Real model, no habits. In the CRRA version of the flexible-price model with trivial capital accumulation, quantity dynamics are straightforward: $D_t = \alpha C_t$, so dividends move one-for-one with consumption and their growth rates have the same volatility. Because this model implies constant hours, the growth rates of real wages and labor income also exhibit the same volatility as consumption growth.

With CRRA preferences, the risk-aversion coefficients must coincide with the inverse EIS of 2. Consequently, such low risk-aversion coefficient generates an equity premium only about one-sixth of the observed value. Other asset pricing implications are similarly counterfactual, with flat term structures of equity and bond yields and trivial risk premia on short-duration equity strips. Finally, as inflation is indeterminate in this real model, it delivers no implications for inflation and nominal bonds.

Real model, one habit. As we introduce habit formation in only market consumption, we run into the quantity puzzle. The high risk-aversion coefficient now gives households strong incentives to smooth consumption by absorbing shocks through labor supply. Consequently, real wages and labor income are 7.5-10 times more volatile than in the data, while the volatility of consumption growth falls to about 40 percent of its empirical value.

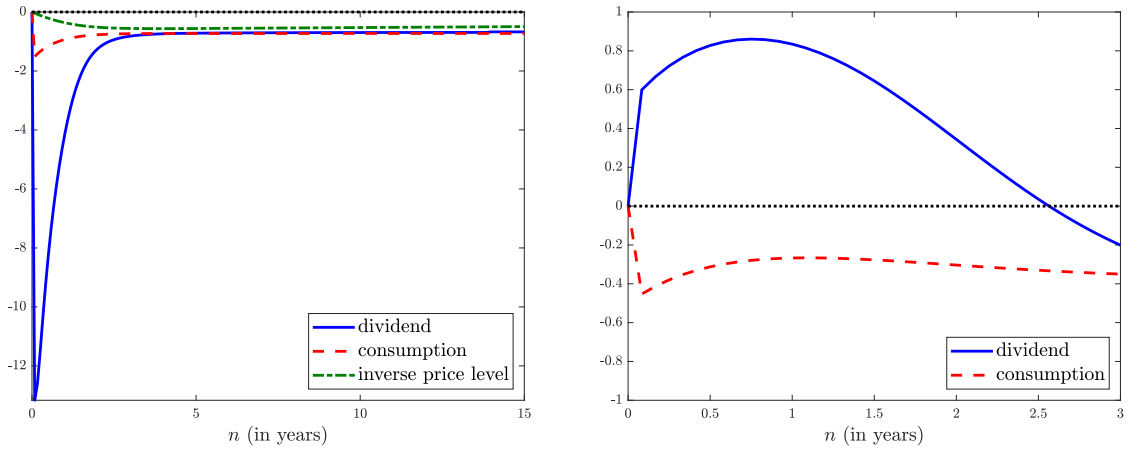
Habits now break the equality between the inverse EIS and the risk aversion coefficient. Still, despite the high risk aversion, the equity premium remains low because consumption is now too stable. The term structure implications show only minor improvements over the no-habit case: risk premia on short-duration equities are still too small, as dividend and consumption growth continue to move one-for-one, and the slopes of equity and bond yields are still nearly zero.

Real model, two habits. Introducing both habits in market and home consumption, the parameterization that enforces MFS ($\xi_1 = \xi_2 = 0$) brings, by definition, quantities back to the no-habit case. Consumption growth volatility matches the data, but dividends still exhibit no leverage over consumption, with identical growth rates.

The now high risk-aversion coefficient generates a realistic equity premium and produces implications for the term structure of real bonds that closely resemble those in the baseline. A key difference, however, lies in the properties of dividend claims. Since dividends still move one-for-one with consumption, short-term dividends carry much lower risk premia than the aggregate market, and both equity premia and yields rise with the horizon. Therefore, the model is unable to generate negative equity term premia and yield spreads, as observed in the data.

Real model with capital. Finally, we verify that capital accumulation cannot by itself generate the observed leverage of dividends over consumption in the model with flexible prices. Table 7 shows how the flexible-price version of the two-habit model with capital accumulation cannot produce much leverage in dividends over consumption. Dividend growth now has only about twice the volatility of consumption growth. More importantly, despite the higher volatility, dividends are now less procyclical than consumption. This property can be readily seen in Figure 4b, which plots the reaction of consumption and dividends to a negative productivity shock in the model. While consumption falls after a negative shock,

