Durable Goods, Inflation Risk, and Equilibrium Asset Prices

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Abstract

High expected inflation is known to have a negative impact on future real growth. We show that this effect is significantly more pronounced in durable relative to non-durable goods sectors of the economy. Consistent with this macroeconomic evidence, the equity returns of durable-goods-producing firms have a larger negative exposure to expected inflation risks. We estimate a recursive utility model which features persistent growth fluctuations and inflation non-neutrality for durable and non-durable consumption. Our model can quantitatively account for the key moments of nominal bond prices and the levels, volatilities, and exposures of equity returns to expected inflation and bond returns.

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1 Introduction

The impact of inflation risk on stock and bond prices is one of the long-standing questions in finance. Empirically, shocks to expected inflation depress bond and stock prices and contribute positively to the asset risk premia (see e.g. Fama and Schwert (1977), Fama (1990), Bekaert and Wang (2010)). This evidence is counter to the traditional view that real assets, such as stocks, serve as a hedge against inflation and therefore should command a negative risk premium. A large number of studies, going back to Fama (1981), build on the empirical evidence that expected inflation has a non-neutral and negative effect on real growth, which can economically explain a negative correlation of stock prices with expected inflation and a positive risk premium on nominal bonds. In this paper, we provide novel evidence that the magnitude of this inflation non-neutrality varies substantially across economic sectors: it is significantly more pronounced for durable goods sectors, relative to non-durable goods and the aggregate economy. Consistent with this macroeconomic evidence, the equity returns of durable-goods-producing firms are more exposed to expected inflation and have a larger correlation with bond returns, relative to firms in a non-durable goods sector. We set up and estimate an economic model which accommodates the inflation non-neutrality for durable and non-durable consumption. Our model can quantitatively account for the key features of the nominal bond and equity price data and in particular, the levels, volatilities, and the exposures of equity returns in durable and non-durable goods sectors to expected inflation and bond returns.

The key empirical motivation for our paper is that news of high expected inflation has a negative and persistent impact on real long-term economic growth rates, and the magnitude of the growth response is more pronounced in durable sectors of the economy. We provide direct evidence for this inflation non-neutrality in the macroeconomic data, using both the direct regressions of future real growth rates on current inflation, and from the estimates of a VARMA(1,1) model of the macroeconomic series. In our VARMA model we use the growth rates of durable and non-durable real consumption, inflation, and dividend growth rates for durable- and non-durable-goods-producing firms as observable variables. As in Bansal and Yaron (2004), the model also includes unobservable factors that represent the conditional expectations of the respective macro factors. We estimate the model by Bayesian Markov Chain Monte Carlo (MCMC) methods without using any of the asset-price data, and we find that it provides a very good fit to the macroeconomic data. Consistent with Yogo

(2006) and Yang (2011), we document that expected durable consumption is much more persistent than the expected non-durable consumption growth. Further, the estimation underscores a more negative and significant impact of expected inflation on future growth rates in the durable sector relative to non-durable sector, and a strong connection between the dividends and consumptions in the corresponding sectors. The model thus provides a parsimonious and realistic description of the exogenous macroeconomic inputs which we can use to address the asset-pricing evidence in the bond markets, and the equity markets in durable and non-durable sectors.

Motivated by our empirical evidence for the macroeconomic growth rates, we formulate a long-run risk model aimed at explaining a number of asset pricing puzzles. Our model extends the models in Bansal and Yaron (2004), Piazzesi and Schneider (2006), Eraker (2006), Hasseltoft (2012), Yang (2011), and Bansal and Shaliastovich (2013) to a nominal two-good economy. In the model, the agent has a recursive utility defined over the consumption of durable and non-durable goods. As shocks to expected inflation negatively impacts real growth, they contribute to a positive risk premium for nominal bonds. In particular, because of the higher persistence of expected durable shocks, inflation non-neutrality for durable consumption represents an important model channel, absent in the earlier literature, which can generate a significant risk compensation for expected inflation risks. Further, because dividend cash-flows are exposed to the aggregate consumption risks through the dividend leverage channel, equity claims are risky and demand risk compensation for the exposure to expected non-durable, durable, and inflation risks.

To assess the model performance, we estimate the preference parameters of the model. We fix the first-step estimates of the parameters of the macroeconomic model, and estimate the risk aversion and the intra- and intertemporal elasticity parameters by targeting a number of asset-pricing moments. We estimate the intertemporal elasticity of substitution to be 1.26, the risk-aversion to be 14.29, and the intratemporal elasticity of substitution between the two goods to be 0.41. Our parameter estimates are close to the values documented in the literature. We show that our model successfully captures known asset pricing puzzles. It closely matches the level, slope, and curvature of the nominal interest rates and captures well the volatility of the yield curve. Our model generates a low discrepancy between the observed trajectory of nominal rates and model-implied rates. On the equity side, we follow Gomes, Kogan, and Yogo (2009) and construct portfolios of stocks that we classify as durable or non-durable goods producers. We show that our model generates equity premiums that are very close to that observed in the data for the two portfolios. Further, the model can account for a higher correlation (in absolute value) of durable equity returns with expected inflation and bond returns, relative to non-durable equity returns.

Empirically we find that the most important risk factor in our model is the expected inflation, which explains a large part of the variation in short term rates and even more variation in long term rates. This generates an upward sloping nominal yield curve in our model. The model mechanism is similar to Piazzesi and Schneider (2006), but our results are obtained without a large risk aversion parameter, as the amount of the inflation premium in our two-good economy is significantly larger than in an economy with a single consumption good. We find that high expected durable growth lowers yields in the data and in the model, and have sizeable economic contributions to the levels of the bond risk premia and variations in bond yields at long horizons.

The model further generates a positive correlation between stock and bond returns. This is a discounting effect: a positive shock to expected inflation, the main driver of bond returns, increases nominal yields and therefore mechanically leads to a negative bond return. Since expected inflation shocks correlate negatively with future real dividend, a positive shock also leads to a negative equity price reaction in our model. Because durable cash flows are more exposed to inflation risks, the magnitude of the correlation of expected inflation with stock returns is larger, in absolute value, for durable than for non-durable equities. When we shut down the impact of expected inflation on dividend growth rates the model produces a near-zero stock and bond correlation.

To the best of our knowledge, this paper is the first to consider a nominal two-good version of the Bansal and Yaron (2004) long-run risk model to study the cross-section of equity and bond returns. In the context of long-run risks literature, our paper is related to Eraker (2006) and Piazzesi and Schneider (2006) who highlight the importance of inflation non-neutrality to account for the features of nominal bond prices. Hasseltoft and Burkhardt (2012) show that the regime changes in such cyclicality of inflation can account for the time-variation in the correlation of stock and bond returns in the data. Hasseltoft (2012) and Bansal and Shaliastovich (2013) further document the importance of the fluctuations in macroeconomic uncertainty for the movements in bond risk premia. We differ from this literature in our attention to the durable-goods channel as an important source of economic risk. For parsimony, we do not entertain the time-variation in the volatilities and the risk premia in the asset markets. Gomes et al. (2009), Guo and Smith (2010), and Yang (2011) study the asset pricing implications of durable consumption, but they abstract away from inflation. We show that inflation plays a key role for asset prices precisely through the durable consumption channel. In the context of the habits model, Wachter (2006) consider the role of the time-varying risk aversion for the bond prices and bond risk premia, while Bekaert, Engstrom, and Xing (2009) and Bekaert and Engstrom (2010) show that the fluctuations in the risk aversion play an important role to jointly account for the bond and equity market features. Among others, Eichenbaum and Hansen (1990) and Ogaki and Reinhart (1998) explore asset pricing settings with multiple goods using time-additive preferences. We show that with recursive preferences, long-run news on inflation and durable consumption growth play a significant role for the asset prices. Similarly to us, Lustig and Verdelhan (2007) and Colacito and Croce (2013) propose long-run risk models with multiple goods, but they study currency risk premia and the cross-section of international returns.

The remainder of the paper is organized as follows: in Section 2, we present motivating empirical evidence for our empirical macro model. We also present estimates of the parameters in the VARMA(1,1) model using macroeconomic data that are assumed exogenous to the asset markets. Section 3 elaborates the equilibrium model. Section 4 presents our empirical results, Section 5 discusses the robustness check, and Section 6 concludes.

2 Empirical Motivation

2.1 Data

We collect quarterly data on nominal expenditures on non-durable and durable goods and services and price levels of non-durable and durable goods from the Bureau of Economic Analysis (BEA) for 1963Q1 to 2006Q4 sample period.[1] The data are sea-

[1] Bils (2009) and Bils and Klenow (2001) argue that the CPI inflation series released by the Bureau of Labor Statistics is mis-measured because consumers shift purchases of durable goods items from old to higher quality new models; see also the Boskin Commission Report (Boskin, Dulberger, Gordon, Griliches, and Jorgenson (1996)) and references therein. In our implementation,

sonally adjusted by the BEA.[2] We deflate aggregate nominal series by the appropriate price levels and divide by the total population to obtain real per-capita quantities. Since the BEA only reports the year-end durable goods stock levels, we back out the quarterly durable goods stock level using the depreciation and expenditure data as in Yogo (2006).

In terms of the asset price data, we collect bond prices of zero-coupon U.S. Treasures from CRSP. We further construct equity portfolios of durable- and non-durable-good producing firms and the market. Following Gomes et al. (2009), we use the benchmark input-output accounts table in the BEA to identify industries whose final demand has highest value added to personal consumption expenditures on non-durable goods and services (non-durable sector portfolio) and personal consumption expenditures on durable goods (durable sector portfolio).[3] We collect price and cash flow data for these portfolios using CRSP database.

2.2 Evidence from Reduced-Form Regression

In this section we present the empirical evidence that motivated us to develop our theoretical asset pricing model. We start by presenting evidence from the reduced-form regressions reported in Table 1. Panel A of Table 1 shows the regression coefficients and corresponding R^2s for projections of future real growth rates of durable and non-durable consumption onto the present inflation. There are two important findings: (1) The slope coefficients are negative, implying that a shock to inflation today has negative impact on real growth in the future. These findings of non-neutrality for non-durable consumption are consistent with evidence in Piazzesi and Schneider (2006) and Bansal and Shaliastovich (2013). (2) The negative response of real growth rates to inflation shocks is larger in durable goods than non-durable goods. This is true for all forecasting horizons and the difference is sizable: at a three-year forecasting horizon, the slope coefficient of durable is more than three times that of the non-durable (-0.31 vs. -0.075). The R^2s are uniformly larger for the durable growth

as in Piazzesi, Schneider, and Tuzel (2007), we use non-durable consumption as the numeraire and use the inflation rate for non-durable goods.

[2]We checked that our results are robust to alternative seasonality adjustment procedures.

[3]Gomes et al. (2009) consider separately services, non-durables, durables, and investment industries. To be consistent with our model, we aggregate services and non-durables into a single value-weighted non-durable portfolio. Our results are similar, and in many cases are even stronger, using equal weights, or using only non-durable-good producing firms in the portfolio.

rates. These findings complement earlier evidence by Erceg and Levin (2006), who document that a monetary policy shock in interest rates has an impact on consumer durables spending that is several times larger than its impact on other expenditures.

These empirical results suggest that inflation has an adverse effect on future aggregate growth, and its effect is much more pronounced in the durable sector of the economy. Intuitively, because durable goods purchases are long-lasting, they are more exposed to aggregate price fluctuations than non-durable goods consumed in the same period. This has potential implications for prices of equity claims. For firms producing either durable or non-durable goods, their revenues fluctuate proportionally to aggregate consumption of the two goods. Investments in durable-goods-producing firms could be more sensitive to business cycles. Panel B of Table 1 presents results from regressing the real dividend growth rates of durable- and non-durable-goods-producing firms onto inflation. As seen, the evidence confirms the notion that the expected dividend growth rate of durable goods producers is more sensitive to inflation shocks than that of non-durable goods producers: Ordinary Least Squares (OLS) point estimates for durable dividends are on the order of two- to three-times greater in absolute value than for non-durable dividend growth. These findings are consistent with empirical evidence in Boudoukh, Richardson, and Whitelaw (1994), who document that the output growth in highly cyclical industries (e.g., those involved in manufacturing of durable goods) tends to be more negatively correlated with inflation relative to less cyclical firms (such as those that provide necessities).

In checking whether these results are robust to the choice of corporate output measures, we ran similar regressions using BEA industrial production data, corporate sales, as well as alternative measures of corporate cash flows. The results are consistent with our benchmark findings, and are omitted for brevity.

2.3 A Macro-Econometric Model

The reduced-form predictive regression presented above provides evidence of the inflation non-neutrality on real consumption growth and dividend growth. In this section, we estimate a VARMA(1,1) model designed to capture the joint dynamics of the macro variables. This allows us to formally quantify the impact of expected inflation on aggregate consumption of durable and non-durable goods and measure the exposures of equity dividends to the consumption risks.

Denote by g_t a vector of observed macroeconomic variables which includes non-durable consumption growth, $\Delta c_t = \log\left(C_t/C_{t-1}\right)$, non-durable inflation, $\pi_t = \log\left(P_t^{\$}/P_{t-1}^{\$}\right)$, and the growth rate of durable goods stock, $\Delta s_t = \log\left(S_t/S_{t-1}\right)$. The dynamics of g_t is specified exogenously and incorporates a component of time-varying expected growth rates x_t which we model as a VAR(1) process

$$\begin{aligned} g_{t+1} &= \mu_g + x_t + \Sigma_g \eta_{t+1}, \\ x_{t+1} &= \Pi x_t + \Sigma_x u_{t+1}. \end{aligned} \tag{1}$$

where vector μ_g is the unconditional mean, Σ_g and Σ_x are the covariance matrices, and η_{t+1} and u_{t+1} are vectors of independent Gaussian innovations. The matrix Π captures the persistence and potential feedback between the expected growth states.

We also assume the real dividend growth rates in non-durable and durable goods sectors, $\Delta d_{nd,t}$ and $\Delta d_{d,t}$, expressed in the appropriate numeraire units,[4] load on the underlying expected growth factors:

$$\Delta d_{i,t+1} = \mu_i + \phi_i' x_t + \sigma_i^{div} \zeta_{i,t+1}, \quad \text{for } i = \{nd, d\}. \tag{2}$$

The quarterly dividend data contain substantial amounts of negative autocorrelation. This is likely due to the fact that firms avoid paying monthly dividends and rather prefer annual payouts. As a result, the sample path of aggregate dividends reflect idiosyncratic firm level decisions about payout times. This is one likely cause of the negative auto-correlation in aggregate dividend streams. To overcome this problem in our econometric estimation we assume that the aggregate dividend paid by durable and non-durable producers contains a white noise component. The level of dividend is therefore

$$d_{i,t}^{*} = d_{i,t} + \sigma_i^{me} \xi_{i,t}, \quad \text{for } i = \{nd, d\}, \tag{3}$$

where $\sigma_i^{me} \xi_{i,t}$ is essentially a measurement error.

