Durable Goods, Inflation Risk and the Equilibrium Asset Prices

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Abstract

High inflation predicts a decline in future real consumption and equity cash-flows, and the inflation non-neutrality is stronger for durable than for non-durable goods. This suggests that durables is an important channel through which inflation affects long-term aggregate growth and ultimately, asset prices. We derive and estimate an equilibrium two good nominal economy with recursive utility over durable and nondurable consumption, persistent variations in real expected growth and inflation, and inflation non-neutrality. Our model can quantitatively account for the unconditional moments and conditional movements in prices of nominal bonds and equity in durable and nondurable sectors. In the model, as in the data, durable equities earn higher risk premia, correlate more negatively with expected inflation and more positively with returns on bonds than nondurable stocks. We show that two-good structure, early resolution of uncertainty and inflation non-neutrality play the key role to explain these data features.

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1 Introduction

Empirically, the consumption and output of durable goods is more sensitive to economic fluctuations than of non-durable goods. It is intuitive that consumers would hold off on the purchase of a durable good, such as a car, in response to an adverse economic shock, rather than non-durable goods such as food. In structural economic models, the level and the difference in the exposures of durables and nondurables growth to aggregate shocks have important implications for the equilibrium valuations of financial assets, as shown, for example, in Yogo (2006) and Yang (2010) in the context of real two-good consumption-based economies. In this paper, we focus on the inflation-premium channel which arises from a long-run negative impact of inflation on real durable cash-flows, and show that it plays a significant role to account for the unconditional levels and the conditional dynamics of the nominal bond and equity prices of the durable and nondurable good producing firms.

There are several empirical observations that lead us to believe that durable growth and its interplay with inflation is important in explaining the asset markets:

- Shocks to durable consumption growth are significantly more persistent that shocks to non-durable consumption growth.
- Long-term durable growth is more sensitive to shocks in inflation than non-durable. In particular, we show that higher inflation has a more adverse impact on future consumption of durables and on future cash-flows of durable-producing firms, relative to consumption of non-durable goods and cash-flows in non-durable producing sectors.
- Movements in the nominal yield curve predict future real consumption growth of durable goods. The predictability is stronger for durables than for non-durables.

The first point, which is consistent with the evidence in Yogo (2006) and Yang (2010), suggests that fluctuations in durable goods constitute an important risk factor for an investor, in addition to non-durables, due to their longer-lasting impact on the economy. The second point implies that inflation is a bad news for long-run durable growth, which gives rise to a significant inflation risk premium component that impacts the valuation of financial assets. Finally, our last observation suggests that the asset markets contain separate information about durable and nondurable growth.

These findings motivate the specification of our economic model which explicitly introduces durable and nondurable consumption and a non-neutral effect of inflation on real durable and nondurable growth.

Specifically, our model is based on a nominal two-good extension of the long-run risks specification of Bansal and Yaron (2004). The key ingredients of our model are recursive utility with a non-separability between durable and nondurable goods in the preferences, persistent fluctuations in expected growth rates, and non-neutrality of inflation for future consumption. In the benchmark model, investors are concerned about the fluctuations in expected non-durable consumption, expected durable consumption, and expected inflation. Specifically, the negative shocks in expected consumption of durables and nondurables and positive shocks in expected inflation represent bad states for the investor, so the market prices of expected growth risks are positive and the market price of expected inflation is negative.

As in a standard one-good model, equilibrium prices of risk-free assets hedge fluctuations in expected consumption of nondurables, which contributes negatively to the term premium and the slope of the real term structure. However, when the two goods are relatively hard to substitute, a risk-free claim to nondurable consumption becomes more valuable when expected durable growth is high. The risk-free bond is now risky with respect to the fluctuations in expected durable growth, which contributes positively to the term premium and the slope of the real term structure. We show that when the durable channel is strong enough, the implied real term structure can be upward sloping. In addition to these real channels, the equilibrium prices of nominal bonds are further affected by the interaction of expected inflation with real growth. Nominal bond prices fall and nominal yields rise at times of high expected inflation, which are bad states of the economy as they signal low growth of future durable and nondurables consumption. This leads to a positive inflation premium on nominal bonds, a significant amount of which, we show, arises through the durable channel. Finally, we provide a parsimonious model of the equity dividend claims in durable and nondurable producing sectors as a levered consumption on durables and nondurables respectively. We show that as durable consumption is more persistent and more sensitive to inflation, this makes equity returns for durable firms to be more exposed to risks in expected durable and expected inflation. In the model, durables are riskier than nondurables, and further, they react more to shocks in inflation and correlate more with returns on bonds relative to nondurable equities.

We estimate the model to further validate its economic channels and disentangle the contribution of its economic inputs. Our model of the macro-economy can be seen as a VAR(1) model of the three expected growth components. We estimate this model using Bayesian methods for sampling on the posterior of the parameter space. Our benchmark estimation is a two-stage estimation of the model. In the first stage, we estimate the model parameters and extract the latent states that govern the dynamics of macro variables using only the time series of observable macro variables. In the second step, we estimate the preference parameters using nominal bond yield data and calibrate the dividend leverage parameters for the equities. Thus, the estimation of macro dynamics is independent of the equilibrium model specification and based only on the observed macro data. Hence, the implications for the term structure can be viewed as effectively "out-of-sample." As a robustness check, we also conduct a joint estimation of the model by estimating both macro and preference parameters in one stage using macro and yield data.

We find that our macroeconomic model captures the observed macroeconomic data very well. Expected growth rates are estimated to be persistent with an autocorrelation of 0.41 for expected non-durable growth, 0.92 for durable growth, and 0.94 for inflation. Inflation shocks have a negative impact on non-durable consumption, and a significantly larger and more permanent impact on durable consumption. The preference parameters are estimated in the second step from the term structure data; the estimated risk aversion coefficient is about 24 on quarterly frequency, and the intertemporal elasticity of substitution is about 2.6. At these preference parameters, we find that the model can explain the unconditional and conditional features of the nominal yields in the data quite well.

Our model features an upward sloping nominal term structure. The positive slope is due to an inflation risk premium, and a large portion of this premium comes through the durable channel. Our general model matches exactly the average term spread of 60 basis point we observe in the data. Restricting the specification to a one good economy decreases the spread from 60 basis points to 11 basis points. Further, we show that model-implied equilibrium bond yield loadings on expected non-durable, expected durable consumption and expected inflation match their estimates in the data very well. In particular, the bond yield loading on expected durable consumption is negative both in the model and in the data; this, we show, cannot be obtained in the restrictions of the models to one non-durable consumption good, or in the case of expected CRRA utility. The implied real term structure is U-shaped when the real bond is defined to pay one unit of non-durable consumption.

In the model, as in the data, durable equities are riskier and require higher risk premium compensation despite the fact that the dividend leverage parameter is higher for nondurables. In our benchmark model, durable equity premium is 6.7% relative to 4.5% for the nondurables and 5.0% for the average market, which compares well to the estimates in the data of 6.8%, 5.8% and 5.9%, respectively. High riskiness of the durable equities also leads to a higher unconditional volatility of stock returns and lower levels of the price-dividend ratio. In the model, the standard deviation of excess returns in a durable sector is 18.1% while the standard deviation of a nondurable equities is 6.4% lower and is equal to 11.7%. In the data, the volatility of durables is 21%, and the gap between the volatility of durables and nondurables of 6.4% is exactly the same as in the model. Finally, as both bond and equity prices fall in high expected inflation times, our model predicts that excess stock returns should have a negative correlation with inflation and a positive correlation with bond returns, and this effect is more pronounced for durable portfolios which are more exposed to inflation risk. These model predictions are supported by the data. The correlation of excess returns with shocks in expected inflation, is -0.41 for the durable equities, relative to -0.32 for nondurables and -0.22 for the average market. In the model, this correlation is -0.23 for the durables which is higher than -0.18 for the nondurable returns. For stock and bond returns, the correlation of durable portfolio excess return with 2-year nominal bond returns is 0.53 in the data, relative to 0.38 for nondurables and 0.32 for the market. In the model, the corresponding correlations are equal to 0.59 for durables, 0.13 for non-durables and 0.31 for the market, which match the data quite well. Similar to the nominal bond markets, the recursive utility and two-good structure play an important role to match the level and the signs of these effects in the data.

Our paper is connected to the extant literature in a number of ways. Early empirical work, such as Fama (1975) and Fama and Schwert (1977), show that nominal bond yields move approximately one-to-one with inflation[1]. Fama and Schwert also show that stock returns are contemporaneously negatively correlated with shocks to expected inflation, consistent with evidence in Chen, Roll, and Ross (1986). This ev-

[1]The so-called Fisher hypothesis, that interest rates move one-to-one with inflation is consistent with a neutral role of money. A more recent empirical literature challenges this finding, see Coorey (2002) for a literature review.

idence is also broadly consistent with recent regression evidence in Bekaert and Wang (2010) where stocks are shown to be negatively correlated with changes in expected inflation in a sample of international stock markets. Boudoukh and Richardson (1993) show that long horizon nominal stock returns are positively related to long horizon inflation.

The observed negative correlation between stock returns and expected inflation is suggestive of a non-neutral role of money. Fama and Gibbons (1982) find a negative relation between expected inflation and real interest rates. Fama (1990) uses the nominal term structure slope to forecast inflation. He finds that the term structure can be utilized to forecast long, but not short, horizon changes in inflation. Theoretical models that explore non-neutrality of money have been explored by Stulz (1986), Pennachi (1991), Marshall (1992a), Sun (1992), and Bakshi and Chen (1996), among others.

There is a large literature on reduced form term structure models with latent risk factors. This literature (see for example Singleton (2006) for a review) tend to suggest that multiple factors, perhaps as many as four, are needed to characterize the yield curve. Our paper is part of the recent literature attempting to bridge the latent factor literature to interpretable factors such as expected real growth, expected inflation, output-gap, growth volatility etc. In particular, Bekaert and Grenadier (2001), Wachter (2006), Gallmeyer, Hollifeld, Palomino, and Zin (2009) and Ehling, Gallmeyer, Heyerdahl-Larsen, and Illeditsch (2012) develop models with exogenous habit, or preference shocks. These models contain a single unobservable factor interpretable as a habit or taste shock factor in addition to observable macro factors. Bekaert, Ang, and We (2008) propose a three factor model of which two factors are latent and one is the observed inflation. Drift and volatility of these factors follow a regime switching process, aka Dai, Singleton, and Yang (2007).

Our paper is connected to the earlier literature on multiple consumption goods including the term structure papers by Eichenbaum and Hansen (1990), Dunn and Singleton (1986), and Ogaki and Reinhart (1998). While most of this literature is based on additive utility specifications, Dunn and Singleton (1986), using term-structure data, find evidence against a specification of expected non-separable utility over durables and non-durables. Erceg and Levin (2006) study optimal monetary policy in the presence of durable and non-durable goods using an exogenous interest rate.