	Data	Baseline			Model with capital		
		5%	50%	95%	5%	50%	95%
Quantities							
$std(\Delta c_{t+1y})$	1.3	1.3	1.4	1.5	0.9	1.3	1.8
$std(\Delta d_{t+1y})/std(\Delta c_{t+1y})$	10.6	11.0	14.3	16.5	18.7	36.6	78.3
$std(\pi_{t+1y})/std(\Delta c_{t+1y})$	1.0	0.7	0.8	0.9	0.5	1.1	2.1
$std(\Delta y_{t+1y})/std(\Delta c_{t+1y})$	1.5	1.0	1.0	1.0	1.1	1.5	2.1
$corr(\pi_t, \Delta c_t)$	-0.33	-0.46	-0.44	-0.43	-0.40	-0.31	-0.24
$E[L_t/C_t]$	0.86	0.85	0.86	0.86	0.82	0.85	0.87
$E[C_t/Y_t]$	0.69	1.0	1.0	1.0	0.68	0.69	0.70
Dividend claims							
$E[r_{m,t} - r_{f,t}]$	6.5	3.8	5.6	7.8	4.1	7.3	11.9
$std(r_{m,t} - r_{f,t})$	15.3	9.4	12.6	15.5	10.0	18.6	30.9
$E[y_{d,t}^{(1y)} + \Delta d_{t+1y}]$	5.5	4.6	6.9	10.0	4.3	10.4	21.8
$E[y_{d,t}^{(2y)} - y_{d,t}^{(1y)}]$	-0.2	-2.3	-1.2	-0.1	-2.8	-1.0	1.7
$E[r_{m,t+1y} - r_{d,t+1y}^{(1y)}]$	-1.3	-1.4	0.0	1.3	-1.6	-0.1	1.4
$corr(dp_t, y_{d,t}^{(2y)} - y_{d,t}^{(1y)})$	-38.7	-91.2	-61.4	-34.2	-99.0	-77.8	-56.0
$corr(dp_t, r_{m,t+1y} - r_{d,t+1y}^{(1y)})$	29.6	10.0	25.9	40.9	-11.3	7.0	26.3
Nominal bonds							
$E[i_t]$	3.8	2.9	3.7	4.5	1.6	3.7	6.9
$std(i_t)$	3.0	1.8	2.1	2.4	1.3	2.2	3.5
$E[y_{-p,t}^{(1y)} - \pi_{t+1y}]$	1.6	1.2	1.6	2.0	-0.3	1.5	4.6
$E[y_{-p,t}^{(2y)} - y_{-p,t}^{(1y)}]$	0.3	0.1	0.2	0.3	0.3	0.3	0.3
$E[y_{-p,t}^{(10y)} - y_{-p,t}^{(1y)}]$	1.6	0.7	0.8	0.9	1.9	2.0	2.2
$corr(dp_t, y_{-p,t}^{(2y)} - y_{-p,t}^{(1y)})$	30.8	31.8	60.1	88.2	78.0	85.5	92.4
$corr(dp_t, y_{-p,t}^{(10y)} - y_{-p,t}^{(1y)})$	4.5	28.6	56.6	86.8	86.0	91.3	95.4
$corr(dp_t, r_{-p,t+1y}^{(2y)} - r_{-p,t+1y}^{(1y)})$	27.1	-12.1	12.3	32.9	-17.1	6.5	28.2
$corr(dp_t, r_{-p,t+1y}^{(10y)} - r_{-p,t+1y}^{(1y)})$	17.7	-11.9	13.8	34.7	-16.1	7.7	29.6
Real bonds							
$E[r_{f,t}]$	1.0	0.7	0.9	1.2	0.3	0.9	2.0
$std(r_{f,t})$	1.8	0.7	0.8	0.9	0.5	0.8	1.2
$E[y_{0,t}^{(1y)}]$	1.5	0.9	1.1	1.4	0.5	1.2	2.3
$E[y_{0,t}^{(2y)} - y_{0,t}^{(1y)}]$	0.1	0.0	0.1	0.1	0.1	0.1	0.1
$E[y_{0,t}^{(10y)} - y_{0,t}^{(1y)}]$	1.0	0.3	0.3	0.4	0.7	0.8	0.9
$corr(dp_t, y_{0,t}^{(2y)} - y_{0,t}^{(1y)})$	14.8	35.2	61.1	88.5	76.4	84.4	92.2
$corr(dp_t, y_{0,t}^{(10y)} - y_{0,t}^{(1y)})$	1.5	43.5	64.2	88.2	87.0	93.0	96.9
$corr(dp_t, r_{0,t+1y}^{(2y)} - r_{0,t+1y}^{(1y)})$	26.8	-11.6	13.0	33.7	-17.2	6.3	27.9
$corr(dp_t, r_{0,t+1y}^{(10y)} - r_{0,t+1y}^{(1y)})$	11.6	-10.8	16.5	38.3	-16.0	8.1	29.9



(a) *Model with capital and sticky prices* (b) *Real model with capital*

Figure 4: Model with capital: Generalized impulse response to −1 standard deviation productivity shock, starting from the ergodic mean of the states; percentage changes in cash flows over a given horizon

dividends initially *rise*, and only after about three years do they turn negative, reverting toward consumption because of their cointegration relationship.

To understand this countercyclicality of dividends note that, as emphasized by Kaltenbrunner and Lochstoer (2010), in such a real business cycle setup firm payouts are given by $D_t = \alpha Y_t - I_t$, while consumption is $C_t = Y_t - I_t$, so dividends are necessarily less procyclical than consumption. As firms decrease investment in recessions, they can even end up increasing their payouts. Consequently, when turning to the asset pricing implications, this model generates only a small equity premium, reflecting the lower riskiness of dividends relative to consumption, and short-run dividend claims that carry an expected return below the risk-free rate. Thus, the equity term structure fails to generate realistic risk premia at both short and long horizons.

Overall, incorporating nontrivial capital accumulation, if anything, reinforces our conclusion that nominal price rigidities are a crucial ingredient in explaining macro-financial comovement. Indeed, the operating leverage generated by nominal rigidities is enough to offset the effects of investment on dividends in the flexible-price model. As a result, the response of cash flows in our model extension with capital accumulation, shown in Figure 4a, resembles that of the baseline model, depicted in Figure 1b.

6.2. The role of nominal rigidities

Section 4.3 rationalized some rich features of equity and bond markets using a simple New Keynesian model in which nominal rigidities play a central role. By contrast, the previous subsection demonstrated that a flexible-price model fails to do so, even under MFS. In this section, we explore how the term structure behaves in a model with MFS as we vary the degree of price stickiness from zero up to the baseline level.