[4] In the equation for $\Delta d_{d,t+1}$, we convert the durable dividend growth into the durable goods numeraire to facilitate the interpretation of the loading parameters and ensure the consistency between the units on the right- and left-hand sides of the equation.

In order to reduce the number of parameters, we impose the following restrictions. First, in the persistence matrix Π, we zero out the interaction terms between durable and non-durable consumption growth rates ($\Pi_{1,3} = \Pi_{3,1} = 0$) and shut down the feedback effects from consumption growth to future inflation ($\Pi_{2,1} = \Pi_{2,3} = 0$).[5] Second, we allow dividend growth rates to load only on the corresponding expected consumption growth rates: durable dividends on durable consumption and non-durable dividends on non-durable consumption, respectively. Statistically, that allows for a sharper identification of the dividend leverage parameters, and economically, such dividend dynamics are similar to the levered consumption specification considered in Abel (1999), Bansal and Yaron (2004), and Campbell and Cochrane (1999). Finally, we set the means of dividend growth rates to the means of the corresponding consumption growth rates. While our setup does not feature co-integration of dividends and consumption, the last restriction ensures that on average, dividends grow at the same rate with consumption in each sector. In Section 5 we assess the importance of these restrictions, and show that they do not materially affect statistical fit or economic implications of the model.

We estimate the model parameters using Bayesian MCMC simulation and back out the unobserved expected growth rates x_t using Kalman filtering technique; all the estimation details are provided in the Appendix A. The top panel of Table 2 summarizes the estimated model parameters, which underscore three main features of the macro variables in data.

First, the expected durable consumption growth and expected inflation are significantly more persistent than the expected non-durable consumption growth: the implied first-order autocorrelation of expected non-durable growth is 0.4, relative to about 0.9 for expected durable growth and expected inflation. This implies the shocks to expected durable growth and expected inflation have more persistent effects.

Second, the expected inflation shocks have a large negative impact on expected consumption growth in both sectors, and this inflation non-neutrality is more pronounced for the durable goods sector. While the one-period feedback coefficients of expected inflation are not significantly different for durable and non-durable consumption growth, the inflation impact on future durable consumption growth is magnified

[5]In Section 5 we show that in an unrestricted estimation these coefficients are insignificant from zero. Setting them to zero does not affect the estimated inflation non-neutrality, but allows for a cleaner interpretation of the model.

over time due to a much larger persistence of the expected durable consumption growth. The impulse responses in Figure 3 show that the expected inflation has a similar impact on durables and non-durables initially. However, the expected inflation impact on non-durables subsides after one year and becomes insignificant in two years, but the inflation impact on durables peaks at 2.5 years, and persists even after five years in the future.

Third, the model estimation suggests a strong link between the dividend growth rates and the expected consumption growth in the corresponding sectors. The dividend leverage parameter is estimated to be about five in the non-durable sector and 5.5 in the durable sector. Our estimates of dividend leverage parameters are larger than the typical magnitudes of 2.5 to 3.5 used in the literature for the aggregate market dividends (e.g., Abel (1999), Bansal and Yaron (2004), and Campbell and Cochrane (1999)). We verify that our estimates are not specific to our estimation approach: for example, running standard projections of sectoral dividends on corresponding realized consumption growth rates, we obtain similar leverage coefficients of around five. This evidence suggests that decomposing real growth into sectoral components allows us to better identify the link between corporate and macroeconomic growth rates. The strong link between dividend and consumption also implies that the inflation non-neutrality is more pronounced on equity of durable producer portfolio. Our estimates also indicates that measurement noise is substantial and accounts for about half of the total variation in quarterly dividend growth rates.

We investigate our model fit through different aspects. First, Figure 1 shows that the expected growth rates estimated from the model very closely track the persistent movements in the aggregate macroeconomic variables. Second, we use the posterior estimates of the parameters to simulate our model at a quarterly frequency and then time-aggregate the output to an annual horizon. Table 3 documents the model fit to the main unconditional moments of the data in the long simulation (population values) and in short samples whose size equals the length of the data. As shown in the table, the model can capture very well the means, standard deviations, and persistence in annual consumption and inflation: most data values are almost identical to the model, and all are contained in the 5-95% small-sample confidence interval. The bottom panel of the table shows model implications for the annual dividend growth rates. The model quantitatively captures a larger volatility of dividends, a strong co-movement between consumption and dividend growth, and a larger correlation of inflation with durable dividends.

Overall, our estimated model provides a very good fit to the macroeconomic data. It underscores a negative and significant impact of expected inflation on future growth (inflation non-neutrality), and a strong exposure of the dividend cash-flows to the corresponding consumption growth rates in the non-durable and durable sectors. The model thus provides a parsimonious and realistic description of the exogenous macroeconomic inputs which we can use to address the asset-pricing evidence in the bond markets, and the equity markets in durable and non-durable sectors.

3 Model Setup

3.1 Preferences and Stochastic Discount Factor

We specify an infinite-horizon, discrete-time, endowment economy where investors consume durable and non-durable goods. The investors' preferences over future consumption are described by the Kreps-Porteus, Epstein-Zin recursive utility function (see Kreps and Porteus (1978) and Epstein and Zin (1989)):

$$U_t = \left[(1-\beta) u_t^{1-\frac{1}{\psi}} + \beta \left(E_t U_{t+1}^{1-\gamma} \right)^{\frac{1-\frac{1}{\psi}}{1-\gamma}} \right]^{\frac{1}{1-\frac{1}{\psi}}}, \tag{4}$$

where U_t is the lifetime utility function, u_t is the intra-period consumption aggregator, β is the subjective discount factor, ψ is the elasticity of intertemporal substitution (IES), and γ is the relative risk aversion coefficient. For ease of notations, we define $\theta = (1-\gamma)/(1-1/\psi)$. Note that when $\theta = 1$, that is, when $\gamma = 1/\psi$, the recursive preferences collapse to a standard Constant Relative Risk Aversion (CRRA) expected utility.

In our economy, the agent derives utility from non-durable consumption C_t and a service flow from durable goods, which we assume is proportional to the stock of durables S_t (see e.g. Ogaki and Reinhart (1998), Yogo (2006), and Yang (2011)).

Unlike the non-durable consumption, the stock of durable goods accumulates over time through the purchases of durable goods E_t net of the depreciation at the rate δ :

$$S_t = (1-\delta)S_{t-1} + E_t. \tag{5}$$

The intra-period consumption aggregator takes a constant elasticity of substitution (CES) form, and thus can be expressed in the following way:

$$u(C,S) = \left[(1-\alpha)C^{1-\frac{1}{\epsilon}} + \alpha S^{1-\frac{1}{\epsilon}}\right]^{\frac{1}{1-\frac{1}{\epsilon}}}. \tag{6}$$

Parameter $\alpha \in [0,1]$ determines the relative importance of durable consumption: with $\alpha = 0$ the economy collapses to a standard specification with a single perishable good. Parameter ϵ captures the intratemporal elasticity of substitution between the two goods. High values of ϵ indicate that the two goods can be easily substituted by the agent, while small values for ϵ capture the complementarity between the two goods.

As described in Yogo (2006), the equilibrium stochastic discount factor, valued in the units of non-durable consumption, is driven by the fluctuations in the relative share of non-durable goods Z_{t+1}, consumption growth of non-durables C_{t+1}/C_t and the return on the total wealth $R_{c,t+1}$:

$$M_{t+1} = \beta^{\theta}\left(\frac{Z_{t+1}}{Z_t}\right)^{\frac{\theta}{1-\frac{1}{\epsilon}}\left(\frac{1}{\psi}-\frac{1}{\epsilon}\right)}\left(\frac{C_{t+1}}{C_t}\right)^{-\frac{\theta}{\psi}} R_{c,t+1}^{\theta-1}. \tag{7}$$

The relative share of non-durable consumption of the agent Z_t is defined as:

$$Z_t = \frac{C_t}{C_t + Q_t S_t}, \tag{8}$$

and Q_t is the user cost of durable goods given by the ratio of the marginal utilities of durable to non-durable consumption:

$$Q_t = \frac{u_{st}}{u_{ct}} = \frac{\alpha}{1-\alpha}\left(\frac{S_t}{C_t}\right)^{-\frac{1}{\epsilon}}. \tag{9}$$

The consumption return $R_{c,t+1}$, which captures the return on the total wealth portfolio of the investor, pays off the basket of non-durable consumption and durable consumption valued by its user cost Q_t:

$$R_{c,t+1} = \frac{W_{t+1}}{W_t - (C_t + Q_t S_t)}. \tag{10}$$

Notably, in a single good economy $Z_t \equiv 1$, and we obtain a standard expression for the stochastic discount factor, derived in Epstein and Zin (1991):

$$M_{t+1}^{Non-Dur} = \beta^{\theta} \left(\frac{C_{t+1}}{C_t}\right)^{-\frac{\theta}{\psi}} R_{c,t+1}^{\theta-1}. \tag{11}$$

Thus, relative to a one-good economy, the specification with two goods incorporates fluctuations in the relative share of the goods, and further, the wealth portfolio of the agent is now composed of both the non-durable and durable consumption.

To solve for the equilibrium bond and equity prices, we use a standard Euler condition:

$$E_t[M_{t+1} R_{i,t+1}] = 1, \tag{12}$$

which holds for any return $R_{i,t+1}$ including the endogenous wealth portfolio of the agent. The above pricing equation is specified in real terms using non-durable consumption as a numeraire. To change the numeraire, denote $\tilde{\Pi}_t$ the value of one unit of non-durable consumption in units of a new numeraire. Then, we can price payoffs expressed in units of a new numeraire using a standard Euler equation (12) under the numeraire-adjusted stochastic discount factor $\tilde{M}_{t+1}$,

$$\tilde{M}_{t+1} = M_{t+1} \frac{\tilde{\Pi}_t}{\tilde{\Pi}_{t+1}}. \tag{13}$$

When Π_t denotes the dollar price of non-durables, the equation above defines the nominal discount factor, which allows us to derive the nominal bond and equity prices.

3.2 Equilibrium Model Solution

We solve for the equilibrium asset prices given the preferences and the stochastic discount factor in (7), and the exogenous dynamics for non-durable and durable consumption growth rates, inflation, and dividend cash flows in (1)-(2). The macro-econometric specification highlights three key empirical features of the data: 1) the persistent fluctuations in the long-term expected growth rates of the series; 2) a negative effect of expected inflation on future growth; and 3) the exposure of the equity cash flows to the underlying consumption shocks. We take these features of the macroeconomic data as exogenous inputs into our asset-pricing model, and show they play an important role in interpreting the evidence in the asset markets.

To obtain closed-form analytical solutions to the asset prices, we rely on a standard log-linearization of the return on the wealth portfolio (see Appendix B for the details), and we further log-linearize the relative share process:[6]

$$\Delta z_{t+1} = \log \frac{Z_{t+1}}{Z_t} \approx \chi(\Delta q_{t+1} + \Delta s_{t+1} - \Delta c_{t+1}) = \chi \left(1 - \frac{1}{\epsilon}\right)(i_s - i_c)' g_{t+1}, \tag{14}$$

where i_c and i_s pick out non-durable and durable consumption growth from g_t, and the parameter $\chi \in (0, 1)$ is an approximating constant equal to the average expenditure on durables in the economy, $\chi = \frac{\bar{Q}\bar{S}}{\bar{Q}\bar{S}+\bar{C}}$. This parameter captures the importance of durable goods in the economy. In particular, for $\chi = 0$, the specification reduces to a one-good economy.

Under the considered log-linearizations, the economic asset-pricing model is affine. The equilibrium price-consumption ratio is a linear function of the economic states x_t :

$$pc_t = A_0 + A_x' x_t. \tag{15}$$

[6] The linearization of the relative share shuts off the variation in the asset volatilities and risk premia due to the relative share movements (see Cochrane, Longstaff, and Santa-Clara (2008) and Colacito and Croce (2013)). These fluctuations are not likely to be important for the unconditional levels of prices, which is the key focus of our paper. We have verified that the log-linearization error for the consumption asset does not have a material impact on model solutions, and report the results in Section 5.3.

Using the Euler equation for the consumption asset, we obtain that the price-consumption loadings satisfy:

$$A_x = \left(1 - \frac{1}{\psi}\right)\left(I - \kappa_1 \Pi'\right)^{-1}\left((1-\chi)i_c + \chi i_s\right), \tag{16}$$

where $\kappa_1 \in (0,1)$ is the log-linearization coefficient whose solution is provided in Appendix B. When the intertemporal elasticity of substitution ψ is above one, the substitution effect dominates the wealth effect. Hence, the equilibrium price of the consumption claim increases with a positive shock to expected non-durable or durable consumption. This intuition naturally extends a standard single-good long-run risks model. Furthermore, because positive expected inflation shocks forecast negative future real growth, the loading on the expected inflation is negative: high expected inflation depresses real asset valuations.

The real stochastic discount factor, expressed in units of non-durable numéraire, can be written in terms of the fundamental states and shocks in the economy in the following way:

$$m_{t+1} = m_0 + m_x' x_t - \lambda_g' \Sigma_g \eta_{t+1} - \lambda_x' \Sigma_x u_{t+1}, \tag{17}$$

where m_x captures the loadings of the discount factor on the expected growth components, and λ_g and λ_x are the market prices of immediate and expected growth risks.

The discount factor loading on the expected growth satisfies

$$m_x = -\left(\frac{1}{\psi}(1-\chi) + \frac{1}{\epsilon}\chi\right) i_c + \chi\left(\frac{1}{\epsilon} - \frac{1}{\psi}\right) i_s. \tag{18}$$

The two components in brackets capture the loadings of the discount factor on the expected non-durable consumption and expected durable consumption, respectively. When $\chi = 0$ the specification reduces to a one-good non-durable model and the discount factor loading is equal to the negative of the reciprocal of the IES. With durable goods, both the intertemporal and intratemporal elasticities of substitution determine the response of the discount factor to the underlying economic states. In a two-good economy, similar to a one-good economy, the loading on expected non-durable consumption is negative. On the other hand, when $\epsilon < \psi$ the loading on the expected durable consumption is positive: when two goods are relatively hard to substitute, an expected increase in durable consumption for a given expected consumption of non-durables actually results in an increase in the expected marginal utility of the agent. Thus, because of the complementarity between the two goods, the shocks in expected durable and expected non-durable consumption can have opposite effects on the discount factor.