Our approach follows the recent long-run-risk paradigm of Bansal and Yaron (2004). Thus, preferences are described by the general recursive preferences of Kreps and Porteus (1978), Epstein and Zin (1989) and Weil (1989) over future consumption of the two goods. Papers that analyze yield curve implications of long-run consumption risks include Bansal and Yaron (2004), Piazzesi and Schneider (2006), Eraker (2006), Bansal and Shaliastovich (2011), Doh (2010), Hasseltoft (2011), and Le and Singleton (2012). Ulrich (2011) shows that real term structure can become upward sloping in ambiguity model. In the context of general equilibrium long-run risks type models, Yang (2010) specifies a model where non-durable consumption is a random walk and durable consumption has a persistent, long run risk component. Yang (2010) calibrates his model to the unconditional moments of equity markets and notes that his model produces an upward sloping average real yield curve. Fillat (2010) and Ready (2010) use a similar framework to address the importance of housing consumption risks and oil consumption risks, respectively. Pakos (2007) highlights the implications of a high intratemporal complementarity between non-durables and durables for the asset prices and risk premia, and shows that with a preference for early resolution of uncertainty, the durable good channel goes a long way to explain the equity premium, the risk-free rate puzzle and size and value puzzles. Colacito and Croce (2011) study the implications of a two good economy in the international context. Yogo (2006) uses the stochastic discount factor implied by the recursive preference structure to study the cross-section of asset returns, while Lustig and Verdelhan (2007) explores it in the cross-section of currency returns. Guo and Smith (2010) show the implications of the long-run risks in durable consumption for the U.K. financial markets. Gomes, Kogan, and Yogo (2009) addresses the implications of durability of goods for the cross-section of asset returns in a production setting. These papers do not focus on the implications of durable risks for the term structure of interest rates.

The paper is organized as follows: the next section presents the preference model setup, and the equilibrium solution to the model. In Section 3, we present and solve a benchmark model of the economy to highlight the qualitative role of the durable risk channel. Section 4 focuses on the empirical estimation results and model implications for the term structure. Section 5 concludes the paper. Model derivations are given in the Appendix.

2 Empirical Motivation

2.1 Data

We collect quarterly data on nominal expenditures on non-durable goods and services, nominal durable goods expenditures, and non-durable and durable good price levels from the Bureau of Economic Analysis (BEA) from 1963Q1 to 2009Q4. Since the BEA only reports the year-end durable good stock levels, we back out the quarterly durable good stock level using the depreciation and expenditure data as in Yogo (2006). Aggregate nominal service flows are deflated by the appropriate price levels and divided by the the total population to yield the real service flow per capita. The growth rates of consumption and the inflation exhibit strong seasonality at quarterly frequencies, which we remove from our data. The data on nominal bond prices of zero-coupon US Treasures come from CRSP. We further collect the price and dividend data for the broad market index and for the portfolios of nondurable and durable equities. The construction of durable and nondurable portfolios follows Gomes et al. (2009), who identify these sectors based on the industry classification. [2]

Table 1 presents basic descriptive statistics for our aggregate macroeconomic data. The mean of non-durable consumption growth over the sample is 2%, annualized, while the average growth of durable consumption is 4.4%. The inflation of nondurable goods prices is equal on average to 4.2%, and its standard deviation is 1.3% relative to the 1% for both non-durable and durable consumption growth. Consumption growth rates of nondurables and durables are positively correlated with a correlation coefficient of 0.33, while the correlations of contemporaneous inflation rate with real growth rates are negative and equal to -0.16 for nondurable and -0.03 for durable consumption. Interestingly, while there is only a weak evidence for a negative co-movement between real growth rates and inflation contemporaneously, there is a significant long-run impact of inflation on future long-term cash-flows, which is more pronounced for durable growth. We discuss this evidence in the next section.

[2] Gomes et al. (2009) consider nondurable and durable services separately. We aggregate the returns on the two sectors into a single nondurable portfolio using value weights. Results using equal weights are similar, and in many cases even stronger than for value weights.

2.2 Predictability of Economic Growth

The key empirical motivation for our paper is that in the data, long-term real cash-flows are predictable and respond negatively to inflation, and such a non-neutrality of inflation for future growth is significantly more pronounced for durable relative to nondurable cash-flows.

Indeed, as shown in Table 1, while both nondurable and durable consumption growth rates are persistent in the data, the shocks in consumption growth of durables are significantly more long-lasting: the first-order autocorrelation of durable consumption growth of 0.76 is much larger than 0.42 of non-durables and is almost the same as 0.78 of inflation rate. The persistence of shocks in durable consumption growth decays slowly over time, as shown in Figure 1. For durable consumption growth, the autocorrelation coefficients remain positive and significant up to ten quarter horizon, while the autocorrelation coefficient of non-durable consumption growth becomes insignificant at about one year. This evidence of a high persistence in durable consumption is consistent with the findings in Yang (2010).

We further find that in the data, there is a substantial evidence for a long-run interaction for non-durable and durable growth rates with the inflation rate. To measure these interactions, we regress cumulative average cash-flow growth on the current inflation rate:

$$\bar{g}^i_{t\to t+h} = const + b^i_h \pi_t + error_{t\to t+h}, \tag{1}$$

where $\bar{g}^i_{t\to t+h}$ stands for an average future cumulative real growth over $h-$quarter horizon, and π_t is the inflation rate. We report the predictability evidence for non-durable and durable consumption in Table 2. As shown in the Table, the slope coefficients are all negative and significant, which suggests that high current inflation has a non-neutral and adverse effect on future real growth. Our findings of inflation non-neutrality for nondurable consumption is consistent with the evidence reported in Piazzesi and Schneider (2006) and Bansal and Shaliastovich (2011). The novel evidence that motivates this paper is that inflation is also non-neutral for durable consumption, and the inflation effect on durables seems much stronger than for non-durables. Indeed, the slope coefficient in non-durable consumption regressions is -0.80 for a one-year horizon, and it uniformly decreases in absolute value with the regression horizon to -0.14 at 5 years. The R^2s in these regressions decrease from 17% at one year to 2% at five years. For durable growth, the inflation slope coefficient is -0.73 at a one-year horizon. It increases to -1.14 at three years at which point it is almost three times as large as the corresponding coefficient in non-durable consumption regressions, and it finally decreases to about -0.93 at a five-year horizon. The R^2's in the durable consumption regressions reach 25% at 3 to 5 year horizons. That is, while inflation is bad news for both non-durable and durable consumption, it affects future consumption of durables much more than that of non-durables. Intuitively, because durable purchases are long-lasting, they respond more significantly to price fluctuations relative to non-durables which are consumed in the same period. This is consistent with Erceg and Levin (2006) who point out that durable goods purchases are more sensitive to interest rates than are non-durables.

We obtain similar evidence for inflation non-neutrality using the data on real dividends of durable and non-durable equity portfolios of Gomes et al. (2009). Overall, the dividend data are much noisier than consumption; indeed, the volatility of dividends is 10 to 20 times higher than the volatility of aggregate consumption. Further, dividends exhibit significant seasonality at high frequency. To mitigate these issues, we aggregate dividends to an annual horizon and perform our analysis at an annual frequency. Table 3 shows the projections of average cumulative dividend growth rates on inflation. Future durable dividend growth respond negatively to the news of higher inflation: the slope coefficient is -2.60 at one-year horizon, -1.24 at 3 years and it drops to -0.49 at a five-year horizon. As dividends are quite noisy and the regression frequency is annual, the estimates are less precise than for the consumption regressions, and are not significant beyond 3 years. The effect of inflation for nondurable sector dividends is also negative but is much weaker relative to durables. Indeed, the slope coefficient for nondurable dividends is -0.36 at one year, -0.13 at 3 years and it is 0.05 at five years. None of these coefficients are significant, and the R^2s do not exceed 1%. We further show the results for the projection of the future market dividends on current inflation. Naturally, the estimates of slope for the market dividends are in between those for the durable and nondurable sectors. The slope coefficient is negative and equal to -1.02 at 1 year horizon, and it drops to -0.32 at five years.

For robustness, we verify that our findings of a pronounced effect of inflation on future growth also hold using alternative measures of sector performance. For example, the slope coefficient in the regression of one-year future real sales growth on inflation is -1.24 (0.31) for a durable portfolio relative to -0.54 (0.24) for nondurables, and the R^2 of 28% for durables is almost 3 times as high as that for nondurables. At 3-year horizon, the slopes are -0.64 (0.21) for durable portfolio and -0.58 (0.19) for nondurables; after three years the estimates are insignificant. Similar results obtain using the growth rate of earnings of the portfolios as a measure of sector growth.

We further find that long-term movements in real growth are related to the asset markets in the data, and durable consumption is more predictable by the asset prices than nondurable consumption. Specifically, we regress the cumulative average consumption growth on a nominal short rate. As shown in Table 2, for non-durable consumption an increase in yield predicts a fall in non-durable consumption growth up to a three-year horizon, and the effect becomes insignificant afterwards. The R^2's in the regressions is 9% at a one-year horizon, and it decays to zero after three years. On the other hand, interest rates significantly and negatively forecast future durable goods growth. The regression slope coefficient is -0.24 and -0.13 at one-year and five-year horizons, respectively, and the R^2's increase from 15% at one-year to 20% at two and three years. Interestingly, the predictability of future durable growth by interest rate is not entirely due to the inflation component in nominal yields. Indeed, as shown in the lower panel of Table 2, in multivariate regressions of future durables on both the short rate and the inflation rate, the slope on the yield remains negative and significant up to three-year horizon, while the slope coefficient for non-durable consumption is insignificant and turns positive at three years. Our findings on the relative predictability of future durable consumption relative to non-durable consumption by the nominal rates complement earlier evidence by Yogo (2006) and Yang (2010) in the case of price-dividend ratios.

To sum, our results suggest that 1) durable consumption is more persistent than nondurables; 2) inflation impacts long-term real growth in the economy, and its effect on durable cash-flows is more pronounced than on nondurables, and 3) asset prices, such as nominal interest rates and price-dividend ratios, contain information about future long-term growth on long-term growth, and more so in the case of durables. These empirical findings motivate our structural asset-pricing model which explicitly introduces durable and nondurable consumption and a non-neutral effect of inflation on real growth, that can operate both through the durable and nondurable cash-flow channel. We use our equilibrium model to understand the implications of these economic channels on the pricing of nominal bonds and equities in durable and non-durable sectors, and their link to aggregate macroeconomic variables and each other.

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 Epstein and Zin, 1989; Kreps and Porteus, 1978):

$$U_t = \left[(1-\beta) u_t^{1-\frac{1}{\psi}} + \beta \left(E_t U_{t+1}^{1-\gamma} \right)^{\frac{1-\frac{1}{\psi}}{1-\gamma}} \right]^{\frac{1}{1-\frac{1}{\psi}}}, \tag{2}$$

where U_t is the life-time 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 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); Yang (2010)). Unlike the nondurable 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 :

$$S_t = (1-\delta) S_{t-1} + E_t. \tag{3}$$

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

$$u(C,S) = \left[(1-\alpha) C^{1-\frac{1}{\epsilon}} + \alpha S^{1-\frac{1}{\epsilon}} \right]^{\frac{1}{1-\frac{1}{\epsilon}}}. \tag{4}$$

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. In our paper, we use a standard specification of preferences which feature a homothetic utility function and constant preference weights to two consumption goods. Pakos (2005) and Ready (2010) consider the extension of the model to non-homethetic preferences and show its implications for the equilibrium asset prices.