Figure 5 quantifies the effect of the degree of price stickiness and highlights its role in generating an initially downward-sloping term structure of market equity and in flattening the

	Data	Real, no habits			Real, one habit			Real, two habits			Real with capital		
		5%	50%	95%	5%	50%	95%	5%	50%	95%	5%	50%	95%
Quantities													
$std(\Delta c_{t+1y})$	1.3	1.1	1.3	1.5	0.4	0.5	0.6	1.1	1.3	1.5	1.1	1.3	1.6
$std(\Delta d_{t+1y})/std(\Delta c_{t+1y})$	10.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.7	2.2	2.8
$std(\pi_{t+1y})/std(\Delta c_{t+1y})$	1.0	—	—	—	—	—	—	—	—	—	—	—	—
$std(\Delta w_{t+1y})/std(\Delta c_{t+1y})$	1.2	1.0	1.0	1.0	10.1	11.2	12.4	1.0	1.0	1.0	0.9	1.0	1.1
$std(\Delta \ell_{t+1y})/std(\Delta c_{t+1y})$	2.0	1.0	1.0	1.0	13.5	14.9	16.4	1.0	1.0	1.0	1.3	1.5	1.8
$std(\Delta y_{t+1y})/std(\Delta c_{t+1y})$	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.3	1.5	1.8
$E[L_t/C_t]$	0.86	0.86	0.86	0.86	0.73	0.87	1.0	0.86	0.86	0.86	0.81	.84	.86
$E[C_t/Y_t]$	0.69	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.70	.72	.74
Dividend claims													
$E[r_{m,t} - r_{ft}]$	6.5	0.4	1.1	1.9	-0.5	1.4	3.2	3.4	5.1	7.0	0.3	0.5	0.7
$std(r_{m,t} - r_{ft})$	15.3	2.4	2.6	2.7	5.8	6.3	6.8	8.8	11.6	14.1	10.1	13.3	16.0
$E[y_{d,t}^{(1y)} + \Delta d_{t+1y}]$	5.5	0.9	1.1	1.3	-0.1	1.1	2.3	1.4	2.0	2.6	-0.1	0.5	1.7
$E[y_{d,t}^{(2y)} - y_{d,t}^{(1y)}]$	-0.2	0.0	0.0	0.0	-0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.2	0.3
$E[r_{m,t+1y} - r_{d,t+1y}^{(1y)}]$	-1.3	0.9	1.0	1.1	-0.5	1.1	2.6	2.1	3.4	4.9	2.3	4.5	6.8
Nominal bonds													
$E[i_t]$	3.8	—	—	—	—	—	—	—	—	—	—	—	—
$std(i_t)$	3.0	—	—	—	—	—	—	—	—	—	—	—	—
Real bonds													
$E[r_{ft}]$	1.0	0.5	1.0	1.5	-0.5	1.0	2.6	0.5	1.0	1.5	-0.3	1.0	2.8
$std(r_{ft})$	1.8	1.4	1.6	1.9	1.7	2.1	2.5	1.4	1.6	1.9	2.1	2.6	3.2
$E[y_{0,t}^{(1y)}]$	1.5	0.9	1.0	1.2	-0.1	1.1	2.3	1.1	1.5	1.9	0.5	1.6	3.4
$E[y_{0,t}^{(2y)} - y_{0,t}^{(1y)}]$	0.1	-0.1	0.0	0.1	-0.1	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3
$E[y_{0,t}^{(10y)} - y_{0,t}^{(1y)}]$	1.0	-0.1	0.0	0.2	-0.3	0.1	0.5	0.4	0.5	0.6	1.2	1.4	1.8

Table 7: Results of flexible-price versions of the model. In the real versions of the two-habit models (with and without capital), the σ parameter is rescaled to preserve the volatility of consumption growth. Across versions, β is reparameterized to preserve the implications for the mean short-term real risk-free rate; in the one-habit version, the spillover parameters ξ_1 is set to 0; in the two-habit version, the spillover parameters ξ_1 and ξ_2 are set to 0.

bond yield curve. Equilibrium risk premia on zero-coupon equities shift upward as the degree of nominal price rigidity increases, whereas the opposite occurs for zero-coupon nominal bonds. In the limiting case as nominal rigidities disappear (price duration ≈ 1 month), there is no endogenous difference between the term structures of consumption and market equity. We defer to Section 7 a discussion of approximate analytical formulas to understand the role of nominal rigidities.

The effect on the term structures is mainly driven by cash flows, as stickier prices make dividends more volatile—which exacerbates the negative slope in the term structure of equity—and the conditional mean of consumption growth and inflation more stable—which flattens the term structure of nominal interest rates and reduces the inflation risk premium. Note how a similar flattening of the term structure occurs also for zero-coupon real bonds.

7. Inspecting the Mechanism

Even though we solved the model by a global projection method, it is useful to gain analytic insight with a first-order approximation around the risky steady state (see Lopez et al., 2016), which accounts for time-varying components contained in conditional second moments—including time variation in risk premia—that are crucial in a world with Campbell and Cochrane (1999) habits, and that are otherwise captured only by conventional approximations around the deterministic steady state of third order.