In a similar way, we can decompose the market prices of expected growth and short-run risks in the economy:

$$\begin{aligned} \lambda_x &= (1-\theta)\kappa_1 A_x, \\ \lambda_z &= \left(\gamma(1-\chi) + \frac{1}{\epsilon}\chi\right) i_c + \left(\gamma - \frac{1}{\epsilon}\right) \chi i_s. \end{aligned} \tag{19}$$

In the full model with recursive utility, the agent cares about shocks to expected non-durable consumption, durable consumption, and expected utility. When the intertemporal elasticity of substitution and risk aversion coefficient are above one, the shocks in expected durable and non-durable consumption have positive market prices of risk. Indeed, under high intertemporal substitution, investors wealth relative to consumption drops when either durable or non-durable growth is expected to decline (see equation 16). Hence, the states with low expected consumption (non-durables or durables) are associated with a high marginal utility of investor. This effect on marginal utility is magnified by the persistence of the shocks as fluctuations in expected growth are perceived to be long-lasting by the investors. Due to a non-neutral effect of expected inflation on future growth, the price of the expected inflation risks is non-zero. In particular, as we expect high inflation to be bad news for expected growth, the price of the expected inflation risks is negative. Notably, the non-neutrality of expected inflation operates both through the non-durable and durable channels, as expected inflation is bad news both for future non-durable and durable consumption.

Under expected utility ($\gamma = 1/\psi$), the market prices of expected durable and non-durable consumption and expected inflation risks are all equal to zero: $\lambda_x = 0$. In this case, only the short-run innovations in consumption are priced. The market prices of short-run consumption risks λ_z depend on preference parameters and the importance of durables in the agent's total consumption, and for typical parameter values these market prices of risk are positive.

3.3 Equilibrium Asset Prices

Using the solution for the stochastic discount factor in (17), we can characterize equilibrium prices of bond and equity claims in the model. We show main results and intuition below, and present the computational details in the Appendix B.

In a multiple-goods economy, there are various ways to define a real risk-free asset, which depend on the choice of the basket of goods to be delivered in the future and the payoff numeraire. For our benchmark analysis, as in Yang (2011), we consider a real bond which delivers one unit of non-durables in the future, and the price of the bond is expressed in units of non-durable consumption. Then, the price of the bond with n periods to maturity satisfies a standard Euler equation:

$$P_{t,n} = E_t[M_{t+1}P_{t+1,n-1}]. \tag{20}$$

In our model, the equilibrium log bond prices $p_{t,n} = \log P_{t,n}$ and yields $y_{t,n} = -\frac{1}{n}p_{t,n}$. are linear in the economic states, e.g.

$$p_{t,n} = -B_{0,n} - B'_{x,n}x_t, \tag{21}$$

where the bond loadings depend on model and preference parameters. For a one-period real bond, $y_{t,1} = const - m'_x x_t$. Following our earlier discussion, the one-period risk-free rate responds positively to news about long-run expected non-durable consumption, and negatively to news of long-run expected durable consumption if $\epsilon < \psi$, and generally the same holds true for the real bonds at longer maturities.

The sensitivities of bond yields to economic states determine the magnitudes of the bond risk premia and the shape of the yield curve. Consider the excess log return on buying an n-month bond at time t and selling it next period as an $n-1$ period bond:

$$rx_{t+1,n} = -p_{t,n} + p_{t+1,n-1} + p_{t,1}. \tag{22}$$

The expected excess return on n-period bonds is given by the covariance of the discount factor with the excess bond return:

$$
\begin{aligned}
E_t rx_{t+1,n} + \frac{1}{2} Var_t rx_{t+1,n} &= -Cov_t(m_{t+1}, rx_{t+1,n-1}) \\
&= -B'_{x,n-1} \Sigma_x \Sigma'_x \lambda_x .
\end{aligned} \tag{23}
$$

The bond risk premia capture the contribution of the expected non-durable consumption risk, expected durable consumption risk, and risks in expected inflation, so that the expected excess return on bonds depends on bond sensitivity $B_{x,n}$, and the market compensation for these risks, $\Sigma_x \Sigma'_x \lambda_x$.

The equilibrium price of nominal bonds and nominal bond risk premia are derived in an analogous way using the solution to the nominal discount factor. The nominal yields are affine functions of the expected consumption growth rates and the expected inflation factors. Relative to the real bonds, a significant component of the nominal bond yields now comes from the expected inflation shocks. Indeed, consider a Fisher-type equation for nominal bonds:

$$
y^{\$}_{t,n} = y_{t,n} + E_t \pi_{t \to t+n} - \frac{1}{2} \frac{1}{n} Var_t \pi_{t \to t+n} + \frac{1}{n} Cov_t(m_{t \to t+n}, \pi_{t \to t+n}), \tag{24}
$$

where $\pi_{t \to t+n}$ and $m_{t \to t+n}$ denote the t to $t+n$ multi-period inflation rate and stochastic discount factor, respectively. First, as nominal bonds pay in nominal dollar terms, an increase in expected inflation raises nominal yields and decreases nominal bond prices. When high expected inflation predicts a persistent decline in expected real growth in the economy, the last term in the above equation, which captures the inflation premium is positive and increasing at long maturities, will produce a positive risk premium and a positive slope of the term structure for the nominal bonds. In a single-good economy, the inflation premium arises only to the long-run inflation's interaction with future non-durable growth, as discussed in Piazzesi and Schneider (2006) and Bansal and Shaliastovich (2013). With multiple goods, the inflation non-neutrality also arises through a persistent negative covariation of inflation with durable consumption, which opens up an additional channel for the inflation premium. As the durable growth is persistent and much more affected by the inflation risk, the inflation premium through the durable consumption will have a significant effect on the level of the nominal bond risk premium and the slope of the nominal term structure, relative to a one-good economy.

The equilibrium solutions to the equity price-dividend ratios are linear in the economic state variables, and are given by,

$$pd_{i,t} = H_{i,0} + H'_{i,x} x_t. \tag{25}$$

Similarly to the price-consumption ratio in (16), the price-dividend ratios load positively on expected consumption of durables and non-durables, and negatively on expected inflation. The magnitudes of loadings depend on the model and preference parameters, such as the intra- and intertemporal elasticity of substitution, persistence of the state variables, and the dividend leverage ϕ. Specifically, because dividend cash flows are exposed to the aggregate consumption risks through the dividend leverage channel, equity claims are risky and demand risk compensation for the exposure to expected non-durable, durable, and inflation risks.

4 Empirical Model Evaluation

4.1 Asset-Price Data

We start our empirical investigation with descriptive and summary statistics of the key asset-pricing moments in data. Table 4 presents the data moments of the nominal bond and equity prices. As seen in the first panel, nominal term structure is upward-sloping with a five-year term spread of 58 bps. The volatilities of bond yields decrease with maturity from 2.76% for a one-year bond to 2.53% for a five-year bond. The yields are very persistent with AR(1) coefficients ranging from 0.93 to 0.96 in our sample.

The bottom panel of Table 4 presents evidence on the equity returns in non-durable and durable sectors. Consistent with Gomes et al. (2009), we find that durable-goods-producing firms are riskier than non-durable ones: the risk premium on the durable portfolio is 7.11% in the data, compared to 5.62% for non-durables. Equity returns of durable goods producers also have a substantially higher volatility (21%) relative to non-durables (about 15%). Finally, as shown in Table 4, durable equity returns have a higher correlation with nominal bond returns, and are more exposed to the expected inflation risks in the economy. The correlation of stock and bond returns is larger for durables relative to non-durables for the whole sample, and also in the various subsamples, as can be seen based on a 10-year rolling window plot in Figure 4.

4.2 Preference Parameter Estimation

Our empirical evaluation of the economic model takes the joint dynamics of the consumption, dividends, and inflation as exogenous and explore the key asset pricing implications in model equilibrium. We adopt the VARMA specification of the joint dynamics as estimated in Section 2.3. The estimate of the joint dynamics and the latent expected growth rates only used the macro data, which is appealing because the estimation then is not affected by any possible mis-specification of the asset-pricing model. Naturally, using macro data alone does not allow us to identify preference parameters. We therefore estimate them from the observations on bond and equity prices.

Specifically, we estimate the preference parameters γ, ψ, χ, and ϵ, as defined in Section 3, by targeting the average nominal yields over maturities from one to five years, average equity premia for non-durable and durable goods producer portfolios, and the sensitivities of nominal yields to the expected consumption growth rates and the expected inflation. In addition to that, we include the moment condition for the relative share of non-durable consumption, as well as for the slope coefficient in the regression of log real user cost of durable goods on log difference between the quantities of durable and non-durable goods in the data. These macroeconomic moments help identify χ and ϵ in the data. To compute the standard errors of the preference parameters, we take into account the parameter uncertainty in the VARMA specification. That is, we repeat the preference parameter estimation for each draw of the VARMA parameter estimates obtained in the Bayesian MCMC chain. This approach generates a chain of preference parameters, and the standard errors of the preference parameters are computed directly from this chain.

The estimates of preference parameters are reported in the bottom panel of Table 2. For identification purposes, we fix the subjective discount factor at 0.995.[7] At quarterly frequency, the estimated intertemporal elasticity of substitution is 1.26,

[7]This is related to the discussion of identification issues in Kocherlakota (1990) and is similar to the approach in Marshall (1992) and Bansal and Shaliastovich (2013).

and the risk aversion coefficient is 14.29. These estimates are similar to the ones obtained by Bansal and Shaliastovich (2013) and Doh (2013). Notably, the risk aversion coefficient is estimated with sizable standard errors. This reflects the fact that the estimate of risk aversion coefficient is sensitive to the estimated persistence of durable and/or inflation parameters. The intertemporal elasticity of substitution ϵ is estimated at 0.41 (0.20). There is a wide range of estimates in the literature, from 0.13 in Flavin and Nakagawa (2008) to 1.75 in McGrattan, Rogerson, and Wright (1997), which could be attributed to considerable measurement errors in estimating this parameter from a noisy consumption and relative price data. Our estimate additionally incorporates asset markets data, and is close to the values found in recent papers which study the role of the durable channel for the asset prices. These studies, such as Yogo (2006) and Gomes et al. (2009) highlight the importance of the complementarity of non-durable and durable consumption goods, and estimate this coefficient to be below one, around 0.7 to 0.8. Finally, the parameter which governs the share of durable goods χ is estimated at 0.46 with a standard error of 0.35.

4.3 Model Implications for Bond Prices

In this subsection, we investigate the model implications for bond prices. We show that our model, with the estimated preference parameters, closely matches both the unconditional moments and the conditional fluctuations of nominal yields, term spreads, and bond excess returns. We also find that the durable consumption growth, the novel channel in our two-good economy model, contributes more than the non-durable consumption growth in determining the long-term yields and term spreads, and is more predictable by the term structure of yields.

We start our investigation with the unconditional moments of bond prices. Table 5 presents the benchmark model implications for the bond yields and bond returns. The table reports model-implied moments obtained from a long simulation (population values), and also short samples whose size is equal to the length of the data. As shown in the top and middle panels of Table 5, our model matches very well the level, slope, and curvature of the nominal yield curve. The model-implied short rate (i.e., one-year nominal yield) is 6.19% on average, compared to 6.26% in data. The nominal yield curve is upward sloping, with a five-year term spread equal to 75 bps in the model and 58 bps in the data. Our model also perfectly captures the level of the three-year nominal yield, implying a good fit of the yield curve curvature. The model can further account for the volatility and persistence of nominal yields and term spreads. Yield volatilities decline with maturities both in the model and in the data. Though the model-implied volatility is slightly lower than the observed volatility in data for long-term bonds, the data estimates are well within the 5-95% model-implied small-sample confidence interval. Both nominal yields and term spread are highly persistent, and the discrepancy between the model estimate and data is negligible. The bottom panel of Table 5 confirms that the model also produces satisfactory fit of the short-term (two-year) and long-term (five-year) bond excess returns. Long-term bonds earn higher excess returns and exhibit higher volatility than short-term bonds in data, consistent with our model predictions.

Our model not only matches closely the unconditional moments described above, but also captures well the conditional fluctuations in the short rates, term spreads, and bond returns, as illustrated in Figure 5. Generally, the model tracks the observed data quite well. Some of the noticeable deviations of the model predictions to the data include the mid-1980s, where interest rates peaked significantly above what is predicted by our model, as well as the recent episode in early- and late-2000s, where the yields in the data were below the model predictions. These data-model deviations are possibly explained by monetary policy changes (see, e.g., Gallmeyer, Hollifeld, Palomino, and Zin (2009)). Our model implies a linear, stationary relationship between rates and state-variables (real growth rates and expected inflation), so it is not too surprising that these episodes, which represent possible non-linearities or regime-specific responses, would represent deviations between the model and the data.[8]

We formally evaluate the model fit through the mean-squared error (MSE). The MSE for the bond yields, reported in Table 5, are about 2%. The MSE for the term spread is about 1%, and the MSE for the bond returns range from 1.8% for a two-year bond to about 6% for a five-year bond. A relatively large MSE for a long-term bond return is obtained primarily from a somewhat larger mean bond return in the

[8]Note that our model abstracts from other economic channels, such as interest rate shocks and changes in the monetary policy regimes, or fluctuations in risk aversion and uncertainty which can further improve the fit of the model to the bond prices. The former channels are discussed in Hasseltoft and Burkhardt (2012), Gallmeyer et al. (2009), Bansal and Zhou (2002), Baele, Bekaert, Cho, Inghelbrecht, and Moreno (2012), and Bikbov and Chernov (2013); while Bekaert et al. (2009), Wachter (2006), and Bansal and Shaliastovich (2013) highlight the time-variation in risk premia in the bond markets.

model relatively to the data. The MSE obtained from our model is similar to that in Piazzesi and Schneider (2006).