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 total wealth $R_{c,t+1}$:

$$M_{t+1} = \beta^{\theta} \left(\frac{Z_{t+1}}{Z_t} \right)^{\frac{\theta}{1-\frac{1}{\epsilon}} \left(\frac{1}{\psi} - \frac{1}{\epsilon} \right)} \left(\frac{C_{t+1}}{C_t} \right)^{-\frac{\theta}{\psi}} R_{c,t+1}^{\theta-1}. \tag{5}$$

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):

$$M_{t+1}^{Non-Dur} = \beta^{\theta} \left(\frac{C_{t+1}}{C_t} \right)^{-\frac{\theta}{\psi}} R_{c,t+1}^{\theta-1}. \tag{6}$$

Thus, relative to a one-good economy, the specification with two goods gives rise to an additional risk factor which captures the 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.

Specifically, the relative share of non-durable consumption of the agent Z_t is equal to:

$$Z_t = \frac{C_t}{C_t + Q_t S_t}, \tag{7}$$

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

$$Q_t = \frac{u_{st}}{u_{ct}} = \frac{\alpha}{1-\alpha} \left(\frac{S_t}{C_t} \right)^{-\frac{1}{\epsilon}}. \tag{8}$$

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:

$$R_{c,t+1} = \frac{W_{t+1}}{W_t - (C_t + Q_t S_t)}. \tag{9}$$

The consumption return is not the same as the stock market return as the total consumption of the agent is much larger than the dividends on the stock market. To solve for the endogenous consumption asset, we rely on a standard Euler condition which can be used to price any asset in the economy, including the return on the wealth portfolio:

$$E_t M_{t+1} R_{i,t+1} = 1. \tag{10}$$

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 nondurable consumption in units of a new numeraire. Then, we can price payoffs expressed in units of a new numeraire using standard Euler equation (10) under the numeraire-adjusted stochastic discount factor $\tilde{M}_{t+1}$,

$$\tilde{M}_{t+1} = M_{t+1} \frac{\tilde{\Pi}_t}{\tilde{\Pi}_{t+1}}. \tag{11}$$

We can use this result to solve for the equilibrium nominal prices of the assets. Indeed, denote Π_t the dollar price of non-durables. Then, the equation above defines the nominal discount factor which allows us to derive the nominal bond and equity prices.

3.2 Economy Dynamics

Denote g_t the vector of macroeconomic variables which includes non-durable log consumption growth, $\Delta c_t = \log(C_t/C_{t-1})$, non-durable log inflation rate, $\pi_t = \log(\Pi_t/\Pi_{t-1})$, and log growth rate of a stock of durables, $\Delta s_t = \log(S_t/S_{t-1})$. Following the long-run risks model (Bansal and Yaron (2004)), we model their dynamics by incorporating a time-varying expected growth component x_t :

$$g_{t+1} = \mu_g + x_t + \Sigma_g \eta_{t+1}, \tag{12}$$

where η_{t+1} is a three-dimensional vector of independent Gaussian shocks, μ_g is the vector of unconditional means of the variables, and Σ_g is the volatility matrix. The three-dimensional state vector x_t captures the persistent variations in expected growth of non-durable consumption, expected inflation and expected growth of durable stock. We model x_t as a flexible VAR(1) process:

$$x_{t+1} = \Pi x_t + \Sigma_x u_{t+1}, \tag{13}$$

where Σ_x is the volatility matrix and u_{t+1} is a three-dimensional vector of independent innovations in expected growth which are assumed to be uncorrelated with short-run news η_{t+1}. Π is the persistence matrix which captures the persistence and feedback effects between the expected growth rates of non-durable and durable consumption and expected inflation. In particular, an important feature of the data is a non-neutrality of inflation, so that an increase in expected inflation forecasts a decline in future expected consumption of durables and non-durables. Such an inflation non-neutrality operating both through durable and non-durable channels can be captured by our expected growth specification above.

Our two-good economy dynamics extends typical specifications of the model in the long-run risk literature. The original specification in Bansal and Yaron (2004) features a real economy with a single non-durable good. Bansal and Shaliastovich (2011), Eraker (2006), and Piazzesi and Schneider (2006) consider a nominal economy with a single consumption good and specify a bi-variate model for the dynamics of expected consumption and expected inflation. In the two good real economy of Yang (2010), the dynamics of durable and non-durable consumption are driven by a single expected growth component. In our specification of a nominal two good economy, we allow for separate processes in expected non-durable consumption growth, the expected durable consumption growth, and the expected inflation rate. We filter these expected growth rates out from the observed data using Kalman filtering.

For parsimony, in our model, the volatilities of all of the shocks in the economy are constant so that the asset price volatilities and the asset risk premia are constant as well. It is important to note that that the key focus of our paper is on the unconditional levels of the risk premia, their source as a durable versus non-durable consumption, and their unconditional implication for the levels of the nominal term structure and equities. To highlight these effects, we present a flexible model specification for the expected growth state x_t driven by homoscedastic shocks.[3]

3.3 Equilibrium Model Solution

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 A for the details), and we further log-linearize the relative share process[4]:

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

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.

The equilibrium price-consumption ratio is a linear function of the economic states x_t :

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

[3] Using calibrations we checked that adding time-varying macroeconomic volatility has second-order implications for the unconditional levels of risk premia and yields.

[4] 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)); these fluctuations are not likely to be important for the unconditional levels of prices which is the key focus of our paper. In Section 5.4, we further document that the approximation is quite accurate since the relative share of durables is quite stable in the data.

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 A. When the intertemporal elasticity of substitution ψ is above one, the substitution effect dominates the wealth effect. Hence, price of the consumption claim increases with a positive shock to expected non-durable consumption or long-run expected 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.

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. To gain further intuition on the sources and compensation for the aggregate risks in the economy, we can decompose discount factor loadings and the market prices of risks into the components related to non-durable and durable consumption state variables. Specifically, 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:

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

When the inter-temporal elasticity of substitution and risk aversion coefficient are above 1, the fluctuations in expected durable and non-durable consumption are risky and have positive market prices of risk. Indeed, under high inter-temporal substitution investor's wealth relative to consumption drops when either durable or non-durable growth is expected to decline (see equation 16), so the states with low expected consumption (nondurables or durables) lead to 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. Hence, relative to a one-good economy where only the risk to expected nondurables is priced, with multiple goods the shocks to expected durables also contribute to the risk compensation on the assets, which can be significant given a high persistence of durable consumption in the data. 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. The effects on market prices of risk arise in the economy with recursive utility when agents have preference for early resolution of uncertainty and the inter-temporal elasticity of substitution is high enough to dominate income effect. With an 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.

3.4 Equilibrium Bond 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.

In a multi-good 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 (2010) we consider a real bond which delivers one unit of nondurables in the future, and the price of the bond is expressed in units of nondurable 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 $p_{t,n} = \log P_{t,n}$ are linear in the economic states,

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

where the bond loadings depend on model and preference parameters. Specifically, consider the solution to a one-period risk-free rate:

$$y_{t,1} = const - m'_x x_t. \tag{22}$$

Following our discussion in the previous section, 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.

To highlight the intuition for the pricing of real bonds, consider the excess log return on buying an n month bond at time t and selling it at time $t+m$ as an $n-m$ period bond:

$$rx_{t+m,n} = -p_{t,n} + p_{t+m,n-m} + p_{t,m}. \tag{23}$$

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

$$\begin{aligned} E_t rx_{n,t+1} + \frac{1}{2}Var_t rx_{n,t+1} &= -Cov_t(m_{t+1}, rx_{t+1,n-1}) \\ &= -B'_{x,n-1}\Sigma_x \Sigma'_x \lambda_x. \end{aligned} \tag{24}$$

The bond risk premia capture the contribution of 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, $\Sigma_x \Sigma'_x \lambda_x$. It is well-known that in a single-good economy real bonds hedge news in expected consumption: the price of a real bond goes up when expected consumption is low, so that the real term premium and the slope of the real term structure are negative (see Campbell, 1986). In a two good economy, a price of a real bond is still a hedge to the risks in expected consumption of nondurables. However, when two goods are relatively hard to substitute, a risk-free claim to non-durable consumption becomes more valuable when expected durable growth is high. The risk-free bond is now risky with respect to the fluctuations in expected durable growth, which has a positive market price of risk and thus contributes positively to the real term premium and the slope of the real term structure. The total effect on the bond risk premium depends on the magnitude and persistence of expected growth risks and preference parameters. Overall, the durable risk premium component can play a significant role in determining the level of the risk premium and the shape of the real term structure relative to a single good economy.

The equilibrium price of nominal bonds and nominal bond risk premia are derived in an analogous way to the real ones in (21)-(29) using the solution to the nominal discount factor. In particular, in addition to a contribution from expected nondurable and durable growth risks, a significant component of the nominal risk premium now comes from the expected inflation shocks. Indeed, consider a Fisher-type equation for nominal bonds:

$$y^{\$}_{t,n} = y_{t,n} + E_t\pi_{t\to t+n} - \frac{1}{2}\frac{1}{n}Var_t\pi_{t\to t+n} + \frac{1}{n}Cov_t(m_{t\to t+n}, \pi_{t\to t+n}), \tag{25}$$

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, which leads to 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, and is discussed in Piazzesi and Schneider (2006) and Bansal and Shaliastovich (2011). 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.

Note that in expected CRRA utility, market prices of expected durable and non-durable risks, and expected inflation are all equal to zero. Therefore, up to Jensen's inequality term, all the bond risk premia are zero, and the term structure of interest rates is flat. Further, recall that all the shocks in our economy are homoscedastic, so that the risk premia do not vary over time. The extension of the model to stochastic volatility and time-variation in risk compensation, along the lines of Bansal and Shaliastovich (2011) and Hasseltoft (2011), is left for future research.

3.5 Equilibrium Equity Prices

To highlight model implications for the equity markets, we consider the most parsimonious representation of log real dividend growth of the form,

$$\Delta d_{i,t+1} = \mu_{i,d} + \phi_i'(g_{t+1} - \mu_g). \tag{26}$$

As in Abel (1999), the equity represents a levered claim on consumption, and for simplicity we do not entertain dividend-specific innovations independent from the fundamental consumption shocks. We consider three types of equities in the model, which are designed to capture durable equity portfolio, non-durable portfolio, and the market. For the durable portfolio, parameter ϕ_d has a zero loading on expected inflation and expected non-durable growth, and a positive leverage on expected durables. Similarly, for non-durable dividends ϕ_{nd} is zero everywhere except for the loading on non-durable growth. For the market portfolio, we set its dividend growth rate equal to the weighted average combination of nondurables and durables with a weight parameter χ, so that $\phi_m = \chi\phi_d + (1-\chi)\phi_{nd}$.

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

$$pd_{i,t} = H_{i,0} + H_{i,x}' x_t. \tag{27}$$

Similar to the price-consumption ratio in (16), the price-dividend ratios load positively on expected consumption of durables and nondurables, and negatively on expected inflation. The magnitudes of loadings depend on the model and preference parameters, such as the intra- and inter-temporal elasticity of substitution, persistence of the state variables and the dividend leverage ϕ. Indeed, consider a log-linearized solution for the price-dividend ratio on the portfolio:

$$\begin{aligned} pd_{i,t} &= const + E_t \sum_{j=1}^{\infty} \kappa_{1,i}^j \Delta d_{i,t+j} - E_t \sum_{j=1}^{\infty} \kappa_{1,i}^j r_{i,t+j-1} \\ &= const + \phi_i' E_t \sum_{j=1}^{\infty} \kappa_{1,i}^j \Delta g_{t+j} - E_t \sum_{j=1}^{\infty} \kappa_{1,i}^j y_{t+j-1,1}, \end{aligned} \tag{28}$$

where $\kappa_{1,i}$ is the log-linearization coefficient, and the last equation follows because in our model the risk premia are constant, so that the expectations of portfolio returns $r_{i,t+j}$ are equal to the expectations of future risk-free rates $y_{t+j,1}$. Thus, in our economy the difference in sensitivities of asset prices to economic states correspond to the difference in impact of the states on future equity cash-flows. Durable dividends have more persistent expected growth rates and are more sensitive to the fluctuations in expected inflation than non-durable dividends. Hence, prices of durable equities are expected to be more risky with respect to expected durable and expected inflation risk: they rise more at times of high expected durable growth and fall more in times of high expected inflation than non-durable equity.