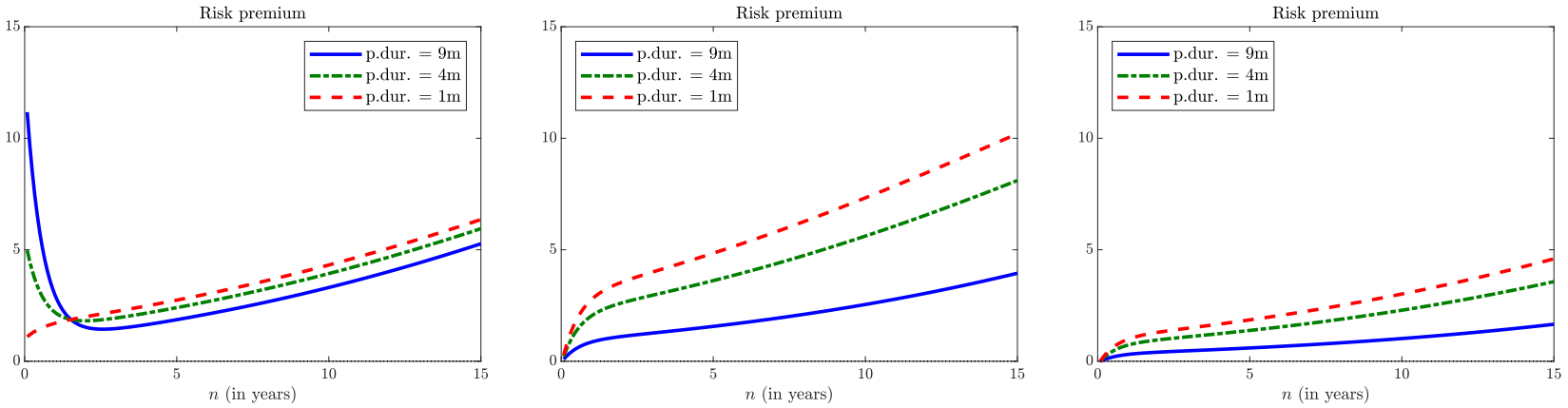
Under MFS, the properties of quantities are the one implied by the familiar New Keynesian model without habits. To a first-order perturbation around the risky steady state, the approximate solutions for consumption and inflation are

$$c_t - a_t = (1-\alpha)n + \psi_{cu} u_t, \qquad \pi_t = \pi^* + \psi_{\pi u} u_t \tag{24}$$

In words, the equilibrium dependence of consumption and inflation on surplus consumption is zero—what we previously called MFS. Note also that to a first-order approximation price dispersion is a trivial process, $\Delta_t = 0$, and hence we omit it as a state variable.

As described in Table 1, the specific calibration of the spillover parameters ξ_1 and ξ_2 that achieves an approximate MFS is close to the point $\xi_1 = \xi_2 = 0$, and implies (24). By the standard mechanism in New Keynesian models without habits, higher nominal rigidities imply a greater elasticity of consumption, ψ_{cu}, and a smaller elasticity of inflation, $\psi_{\pi u}$, to changes in u_t, consistent with the quantitative effects of nominal rigidities in shaping asset markets in Section 6.2.

As illustrated in Figure 1b, in a downturn consumption and surplus consumption fall on impact, and hence exposure to the shock is risky. However, the negative shock makes expected productivity growth u_t *increase*; since productivity is partly mean reverting, better times are ahead. In this context, an asset with a sufficiently large cash flow exposure to u_t serves as insurance. Indeed, dividends are expected to recover fast, while the payoff of nominal bonds is expected to fall more and more as time passes. From a purely cash flow perspective, a claim to dividends a few years out is less risky than a claim to tomorrow's dividends, while a claim to a unit of numeraire a few years out is more risky than a claim to tomorrow's numeraire.



(a) *Dividend strips.* (b) *Nominal bonds.* (c) *Real bonds.*

Figure 5: Term structures of one-period dividend strip, nominal bond, and real bond returns (in percent p.a.) for different degrees of price stickiness across macro-financially separate models. Different lines represent different calibrations for the average price duration: one month (dashed), four months (dash-dotted), and nine months (solid line). As we change the degree of price stickiness, we adjust the habit parameters ξ_1 and ξ_2 to maintain approximate MFS.

This intuition is key to understanding the downward- and upward-sloping term structures of equity and interest rates. Still, it is incomplete, because it disregards the discount-rate effect of a shock, to which we turn next.

To derive approximate formulas, we set up the approximate solution for cash flows as

$$\begin{aligned}\Delta g_{t+1} &= \mu_g + C_{g,u}u_t + C_{g,s}\hat{s}_t + D_g\varepsilon_{t+1}\\ u_{t+1} &= \rho_u u_t - \phi\sigma\varepsilon_{t+1}\\ \hat{s}_{t+1} &= \rho_s\hat{s}_t + \Lambda_{c,t}D_c\varepsilon_{t+1}\end{aligned}$$

where $g \in \{d, c, 0, -p\}$ denotes the four different cash flow processes (dividends, consumption, the numeraire, and the inverse of the price level), and C_u, C_s, and D contain the reduced-form coefficients of the model's solution. We also rewrite the one-period stochastic discount factor as

$$m_{t+1} = \ln(\beta) - \gamma E_t\Delta c_{t+1} + \gamma(1-\rho_s)\hat{s}_t - x_t\varepsilon_{t+1}$$

where we define $x_t \equiv \gamma(1+\Lambda_{c,t})D_c$ as the *price of risk*.

To gain intuition we can solve approximately for the no-arbitrage price of a claim to cash flow g that will be realized in n periods, which obey the recursive price formulas

$$P_{g,t}^{(n)} = E_t(M_{t,t+n}G_{t+n}) = E_t(M_{t,t+n}P_{g,t+1}^{(n-1)}) \quad \text{with} \quad P_{g,t}^{(0)} = G_t \tag{25}$$

7.1. Model intuition: Yields

We again rely on the risk-adjusted approximation to gain intuition for our numerical results. Namely, the log price-dividend ratio at time t on a claim to cashflow G_{t+n}, denoted $pd_{g,t}^{(n)} = \ln(P_{g,t}^{(n)}/G_t)$, takes the approximate form

$$pd_{g,t}^{(n)} = A_g^{(n)} + B_{g,u}^{(n)}u_t + B_{g,s}^{(n)}\hat{s}_t \tag{26}$$

with $pd_{g,t}^{(0)} = 0$, where the coefficients are provided in the appendix. Yields relate to these log price-dividend ratios as $y_{g,t}^{(n)} = -pd_{g,t}^{(n)}/n$.