Since the expected durable consumption growth is a novel channel in our two-good economy model, we investigate and highlight its role in determining the yield curve dynamics. We first demonstrate that the shocks to non-durable and durable consumption growth rates have opposite effects on nominal yields. Specifically, a positive shock to the expected non-durable consumption growth increases nominal yields, while a positive shock to the expected durable consumption growth decreases nominal yields. To do so, we regress the nominal yields on the expected non-durable and durable consumption growth rates and the expected inflation. Figure 6 contrasts the regression coefficients obtained from data with the coefficients implied by our model over different maturities. The nominal yields load positively on the expected non-durable consumption and expected inflation, but negatively on the expected durable consumption growth. The loadings in the model and in the data are not statistically different from each other. Furthermore, recall that our model does not feature a time-varying bond risk premium and therefore is expected to only capture the fluctuations in the expected future short rate, or the so-called "Expectation Hypothesis" component. We confirm in Figure 6 that the model-implied loadings of yields are much more closer to this risk-premia adjusted component of yields in the data.[9] We leave a more detailed study of the impact of real growth variables on the fluctuations in bond risk premia for future research.[10]

The loadings of yields also reveal that long-term bonds are much more sensitive to the expected durable consumption growth. In particular, we find that short-term yields load similarly in magnitude on the expected non-durable and durable consumption growth rates (2.5 for non-durable vs. -2.5 for durable), but long-term yields load more significantly on the expected durable consumption growth than on the expected

[9] To obtain the "Expectation Hypothesis" component of yields, we remove the time-varying bond risk premium component from the long-term yields in the data. Specifically, we consider a reduced-form VAR(1) which includes short-term yields with 1 quarter, 1 year, 3 year and five-year to maturity, as well as our macroeconomic states. Based on the VAR, we compute the "Expectation Hypothesis" component of the long-term yield which would prevail under the constant risk premia assumption:

$$y_{t,n}^{EH} = \frac{1}{n} E_t \sum y_{t+j-1,1}. \tag{26}$$

Note that up to a constant, the long-term yields in our model satisfy the above equation.

[10] This evidence is related to Joslin, Priebsch, and Singleton (2010), Cooper and Priestley (2009) and Ludvigson and Ng (2009) who also show that aggregate growth variables can predict future bond returns.

non-durable consumption growth (0.5 for non-durable vs. -1.2 for durable). This finding implies that durable consumption growth contributes more than the non-durable consumption growth in determining long-term yields and term spreads.

Finally, we consider the equilibrium model implications for the univariate predictability of future real consumption growth rates by the term structure variables. We simulate a time series of non-durable and durable consumption growth rates in the model and regress the simulated consumption growth rates up to five years in the future on the model-implied short rate and term spread. Figure 7 contrasts the projection slope coefficients obtained from the model with those obtained from data. Our model can broadly account for the signs and magnitudes of the projection evidence: short rates predict future consumption growth of both non-durable and durable goods and the coefficients are much larger for durable goods. Further, the term spread forecast positively future consumption growth rates, and again the slope coefficients are larger for the durable consumption regression. The model is generally consistent with the data regarding the predictability of future consumption growth by short rates and term spreads.

We also check model implications for the real bonds, defined as the asset which pays one unit of non-durable consumption in the future. In the model, the real term structure is nearly flat with a slight U-shape. The one-year yield is 1.86%, which declines to 1.82% at three years, and increases to about 1.90% at ten years.[11]

4.4 Model Implications for Equity Prices

In this subsection, we present the model implications for equity prices. Our model captures very well the average equity premium and return volatilities in both non-durable and durable production sectors. It features a higher equity premium and volatility for durable-goods-producing firms. Driven by the common exposure to inflation risks, the model-implied equity returns and bond returns exhibit strong positive correlation and the correlation is more pronounced for the durable-goods-producing firms. The average correlation between equity returns and expected inflation is negative, which

[11] Our real yield implications are broadly consistent with Bekaert, Ang, and Wei (2008) who estimate an alternative no-arbitrage term-structure model and find that the real term spread is close to zero.

again is more pronounced for the durable production sector. We document strong empirical support for these model implications.

Table 6 summarizes the model-implied equity returns in non-durable and durable production sectors, alongside with the corresponding statistics in the data. In our model, equity portfolios represent levered claims to the aggregate consumption, and thus are exposed to aggregate consumption and inflation risks. This makes equities quite risky, which leads to a high unconditional equity premium and a high volatility of returns. As in the data, the portfolio of durable goods producers in the model is riskier than the portfolio of non-durable goods producers. The average equity premium is 7.2% for the durable production sector relative to 4.0% for the non-durable production sector, which is comparable to the estimates in the data of 7.1%, and 5.6%, respectively. Further, the model-implied volatility of excess returns in the durable production sector is 28.7%, which is larger than that in the non-durable production sector of 19.1%. This is consistent with the empirical evidence in the data, which shows that the volatility of durable equity returns is 21.1% and the volatility of non-durable equity returns is 14.7%.

We further consider model implications for the covariation of stock returns with expected inflation and bond returns. In the model, equity valuations decrease at times of high expected inflation. As a result, excess stock returns have a negative correlation with expected inflation, which is more pronounced for durable portfolios that are more exposed to inflation risk. These predictions of the model are supported by the data. As shown in Table 6, the model-implied correlation of equity returns with expected inflation is -0.33 for the durable production sector relative to -0.28 for the non-durable sector. In the data, while the levels and the gaps between the correlations are somewhat bigger (-0.54 relative to -0.44), the estimates are in the confidence interval of the model. Further, our model implies that excess bond returns and excess equity returns co-move positively, and the degree of the co-movement is larger for the durable portfolio which is more sensitive to expected durable growth and expected inflation risks. These model implications are also supported by the data. Specifically, the model-implied correlation between excess returns of the durable portfolio with excess bond returns is 0.41, relative to 0.30 for the non-durable portfolio, and the model-implied correlations are nearly identical to the data.

4.5 Importance of Model Channels

In this section we assess the importance of the key economic channels of the models to explain the asset-pricing evidence in the bond and equity markets. Specifically, we consider the relative impact of the fluctuations in the expected consumption growth and inflation on the asset prices, the significance of the inflation non-neutrality, and the role of the preference structure.

In the model, the levels of bond risk premia and the fluctuations in yields and the stochastic discount factor are determined by three state variables which drive the movements in the expected consumption growth of non-durable and durable goods and expected inflation:

$$\begin{aligned} Var_t(y_{t,n}) &= \left(\frac{1}{n}\right)^2 B'_{x,n}\Sigma_x\Sigma'_x B_{x,n}, \\ Var_t(m^{\$}_{t,n}) &= \lambda'_x\Sigma_x\Sigma'_x\lambda_x, \\ E_t rx_{t+1,n} + \frac{1}{2}Var_t rx_{t+1,n} &= -B'_{x,n-1}\Sigma_x\Sigma'_x\lambda_x. \end{aligned} \tag{27}$$

To understand the relative importance of the economic channels, we decompose these quantities into the components associated with each source of risks. As the three shocks are correlated and the volatility matrix Σ_x is non-diagonal, to simplify the presentation we distribute the covariance terms with the weight proportional to the variance of the factor. Table 7 documents the results of the variance decomposition. The key state variables which drive the movements of the yields are the expected inflation and the expected durable-good growth rate. Indeed, the expected inflation factor contributes about 67% to the total variance of the one-year yield. As the expected inflation is the most persistent factor, its relative role increases with maturity, and reaches 80% for five year yields and almost 85% for the ten-year yields. The contribution of the durable factor is about 30% for the one-year yield, and it still contributes a non-trivial amount of about 20% at the five- and ten-year bond maturities. The contribution of non-durable expected growth factor is virtually zero: the percentages are even slightly negative at long maturities because of the negative covariance terms.

Similarly, the expected inflation and the expected durable growth are the key risk factors which generate positive risk premium on nominal bonds. In our model, most of the bond risk premia at long maturities is the compensation for the expected inflation risks. Bonds hedge movements in expected non-durable consumption, so that the risk compensation for non-durable risks is negative. On the other hand, bond are risky with respect to the expected durable consumption. The durable risk factor contributes about 45% to the bond risk premia at one year, and about 15% at five-year and longer maturities.

The variance decomposition of the stochastic discount factor provides another measure of risk of the economy. Consistent with our previous discussion, agents are very averse to shocks to expected inflation. Due to their high persistence and an adverse effect on future real growth, the expected inflation shocks account for 67% of the variance of the stochastic discount factor. The remaining premia is split equally between the shocks to expected non-durable and durable consumption. We also entertain similar decomposition for the equity risk premia. The implications for the inflation risks are quite similar; for consumption risks, naturally, non-durable equity premium loads relatively more on expected non-durable growth, while durable premium is more affected by the risks of durable consumption growth.

In our model, the key economic channel which allows us to explain the inflation risks in bond and equity markets is the inflation non-neutrality. We quantify the importance of this channel in Table 8. In the benchmark model, inflation has a negative effect on both non-durable and durable consumption growth. The first column of the table shows the benchmark model implications for the levels of yields, inflation premium defined as the covariance of long-term inflation and the stochastic discount factor, the equity premium, and the correlation of equity returns with bonds and expected inflation. The benchmark model produces sizeable bond and stock risk premia. The inflation premium is positive and increasing with the maturity. It is equal to 0.23% at 1 year horizon and reaches 0.92% at 5 years. These magnitudes are consistent with the estimates in Bekaert et al. (2008), who consider an alternative no-arbitrage term structure model, and find the inflation premia of 0.31% and 1.14%, respectively.

In the following columns of the table, we report model implications in the restricted model specifications where inflation is neutral for non-durable consumption; for durable consumption; and when inflation has no effect on either of the two consumptions in the future. To make expected inflation neutral, we set the appropriate coefficients which govern the co-movements of expected inflation and expected consumption to zero. For inflation neutrality for non-durables, these coefficients are $\Pi(1,2)$ and $\Sigma_x(2,1)$; for durables, these coefficients are $\Pi(3,2)$ and $\Sigma_x(3,2)$, and all four coefficients are set to zero when inflation is neutral for both non-durable and durable growth. In Figure 8 we show the impulse responses of expected inflation to expected non-durable and durable consumption growth across the restricted model specifications. The responses confirm that, for example, in the case when inflation is neutral for non-durable growth, expected inflation has a zero effect on future expected durables across all the horizons, while its impact on expected durables is identical to the benchmark model. Similarly, under inflation neutrality for durables, expected inflation has no effect on durable growth, and its effect on non-durable is identical to the benchmark model. Under neutrality for both durables and non-durables, the inflation has no effect on either consumption growth rates in the future.

As shown in Table 8, removing the inflation effect for real growth diminishes the role of the inflation in the economy, and significantly affects the model fit to the asset-pricing variables. Indeed, under full inflation neutrality, the nominal term structure is effectively flat, the inflation premium is zero, the equity premia is reduced by about a half, and the correlations of stock returns with bonds and with expected inflation are nearly zero. Quantitatively, because of the high persistence of the expected durable factor, the most important channel for the inflation risks is through its interaction with future durable growth. For example, the slope of the term structure reduces by about 10 basis points when expected inflation has no impact on future non-durables, while it reduces by 50 basis points when expected inflation has no effect on future durables. Similarly, the five-year inflation premium is diminished from 90 basis points in the full model to 60 basis points under inflation neutrality for non-durables, and it goes down to 30 basis points when inflation is neutral for durables.

Finally, in Table 9 we assess the ingredients of the preference structure which features two goods with a low (below one) elasticity of intratemporal substitution and a preference for early uncertainty resolution. In this table, we show model implications for the market prices of risks, nominal bond loadings, and the levels of the nominal bond and equity risk premia. First, we consider a restriction of the model to one-good economy by setting the relative weight χ parameter to zero. In our specification, this directly implies that the market price of expected durable risks is zero. Further, removing agents' concerns about durables reduces, in absolute terms, the market price of expected inflation risks by about half relative to the benchmark case. As a result, the model cannot generate the levels of the bond and equity risk premia as in the benchmark model, and it further cannot explain the negative effect of expected durables on the nominal bond yields. In a second exercise, we entertain a high (above one) elasticity of intra-temporal substitution $\epsilon = 1.5$. The elasticity of intratemporal substitution does not impact the market prices of risks; however, it affects the interest rate loadings on the factors. In particular, when goods are viewed as substitutes, an increase in expected durables actually raises interest rates, opposite to the benchmark model and the data. Raising the elasticity of substitution further reduces the levels of the bond risk premia implied by the model. Finally, in the last specification we set the elasticity of intertemporal substitution ψ to 0.05. In this case, ψ is less than $1/\gamma$, which implies that the agents have a preference for late resolution of uncertainty. With this specification, all the market prices of risks have opposite signs to the benchmark specification. Counter to the data and the benchmark model, the model-implied yields now load positively on the expected durables, and negatively on the expected inflation. This model specification also implies implausibly high values of the yields of above 60%.

5 Robustness

5.1 Alternative Model Estimations

In our benchmark model specification, we impose economic and statistical restrictions on the model parameters. In this section, we assess the importance of these restrictions, and show that they do not materially affect the statistical fit or economic implications of the model.

In the first robustness check, we relax the restriction on the persistence matrix, that is, we allow $\Pi_{1,3}$, $\Pi_{3,1}$, $\Pi_{2,1}$, and $\Pi_{2,3}$ to be estimated from the data, rather than imposing them to be zero. The new estimated parameters are presented in Appendix C in Table C.1. Nearly all parameter estimates are very similar to the benchmark model, and the estimated $\Pi_{1,3}$, $\Pi_{3,1}$, $\Pi_{2,1}$, and $\Pi_{2,3}$, which are zeroed out in the benchmark specification, are all insignificant. To further assess their impacts on the model-implied dynamics of macro variables, we compare the expected consumption growth rates and expected inflation rate estimated from the benchmark model and the unrestricted model. Figure C.1 plots the time series of the expected growth rates estimated from the two models. The expected growth rates estimated from the two models nearly overlap with each other, confirming that the restrictions imposed in the benchmark model on the persistence matrix does not affect our estimation of the expected consumption growth rates and expected inflation. We then investigate whether the restrictions on the persistence matrix may affect the interactions between these macro variables over multiple periods. In Figure C.2, we compare the Impulse Response Functions (IRF) of the macro variables to shocks in the expected consumption growth rates and inflation. Again, we find that the IRFs computed from the benchmark model are very similar to those computed from the unrestricted model, and the differences are insignificant at 10% level.

In the second robustness check, we relax the restriction on the dividend growth specification. In particular, we allow the dividend growth rates to load on the expected inflation and the expected consumption growth of both goods. The new estimated parameters are reported in Table C.2. All parameter estimates remain very similar to that in the benchmark model except for the loadings of dividend growth rates, which now become insignificant. We examine how the restrictions on the dividend growth rate loadings affect the interaction between macro variables and the expected dividend growth rates. In Figure C.3, we compare the IRFs of expected dividend growth rates to shocks in the expected consumption growth rates and expected inflation in the benchmark model and the unrestricted model. IRFs computed from both models do not exhibit significant differences.