The difference in risk of nondurable and durable equities has implications for the level of the risk premium and the co-movement between returns on stocks and bonds. Consider first risk compensation on equities:

$$\begin{aligned} E_t r_{i,t+1} - y_{t,1} + \frac{1}{2} Var_t r_{i,t+1} &= -Cov_t(m_{t+1}, r_{i,t+1}) \\ &= \kappa_{1,i} H'_{i,x} \Sigma_x \Sigma'_x \lambda_x + \phi'_i \Sigma_g \Sigma'_g \lambda_g. \end{aligned} \tag{29}$$

Durable equities are more sensitive to expected durable and expected inflation risk, and thus require a higher unconditional risk premium relative to non-durables. Further, negative loading of equities to expected inflation shocks leads to a negative correlation of returns with inflation state variables. As nominal bond prices and nominal bond returns also fall at times of high expected inflation, this implies that model-implied equity returns co-move positively with nominal bond returns. The correlations of equity returns with inflation and bond returns are more pronounced for the portfolios which are more exposed to inflation, that is, a durable portfolio.

To sum, our model, which features durable and nondurable consumption and inflation non-neutrality for future growth, delivers a wide range of unconditional and conditional implications for returns on nominal bonds and equity in durable and nondurable sectors. In the next section, we estimate the model and show that its equilibrium implications are consistent with the key features of the asset markets in the data.

4 Empirical Results

Our empirical evaluation of the benchmark model is carried in several stages. In the first stage, we estimate the model parameters and extract the latent states that govern the dynamics of macro variables in equations (12)-(13) using only the time series of observable macro variables. As using macro data alone does not allow us to identify preference parameters, given the first-stage estimates of the macro dynamics, we estimate preference parameters in the second step using the observations on yields, and calibrate the dividend leverage parameters. Thus, in the benchmark case the estimation of macro dynamics is independent of the structural model specification and based only on the observed macro data. This is economically appealing because 1) the implications for the term structure and equities are effectively "out-of-sample" and subject only to the choice of the preference and dividend leverage parameters; 2) the estimation of the macroeconomic model and the extraction of economic states using only the macro data is not affected by a possible mis-specification of the economic model; and 3) such an approach allows us for an easier comparison of alternative models keeping the fundamental macroeconomic dynamics unchanged. Naturally, ignoring yield information in the estimation of macro parameters is costly since it is hard to estimate precisely the small but persistent components in expected growth dynamics using macro data alone. As a robustness check, we therefore also conduct a joint estimation of the model by estimating both macro and preference parameters in one stage using macro and yield data.

4.1 Empirical Estimation

We carry out our first stage of estimation using Bayesian Markov-Chain-Monte-Carlo under uninformative (uniform) priors. The likelihood function is standard and is computed using Kalman filtering techniques; all the estimation details are provided in the Appendix. The advantage of Kalman filtering is that we recover estimates of the unobserved latent state-variables, x_i for $i = \{c, s, \pi\}$.[5] Bayesian MCMC algorithm also provides a posterior distribution of estimated parameters and latent variables which can be used to construct confidence intervals for the estimators. Importantly,

[5] We do not use the data on dividends in durable and nondurable sectors as these data are very noisy and only available at annual frequency.

we construct the estimates of the filtered state variables and the model parameters without using the financial markets' data.

Table 4 reports the parameter estimates of our model. Consistent with our earlier findings, expected durable consumption and expected inflation are more persistent than expected non-durable growth. The implied autocorrelation for expected non-durable growth is 0.41, relative to 0.92 for durable and 0.94 for inflation. Overall, the estimated model can very well match the magnitude of the persistence and the decay in the autocorrelations in the macroeconomic variables with the horizon, as shown in Figure 1. Inflation shocks have a negative impact on non-durable consumption and a significantly larger and more permanent impact on durable consumption: the VAR loading of expected non-durable consumption on the lag of expected inflation is -0.06, relative to -0.10 for expected durables. Because of a high persistence of expected durables and expected inflation, inflation non-neutrality is magnified even further at longer frequencies. To highlight dynamic multi-horizon interactions between the expected growth rates, we plot impulse response functions for the three expected growth shocks in Figure 2. A one-standard deviation shock to non-durable expected growth increases future non-durable consumption growth, but the impact disappears very quickly after a year. Shocks to nondurable expected growth do not have significant impacts on future inflation and durable growth. On the other hand, shocks to expected inflation are very persistent and significantly affect the economy for up to five years. Specifically, positive shocks to expected inflation lower both future nondurable and durable growth. The negative impact of inflation, however, is much stronger at all the horizons and much more long lasting for expected durable growth than for expected growth of non-durables, which confirms our earlier findings in Table 2.

Overall, our macroeconomic model captures very well the dynamics of macroeconomic variables in the data. As shown in Figure 3, the filtered expected states track closely data realizations. The expected non-durable growth predicts the next-quarter realized non-durable consumption with an R^2 of 10%. The R^2's in the regressions of the next-period durable consumption and inflation on their corresponding expectations are 59% and 54%, respectively.

In the first stage of estimation, we obtain the macroeconomic model parameters and the time series of latent expected growth variables. This step does not allow us to identify the preference parameters δ, ψ, γ and ϵ and the relative importance of durables χ. We follow Ogaki and Reinhart (1998), Piazzesi, Schneider, and Tuzel (2007) and Yogo (2006) and estimate the elasticity of intertemporal substitution ϵ from the regression of the user cost of durables on durable and non-durable consumption levels. Indeed, from the intratemporal condition for the user cost of durables in Equation (8) we obtain that

$$q_t = \frac{1}{\epsilon}(s_t - c_t), \tag{30}$$

which allows us to estimate the elasticity of substitution ϵ using the data measurements of user cost of capital and levels of goods. Our estimate of $\epsilon = 0.81$ agrees very well with the above studies. The durable parameter χ captures the relative expenditure of durable goods. We set χ to 15% which is equal to the average relative expenditure on durables in our sample.

For identification purposes, we fix the subjective discount factor at 0.996.[6] In our benchmark estimation, we choose the remaining preference parameters ψ and γ in the second stage of estimation by minimizing the mean-squared error (MSE) calculated from the 1 and 5 year model implied and historical yield data. That is, let Y_t^{data} denote the vector of 1 and 5 year yield observed in the data, and let Y_t be the equilibrium yields in the model. In the second step, we estimate preference parameters to minimize the squared pricing errors:

$$\min_{\gamma,\psi} \sum_{t=1}^{T} (Y_t - Y_t^{data})'(Y_t - Y_t^{data}). \tag{31}$$

We compute the standard errors on the preference parameters accounting for the estimation error from the first stage. In particular, we perform a parametric bootstrap where we simulate data of the same size as our sample. We then apply the same two-stage estimation approach as in the data and obtain a new set of estimated preference parameters. The standard errors are computed by the standard deviation of the preference parameters across a number of model simulations. The estimates of preference parameters are reported in Table 4. At quarterly frequency, the estimated inter-temporal elasticity of substitution is 2.56, and the risk aversion coefficient is 24.12. These estimates are similar to ones obtained by Bansal and Shaliastovich (2011) on quarterly frequency. Notably, the risk aversion coefficient is estimated very imprecisely. This reflects the fact that it is hard to estimate accurately persistent

[6]This is related to the discussion of identification issues in Kocherlakota (1990) and is similar to the approach in Marshall (1992b) and Bansal and Shaliastovich (2011).

risks from the macroeconomic data alone: a small decrease in the estimated persistence of durables and/or inflation would require a substantial increase in the risk aversion to match the slope of the term structure. Indeed, we show in Section 5 that risk aversion estimates become smaller and much more precise once we increase the share of durables in the economy. The precision of the risk aversion parameter also significantly improves in a one-stage estimation of the model.

4.2 Implications for Bond Prices

The model implications for nominal yields are reported in Table 5, while Figures 4 and 5 plot time-series of the short rate and term spread in the data and in the benchmark model. Unconditionally, our model matches perfectly the levels of 1 year and 5 year nominal yields, and the fit to 3-year yield is nearly exact as well. The volatilities of nominal yields are somewhat lower in the model (e.g., 1.9% in the model relative to 2.9% in the data for a 1-year yield); we show in Section 5.3 that the volatilities of yields in the model become much closer to the data in the joint macro-yield model estimation. Generally, the model-implied yields track the empirical yields in the data quite well, as shown in Figures 4 and 5. Some of the noticeable deviations of the model predictions to the data include the mid-eighties, where interest rates peaked significantly above what is predicted by our model, as well as the recent episodes in early and late 2000s, where the yields in the data were below the model predictions. These episodes have to do with particularities of the interest rate policies and the movements in the aggregate uncertainty which are outside our model, see Bikbov and Chernov (2008) and references therein for discussion.

Table 5 shows additional conditional implications of the model which we obtain by regressing a short nominal rate on the three filtered expected growth states. In the data, short term interest rates load positively on the expected non-durable growth and the expected inflation, and negatively on the expected durable growth. In our benchmark model, the signs and magnitudes of the bond loadings match the data quite well. Indeed, the slope coefficients on expected non-durable growth is 2.67 in the data compared to 2.25 in the model. The slope is 4.0 on expected inflation both in the model and in the data, and it is -1.31 on expected durables in the data relative to -0.69 in the model. These findings in the data are consistent with our earlier evidence for the predictability of future durable consumption growth by the yields (see Table 2): an increase in yields predicts a decrease in future durable consumption, even controlling for the current expected inflation in the economy. In the model, a negative response of yields to expected durable consumption is an important equilibrium implication which depends, among other things, on the magnitudes of elasticity of substitution parameters and the underlying preference structure. Indeed, as we discuss below, the negative response of yields to expected durable growth shocks cannot be obtained in a one good economy, or under the restriction of the preferences to power utility.

To highlight the role of the durable channel and the recursive utility for the nominal term structure, we first remove the durables from the preferences of the agent by setting their relative weight χ to zero. We refer to this model specification as $ND-EZ$ in the Tables. It is important to note that the dynamics of the macroeconomic variables is fixed through all the model variations, so all the changes in equilibrium asset prices are driven only by the change in the preference structure. In the recursive utility model specification based on a single non-durable good, the model can still generate an upward sloping term structure, but the term spread (11 basis points) is much smaller than in the data and in the full benchmark model (60 basis points). This confirms that a significant component of a positive risk premia on nominal bonds is a result of the durable channel. Notably, the one good version of the model can still deliver a sizable nominal bond risk premium if we increase the risk aversion coefficient to above 100 to magnify the inflation risk premium channel from the negative interaction between expected inflation and expected non-durable growth, as in Piazzesi and Schneider (2006).[7] However, in a single good version of the economy, the loading of short-term nominal yield on expected durable growth is zero at any risk aversion parameter, as shown in Table 5. That is, the non-durable model cannot capture an interaction between yields and durable consumption in the data.

