Examining the Bond Premium Puzzle with a DSGE Model

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Outline

1. Motivation and Background
2. The Term Premium in a Benchmark New Keynesian Model
3. Benchmark Results
4. Slow-Moving Habits and Labor Market Frictions
5. Conclusions
The equity premium puzzle: excess returns on stocks are much larger (and more variable) than can be explained by standard preferences in a DSGE model (Mehra and Prescott, 1985).
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Note:
- Since Backus, Gregory, and Zin (1989), DSGE models with nominal rigidities have advanced considerably.
Kim-Wright Term Premium on 10-Year Zero-Coupon Bond
Why Study the Bond Premium Puzzle?

The bond premium puzzle is important:

- DSGE models increasingly used for policy analysis; total failure to explain term premium may signal flaws in the model
- many empirical questions about term premium require a structural DSGE model to provide reliable answers
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The equity premium puzzle has received more attention in the literature, but the bond premium puzzle:

- provides an additional perspective on the model
- tests nominal rigidities in the model
- only requires modeling short-term interest rate process, not dividends or leverage
- applies to a larger volume of U.S. securities
Recent Studies of the Bond Premium Puzzle

- Wachter (2005)
  - can resolve bond premium puzzle using Campbell-Cochrane preferences in endowment economy
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Moreover, in the present paper, we show:
- in the Christiano, Eichenbaum, Evans (2006) model, term premium is 1 bp
The Term Premium in a Benchmark New Keynesian Model

- Define Benchmark New Keynesian Model
- Review Asset Pricing
- Solve the Model
Benchmark New Keynesian Model (Very Standard)

Representative household with preferences:

$$\max E_t \sum_{t=0}^{\infty} \beta^t \left( \frac{(c_t - h_t)^{1-\gamma}}{1-\gamma} - \chi_0 \frac{l_t^{1+\chi}}{1+\chi} \right)$$
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Benchmark model: let $h_t \equiv b C_{t-1}$
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\]

Benchmark model: let \( h_t \equiv bC_{t-1} \)

Stochastic discount factor:

\[
m_{t+1} = \frac{\beta (C_{t+1} - bC_t)^{-\gamma}}{(C_t - bC_{t-1})^{-\gamma}} \frac{P_t}{P_{t+1}}
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Parameters: \( \beta = .99, \ b = .66, \ \gamma = 2, \ \chi = 1.5 \)
Benchmark New Keynesian Model (Very Standard)

Continuum of differentiated firms:
- face Dixit-Stiglitz demand with elasticity $\frac{1+\theta}{\theta}$, markup $\theta$
- set prices in Calvo contracts with avg. duration 4 quarters
- identical production functions $y_t = A_t \bar{k}^{1-\alpha} l^\alpha$
- have firm-specific capital stocks
- face aggregate technology $\log A_t = \rho_A \log A_{t-1} + \varepsilon_t^A$

Parameters $\theta = .2, \rho_A = .9, \sigma_A^2 = .01^2$

Perfectly competitive goods aggregation sector
Benchmark New Keynesian Model (Very Standard)

Government:
- imposes lump-sum taxes $G_t$ on households
- destroys the resources it collects
- \[ \log G_t = \rho_G \log G_{t-1} + (1 - \rho_g) \log \bar{G} + \varepsilon_t^G \]

Parameters $\bar{G} = .17 \bar{Y}$, $\rho_G = .9$, $\sigma_G^2 = .004^2$
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Monetary Authority:
- \[
i_t = \rho_i i_{t-1} + (1 - \rho_i) \left[ \frac{1}{\beta} + \pi_t + g_y (y_t - \bar{y}) + g_\pi (\bar{\pi}_t - \pi^*) \right] + \varepsilon_i^i
\]

Parameters $\rho_i = .73$, $g_y = .53$, $g_\pi = .93$, $\pi^* = 0$, $\sigma_i^2 = .004^2$
Asset Pricing

Asset pricing:

\[ p_t = d_t + E_t[m_{t+1}p_{t+1}] \]

Zero-coupon bond pricing:

\[ p_{t}^{(n)} = E_t[m_{t+1}p_{t+1}^{(n-1)}] \]

\[ i_{t}^{(n)} = -\frac{1}{n} \log p_{t}^{(n)} \]