5.2 Alternative Numeraires and Implications for CPI

In our benchmark model, we choose the non-durable consumption as a numeraire and use the change in its price index, that is, the inflation rate for non-durable goods, to compute the equilibrium prices for nominal assets. An alternative to our procedure could be 1) to use durable goods as the numeraire, or 2) to define a numeraire to be the aggregate consumption basket of non-durable and durable goods. Because of the data and measurement issues, and consistent with the existing literature, we chose to proceed with non-durable numeraire. First, the standard estimates for the relative user cost of durable goods Q in the literature typically rely on the Euler condition equation:

$$Q_t = P_t^d - (1-\delta)E_t[M_{t+1}P_{t+1}^d], \tag{28}$$

where P_t^d is the real purchase price of durable goods in terms of non-durable goods. These implied user costs are very noisy, and are quite sensitive to the measurement assumptions, specifically, to those regarding computing expectations and approximations of the stochastic discount factors. The literature typically replaces the stochastic discount factor with one over the risk free rate, and replaces expectations by future realized values, current values, or AR(1) forecasts. We find that changes in user costs implied by these computations are only weakly, and sometimes even negatively correlated across the measurements, and have quite different first-order properties. For this reason, we choose to minimize the direct use of the user cost for the estimation of the model, and use non-durable numeraire.

We further choose not to use the Consumer Price Index (CPI) numeraire implied by basket of goods. In the model, one can compute the ideal price index associated with the preferences of the agent. However, the aggregate consumption and CPI inflation series in the data which aggregate quantities and prices of both non-durable and durable goods are based on the weights according to the National Income and Product Account (NIPA) conventions, which, in principle, can be very different from the weights in the economic model. Hence, as in Piazzesi et al. (2007), we choose to use dis-aggregated series for non-durable and durable consumption and non-durable inflation to specify and estimate the model.

As a robustness check, we consider our model implications for the aggregate price index, and compare its dynamics to the CPI inflation in the data. Following the literature, the appropriate nominal price of the basket of goods is given by the ideal price index associated with agents' preferences, which is equal to:

$$P_t^{basket} = \Big((1-\alpha)P_t^{\$ 1-\epsilon} + \alpha(P_t^{\$}P_t^d)^{1-\epsilon}\Big)^{\frac{1}{1-\epsilon}}, \tag{29}$$

We solve for the inflation rate for the ideal price index in the model, and find that it is close to the CPI inflation in the data: the correlation between the two is 60%, and the means and standard deviations of the two are quite similar.

5.3 Log-Linearization of the Consumption Return

To solve the model analytically, we log-linearized the return on the consumption asset. To check the accuracy of the log-linearization, we also solve the model numerically and compare the numerical solution to our analytical solution. We find that the log-linearization of the consumption return does not have any noticeable impact on the model solution. Indeed, the mean, volatility, and persistence of the wealth-consumption ratio and nominal yields of one- to five-year to maturity, shown in Table D.3, are nearly identical. The analytical solution, which provides close-form equations for equilibrium asset prices, reveals more intuitions about the underlying model mechanism and allows us to give clearer interpretation of the model implications.

6 Conclusions

In the data, high expected inflation has a non-neutral and negative impact on future real growth, and the magnitude of this inflation non-neutrality is larger for durable goods sector than non-durable goods sector. Consistent with these macroeconomic findings, the equity prices in the durable goods sector are more exposed to expected inflation and bond risks.

Motivated by this empirical evidence, we set up and estimate a two-good nominal economy which features recursive utility over consumption of durable and non-durable goods, persistence fluctuations in expected growth rates, and inflation non-neutrality for future real growth in non-durable and durable consumption. The inflation non-neutrality for durable consumption leads to a significant role for the expected inflation risks and large inflation premium in the economy, which goes a long way to account for the key features of the macroeconomic data, nominal bond yields, and equity prices in durable and non-durable sectors. Under plausible preference parameters, the model can generate an upward-sloping nominal yield curve, higher risk premia and volatility for durable-good portfolio, and stronger correlations of durable-goods portfolio returns with expected inflation and bond returns, relative to non-durable goods portfolio. Inflation non-neutrality for durable growth is an important model channel which plays a key role to explain these data features.

Notably, in our model the variance of the underlying shocks are constant, so the correlations of stock returns with expected inflation and bond returns do not fluctuate over time. Recent literature suggests that the conditional correlations vary over time and switch signs in the data. These features of the data can be explained by the fluctuations in time-varying covariance between inflation and real economy (Hasseltoft and Burkhardt (2012) and Campbell, Sunderam, and Viceira (2012)), fluctuations in the volatility and risk premia (Hasseltoft (2009)), time-varying risk aversion (Bekaert et al. (2008)), learning and non-linearities in the dynamics of real growth and inflation (David and Veronesi (2012)) or liquidity factors (Bekaert, Baele, and Inghelbrecht (2010)). In this paper, we focus on unconditional properties of bond and stock data over the whole sample, and we leave these important model extensions for the future research.

References

Abel, Andrew B., 1999, Risk premia and term premia in general equilibrium, *Journal of Monetary Economics* 43, 3–33.

Baele, Lieven, Geert Bekaert, Seonghoon Cho, Koen Inghelbrecht, and Antonio Moreno, 2012, Macroeconomic regimes, working paper.

Bansal, Ravi, and Ivan Shaliastovich, 2013, A long-run risks explanation of predictability puzzles in bond and currency markets, *Review of Financial Studies* 26, 1–33.

Bansal, Ravi, and Amir Yaron, 2004, Risks for the long run: A potential resolution of asset pricing puzzles, *Journal of Finance* 59, 1481–1509.

Bansal, Ravi, and Hao Zhou, 2002, Term structure of interest rates with regime shifts, *The Journal of Finance* 57, 1997–2043.

Bekaert, Geert, Andrew Ang, and Min Wei, 2008, The term structure of real rates and expected inflation, *Journal of Finance* 63(2), 797–849.

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

Bekaert, Geert, and Eric Engstrom, 2010, Inflation and the stock market: Understanding the "fed model", *Journal of Monetary Economics* 57, 278–294.

Bekaert, Geert, Eric Engstrom, and Yuhang Xing, 2009, Risk, uncertainty, and asset prices, *Journal of Financial Economics* 91, 59–82.

Bekaert, Geert, and Xiaozheng Wang, 2010, Inflation risk and the inflation risk premium, *Economic Policy* 25, 755–806.

Bikbov, Ruslan, and Mikhail Chernov, 2013, Monetary policy regimes and the term structure of interest rates, *Journal of Econometrics* 174, 27–43.

Bils, Mark, 2009, Do higher prices for new goods reflect quality growth of inflation?, *Quarterly Journal of Economics* 124, 637–675.

Bils, Mark, and Peter J. Klenow, 2001, Quantifying quality growth, *American Economic Review* 91, 1006–1030.

Boskin, M.J., E.R. Dulberger, R.J. Gordon, Z. Griliches, and D. Jorgenson, 1996, Toward a more accurate measure of the cost of living. Final report to the senate finance committee from the advisory commission to study the consumer price index, Senate Finance Committee, Washington, December 4.

Boudoukh, Jacob, Matthew Richardson, and Robert F. Whitelaw, 1994, Industry returns and the fisher effect, *Journal of Finance* 49, 1595–1615.

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

Campbell, John Y., Adi Sunderam, and Luis M. Viceira, 2012, Inflation bets or deflation hedges? the changing risks of nominal bonds, working paper.

Cochrane, J., F. Longstaff, and P. Santa-Clara, 2008, Two trees, *Review of Financial Studies* 21, 347–385.

Colacito, Riccardo, and Mariano Croce, 2013, International asset pricing with recursive preferences, forthcoming in Journal of Finance.

Cooper, Ilan, and Richard Priestley, 2009, Time-varying risk premiums and the output gap, *Review of Financial Studies* 22, 2801–33.

David, Alexander, and Pietro Veronesi, 2012, What ties return volatilities to price valuations and fundamentals?, working paper.

Doh, Taeyoung, 2013, Long run risks in the term structure of interest rates: Estimation, *Journal of the Applied Econometrics* 28, 478–497.

Eichenbaum, Martin, and Lars Hansen, 1990, Estimating models with intertemporal substitution using aggregate time series data, *Journal of Business and Economic Statistics* 8, 53–69.

Epstein, Larry G., and Stanley Zin, 1989, Substitution, risk aversion and the temporal behavior of consumption and asset returns: A theoretical framework, *Econometrica* 57, 937–969.

Epstein, Larry G., and Stanley Zin, 1991, Substitution, risk aversion and the temporal behavior of consumption and asset returns: An empirical analysis, *Journal of Political Economy* 99, 263–286.

Eraker, Bjørn, 2006, Affine general equilibrium models, *Management Science* 54-12, 2068–2080.

Erceg, Christopher, and Andrew Levin, 2006, Optimal monetary policy with durable consumption goods, *Journal of Monetary Economics* 53, 1341–1359.

Fama, Eugene, 1990, Term structure forecasts of interest rates, inflation and real returns, *Journal of Monetary Economics* 25, 59–76.

Fama, Eugene, and William G. Schwert, 1977, Asset returns and inflation, *Journal of Financial Economics* 5, 115–146.

Fama, Eugene F., 1981, Stock returns,real activity,inflation and money, *American Economic Review* 71, 545–565.

Flavin, Marjorie, and Shinobu Nakagawa, 2008, A model of housing in the presence of adjustment costs: A structural interpretation of habit persistence, *The American economic review* 474–495.

Gallmeyer, Michael, Burton Hollifeld, Francisco Palomino, and Stanley Zin, 2009, Term premium dynamics and the taylor rule, *Working paper, UVA* .

Gomes, Joo F., Leonid Kogan, and Motoshiro Yogo, 2009, Durability of output and expected stock returns, *Journal of Political Economy* 117(5), 941986.

Guo, Na, and Peter Smith, 2010, Durable consumption, long-run risk and the equity premium, working paper.

Hasseltoft, Henrik, 2009, The fed model and the changing correlation of stock and bond returns: An equilibrium approach, *working paper, University of Zurich* .

Hasseltoft, Henrik, 2012, Stocks, bonds and long-run consumption risks, *Journal of Financial and Quantitative Analysis* 47, 309–332.

Hasseltoft, Henrik, and Dominic Burkhardt, 2012, Understanding asset correlations, working paper.

Joslin, Scott, Marcel Priebsch, and Kenneth Singleton, 2010, Risk premiums in dynamic term structure models with unspanned macro risks, working paper, Stanford University.

Kocherlakota, Narayana, 1990, Disentangling the coefficient of relative risk aversion from the elasticity of intertemporal substitution: An irrelevance result, *The Journal of Finance,* 45, 175–91.

Kreps, David M., and Evan L. Porteus, 1978, Temporal resolution of uncertainty and dynamic choice theory, *Econometrica* 46, 185–200.

Ludvigson, Sydney C., and Serena Ng, 2009, Macro factors in bond risk premia, *Review of Financial Studies* 22, 5027–67.

Lustig, Hanno, and Adrien Verdelhan, 2007, The cross section of foreign currency risk premia and consumption growth risk, *American Economic Review* 97, 89–117.

Marshall, David, 1992, Inflation and asset returns in a monetary economy, *Journal of Finance* 47, 1315–42.

McGrattan, Ellen R, Richard Rogerson, and Randall Wright, 1997, An equilibrium model of the business cycle with household production and fiscal policy, *International Economic Review* 267–290.

Ogaki, Masao, and Carmen M. Reinhart, 1998, Measuring intertemporal substitution: The role of durable goods, *Journal of Political Economy* 106.

Piazzesi, Monica, Martin Schneider, and Selale Tuzel, 2007, Housing, consumption and asset pricing, *Journal of Financial Economics* 83, 531–569.

Piazzesi, Monika, and Martin Schneider, 2006, Equilibrium yield curves, NBER Working paper 12609.

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

Yang, Wei, 2011, Long-run risk in durable consumption, *Journal of Financial Economics* 102, 45–61.

Yogo, Motoshiro, 2006, A consumption-based explanation of expected stock returns, *Journal of Finance* 61, 539–580.

Appendix

A MCMC Estimation

In order to perform inference for the parameters in our model we estimate the posterior distributions of the model parameters using Bayesian MCMC.

We compute the posterior distributions for the latent state variables along with the parameters that govern their dynamics by sampling from the posterior distribution of conditional upon the observed macro data.

Let Θ denote the collection of "macro parameters" - that is: every parameter that govern the dynamic evolution of the unobserved state variables (excluding preference parameters).

Let $\eta_t^* = \Sigma_g \eta_t$ is defined as the exogenous random shock to the macro-variables g_t in equation (1),

$$\eta_t^* = y_t - \mu_y - x_t.$$

The posterior is

$$p(y_t \mid y_{t-1}, x_t) p(x_t \mid x_{t-1}) p(\Theta)$$

up to a constant of proportionality. We can now compute the posterior, $p(\Theta \mid y_{0:T})$, (where $y_{0:T}$ denotes the history of observed macro data) explicitly through Kalman filtering. This joint posterior density is non-standard, and we compute it numerically as a bi-product of the Kalman filter.

In a second step, we estimate the preference parameters from the asset market data while averaging over the posterior draws from the first step, as described in the main body of the paper.

B Model Solution

The log-linearization parameter for the consumption asset κ_1 satisfies the following recursive equation:

$$\begin{aligned}
\log \kappa_1 = \log \beta &+ \left(1 - \frac{1}{\psi}\right) \left((1-\chi) i_c + \chi(i_a + i_s)\right)' \mu \\
&+ \frac{1}{2}\theta \left(1 - \frac{1}{\psi}\right)^2 \left((1-\chi) i_c + \chi(i_a + i_s)\right)' \Sigma_g \Sigma_g' \left((1-\chi) i_c + \chi(i_a + i_s)\right) \\
&+ \frac{1}{2}\theta \kappa_1^2 A_x' \Sigma_x \Sigma_x' A_x.
\end{aligned} \tag{B.1}$$

The discount factor parameters are given by

$$m_0 = \theta \log \delta + (1-\theta)\log \kappa_1 - \lambda_g' \mu. \tag{B.2}$$

The nominal discount factor parameters satisfy

$$m_0^\$ = m_0 - i_\pi \mu_g, \quad m_x^\$ = m_x - F' i_\pi, \quad \lambda_g^\$ = \lambda_g + i_\pi, \tag{B.3}$$

where $i_\pi = \begin{bmatrix} 0 & 1 \end{bmatrix}'$.

The solution for real bond price loadings are given by,

$$\begin{aligned} B_{0,n} &= B_{0,n-1} - m_0 - \frac{1}{2}\lambda_g' \Sigma_g \Sigma_g' \lambda_g - \frac{1}{2}(\lambda_x + B_{x,n-1})' \Sigma_x \Sigma_x' (\lambda_x + B_{x,n-1}), \\ B_{x,n} &= \Pi' B_{x,n-1} - m_x, \end{aligned} \tag{B.4}$$

and similar for nominal bonds using the parameters of the nominal discount factor.