Figure 6 plots these coefficients. Figure 6a shows constant terms that decrease with the maturity, with a speed that reflects the average payoff growth and the riskiness of the security. More important for our purpose, the elasticities of strips to the productivity state u, plotted in Figure 6b, are negative and decreasing for consumption claims and bonds, but positive and increasing for dividend claims. These properties combine the elasticity of cash flows with respect to u, $C_{g,u}$, described above and in Figure 1a, and the elasticity of discount rates with respect to u, $-\gamma C_{c,u}$. A higher value of u implies higher future cash flows and inflation and higher discount rates, as consumers prefer to anticipate consumption. For bonds, these effects imply lower valuations. The valuations of consumption claims also decrease, as the discount-rate effect outweighs the cash flow effect because the EIS is smaller than one. For dividend claims, however, the positive cash flow effect is so strong as to outweigh the discount-rate effect, and valuations are higher.

The elasticities of strips to the surplus consumption ratio s, plotted in Figure 6c, are positive and monotonically increasing for bonds and equities towards $B_{g,s}^{(\infty)} = \gamma$—a feature we previously called the habit effect. Indeed, whenever surplus consumption is low, households forecast lower subsequent marginal utility, since their habits will adjust to the lower consumption, and the more so the farther out the horizon; hence, they require compensation to shift resources forward to a time in which they will be less hungry. It follows that the price of long-duration claims is low in a recession, and the more so the longer the claim's duration.

Note that we can write the aggregate equity log price-dividend ratio as

$$pd_t = \ln \sum_{n=1}^{\infty} e^{pd_{g,t}^{(n)}} = \ln \sum_{n=1}^{\infty} e^{A_g^{(n)} + B_{g,u}^{(n)} u_t + B_{g,s}^{(n)} \hat{s}_t}$$

which is driven by both states. In particular, a high productivity state u and a high surplus consumption ratio s both imply high aggregate price-dividend ratios, even though u and s are negatively correlated, since u is high after a bad productivity shock. Quantitatively, however, price-dividend ratios move mostly with surplus consumption, which tends to be low after negative productivity shocks, when u is high. As a consequence, in the model, low price-dividend ratios predict higher future price-dividend ratios, as in Campbell and Cochrane (1999), but also higher future inflation and dividend growth.

Accordingly, as in Figure 3, when price-dividend and surplus consumption ratios are low, nominal yields slope up, predicting higher future rates and inflation, and equity yields slope more negatively on the observable end, predicting higher future dividends.

7.2. Model intuition: One-period returns

The approximate one-period excess return $r_{g,t+1}^{e,(n)} = r_{g,t+1}^{(n)} - r_{f,t}$ associated with the approximate expression for price-dividend ratios of strips can be written as

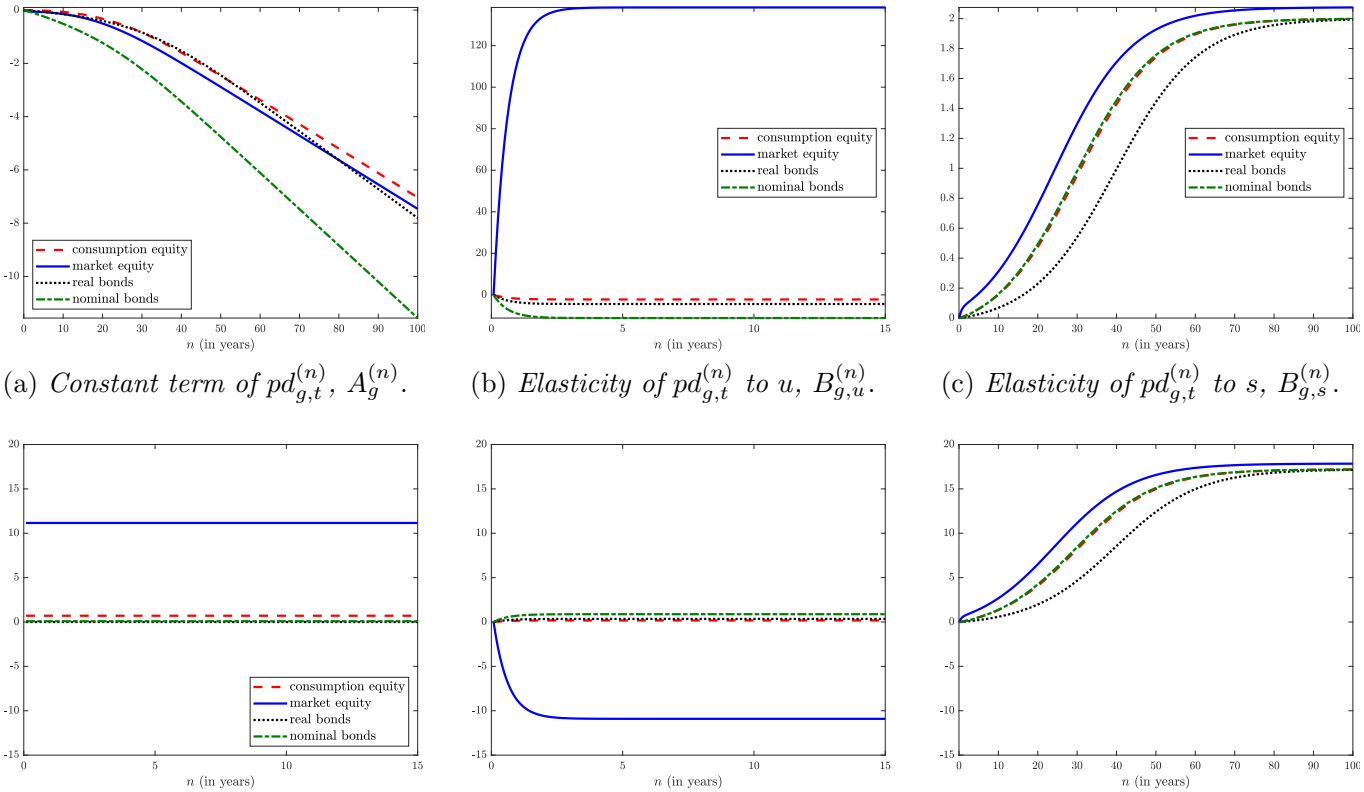
$$r_{g,t+1}^{e,(n)} = E_t r_{g,t+1}^{e,(n)} + V_{g,n-1,t} \varepsilon_{t+1}$$