To highlight the importance of recursive preference structure, we report the equilibrium implications for nominal yields in the expected CRRA utility case in a two good economy ('Dur-CRRA') as well as in a one good economy ('Nd-CRRA'). With power utility, the market prices of expected growth risks are all zero, so the risk premia on bonds are zero, up to Jensen's variance term. As shown in Table 5, the implied

[7]The preference parameter implications are subject to the first-stage estimation of the macro model, and in particular, of persistence of the expected growth states. Bansal and Shaliastovich (2011) use forecast data to better capture the fluctuations in expected growth and report reasonable values of preference parameters in one good economy.

nominal term structure is flat and somewhat downward sloping, and the differences in one- and two good CRRA economies are quite minor. Notably, the CRRA economy with durable goods leads to a positive equilibrium loading on the expected durable growth component: now the elasticity of intertemporal substitution $\psi = 1/\gamma$ is below the elasticity of intra-temporal substitution ϵ, so bond yields respond positively to a shock to expected durable growth. This is counterfactual in the data.

In our empirical implementation we focus on nominal yields as the data on real yields is not available for long maturities. To provide further intuition on the economic channels, we consider model implications on equilibrium real bonds which pay a unit of nondurable consumption. As shown in Table 6, in our benchmark model, the real yield curve is nearly flat and U-shaped: it is downward sloping from 1.7% to 1.67% from 1 to 3 year maturities, and becomes upward sloping and goes up to 1.75% at 10 year horizon. The non-durable channel contributes negatively to the risk premia and term spread on real bonds, and its effect dominates in the short run. Over the long run, the durable channel which contributes positively to the risk premium on real yields takes over and makes the real yield curve upward sloping. As shown in the Table, all model restrictions to a single-good non-durable economy and/or CRRA preferences predict a downward-sloping term structure of real interest rates.

4.3 Implications for Equity Prices

We calibrate the dividend growth rate in (26) to derive the model implications for durable and nondurable equities and the market portfolio. We set the dividend leverage parameters to target a wide range of empirical data features for the sector portfolios. Specifically, the durable dividend growth rate has a loading of 5 on expected durables and a nondurable dividend growth has a loading of 8 on expected non-durables; all other dividend loading parameters are set to zero for parsimony. For simplicity, the market portfolio in the model is the weighted average of the durable and nondurable equity with a weight of χ to the durables.[8] As the data counterparts on equity portfolios are all nominal, to derive equity values we price nominal log dividend growth $\Delta d_{i,t+1} + \pi_{t+1}$ using a nominal stochastic discount factor.

[8]In the data, the durable and nondurable portfolios do not comprise the total market as some industries and firms are left unclassified.

Table 7 shows the equilibrium model implications for equity returns alongside with the corresponding statistics in the data. As we discussed in Section 3, the key underlying intuition for equilibrium equity prices is that durable equities have a higher exposure to expected inflation and expected durable risk than nondurable equities, because expected durable growth rates are much more persistent and more sensitive to news about higher expected inflation. As durable equities are riskier, they require higher risk premia unconditionally. Indeed, in our calibration, durable equity premium is 6.7% relative to 4.5% for the nondurables and 5.0% for the average market, which compares well to the estimates in the data of 6.8%, 5.8% and 5.9%, respectively. Note that the durable risk premium exceeds nondurable risk premium even though the dividend leverage parameter is set at a higher value for nondurable portfolio. If the two dividend leverage parameters are the same, the difference between durable and nondurable equity premia becomes even more pronounced. High riskiness of the durable equities also leads to a higher unconditional volatility of stock returns and lower levels of the price-dividend ratio. In the model, the standard deviation of excess returns in a durable sector is 18.1% while the standard deviation of a nondurable equities is 6.4% lower and is equal to 11.7%. In the data, the volatility of durables is 21%, and the gap between the volatility of durables and nondurables of 6.4% is exactly the same as in the model. Recall that for simplicity our dividend specification abstracts from dividend-specific shocks. Adding them can easily increase the volatility of returns to match the empirical data. Finally, in the data the price-dividend ratio of durable portfolios is lower than the price-dividend ratio of nondurables, and the model can match the estimates in the data very well. Indeed, the log price-dividend ratios for the durables, non-durables and the market are 3.07, 3.31 and 3.27 in the data, compared to 3.01, 3.37 and 3.27 in the model.

In addition to the unconditional implications of the model, we further consider the conditional predictions of the model for the covariation of stock returns with inflation and bond returns. First, as equity prices fall in bad times, our model predicts that excess stock returns should have a negative correlation with inflation, and this effect is more pronounced for durable portfolios which are more exposed to inflation risk. These predictions of the model are qualitatively and quantitatively supported by the data. As shown in the Table 7, the correlation of excess returns with shocks in expected inflation, $Corr(r_{i,t+1} - y_{t,1}, x_{t+1} - x_t)$, is -0.41 for the durable equities, relative to -0.32 for nondurables and -0.22 for the average market. In the model, this correlation is -0.23 for the durables which is higher than -0.18 for the nondurable returns. For robustness, we check the results using the inflation rate itself in place of expected inflation. The signs and relative magnitudes of the correlations are the same and are similar in the model and in the data, while the overall magnitudes are smaller in absolute value.

Further, in the model, equity prices decrease with high expected inflation and increase with high expected durable growth, and more so for durable portfolios. As we showed in Section 4.2, nominal bond prices have the same sensitivity to these economic variables. This implies that excess bond returns and excess equity returns co-move positively in the model, and the degree of the co-movement is larger for durable portfolios. Table 7 shows that these model implications are supported by the data. Unconditionally, the correlation of durable portfolio excess return with 2-year nominal bond returns is 0.53 in the data, relative to 0.38 for nondurables and 0.32 for the market. In the model, the corresponding correlations are equal to 0.59 for durables, 0.13 for non-durables and 0.31 for the market, which match the data quite well. Our findings of an unconditionally positive bond and stock return correlations are consistent with the evidence in the literature (see for example Shiller and Beltratti (1993)). A novel aspect of our work is to show the difference in these correlations for durable and nondurable portfolios, which we can explain in the equilibrium model.

Recall that in our model, the economic shocks have constant volatility, so that all the conditional correlations are constant and do not vary over time. Guidolin and Timmermann (2006), Bekaert, Baele, and Inghelbrecht (2010), Campbell, Sunderam, and Viceira (2012) develop models of time-varying stock and bond inflation. We show the rolling-window estimates of these correlations of equity returns with expected inflation and bond returns on Figure 6. The decline in the correlation between bond and stock returns and a potential switch in its sign in 1990s is consistent with the evidence reported in this literature. Interestingly, however, in relative terms, the estimates of the durable equity return correlation with inflation is almost always more negative, while the estimate of durable equity return correlation with bond returns is almost always larger and more positive than for nondurables. So, in the data, the gap between conditional correlations almost always is of the same sign as delivered by our model.

The key model ingredients which allow us to account for the equity market evidence in the data are the two-good structure of the economy, recursive utility and the non-neutrality of inflation on future real growth operating through the durable growth channel. As shown in Table 7, when the economy is restricted to a single consumption good, the risk premia on durable portfolio drops below the premia for the durables, and similarly, all the correlations of equity returns with inflation and bond returns are closer to zero. With power utility, the model-implied unconditional values for the level and volatility of returns are significantly below the estimates in the data. Further, in expected utility the correlations between stock and expected inflation are now positive, which is counterfactual.

5 Robustness and Other Model Implications

5.1 Long-term Yields

As a robustness check we examine our model's implications for the equilibrium yields at very long maturities. The implied nominal yield at thirty-year maturity is 8%, while the real yield (based on non-durable consumption as a numéraire) is 1.87%. For a more comprehensive assessment of the long-term properties of the economy, we use an approach in Alvarez and Jermann (2005) to decompose the stochastic discount factor into a martingale and permanent component. Alvarez and Jermann (2005) show that the relative contribution of the variance of the permanent component to the total variance of the discount factor captures one minus the risk premium on a long-term bond with infinite maturity to the maximum risk premium in the financial markets. Empirically, the authors argue that this ratio should be close to one. Koijen, Lustig, Nieuwerburgh, and Verdelhan (2010) examine this ratio in the context of a single-good long-run risks model specification and conclude that it can impose a tight restriction on asset-pricing models.

In our benchmark model this ratio for a nominal pricing kernel is around 0.76, implying that the infinite horizon nominal bond risk premium is about 24% of the maximum nominal risk premium in this economy. The model-implied ratio for real discount factor is around 0.98, implying that the infinite horizon real bond risk premium is about 2% of the maximum real risk premium. These ratios are quite close to 1.

5.2 Macro-Yield Joint Estimation

To check the robustness of our findings, we consider a one-step estimation of the model where we use the macroeconomic variables and three yields at 1, 3 and 5-year maturity bond yields to jointly identify the macroeconomic model and preference parameters; see Appendix C for econometric details.

We report point estimates in Table B.1 in the Appendix. The estimate of preference parameters is very close to what we obtain in a two-stage estimation: the estimated risk aversion is 27.2, the intertemporal elasticity of substitution is 2.39. The preference parameters, and in particular, the risk aversion, is estimated much more precisely relative to a two-stage approach. Using yield information somewhat changes the point estimates of the macroeconomic dynamics parameters, however, their implications for the macroeconomic data are quite similar to a two-stage estimation. The two methods further produce quite similar filtered sequences of expected growth variables. The correlation between two extracted expected inflation states is about 70%, and the correlation between the two time series of expected durable growth is 95%. The expected non-durable growth state variable is somewhat more persistent in the macro-yield joint estimation, and the correlation across the two estimations is around 30%.

Overall, the model implications based on one-stage or two-stage estimations are close to each other. The model implications based on the macro-yield joint estimation are presented in Table 8. Both estimations match the level of nominal yields nearly perfectly. Furthermore, the macro-yield joint estimation is able to match the volatility of nominal yield in the data. The MSE reported for macro-yield joint estimation is much lower than that in macro-only case. In Panel B of Table 8, we find that the real yield curve produced by two estimators are very close to each other. As the joint estimation identifies higher persistence in expected durables, the real term structure becomes upward sloping in a joint estimation.

5.3 Log-linearization of Relative Share

To solve the model analytically, we log-linearized the expression for the the relative share (see equation (14)). Because of the log-linearization, the relative share fluctuations do not impact the variations in the fluctuations in the volatilities and premia in the economy (see Cochrane et al. (2008)). To assess the quality of the approximation, we compare the true and log-linearized growth in log share z_t. In the data, the correlation between the two is 0.997, and their two volatilities are identical to each other, 0.0012. Thus, as the share of durables is relatively stable in the data, we do not expect the share log-linearization to have a material impact on the solution.

6 Conclusion

In the data, durable goods consumption growth is persistent, and the long-term growth in durable consumption and the cash-flows of durable goods producing firms are more sensitive to inflation relative to nondurables. This suggests that inflation has a non-neutral and adverse effect for future real growth, and more so for durable goods rather than non-durable goods. Motivated by these findings, we set up a two good, long-run risks-type nominal economy which features nonseparable utility over consumption of durable and nondurable goods, persistence fluctuations in expected growth rates, inflation non-neutrality, and recursive utility with preference for early resolution of uncertainty. We show that the model can successfully, and effectively out-of-sample, explain unconditional moments and the conditional movements in the term structure and equity prices of durable and nondurable goods producing firms. Overall, we find that recursive utility, two-good structure, a high persistence of expected durable goods and non-neutrality of inflation through a durable channel play important role to explain these features of the asset markets.