C Estimation of Alternative Model Specifications

Table C.1: Estimates of the Model with Unrestricted Persistence Matrix

	Π			$\Sigma_x \times 1000$			$\text{diag}(\Sigma_g) \times 1000$
	Δc	$\Delta\pi$	Δs	Δc	$\Delta\pi$	Δs	
Δc	0.312 (0.107)	−0.163 (0.055)	−0.060 (0.086)	3.822 (0.369)			1.421 (0.782)
$\Delta\pi$	0.102 (0.068)	0.969 (0.035)	0.076 (0.045)	−0.312 (0.321)	1.923 (0.331)		1.988 (0.262)
Δs	−0.064 (0.068)	−0.112 (0.035)	0.879 (0.046)	1.511 (0.291)	0.298 (0.294)	1.202 (0.278)	1.579 (0.359)
	ϕ			$\sigma_d \times 100$			$\sigma_d^{me} \times 100$
Δd_{nd}	4.96 (2.28)	0	0	7.58 (0.81)			7.46 (0.93)
Δd_{nd}	0	0	5.43 (2.99)	9.89 (1.47)			14.31 (1.58)

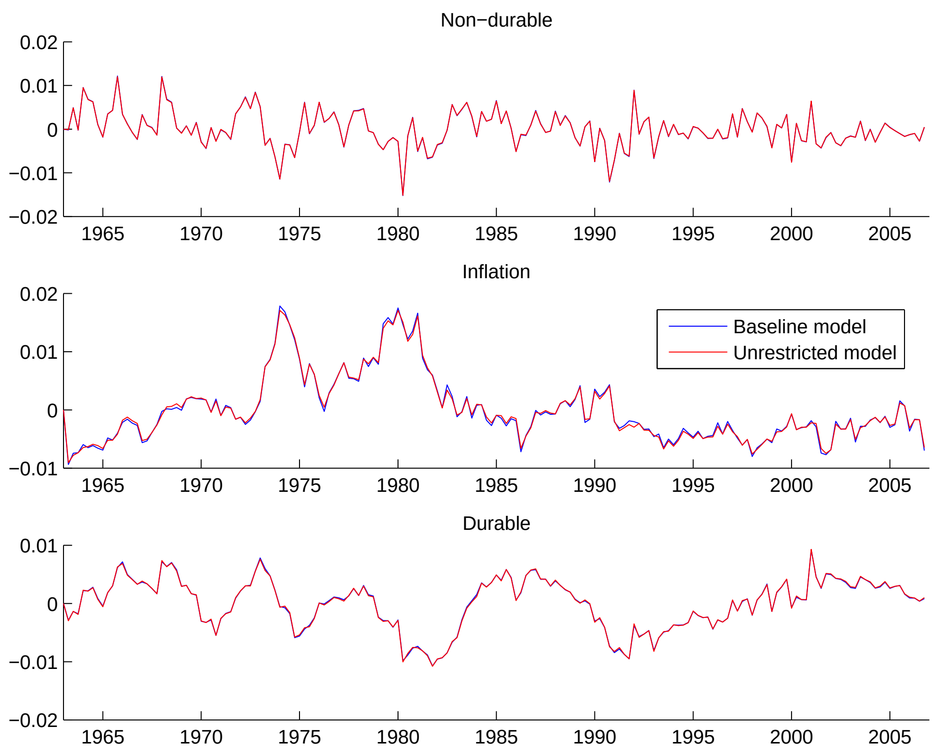
The table shows parameter estimates of the model with an unrestricted persistence matrix. The model parameters reported in the table are estimated by Bayesian MCMC using the quarterly data of observed growth rates of non-durable and durable consumption and inflation from 1963Q1 to 2006Q4.

Table C.2: Estimates of the Model with Unrestricted Dividend Growth Loadings

	Π			$\Sigma_x \times 1000$			$\text{diag}(\Sigma_g) \times 1000$
	Δc	$\Delta \pi$	Δs	Δc	$\Delta \pi$	Δs	
Δc	0.395 (0.099)	-0.136 (0.055)	0	3.602 (0.631)			1.912 (0.912)
$\Delta \pi$	0	0.917 (0.035)	0	-0.102 (0.319)	2.291 (0.301)		1.878 (0.298)
Δs	0	-0.102 (0.027)	0.878 (0.031)	1.393 (0.197)	0.301 (0.205)	1.102 (0.198)	1.598 (0.164)
	ϕ			$\sigma_d \times 100$			$\sigma_d^{me} \times 100$
Δd_{nd}	4.74 (2.720)	-1.10 (1.182)	-0.159 (1.708)		7.45 (0.821)		7.69 (1.027)
Δd_{nd}	5.78 (5.604)	-2.41 (2.113)	2.63 (3.134)		10.35 (1.401)		13.69 (1.642)

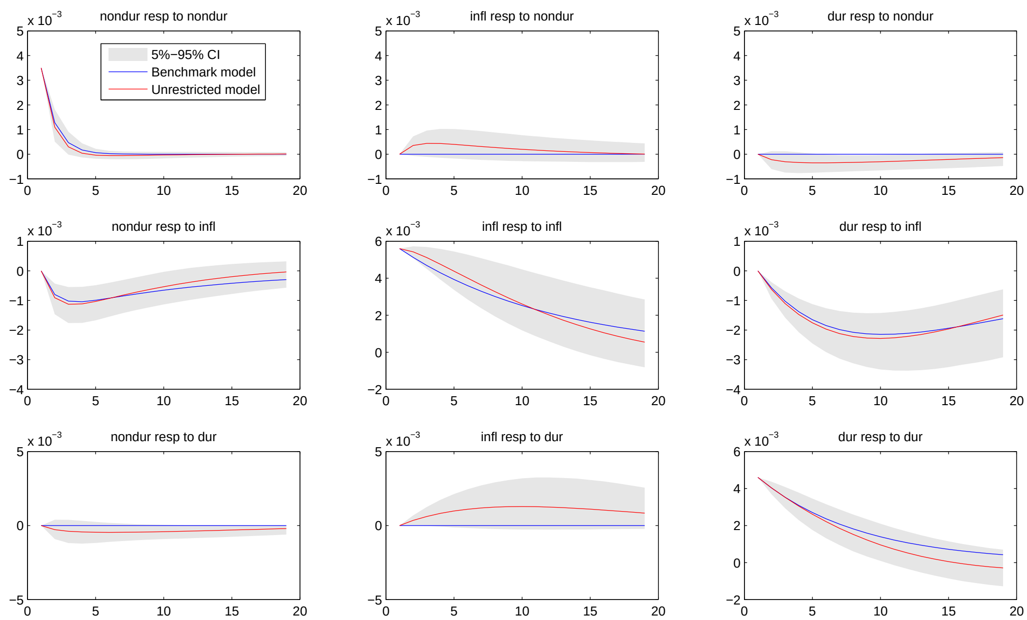
The table shows parameter estimates of the model with unrestricted dividend growth loadings. The model parameters reported in the table are estimated by Bayesian MCMC using the quarterly data of observed growth rates of non-durable and durable consumption and inflation from 1963Q1 to 2006Q4.

Figure C.1: Estimated Economics States Across Models



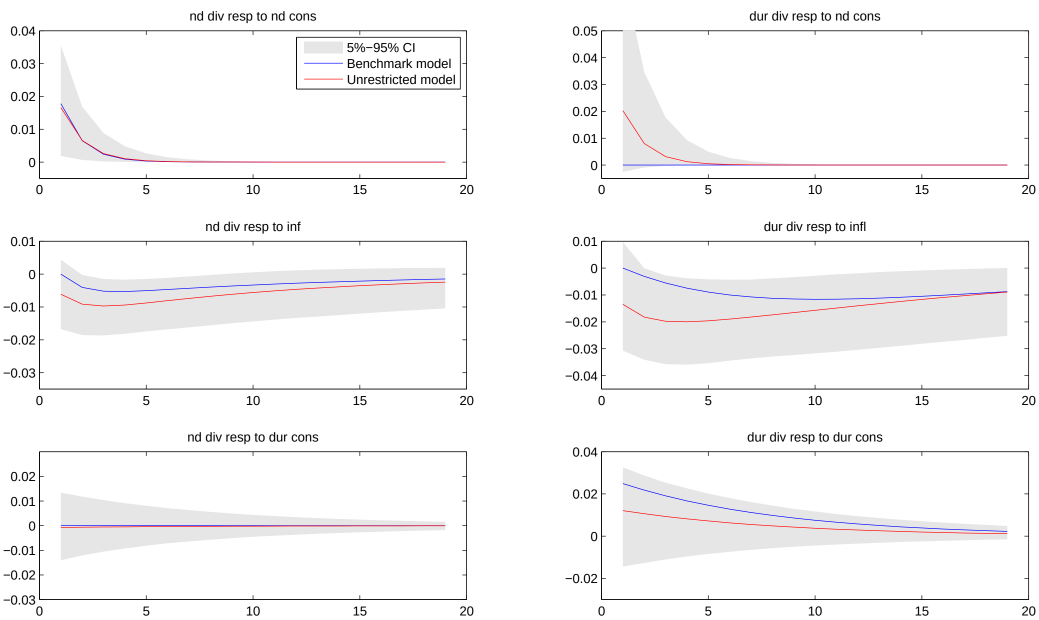
The figure shows the time series of the expected non-durable consumption growth rate, expected non-durable inflation rate, and expected durable consumption growth rate, estimated in the benchmark model and the model with unrestricted persistence matrix.

Figure C.2: Impulse Responses of Expected Growth Shocks Across Models



The figure shows impulse response functions of macroeconomic variables to shocks in expected non-durable consumption, expected durable consumption and expected non-durable inflation, based on the benchmark model and the model with unrestricted persistence matrix. Grey regions correspond to 5%-95% confidence interval.

Figure C.3: Impulse Responses of Dividend Growth



The figure shows impulse response functions of dividend growth to shocks in expected non-durable consumption, expected durable consumption and expected non-durable inflation, based on the benchmark model and the model with unrestricted dividend growth loadings. Grey regions correspond to 5%-95% confidence interval.

D Log-linearization Approach

To obtain closed-form analytical solutions to the asset prices, we rely on a standard log-linearization of the equity returns. To show that the log-linearization error does not have a material impact on model solutions, we solve the model numerically. First, we discretize each expected growth state variable into 10 values. Then we solve for the equilibrium wealth portfolio and the stochastic discount factor numerically through fixed point iteration.

Table D.3: Approximate Analytical Versus Numerical Solution

	Analytical	Numerical
Price-Consumption Ratio:		
Mean	5.597	5.594
Std Dev	0.961	0.993
AR(1)	0.939	0.910
one-year Nominal Yield:		
Mean	6.135	6.125
Std Dev	2.389	2.451
AR(1)	0.900	0.906
five-year Nominal Yield:		
Mean	6.911	6.924
Std Dev	1.569	1.642
AR(1)	0.946	0.949
10-year Nominal Yield:		
Mean	7.456	7.507
Std Dev	0.984	1.038
AR(1)	0.942	0.945

The table reports the moments of the price-consumption ratio and nominal yields under the approximate analytical solution based on the log-linearization of the wealth portfolio, and the numerical solution without the approximation.

Tables and Figures

Table 1: Inflation Non-Neutrality for Real Growth

	1Y	2Y	3Y	4Y	5Y
			Consumption Growth:		
Non-durable	-0.187	-0.119	-0.075	-0.041	-0.029
	(0.056)	(0.062)	(0.061)	(0.053)	(0.047)
R^2	0.144	0.099	0.061	0.027	0.017
Durable	-0.305	-0.329	-0.310	-0.270	-0.230
	(0.073)	(0.085)	(0.091)	(0.084)	(0.067)
R^2	0.201	0.272	0.286	0.260	0.227
			Dividend Growth:		
Non-durable	-1.641	-1.188	-0.787	-0.554	-0.315
	(0.551)	(0.531)	(0.519)	(0.411)	(0.315)
R^2	0.044	0.050	0.039	0.034	0.017
Durable	-4.277	-3.227	-1.915	-1.175	-0.461
	(1.027)	(0.890)	(0.937)	(0.906)	(0.754)
R^2	0.100	0.123	0.067	0.033	0.008

The table reports the slope coefficients, the standard errors, and the R^2s in the projections of average cumulative real economic growth rate on current inflation. The top panel reports the evidence for aggregate consumption growth of non-durable goods and durable goods; and the bottom panel reports the results for dividend growth in non-durable and durable goods production sectors. Quarterly data from 1963Q1 to 2006Q4. Standard errors are Newey-West adjusted.

Table 2: Model Parameter Estimates

Macroeconomic Parameters:

	Π			$\Sigma_x \times 1000$			$\text{diag}(\Sigma_g) \times 1000$
	Δc	π	Δs	Δc	π	Δs	
Δc	0.375	-0.143	0	3.83			1.46
	(0.115)	(0.063)		(0.552)			(0.979)
π	0	0.916	0	-0.16	2.35		1.78
		(0.034)		(0.306)	(0.334)		(0.252)
Δs	0	-0.104	0.876	1.37	0.37	1.20	1.63
		(0.040)	(0.043)	(0.385)	(0.254)	(0.273)	(0.369)
	ϕ			$\sigma_d \times 100$			$\sigma_d^{me} \times 100$
Δd_{nd}	4.98	0	0	7.80			7.56
	(2.12)			(0.80)			(0.91)
Δd_{nd}	0	0	5.45	11.39			12.80
			(2.48)	(1.49)			(1.52)

Preference Parameters:

δ	γ	ψ	ϵ	χ
0.995	14.29	1.26	0.41	0.46
	(8.24)	(0.10)	(0.20)	(0.35)

The table reports parameter estimates of the benchmark model specification. Macroeconomic parameters are estimated by Bayesian MCMC using the quarterly observation on consumption growth rates, dividend growth rates, and inflation. Preference parameters are estimated in the second stage using the moments of nominal yields and equity returns data. Quarterly data from 1963Q1 to 2006Q4.