where the stochastic vector

$$V_{g,n-1,t} \equiv \underbrace{D_g}_{\substack{\text{short-run} \\ \text{cash flow risk}}} + \underbrace{B_{g,u}^{(n-1)}(-\phi\sigma)}_{\substack{\text{long-run cash flow} \\ \text{and discount rate risk}}} + \underbrace{B_{g,s}^{(n-1)} \Lambda_{c,t} D_c}_{\substack{\text{habit-related} \\ \text{discount rate risk}}} \tag{27}$$

represents the *quantity of risk* in the nth cash flow strip.

The closed-form approximate solution (27) provides insight into the determinants of the term structures of risk premia on different cash flow claims. The first term in equation (27) is entirely due to the one-period-ahead volatility in cash flows. The second term captures the effect that news about expected productivity growth have on tomorrow's prices through their effect on future cash flows and discount rates. The third term reflects the effect of movements in risk aversion on tomorrow's prices through their effect on cash flows and, chiefly, on long-run discount rates by the habit effect.



(a) *Constant term of* $pd_{g,t}^{(n)}$, $A_g^{(n)}$. (b) *Elasticity of* $pd_{g,t}^{(n)}$ *to* u, $B_{g,u}^{(n)}$. (c) *Elasticity of* $pd_{g,t}^{(n)}$ *to* s, $B_{g,s}^{(n)}$.

(d) *Level factor.* (e) *Short-run slope factor.* (f) *Long-run slope factor.*

Figure 6: 3-factor decomposition of log price-dividend ratios (top row) and one-period risk premia (bottom row) of different cash flow strips.

We can therefore use the approximation (27) to decompose risk premia

$$\ln E_t R^{e,(n)}_{g,t+1} = cov(-m_{t+1}, \Delta g_{t+1} + pd^{(n-1)}_{g,t+1}) = x_t V_{g,n-1,t}$$

into three determinants: a level factor $x_t D_{g,t}$, a factor that controls the short end of the curve, $x_t B^{(n-1)}_{g,u} \phi\sigma$, and a factor that controls the long end of the curve, $x_t B^{(n-1)}_{g,s} \Lambda_{c,t} D_c$, where the price of risk x_t represents the price of a unit exposure to the structural shock.

Level. The short end of the term structures depends primarily on the loadings on short-term cash flow risk through D_g, which controls the level of the term structures,

$$cov_t(-m_{t+1}, \Delta g_{t+1}) = x_t D_g$$

This level factor in the term structures of risk premia is depicted in Figure 6d, evaluated at the risky steady state under our baseline calibration.

The level of the term structure of dividend strips can be very high because of the high leverage in corporate profits. The first dividend strip tends to have a dramatically low payoff precisely in those states in which households are hit by negative consumption shocks. Relatedly, the first nominal interest rate is strictly positive owing to the negative correlation between inflation and consumption news.

Short-run slope. An expected productivity growth above average tomorrow signals good future cash flows, which increase prices, but also lower future marginal utility, which decreases prices as households want to anticipate consumption. This discount-rate effect dominates the cash flow effect for all claims considered except for market equities, whose future prices therefore increase after a positive shock to u_t, and the more so the longer the strip duration. Since positive shocks to u_t arrive together with bad consumption news, it follows that this effect generates a negative slope in the term structure of equity and upward slopes in the remaining term structures.

In particular, we are able to generate a downward-sloping short end of the term structure of market equity for any calibration such that $B^{(n)}_{u,g}$ is sufficiently positive. In fact, for dividend claims the exposure to u_t commands a price

$$cov_t(-m_{t+1}, B^{(n)}_{g,u} u_{t+1}) = -x_t(C_{g,u} - \gamma C_{c,u}) \frac{1-\rho_u^n}{1-\rho_u} \phi\sigma = -x_t \left(1 - \gamma + \frac{2\gamma}{\alpha}(1-\rho_u)\psi_{cu}\right) \frac{1-\rho_u^n}{1-\rho_u} \phi\sigma$$

which is a negative number for sufficiently rigid prices, as ψ_{cu} starts at 0 when prices are flexible and increases with the degree of price stickiness. Therefore, the risk premium due to exposure to u_t commanded by dividend strips is a negative and convex function of maturity, and the analogous factor in consumption strips and zero-coupon bonds (real and nominal) is a positive and concave function of maturity, as shown in Figure 6e under our baseline calibration.