Appendix

A Model Solution

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

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

The discount factor parameters are given by

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

The nominal discount factor parameters satisfy

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

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

The solution for real bond price loadings are given by,

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

and similar for nominal bonds using the parameters of the nominal discount factor in Equation (A.3).

B Joint Estimation Evidence

Table B.1: Parameter Estimates: One-Step Joint Macro-Yield Estimation

Macro Variable Model Parameters:

	Π			
	Δc_t	$\Delta \pi_t$	Δs_t	
Δc_t	1.0232 (0.0224)	−0.0195 (0.0026)	−0.0296 (0.0137)	
$\Delta \pi_t$	0.4759 (0.0506)	0.8865 (0.0196)	−0.1324 (0.0308)	
Δs_t	0.1169 (0.0843)	−0.0581 (0.0123)	0.8918 (0.0551)	

	$\Sigma_x \times 1000$			$\mathrm{diag}(\Sigma_g) \times 1000$
	Δc_t	$\Delta \pi_t$	Δs_t	
Δc_t	0.6608 (0.1022)			4.4906 (0.2805)
$\Delta \pi_t$	0.8104 (0.4031)	2.3287 (0.1986)		5.8059 (0.3407)
Δs_t	1.4633 (0.3208)	−0.4763 (0.1768)	1.0942 (0.2143)	1.8057 (0.2223)

Preference Parameters:

γ	ψ	δ
27.2 (12.00)	2.39 (0.20)	0.9956

Parameter estimates for the full model specification: $g_{t+1} = \mu_g + Fx_t + \Sigma_g \eta_{t+1}$, $x_{t+1} = \Pi x_t + \Sigma_x u_{t+1}$. Macroeconomic and preference parameters are estimated in one stage by MLE using Kalman filtering based on macro and yield data. Quarterly observations of non-durable consumption, durable consumption, inflation rate from 1963Q1 to 2009Q4.

C 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.

Bayes' theorem says that the posterior $\pi(\Theta \mid Y)$ is proportional to the likelihood multiplied by the prior, $\pi(\Theta \mid Y) \propto \mathcal{L}(Y;\Theta)p(\Theta)$. The likelihood function, $\mathcal{L}$, can be computed through Kalman filtering as described in the following.

Let $\eta_t^* = \Sigma_g \eta_t$ is defined as the exogenous random shock to the macro-variables g_t in equation (12),

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

Let Y_t^{data} denote a vector of observed zero coupon yields of different maturities. Define

$$u_t = Y_t^{\text{data}} - Y_t^{\text{model}}$$

where Y_t^{model} is our model implied counterpart, so that an n maturity zero is $Y_t^{\text{model}} = -p_{t,n}/n$ where $p_{t,n}$ is the log bond price. We assume

$$u_t \sim N(0, \Sigma_u)$$

where Σ_u is diagonal so that we force the pricing errors to be uncorrelated across bonds.

A vector of time t errors are now given by

$$\epsilon_t = \begin{bmatrix} \eta_t \\ u_t \end{bmatrix}$$

where $\epsilon_t \sim N(0, \Sigma)$, and

$$\Sigma = \begin{bmatrix} \Sigma_g & 0 \\ 0 & \Sigma_u \end{bmatrix}.$$

The dynamics of $Y_t = (g_t, Y_t^{\text{data}})$ forms a linear state-space model,

$$Y_t = \mu + Fx_t + \epsilon_t$$

where

$$F = \begin{bmatrix} I_3 & 0 \\ 0 & -B'_{x,n}/n \end{bmatrix}.$$

and $\mu = (\mu_g, -B_{0,n}/n)$ and where $B_{0,n}$ and $B_{x,n}$ are given by the equations (A.4). We can now apply standard Kalman filtering to compute the likelihood function. Specifically, we perform Bayesian posterior simulations using MCMC sampling under an un-informative prior. Let V denote an estimate of the covariance of the posterior distribution. Draw $\Theta_p \sim N(\Theta_J, V)$. Set $\Theta = \Theta_J^p$ with probability $\alpha = \min(1, \pi(\Theta_J^p)/\pi(\Theta))$. In practice, we update fewer than all n parameters in one iteration of the sampler. This avoids the curse of dimensionality associated with sampling in high dimensional parameter spaces.

For the estimation of macroeconomic dynamics without the yield data, we omit Y_t^{data} in the specification of Y_t.

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Tables and Figures

Table 1: Summary Statistics

	Non-Dur Consumption	Non-Dur Inflation	Durable Consumption
Mean	2.04	4.20	4.36
Stdev.	0.95	1.29	0.97
Autocorr	0.42	0.78	0.76
Corr. with Cons.:			
Non-Dur	1.00	-0.16	0.33
Dur	0.33	-0.03	1.00

Mean, volatility, autocorrelation and cross-correlations of real non-durable consumption growth, non-durable inflation and real durable consumption growth. Mean and volatility are annualized, in percent. Quarterly observations from 1963Q1 to 2009Q4.

Table 2: Consumption Growth Predictability

	1 yr	2 yr	3 yr	4 yr	5 yr
Non-durable Consumption Growth:					
By Inflation:					
Slope	−0.804	−0.593	−0.393	−0.237	−0.135
	(0.139)	(0.109)	(0.091)	(0.079)	(0.075)
R^2	0.170	0.153	0.102	0.052	0.019
By Short Rate:					
Slope	−0.135	−0.096	−0.042	0.002	0.025
	(0.033)	(0.026)	(0.022)	(0.018)	(0.017)
R^2	0.092	0.077	0.023	0.000	0.013
By Short Rate and Inflation:					
Slope (yld)	−0.061	−0.054	0.002	0.042	0.070
	(0.046)	(0.036)	(0.031)	(0.026)	(0.024)
Slope (infl)	−0.141	−0.079	−0.083	−0.077	−0.085
	(0.064)	(0.050)	(0.042)	(0.036)	(0.033)
R^2	0.118	0.091	0.045	0.027	0.051
Durable Consumption Growth:					
By Inflation:					
Slope	−0.729	−1.061	−1.135	−1.067	−0.931
	(0.203)	(0.177)	(0.156)	(0.141)	(0.130)
R^2	0.073	0.179	0.243	0.258	0.238
By Short Rate:					
Slope	−0.240	−0.271	−0.243	−0.189	−0.133
	(0.044)	(0.039)	(0.036)	(0.034)	(0.032)
R^2	0.152	0.225	0.214	0.156	0.094
By Short Rate and Inflation:					
Slope (yld)	−0.138	−0.152	−0.103	−0.033	0.0334
	(0.062)	(0.055)	(0.049)	(0.046)	(0.043)
Slope (infl)	−0.197	−0.227	−0.266	−0.297	−0.319
	(0.086)	(0.075)	(0.068)	(0.063)	(0.059)
Adj. R^2	0.179	0.266	0.281	0.256	0.234

Projections of average cumulative future real consumption growth on inflation rate and 3-month nominal interest rate. Top panel is based on non-durable consumption data, while bottom panel uses durable consumption data. Quarterly data from 1963Q1 to 2009Q4. Standard errors are Newey-West adjusted.

Table 3: Dividend Growth Predictability

	1 yr	2 yr	3 yr	4 yr	5 yr
Non-durable Portfolio:					
Slope	-0.36	-0.28	-0.13	-0.08	0.05
	(0.78)	(0.59)	(0.47)	(0.37)	(0.31)
R^2	0.01	0.01	0.00	0.00	0.00
Durable Portfolio:					
Slope	-2.60	-1.82	-1.24	-0.88	-0.49
	(0.98)	(0.79)	(0.73)	(0.61)	(0.54)
R^2	0.14	0.12	0.07	0.05	0.02
Market Portfolio:					
Slope	-1.02	-0.91	-0.75	-0.54	-0.32
	(0.67)	(0.56)	(0.49)	(0.40)	(0.32)
R^2	0.05	0.06	0.05	0.04	0.03

Projections of average cumulative future real dividend growth on inflation for portfolios in a durable sector, non-durable sector and the market. Annual data from 1963Q1 to 2009Q4. Standard errors are Newey-West adjusted.

Table 4: Benchmark Parameter Estimates

Macro Model Parameters:

	Π			$\Sigma_x \times 1000$			$\text{diag}(\Sigma_g) \times 1000$
	Δc_t	$\Delta \pi_t$	Δs_t	Δc_t	$\Delta \pi_t$	Δs_t	
Δc_t	0.385 (0.091)	−0.060 (0.040)	−0.025 (0.029)	4.056 (0.510)			0.999 (0.844)
$\Delta \pi_t$	0.170 (0.072)	0.951 (0.004)	−0.026 (0.049)	−0.781 (0.412)	1.841 (0.399)		3.075 (0.343)
Δs_t	0.003 (0.040)	−0.100 (0.016)	0.877 (0.020)	0.861 (0.217)	0.843 (0.319)	1.159 (0.193)	2.097 (0.166)

Preference Parameters:

γ	ψ	δ
24.12 (39.6)	2.56 (0.55)	0.9958

Parameter estimates of the benchmark model specification. Macroeconomic parameters Π, Σ_x and Σ_g are estimated by Kalman-filter MLE using the macro data on non-durable consumption growth, non-durable inflation and durable goods growth. Preference parameters are estimated based on the Non-linear Least Square fit to 1 and 5 year nominal yields. Quarterly data from 1963Q1 to 2009Q4.

Table 5: Nominal Bond Yields: Data and Models

	Data	EZ Dur	EZ ND	EZ $\tilde{ND}$	CRRA Dur	CRRA $\tilde{Dur}$	CRRA ND	CRRA $\tilde{ND}$
Preferences:								
γ		24.12	24.12	111.81	24.12	10.00	24.12	10.00
ψ		2.56	2.56	2.48	2.56	0.10	2.56	0.10
δ		0.996	0.996	0.997	0.996	1.056	0.996	1.046
Yield Level:								
1y	5.98	5.98	6.42	5.96	62.78	5.99	52.23	5.97
3y	6.35	6.33	6.48	6.27	61.2	5.73	50.81	5.75
5y	6.58	6.58	6.53	6.57	60.67	5.65	50.58	5.71
Yield Volatility:								
1y	2.89	1.90	1.81	1.81	9.64	3.58	7.33	2.97
3y	2.75	1.64	1.5	1.5	6.34	1.87	2.71	1.04
5y	2.63	1.44	1.29	1.28	5.56	1.52	1.73	0.69
MSE:								
1y Yield	0	1.96	2.05	2.00	57.82	4.76	46.95	3.69
5y Spread	0	0.82	0.95	0.82	6.64	2.72	6.30	2.65
Yield Loadings:								
Exp. Nd	2.67 (0.79)	2.25	1.56	1.61	78.21	33.00	96.51	40.00
Exp. Infl.	4.03 (0.29)	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Exp. Dur.	-1.31 (0.42)	-0.69	0.00	0.00	18.30	7.00	0.00	0.00

Levels, volatilities, the Minimum Squared Error (MSE) of nominal yields in the data and across economic models. Yield loadings show the slope coefficients in the regression of a one-quarter nominal yield on the expected growth and inflation states, in the data and across the models. EZ denotes a recursive utility model, while $CRRA$ stands for the model specification under expected utility. Dur indicates that the model is based on durable and nondurable goods, while ND only features nondurable consumption. Tilde ˜ indicates the the preference parameters are changed to match nominal yields (in EZ case preference parameters are re-estimated, while in CRRA γ is set at 10.)