Table 3: Model Fit to Macroeconomic Variables

		Data		Model			
		Est	SE	Pop	5%	50%	95%
		Consumption Growth and Inflation, Quarterly:					
Mean:	Non-durable	2.20	(0.20)	2.20	2.16	2.20	2.27
	Durable	4.32	(0.36)	4.32	4.16	4.32	4.51
	Inflation	4.16	(0.52)	4.16	3.98	4.16	4.34
Std. Dev.:	Non-durable	0.90	(0.07)	0.91	0.85	0.95	1.08
	Durable	0.94	(0.09)	1.10	0.87	1.12	1.77
	Inflation	1.25	(0.19)	1.25	1.00	1.24	1.92
AR(1):	Non-durable	0.33	(0.07)	0.39	0.25	0.39	0.53
	Durable	0.78	(0.06)	0.84	0.76	0.85	0.94
	Inflation	0.85	(0.05)	0.85	0.74	0.84	0.93
		Dividend Growth Rates, Annual:					
Mean:	Non-durable	5.89	(2.17)	2.27	2.10	2.20	2.30
	Durable	4.55	(4.24)	4.34	4.08	4.32	4.55
Std. Dev.:	Non-durable	14.41	(1.48)	14.08	13.13	14.05	16.09
	Durable	28.12	(2.91)	21.05	18.40	21.18	30.36
AR(1):	Non-durable	0.27	(0.14)	0.26	0.23	0.26	0.35
	Durable	0.10	(0.15)	0.38	0.24	0.38	0.66
Corr. with	Non-durable	0.42	(0.13)	0.38	0.16	0.38	0.58
Nondur. Cons:	Durable	0.38	(0.13)	0.29	0.07	0.29	0.53
Corr. with	Non-durable	0.14	(0.15)	0.24	0.09	0.23	0.41
Dur. Cons:	Durable	0.21	(0.15)	0.50	0.11	0.50	0.79
Corr. with	Non-durable	-0.24	(0.15)	-0.18	-0.37	-0.16	-0.05
Inflation:	Durable	-0.32	(0.14)	-0.22	-0.51	-0.20	-0.03

The table reports the data and model properties of non-durable and durable consumption growth, inflation, and dividends growth rates in non-durable and durable production sectors. Summary statistics for consumption and inflation are based on quarterly data, annualized, and dividend data are annual. Population values correspond to a long simulation at the estimated parameter values. The $5\%, 50\%$, and 95% model values capture the model estimate distributions across the small samples whose size equals the data. Standard errors are Newey-West adjusted.

Table 4: Summary Statistics of Asset-Price Data

	1Y	2Y	3Y	4Y	5Y
	Nominal Bond Yields:				
Mean	6.26	6.47	6.63	6.76	6.84
Std. Dev.	2.76	2.71	2.62	2.58	2.53
AR(1)	0.93	0.94	0.95	0.95	0.96
	Excess Bond Returns:				
Mean		0.42	0.68	0.87	0.89
Std. Dev.		1.83	3.45	4.72	5.88

	Non-durable	Durable
	Excess Stock Returns:	
Mean	5.62	7.11
Std. Dev.	14.93	21.37
AR(1)	0.06	-0.02
Corr. with Bond Ret.	0.28	0.38
Corr. with ΔExp. Infl.	-0.44	-0.53

The table reports summary statistics for nominal bond yields, excess nominal bond returns, and excess equity returns in non-durable and durable production sectors. Data are from 1963Q1 to 2006Q4.

Table 5: Model Implications for Nominal Yields

		Data		Model			
		Est	SE	Pop	5%	50%	95%
			Nominal Bond Yields:				
Mean:	1Y	6.26	(0.62)	6.14	5.93	6.16	6.47
	3Y	6.63	(0.60)	6.55	6.41	6.57	6.74
	5Y	6.84	(0.58)	6.91	6.73	6.91	7.07
Std. Dev.:	1Y	2.75	(0.47)	2.39	1.80	2.42	3.78
	3Y	2.62	(0.44)	1.92	1.29	2.00	3.41
	5Y	2.53	(0.42)	1.57	1.00	1.69	3.12
AR(1):	1Y	0.93	(0.02)	0.90	0.81	0.90	0.96
	3Y	0.95	(0.02)	0.95	0.91	0.95	0.98
	5Y	0.96	(0.02)	0.95	0.91	0.95	0.98
MSE:	1Y	2.06					
	3Y	2.02					
	5Y	2.01					
			Nominal Term Spread:				
Mean:		0.58	(0.16)	0.75	0.51	0.75	0.89
Std. Dev.:		0.86	(0.09)	0.87	0.78	0.95	1.17
AR(1):		0.82	(0.07)	0.70	0.59	0.68	0.84
MSE:		1.09					
			Excess Bond Returns:				
Mean:	2Y	0.42	(0.26)	0.41	0.22	0.38	0.54
	5Y	0.89	(0.85)	1.45	0.92	1.40	1.64
Std. Dev.:	2Y	1.83	(0.17)	1.40	1.10	1.41	1.79
	5Y	5.88	(0.57)	4.12	2.98	4.14	5.97
MSE:	2Y	1.81					
	5Y	5.99					

The table reports the data and model output for nominal yields. Population values correspond to a long simulation at the estimated parameter values. The 5%, 50%, and 95% model values capture the model estimate distributions across the small samples whose size equals to the size of the data. Quarterly data from 1963Q1 to 2006Q4. Standard errors are Newey-West adjusted.

Table 6: Model Implications for Excess Equity Returns

		Data		Model			
		Est	SE	Pop	5%	50%	95%
Mean:	Non-durable	5.62	(2.25)	3.95	2.52	4.37	6.32
	Durable	7.11	(3.22)	7.17	3.19	7.14	8.76
Std. Dev.:	Non-durable	14.73	(1.35)	19.14	17.29	20.66	26.79
	Durable	21.11	(1.94)	28.66	23.95	29.56	39.70
Corr. with:	Non-durable	-0.44	(0.13)	-0.28	-0.54	-0.30	-0.11
Exp. Infl.:	Durable	-0.54	(0.11)	-0.33	-0.54	-0.31	-0.14
Corr. with:	Non-durable	0.28	(0.14)	0.30	0.09	0.28	0.54
Bond Ret.:	Durable	0.38	(0.13)	0.41	0.14	0.36	0.63

The table reports the data and model output for equity portfolios of non-durable and durable production sectors. Population values correspond to a long simulation at the estimated parameter values. The $5\%, 50\%$ and 95% model values capture the model estimate distributions across the small samples whose size equals to the size of the data. Quarterly data from 1963 to 2006. Standard errors are Newey-West adjusted.

Table 7: Model Decomposition of Yield Volatility and Risk Premium

		Relative Contributions of Risks:			
	Total	Exp. Nondur	Exp. Infl	Exp. Dur	Short-Run
Yield Volatility:					
1Y	2.39	0.02	0.66	0.32	0
5Y	1.57	-0.03	0.80	0.23	0
10Y	0.98	-0.02	0.84	0.19	0
Bond Premia:					
1Y	0.22	-1.57	2.12	0.45	0
5Y	1.70	-0.16	1.01	0.15	0
10Y	2.25	-0.11	0.99	0.12	0
SDF Volatility:					
SDF	0.42	0.17	0.65	0.17	0.01

This table reports model decomposition of yield volatility, bond premium, and the volatility of the stochastic discount factor (SDF). The relative contribution of risks statistics represent the percentage contribution of the expected durable and expected non-durable consumption growth and expected inflation to the total level of yield variance (top panel), bond premium (middle panel), and variance of the SDF (bottom panel). The covariance terms are assigned to each factor proportionally to the variance of the factor.

Table 8: Role of Inflation Non-Neutrality

	Full Model	Infl. Neutrality NonDur	Dur	All
Yield Level:				
1y	6.14	6.16	6.11	6.06
3y	6.55	6.55	6.24	6.09
5y	6.91	6.86	6.35	6.13
Inflation Premium:				
1y	0.23	0.16	0.07	0.00
3y	0.66	0.43	0.20	0.00
5y	0.92	0.59	0.29	0.00
Equity Premium:				
Non-durable	3.95	2.22	1.90	1.81
Durable	7.07	5.65	3.11	2.71
Corr. with Exp. Infl. :				
Non-durable	-0.27	-0.10	-0.17	0.04
Durable	-0.33	-0.30	-0.03	0.02
Corr. with Bond Ret. :				
Non-durable	0.39	0.18	0.27	0.02
Durable	0.51	0.47	0.19	0.09

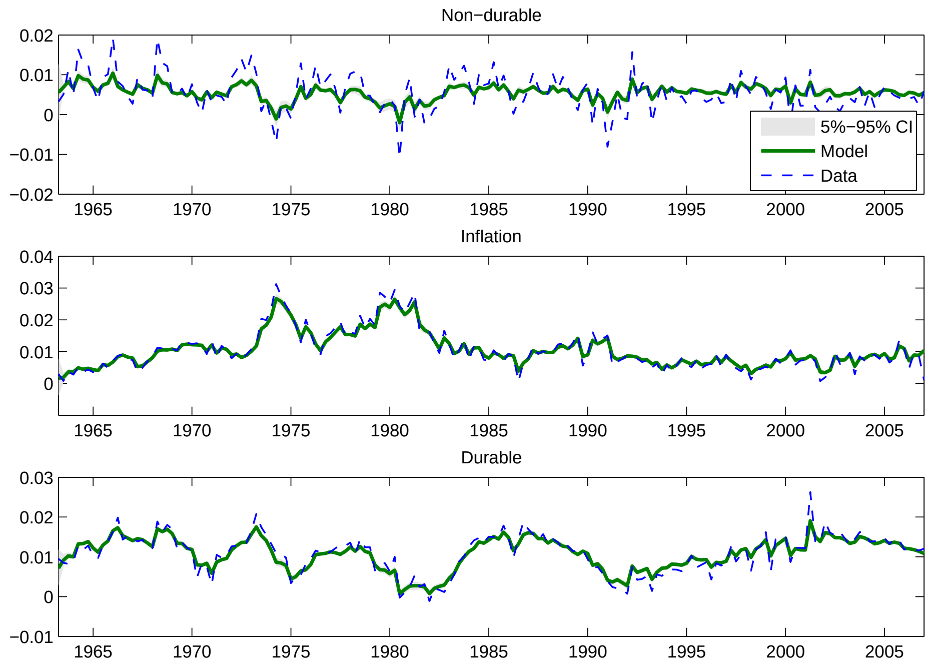
The table shows the impact of inflation non-neutrality on bond and equity moments in the model. Inflation neutrality specifications zero out the impact of expected inflation on expected non-durable consumption growth (NonDur), expected durable consumption growth (Dur), and both (All).

Table 9: Role of Preference Parameters

	Full Model	One Good $\chi = 0$	High ϵ $\epsilon = 1.5$	Low ψ $\psi = 0.05$
Mkt Price of Risk:				
Exp. Nondur	11.68	21.45	11.68	-3.94
Exp. Dur	48.10	0	48.10	-9.07
Exp. Inflation	-75.76	-34.65	-75.76	6.08
1Y Yield Loadings:				
Exp. Nondur	2.44	1.24	1.15	18.83
Exp. Dur.	-2.53	0	0.19	26.50
Exp. Infl.	3.13	3.11	3.11	-6.99
Bond Premia:				
1Y	0.22	0.09	0.26	1.42
5Y	1.70	0.50	1.00	2.78
10Y	2.25	0.61	1.18	3.19
Equity Premia:				
Non-durable	3.95	1.78	2.87	1.01
Durable	7.07	5.05	8.59	0.98

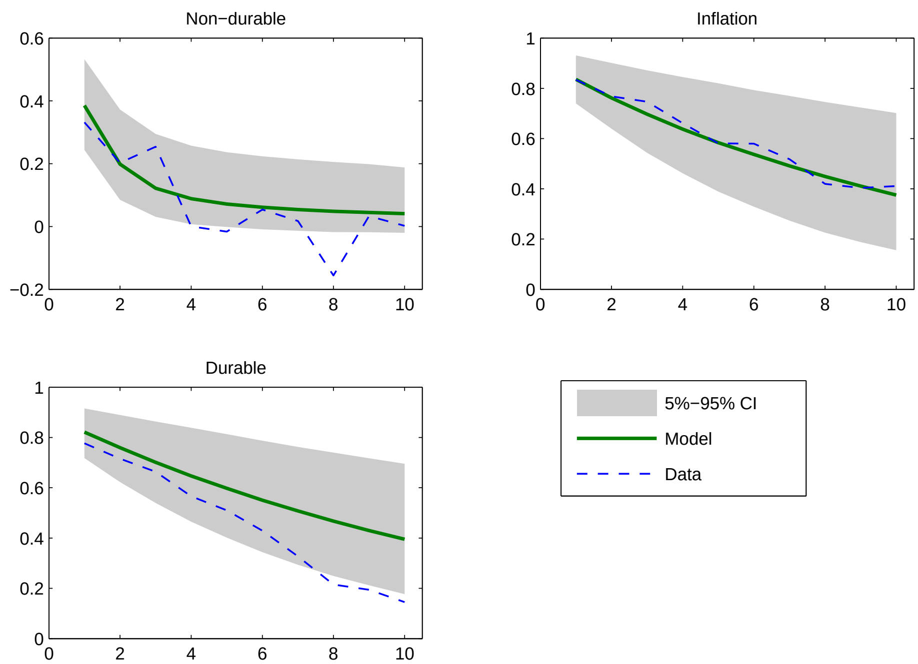
This table reports the impact of preference parameters on the market price of risk, yield loadings, and bond and equity risk premia. Results from the benchmark model (Full Model) are compared with outputs from models with one-good economy (One Good), or high intratemporal elasticity of substitution (High ϵ), or low intertemporal elasticity of substitution (Low ψ).

Figure 1: Realized and Filtered Macroeconomic Variables



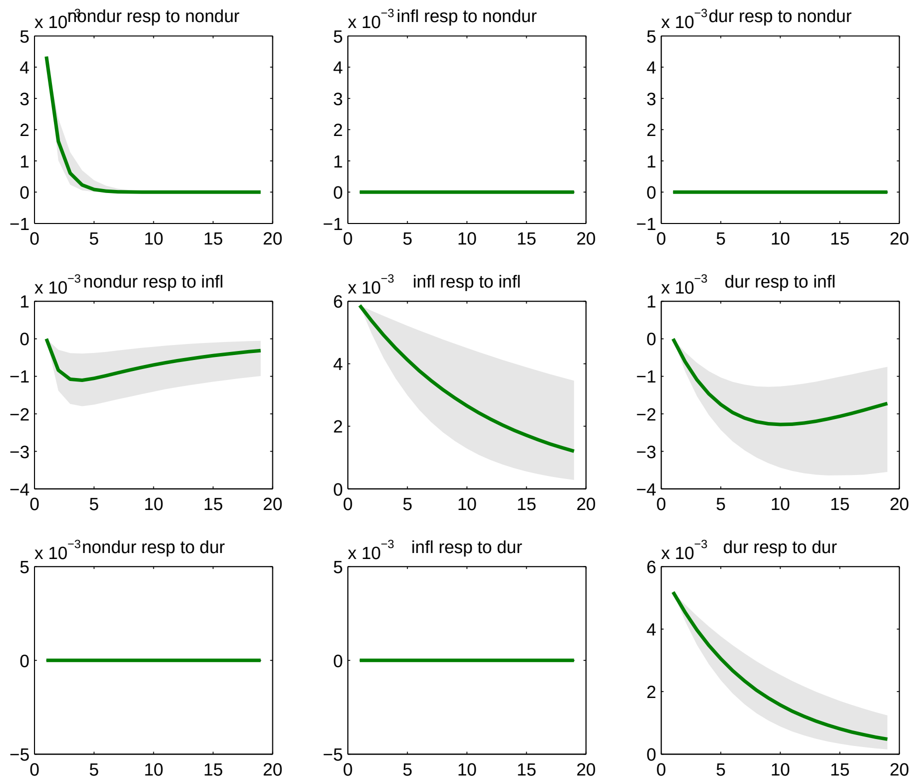
The figure shows the time series of realized (dashed line) and expected (solid line) non-durable consumption growth rate, non-durable inflation rate, and durable goods growth rate. Grey regions correspond to 5%-95% confidence interval.