Notation: let \( i_t \equiv i_t^{(1)} \)
The Term Premium in the Benchmark Model

In DSGE framework, convenient to work with a default-free consol, a perpetuity that pays $1, $\delta c$, $\delta^2 c$, $\delta^3 c$, … (nominal)

Price of the consol:

$\tilde{p}(n) = 1 + \delta c \mathbb{E}_t m_t + 1 \tilde{p}(n) + 1$

Risk-neutral consol price:

$\hat{p}(n) = 1 + \delta c e^{-i t} \mathbb{E}_t \hat{p}(n) + 1$

Term premium:

$\psi(n) \equiv \log(\delta c \tilde{p}(n) - 1) - \log(\delta c \hat{p}(n) - 1)$
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Term premium:

\[
\psi_t^{(n)} \equiv \log \left( \frac{\delta_c \hat{p}_t^{(n)}}{\tilde{p}_t^{(n)} - 1} \right) - \log \left( \frac{\delta_c \hat{p}_t^{(n)}}{\hat{p}_t^{(n)} - 1} \right)
\]
Solving the Model

The benchmark model above has a relatively large number of state variables: \( C_{t-1}, A_{t-1}, G_{t-1}, i_{t-1}, \Delta_t, \pi_{t-1}, \varepsilon^A_t, \varepsilon^G_t, \varepsilon^i_t \)
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We solve the model by approximation around the nonstochastic steady state (perturbation methods)
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We solve the model by approximation around the nonstochastic steady state (perturbation methods)

- In a first-order approximation, term premium is zero
- In a second-order approximation, term premium is a constant (sum of variances)
- So we compute a *third*-order approximation of the solution around nonstochastic steady state
- Perturbation AIM algorithm in Swanson, Anderson, Levin (2006) quickly computes $n$th order approximations
In the benchmark NK model:

- mean term premium: 1.4 bp
- unconditional standard deviation of term premium: 0.1 bp
**Results**

In the benchmark NK model:
- mean term premium: 1.4 bp
- unconditional standard deviation of term premium: 0.1 bp

Intuition:
- shocks in macro models have standard deviations $\approx 0.01$
- 2nd-order terms in macro models $\sim (0.01)^2$
- 3rd-order terms $\sim (0.01)^3$
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- 2nd-order terms in macro models $\sim (.01)^2$
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To make these higher-order terms important,

- need “high curvature” modifications from finance literature
- or shocks with standard deviations $\gg .01$
Robustness of Results

Table 1: Alternative Parameterizations of Baseline Model

<table>
<thead>
<tr>
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<th>Baseline case value</th>
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Hördahl, Tristani, Vestin (2006) match level of term premium using:
- NK model very similar to our benchmark model
- giant technology shocks: $\rho_a = .986, \sigma_a = .0237$
- in our benchmark model, imply term premium of 68.6bp
Models with Giant Shocks

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Ravenna and Seppälä (2007) match level of term premium using:
- NK model similar to above
- preferences: $\frac{(c_t - bC_{t-1})^{1-\gamma}}{1-\gamma} - \xi_t \chi_0 \frac{l_t^{1+\chi}}{1 + \chi}$
- giant preference shocks: $\rho_\xi = .95, \sigma_\xi = .08$
- in our benchmark model, imply consol term premium of 19.7bp
# Models with Giant Shocks

## Table 3: Unconditional Moments

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Slow-Moving Habits and Labor Market Frictions

- Campbell-Cochrane Habits
- Campbell-Cochrane Habits with Labor Market Frictions
Campbell-Cochrane Habits

Preferences: \[
\frac{(c_t - H_t)^{1-\gamma}}{1 - \gamma} - \chi_0 \frac{l_t^{1+\chi}}{1 + \chi}
\]

Habits defined implicitly by \[ S_t \equiv \frac{C_t - H_t}{C_t} \], where:

\[
\log S_t = \phi \log S_{t-1} + (1 - \phi) \log \bar{S} + \frac{1}{\bar{S}} \left( \sqrt{1 - 2(\log S_{t-1} - \log \bar{S})} - 1 \right) (\Delta \log C_t - E_{t-1} \Delta \log C_t)
\]

Campbell-Cochrane calibrate \( \phi = 0.87 \), \( \bar{S} = 0.0588 \)
Campbell-Cochrane Habits: Results

Recall: Wachter (2005) resolves bond premium puzzle using:

- Campbell-Cochrane habits
- endowment economy
- random walk consumption
- exogenous process for inflation
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However, incorporating Campbell-Cochrane habits into our benchmark DSGE model implies:

- mean term premium: 2.7 bp
- standard deviation of term premium: 0.1 bp
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Intuition: in a DSGE model, households can self-insure by varying labor supply
Possible solution:
- add labor market frictions to prevent households from self-insuring

Explore three classes of labor market frictions:
- households pay an adjustment cost: \( \kappa (\log l_t - \log l_{t-1})^2 \)
- staggered nominal wage contracting
- real wage rigidities (Nash bargaining)
Campbell-Cochrane Habits with Adjustment Costs

Figure 1: Mean Term Premium

- Blue line: mean term premium, no C-C habits
- Red line: mean term premium, with C-C habits
### Campbell-Cochrane Habits with Adjustment Costs

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<tr>
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</tr>
<tr>
<td>sd[w']</td>
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# Campbell-Cochrane Habits with Adjustment Costs

## Table 6: Unconditional Moments

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With Campbell-Cochrane habits and nominal wage contracts, term premium in the model decreases to 1.3bp
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Intuition: complete markets provide households with insurance, more than offsets the costs of the wage friction
Real Wage Rigidities

Following Blanchard and Galí (2005), model real wage bargaining rigidity as:

$$\log w^r_t = (1 - \mu)( \log w^r_{t^*} + \omega ) + \mu \log w^r_{t-1}$$
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Intuition: wage friction increases volatility of MRS, but decreases volatility of inflation, interest rates
Additional Robustness Checks

- estimation, “best fit” parameters
- larger models (CEE, LOWW)
- models with investment
- internal habits
- markup shocks
- time-varying $\pi^*_t$

None of these have helped to fit the term premium
Conclusions

The bond premium puzzle remains.
1. The term premium in standard NK DSGE models is very small, even more stable.
2. To match term premium in NK DSGE framework, need high curvature together with labor frictions (not wage frictions).
3. However, matching the term premium destroys the model's ability to fit macro variables, particularly the real wage.
4. There appears to be no easy way to fix this in the standard, habit-based NK DSGE framework.
5. Ongoing work: Epstein-Zin preferences.
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5. Ongoing work: Epstein-Zin preferences
Epstein-Zin-Weil Preferences

Three key ingredients:

1. Nominal rigidities makes bond pricing interesting
2. Epstein-Zin-Weil preferences makes households risk averse
3. Long-run inflation risk introduces a risk households cannot control makes bonds risky
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Standard preferences:

\[ V_t \equiv u(c_t, l_t) + \beta E_t V_{t+1} \]

Note: need to impose \( u \geq 0 \) or \( u \leq 0 \) and

\[ V_t \equiv u(c_t, l_t) - \beta (E_t V_{t+1} - 1)^{\frac{1}{\alpha}} \]

We'll use standard NK utility kernel:

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\[
\begin{align*}
u(c_t, l_t) &\equiv \frac{c_t^{1-\gamma}}{1-\gamma} - \chi_0 \frac{l_t^{1+\chi}}{1+\chi},
\end{align*}
\] (1)
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Household optimality conditions with EZW preferences:

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\begin{align*}
\mu_t u_1|_{(c_t, l_t)} &= P_t \lambda_t \\
-\mu_t u_2|_{(c_t, l_t)} &= w_t \lambda_t \\
\lambda_t &= \beta E_t \lambda_{t+1} (1 + r_{t+1}) \\
\mu_t &= \mu_{t-1} (E_{t-1} V_t^\alpha)^{(1-\alpha)/\alpha} V_t^{\alpha-1}, \quad \mu_0 = 1
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\]

Stochastic discount factor:

\[
m_{t, t+1} = \frac{\beta u_1 \left| (c_{t+1}, l_{t+1}) \right.}{u_1 \left| (c_t, l_t) \right.} \left( \frac{V_{t+1}}{(E_t V_{t+1}^\alpha)^{1/\alpha}} \right)^{1-\alpha} \frac{P_t}{P_{t+1}}
\]
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Long-run inflation risk:

\[ \pi_t^* = \rho_{\pi^*} \pi_{t-1}^* + (1 - \rho_{\pi^*}) \theta_{\pi^*} (\bar{\pi}_t - \pi_t^*) + \varepsilon_t^* \]
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