Table 6: Model-Implied Real Yields

	EZ			CRRA			
	Dur	ND	$\tilde{ND}$	Dur	$\tilde{Dur}$	ND	$\tilde{ND}$
Yield Level:							
1y	1.70	2.26	1.43	58.7	1.92	48.15	1.91
3y	1.67	2.22	1.23	57.12	1.67	46.71	1.69
5y	1.69	2.21	1.18	56.51	1.58	46.44	1.65
10y	1.75	2.21	1.13	55.33	1.39	46.19	1.61

Model-implied term structure of interest rates on real bonds which deliver one unit of nondurable consumption. EZ denotes a recursive utility model, while $CRRA$ stands for the model specification under expected utility. Dur indicates that the model is based on durable and nondurable goods, while ND only features nondurable consumption. Tilde $\tilde{}$ indicates the the preference parameters are changed to match nominal yields (in EZ case preference parameters are re-estimated, while in CRRA γ is set at 10.)

Table 7: Equity Returns: Data and Model

	Data	EZ Dur	EZ ND	EZ $\tilde{ND}$	CRRA Dur	CRRA $\tilde{Dur}$	CRRA ND	CRRA $\tilde{ND}$
Equity Premium:								
Non-Dur	5.76 (2.20)	4.52	3.51	15.19	0.07	0.03	0.01	0.04
Dur	6.82 (3.16)	6.69	3.50	11.07	0.04	0.02	0.00	0.01
Mkt	5.91 (2.48)	5.03	3.51	15.19	0.06	0.03	0.01	0.04
Equity Volatility:								
Non-Dur	14.58 (1.33)	11.70	13.47	12.91	0.16	12.87	0.19	8.43
Dur	20.97 (1.90)	18.09	25.10	19.72	0.25	18.49	0.28	21.96
Mkt	16.37 (1.39)	12.15	13.47	12.91	0.18	12.07	0.19	8.43
Log PD ratio :								
Non-Dur	3.31 (0.03)	3.37	3.48	1.94	0.36	4.34	0.58	3.19
Dur	3.07 (0.03)	3.01	4.31	2.36	0.39	4.64	0.62	3.65
Mkt	3.27 (0.02)	3.21	3.48	1.94	0.37	4.19	0.58	3.19
Corr. with Exp. Infl.:								
Non-Dur	−0.32 (0.12)	-0.18	-0.17	-0.13	0.04	0.21	0.02	-0.02
Dur	−0.41 (0.13)	-0.22	-0.27	-0.18	0.09	-0.08	0.06	-0.21
Mkt	−0.22 (0.14)	-0.23	-0.17	-0.13	0.06	0.20	0.02	-0.02
Corr. with Bonds:								
Non-Dur	0.38 (0.12)	0.13	0.06	-0.03	0.33	-0.11	0.43	-0.10
Dur	0.53 (0.11)	0.59	0.57	0.33	0.43	0.13	0.49	0.16
Mkt	0.32 (0.14)	0.31	0.06	-0.03	0.43	-0.08	0.43	-0.10

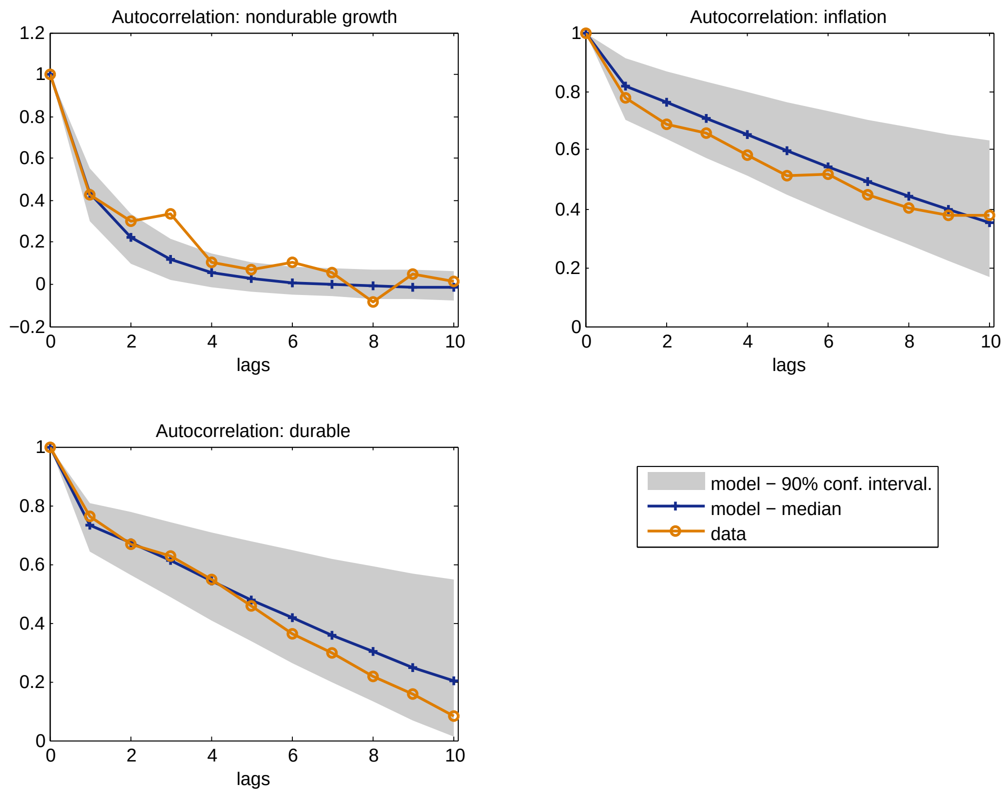
Equity prices of durable and nondurable portfolios and the market in the data and in the model. *EZ* denotes a recursive utility model, while *CRRA* stands for the model specification under expected utility. *Dur* indicates that the model is based on durable and nondurable goods, while *ND* only features nondurable consumption. Tilde˜indicates the the preference parameters are changed to match nominal yields (in EZ case preference parameters are re-estimated, while in CRRA γ is set at 10.)

Table 8: Equilibrium Yields: 2-Stage v.s. Joint Estimation

	1y	3y	5y
Nominal Yields:			
Data	5.98	6.35	6.58
	(2.89)	(2.75)	(2.63)
Joint	5.98	6.35	6.58
	(2.78)	(2.69)	(2.58)
Real Yields:			
Joint	1.71	1.72	1.74
	(0.36)	(0.34)	(0.31)
	Mean	Stdev.	MSE
One Year Yield Fit:			
Data	5.98	2.89	0.00
Joint	5.98	2.78	0.99
Five Year Spread Fit:			
Data	0.60	0.82	0.00
Joint	0.60	0.71	0.39

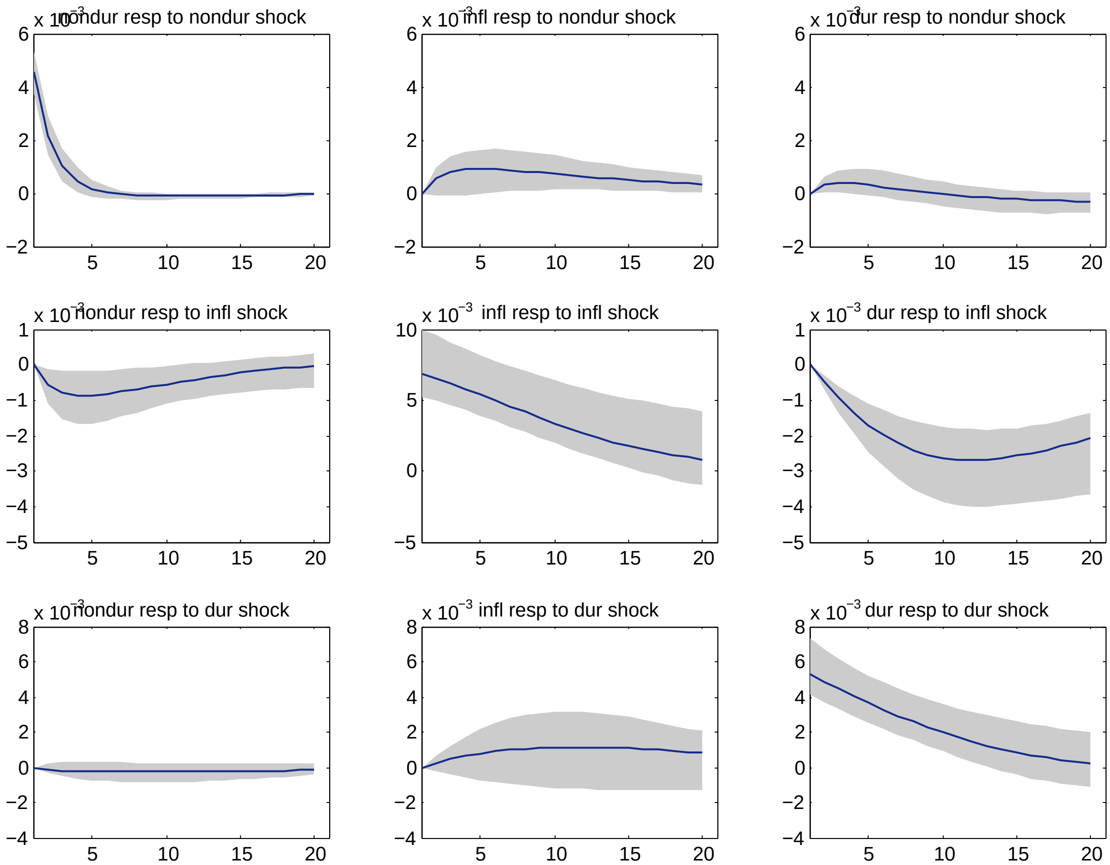
The level, volatilities and mean-squared errors for real and nominal yields in the data and in the model estimated in two stages, and in one step jointly using both macroeconomic and yield data.