Long-run slope. The loading of tomorrow's yields on surplus consumption captures the properties of the premium commanded by long-duration claims; all term structures display an

upward slope at the long end, a property that is driven by the perfectly negative correlation between shocks to consumption and to the price of risk. Tomorrow's price of long-duration claims is low, and hence one-period returns are low, precisely in those states of the world in which surplus consumption is low, and the more so the longer the claim's duration.

In particular, the loadings of yields on surplus consumption converge to the positive number $B_{s,d}^{(\infty)} = \gamma$ for any dividend process, with the speed of convergence controlled by the persistence of habits. Since shouldering surplus-consumption shocks is equivalent to shouldering consumption shocks, the habit-related loading of infinite-duration zero-coupon cash flow claims commands a strictly positive price

$$cov_t(-m_{t+1}, B_{s,g}^{(\infty)} \hat{s}_{t+1}) = \gamma^2 \Lambda_{c,t}(1 + \Lambda_{c,t}) D_c^2$$

Figure 6f plots these loadings under our baseline calibration.

7.2.1. Understanding the cyclicality of equity term premia

For equity claims, the structure for one-period risk premia is U-shaped on average, downward-sloping at first and, after 5 years or so, upward-sloping. The downward slope at the short end of the curve is driven by the mean-reverting productivity state, which drives aggregate equity yields only to a limited extent, while, through the surplus consumption ratio, habits are responsible for the upward slope at the long end of the curve and are the main drivers of aggregate price-dividend ratios.

Under the approximate solution for one-period expected returns we have that, for any $n, m \geq 0$ with $n > m$, the equity term premium can be written as

$$TP_{d,t}^{n,m} \equiv \ln E_t R_{d,t+1}^{(n+1)} - \ln E_t R_{d,t+1}^{(m+1)} = x_t \left(V_{d,n,t} - V_{d,m,t} \right)$$

Therefore, we have the term premium and its elasticity, both evaluated at the steady state,

$$TP_{d,t}^{n,m} = x \left(V_{d,n} - V_{d,m} \right), \qquad \frac{\partial TP_{d,t}^{n,m}}{\partial x_t} = V_{d,n} - V_{d,m} + \frac{1}{S}(B_{d,s}^n - B_{d,s}^m)$$

Importantly, there is a disconnect between the two objects. In particular, the term $V_{d,n} - V_{d,m}$ in the elasticity reflects how the term premium changes with the price of risk and has the same sign as the average term premium, while the term $(B_{d,s}^n - B_{d,s}^m)/S$ reflects how the quantity of risk in future prices changes after a shock. Since, as in Figure 6f, when $n > m$ we have $B_{d,s}^n - B_{d,s}^m > 0$ and S is a small positive number, we can have that $V_{d,n} - V_{d,m} < 0$ (a downward-sloping term structure) and yet $\partial TP_{d,t}^{n,m} / \partial x_t > 0$ (countercyclical term premia).

7.2.2. Additional diagnostics

The online appendix provides two additional analyses. First, it derives the Borovicka and Hansen (2014) dynamic value decomposition, showing that—consistent with the three-factor decomposition of risk premia—cash-flow effects dominate the shape of the term structure over the 1- to 5-year horizon, while discount-rate effects dominate at longer maturities.

Second, it demonstrates that the dynamics of our stochastic discount factor satisfy

the properties postulated in Alvarez and Jermann (2005): our parameterizations generate unit-root dynamics in the marginal utility of wealth with partial mean reversion, yielding a stochastic discount factor with three key features in the language of Alvarez and Jermann—a time-varying permanent component, a time-varying transient component, and variation in their relative importance.

8. Conclusion

We incorporate the variation in discount rates arising from endogenous Campbell-Cochrane external habits in a standard macro model with nominal rigidities. We propose a method to break the apparent tradeoff between matching either the dynamics of macroeconomic variables or asset pricing dynamics in such models. The notion of macro-finance separation (MFS) and small departures from it are shown to be useful for incorporating large discount-rate variation in a DSGE framework while preserving the model's ability to fit quantities.

We derive testable implications for the term structures of equity and interest rates that conform with recent capital market evidence, including the average and cyclicality of the slope of the term structures of equity and of nominal and real interest rates, as well as with more established evidence about the average and cyclicality of the equity premium and the risk-free rate. We showed that our simple theory can go a long way in capturing this rich set of asset pricing facts while preserving a familiar model of macroeconomic quantities.

By focusing on the effects of productivity, we have purposely kept our model and shock structure simple so as to isolate the mechanism, and we have therefore abstracted from a host of potentially relevant extensions of the macroeconomic model, which we leave for future work. For example, a richer shock structure would capture more comprehensively the post-war data, as asset price movements would help the identification of macroeconomic shocks; and a departure from MFS would generate labor and investment wedges, and hence potentially improve the quantity implications. Overall, our results show that integrating Campbell-Cochrane habits in New Keynesian production economies is a tractable and promising avenue of research to understand the effect of macroeconomic shocks and monetary policy on quantities and asset prices.

Appendix

A. Motivation for Our Habit Specifications

The two habits satisfy the same local condition for a sensible habit as in Campbell and Cochrane (1999).