Figure 2: Autocorrelation of Consumption Growth and Inflation



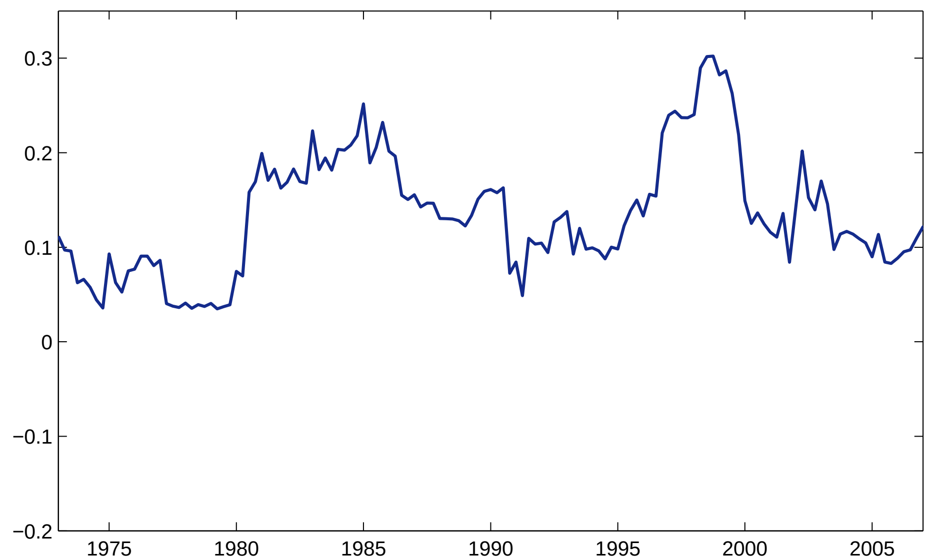
The figure shows the autocorrelation functions of non-durable and durable consumption growth and non-durable inflation rate in the data and implied by the estimated model. Quarterly observations from 1963Q1 to 2006Q4.

Figure 3: Impulse Response of Expected Growth Shocks



The figure shows the impulse response functions for shocks to expected non-durable consumption, expected durable consumption and expected non-durable inflation, based on the estimated benchmark model. Grey regions correspond to 5%-95% confidence interval.

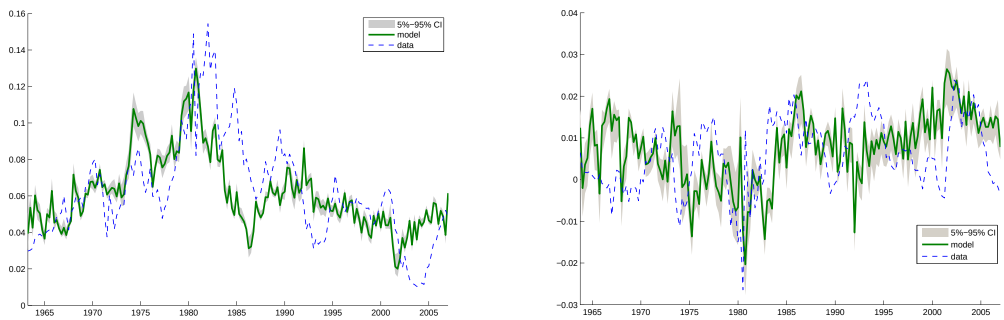
Figure 4: Correlation of Equity with Bond Returns in Durable Relative to non-durable Sector



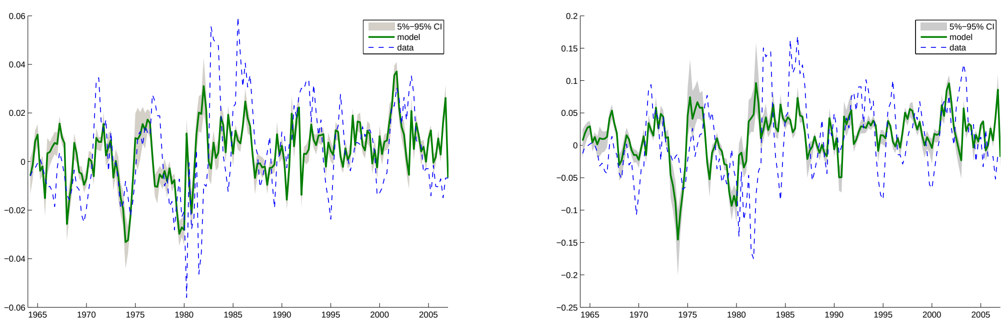
The figure shows the difference between the correlation of the excess returns on durable portfolio and two-year nominal bond and the correlation of the excess returns on non-durable portfolio and two-year nominal bond. The correlations are computed using a 10-year rolling window.

Figure 5: Nominal Bond Prices: Data and Model

One-Year Yield and Five-Year Term Spread:

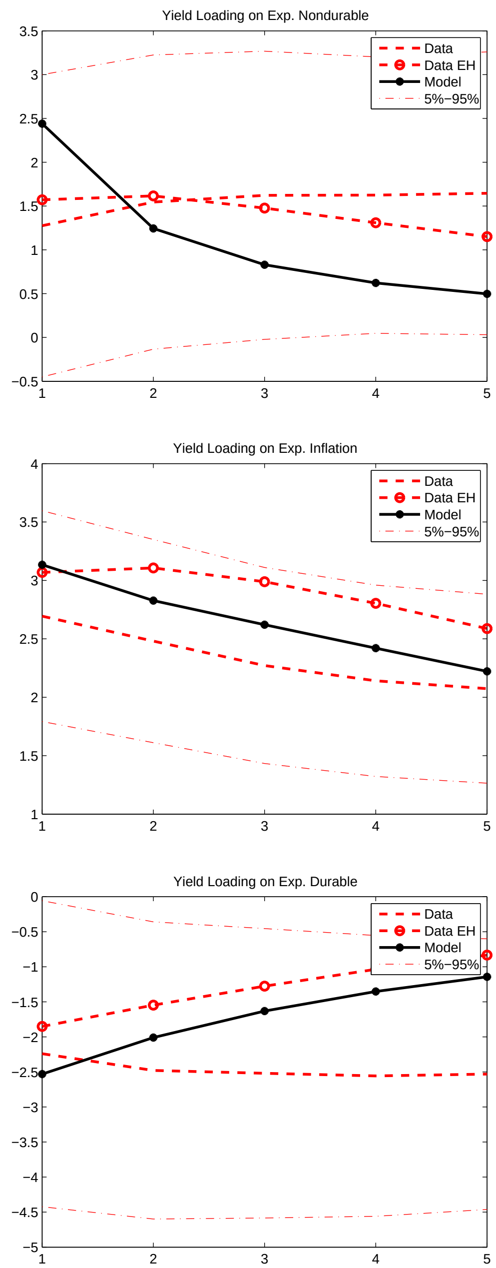


Two- and Five-Year Bond Excess Returns:



The figure shows data and model implications for bond yields and bond excess returns. Top panel shows the time series of one-year nominal yield (left) and five-year term spread (right). Bottom panel shows the time series of two- and five-year nominal bond excess returns. The data is plotted in dashed line and the model-implied time series is plotted in solid line.

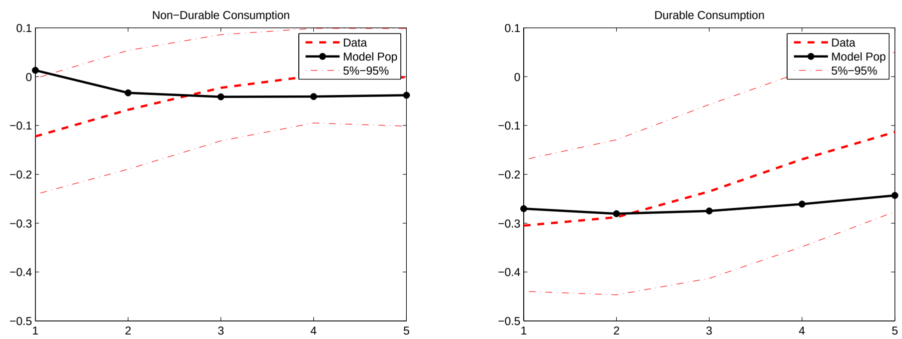
Figure 6: Yield Loadings



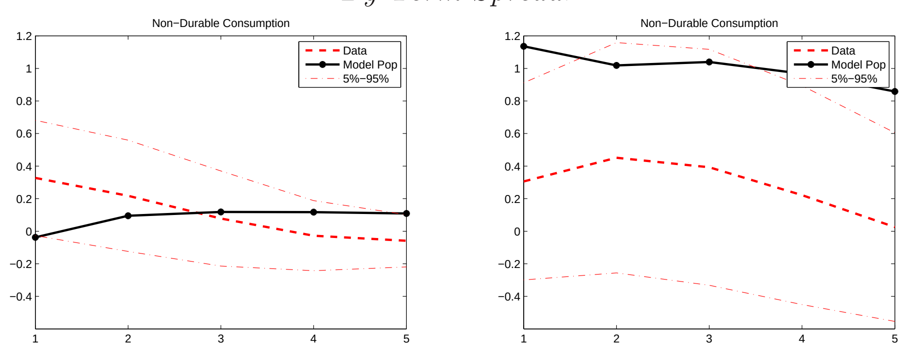
The figure shows the bond loadings on expected non-durable growth (top panel), expected inflation (middle panel), and expected durable growth (bottom panel). Solid line shows bond loadings in the model, dashed line represents bond loadings in the data, and circles show the loadings of the Expectation-Hypothesis component of observed yields in data. 95% confidence interval is based on standard errors in the data.

Figure 7: Model Implications for Consumption Growth Predictability

By Short Rate:



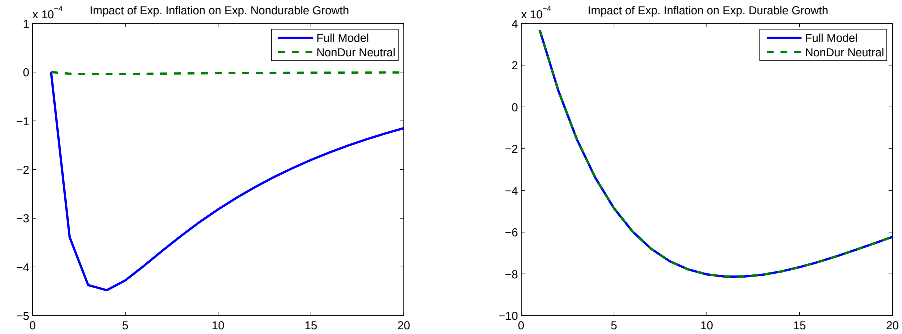
By Term Spread:



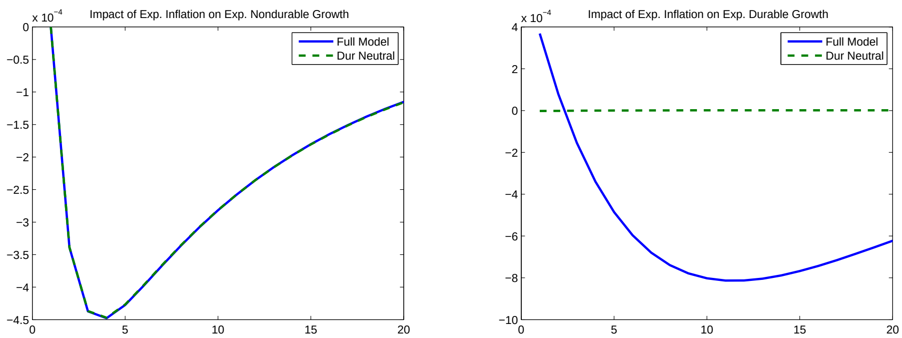
The figure shows the data and model-implied slope coefficients in the regressions of future consumption growth of non-durable goods (left) and durable goods (right panel) on short-term interest rate (top panel) and the term spread (bottom panel). Solid line shows bond loadings in the model, and dashed line represents bond loadings in the data. 5%-95% confidence interval is based on standard errors in the data.

Figure 8: Impulse Responses in Restricted Models

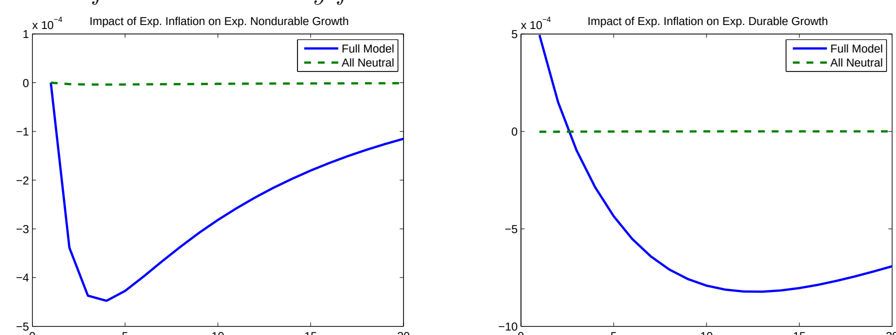
Inflation Neutrality for non-durable Growth:



Inflation Neutrality for Durable Growth:



Inflation Neutrality for non-durable and Durable Growth:



The figure shows impulse responses of expected non-durable growth (left) and durable growth (right) to expected inflation shocks. Top panel compares impulse responses in the full model to the restricted model with non-durable growth inflation neutrality; middle panel shows the results for the durable growth inflation neutrality; and the bottom panel where inflation is neutral both for non-durable and durable growth.