Figure 1: Autocorrelation of Consumption Growth and Inflation



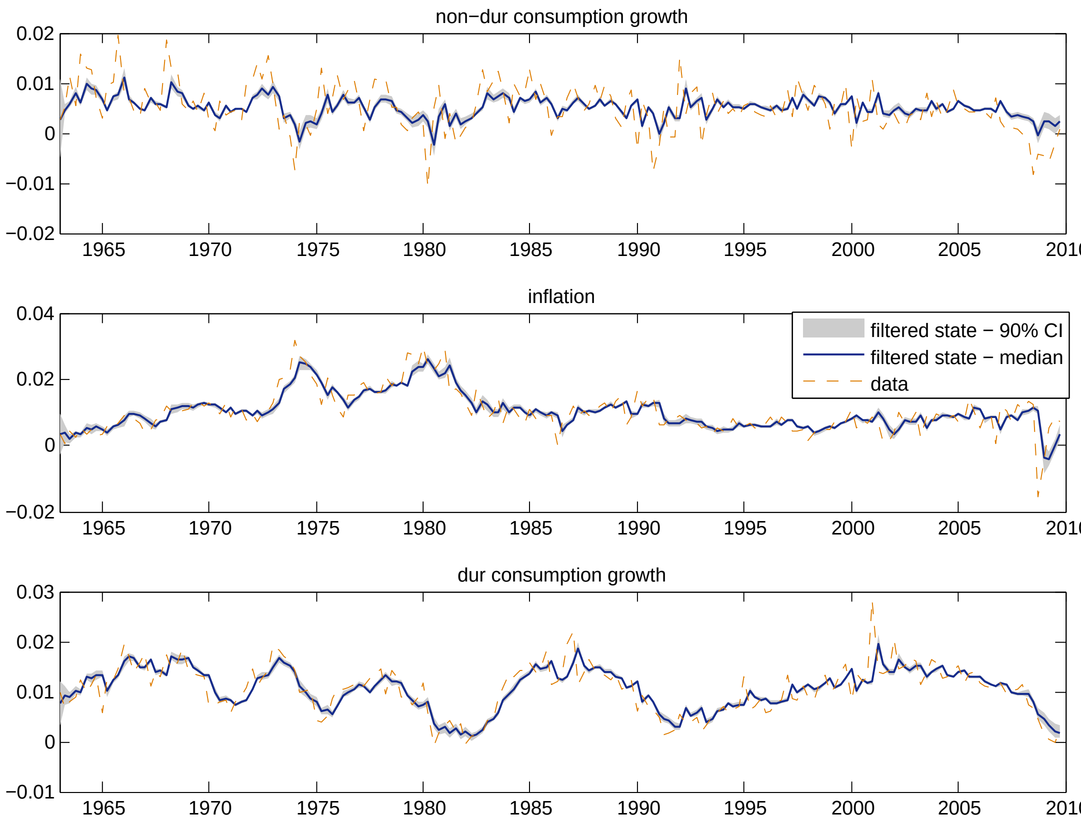
Autocorrelation functions of non-durable and durable consumption growth and non-durable inflation rate based on the estimates in the data and implied by the macroeconomic model. Quarterly observations from 1963Q1 to 2009Q4.

Figure 2: Impulse Response Functions of Expected Growth Shocks



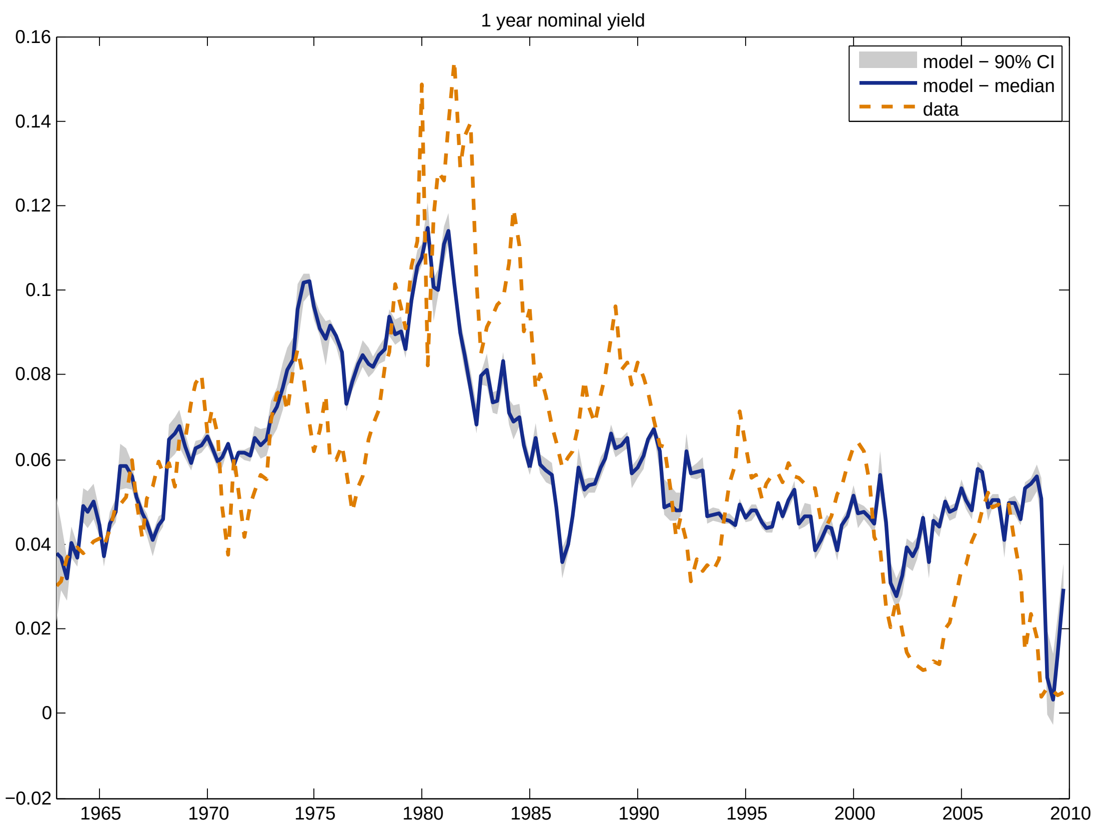
Impulse response functions for shocks to expected non-durable consumption, expected durable consumption and expected non-durable inflation, based on the estimated macroeconomic model. Grey regions correspond to 90% confidence interval.

Figure 3: Realized and Filtered Macroeconomic Variables



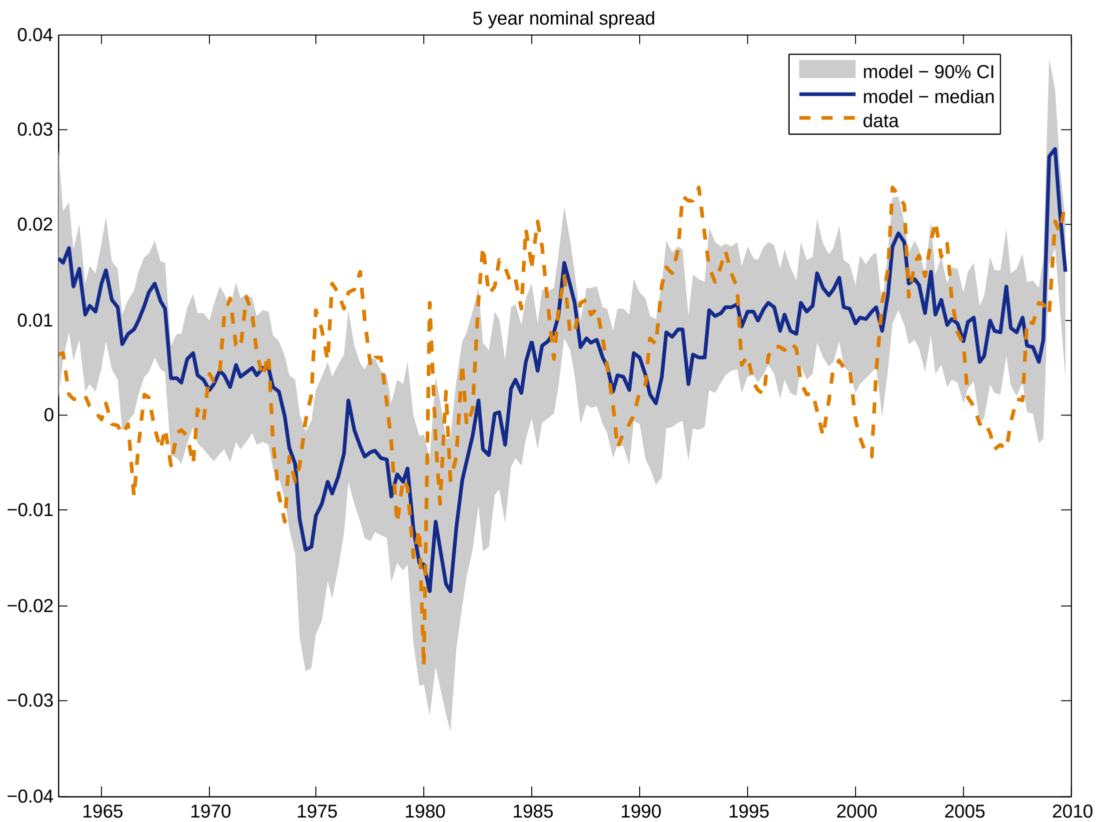
Realized and filtered non-durable consumption growth rate, non-durable inflation rate and durable goods growth rates.

Figure 4: One-Year Nominal Yield: Data and Model



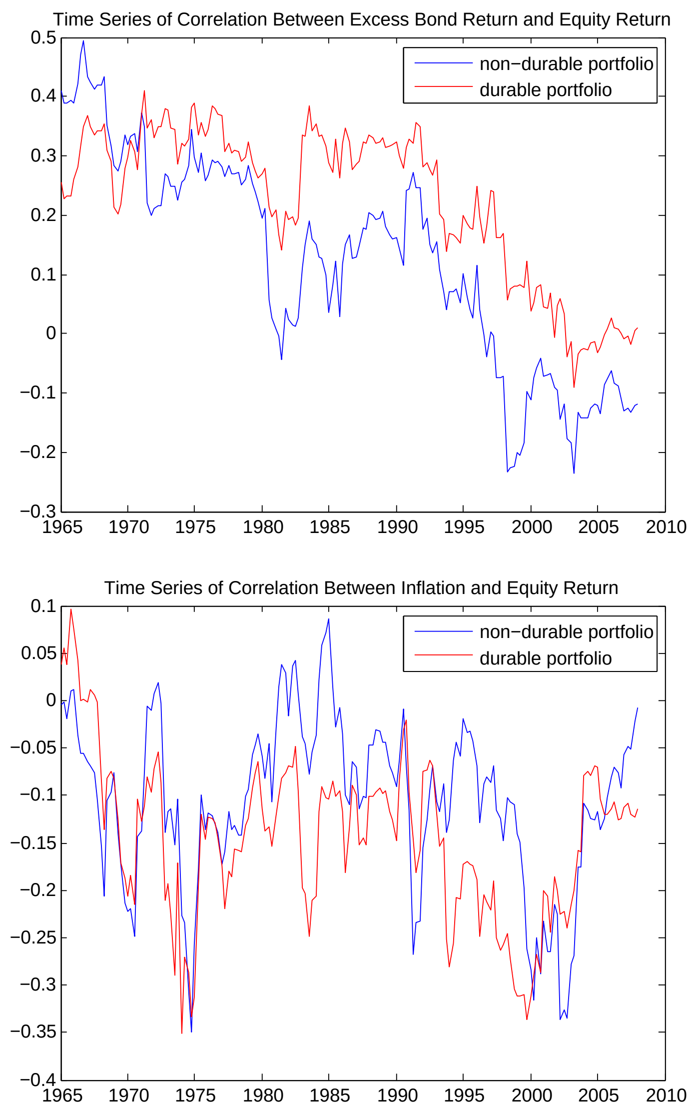
Time series of one-year nominal yield in the data (dashed line) and in the model (solid line).

Figure 5: Nominal Yield Spread: Data and Model



Time series of five minus one year nominal spread in the data (dashed line) and in the model (solid line).

Figure 6: Excess Stock Return Correlations



Rolling window (10-year) correlations of excess stock returns with expected inflation shock (top panel) and 2-year excess bond return (bottom panel), for durable and nondurable portfolios.