A.1. Campbell-Cochrane habit specification in a production economy

The law of motion of surplus consumption assumed by Campbell and Cochrane (1999) in their endowment economy with exogenous random-walk consumption can be cast in at least

two *equivalent* specifications:

$$\hat{s}_{t+1} = \rho_s \hat{s}_t + \Lambda(\hat{s}_t)(E_{t+1} - E_t)c_{t+1} \tag{A.1a}$$
$$= \rho_s \hat{s}_t + \Lambda(\hat{s}_t)(\Delta c_{t+1} - \mu) \tag{A.1b}$$

where $\mu = E(\Delta c)$. The equality breaks down, however, once we allow for a predictable component in consumption growth, consistent with a generic production economy.

We will argue that there is a strong reason to prefer specification (A.1a). To understand which specification we should retain in a production economy it is useful to remember the motivation of the specification in Campbell and Cochrane (1999). First, Campbell and Cochrane pick a specification for habits that implies a risk-free rate that adds to the expression under CRRA utility a linear term in surplus consumption, or, assuming normal consumption innovations,

$$r_{f,t} = r_f + \gamma E_t(\Delta c_{t+1} - \mu) - \xi_1(s_t - s)$$

with $r_f = -\ln(\beta) + \gamma\mu - .5\gamma(1 - \rho_s - \xi_1/\gamma)$ and ξ_1 a free parameter that controls the volatility of the risk-free rate. Importantly, Campbell and Cochrane's specification breaks the equivalence between the inverse EIS γ and the risk aversion coefficient that drives the maximum Sharpe ratio, $\gamma(1 + \Lambda_t)$, a required property to generate discount-rate variation without a risk-free rate puzzle.

Second, for a meaningful notion of habit, Campbell and Cochrane's habit is a slow-moving average of past consumption that is predetermined, at least in a steady state in which all shocks are zero, and that has a nonnegative derivative with respect to consumption.

A.2. No risk-free rate puzzle

With normal consumption innovations, the equilibrium risk-free rates under specifications (A.1a) and (A.1b) are[11]

$$r_{f,t} = r_f + \gamma E_t(\Delta c_{t+1} - \mu) \tag{A.2a}$$
$$r_{f,t} = r_f + \gamma(1 + \Lambda_t) E_t(\Delta c_{t+1} - \mu) \tag{A.2b}$$

As shown by equation (A.2b), specification (A.1b) implies a distorted Euler equation relative to a CRRA specification that would imply a risk-free rate puzzle. Note in fact how only specification (A.2a) breaks the equivalence between the price of risk $\gamma(1 + \Lambda) = \gamma/S$ and the inverse EIS.

We therefore discard specification (A.1b) on the grounds that in production economies it is generically inconsistent with the central idea of the Campbell-Cochrane habits. We thus retain specification (A.1a) and the associated Euler equation (A.2a).

[11] For simplicity, we turn off the spillover parameter ξ_1 since it adds nothing to this argument.

A.3. Local structure and predeterminedness

The market consumption habit specified indirectly by surplus consumption process (A.1a) using $x_t^c = c_t + \ln[1 - \exp(s_t)]$ is a nonlinear function of current and past consumption. However, it is approximately a predetermined, slow-moving average of past consumption, as required for a sensible notion of habit. In fact, a first-order approximation of the expression around $x_{ct} - c_t = \ln(1 - S)$ yields

$$\begin{aligned} x_{t+1}^c &\approx \ln(1-S) + c_{t+1} + \rho_s(x_{ct} - c_t) - \varepsilon_{ct+1} \\ &= \ln(1-S) + c_{t+1} - \sum_{j=0}^{\infty} \rho_s^j \varepsilon_{ct-j+1} \end{aligned}$$

The habit is predetermined because $x_{ct+1} = E_t x_{ct+1}$, and past consumption shocks receive their full weight only asymptotically. Unanticipated movements in consumption move consumption away from habits; surplus consumption is thus essentially detrended consumption.

A.4. Home consumption habits

The local microfoundations of our home consumption habit parallel those of the market consumption habit. Specifically, the home consumption habit can be written locally as

$$\begin{aligned} x_{t+1}^h &\approx \ln(1-Z) + h_{t+1} + \rho_s(x_{ht} - h_t) - \varepsilon_{ht+1} \\ &= \ln(1-Z) + h_{t+1} - \sum_{j=0}^{\infty} \rho_s^j \varepsilon_{ht-j+1} \end{aligned}$$

It follows that the home consumption habit is approximately a predetermined, slow-moving average of past home consumption.

B. Approximate pricing formulas

Up to a first-order approximation around the risky steady state, the log price-dividend ratio (25) at time t on a claim to cashflow G_{t+n} takes the approximate form (26), where the coefficients have the form

$$A_g^{(n)} = A_g^{(n-1)} + \ln(\beta) + (1-\gamma)\mu + \frac{1}{2}\Big(D_g - B_{g,u}^{(n-1)}\phi\sigma - B_{g,s}^{(n-1)}D_c - \frac{\gamma - B_{g,s}^{(n-1)}}{S}D_c\Big)^2$$

$$B_{g,u}^{(n)} = (C_{g,u} - \gamma C_{c,u})\frac{1-\rho_u^n}{1-\rho_u}$$

$$B_{g,s}^{(n)} = \gamma + \rho_s(B_{g,s}^{(n-1)} - \gamma) + C_{g,s} - \frac{1-\rho_s}{\gamma^2}\left(B_{g,s}^{(n-1)} - \gamma\right)^2 - \frac{D_c(D_g - B_{g,u}^{(n-1)}\phi\sigma - B_{g,s}^{(n-1)}D_c)}{S}\left(B_{g,s}^{(n-1)} -\right.$$

with $A_g^{(0)} = B_{u,s}^{(0)} = B_{g,s}^{(0)} = 0$. (The online appendix derives these formulas in detail.)

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