The Bond Premium in a DSGE Model with Long-Run Real and Nominal Risks

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Outline

Why Study Asset Prices in a DSGE Model?

Asset pricing is important:

- DSGE models increasingly used for policy analysis; total failure to explain asset prices may signal flaws in the model
- many empirical questions about asset prices require a structural DSGE model to provide reliable answers

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Equity prices have received much attention in the literature But

bond prices are at least as interesting because they:

- apply to a larger amount of securities
- provide an additional perspective on the model
- test nominal rigidities in the model
- model short-term interest rate process, not dividends

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Note:

- Since Backus, Gregory, and Zin (1989), DSGE models with nominal rigidities have advanced considerably

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We examine to what extent the Piazzesi-Schneider results generalize to the DSGE model and a production economy

Our Analysis

We incorporate Epstein-Zin preferences in standard DSGE model

The model has three key ingredients:

1. Intrinsic nominal rigidities
   - makes bond pricing interesting
2. Epstein-Zin preferences
   - makes households risk averse
3. Long-run risk (productivity or inflation)
   - introduces a risk households cannot offset
   - makes bonds risky

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Can we match the unconditional moments of both bond prices and macroeconomic variables?

Related Strands of the Literature

The Bond Premium in a DSGE Model:

- Backus, Gregory, Zin (1989), Donaldson, Johnson, Mehra (1990), Den Haan (1995), Doh (2006), Rudebusch, Swanson (2008)

Epstein-Zin Preferences and the Bond Premium in an Endowment Economy:

- Piazzesi, Schneider (2006), Colacito, Croce (2007), Backus, Routledge, Zin (2007), Gallmeyer, Hollifield, Palomino, Zin (2007), Bansal, Shaliastovich (2008), Doh (2008)

Epstein-Zin Preferences in a DSGE Model:

- Tallarini (2000), Croce (2007), Levin, Lopez, Salido, Nelson, Yun (2008)

Epstein-Zin Preferences and the Bond Premium in a DSGE Model:

- van Binsbergen, Fernandez-Villaverde, Koijen, Rubio-Ramirez (2008)

A DSGE Model with Epstein-Zin Preferences

2 A DSGE Model with Epstein-Zin Preferences

- Standard Preferences
- Epstein-Zin Preferences
- Firms and Government
- Bond Pricing and Measures of the Bond Premium
- Results

Standard Preferences

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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Stochastic discount factor (nominal):

$$m_{t+1} = \frac{\beta(C_{t+1} - bC_t)^{-\gamma}}{(C_t - bC_{t-1})^{-\gamma}} \frac{P_t}{P_{t+1}}$$

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Parameters: $\beta = .99$, $b = .66$, $\gamma = 2$, $\chi = 1.5$

Epstein-Zin Preferences

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

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We'll use standard NK utility kernel:

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Epstein-Zin stochastic discount factor (nominal):

$$m_{t,t+1} \equiv \frac{\beta u_1|_{(c_{t+1}, l_{t+1})}}{u_1|_{(c_t, l_t)}} \left(\frac{V_{t+1}}{\left(E_t V_{t+1}^{1-\alpha} \right)^{1/(1-\alpha)}} \right)^{\alpha} \frac{P_t}{P_{t+1}}$$

Firms and Government

Continuum of differentiated firms:

- face Dixit-Stiglitz demand with elasticity $\frac{1+\theta}{\theta}$, markup θ
- set prices in Calvo contracts with avg. duration 4 quarters
- identical production functions: $y_t = A_t \bar{k}^{1-\eta} l_t^{\eta}$
- 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

Firms and Government

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:

$$i_t = \rho_i i_{t-1} + (1 - \rho_i)\left[1/\beta + \pi_t + g_y(y_t - \bar{y}) + g_\pi(\bar{\pi}_t - \pi^*)\right] + \varepsilon_t^i$$

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

Bond Pricing

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

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Zero-coupon nominal 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 $i_t \equiv i_t^{(1)}$

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Term premium:

$$\psi_t^{(n)} \equiv \log\left(\frac{\delta_c \widetilde{p}_t^{(n)}}{\widetilde{p}_t^{(n)} - 1}\right) - \log\left(\frac{\delta_c \widehat{p}_t^{(n)}}{\widehat{p}_t^{(n)} - 1}\right)$$

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The model has a relatively large number of state variables: C_{t-1}, A_{t-1}, G_{t-1}, i_{t-1}, Δ_{t-1}, $\bar{\pi}_{t-1}$, ε_t^A, ε_t^G, ε_t^i.
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We examine unconditional moments of standard parameters

We also search for over parameter space for the “best fit” set, which minimizes the average deviation of 13 moments

Definitions of Unconditional Moments Matched

Variable	U.S. Data, 1961-2007
sd[C]	Real consumption*
sd[L]	Labor, total hours worked*
sd[w^r]	Real wage*
sd[π]	Price inflation, Annualized quarterly rate
sd[i]	Short-term nominal interest rate, annualized p.p.
sd[r]	Short-term real interest rate, annualized p.p.
sd[$i^{(10)}$]	10-year zero-coupon nominal rate, annualized p.p.
mean[$\psi^{(10)}$]	Term premium on 10-year zero-coupon bond
sd[$\psi^{(10)}$]	(affine no-arbitrage estimates)
mean[$i^{(10)} - i$]	Yield curve slope
sd[$i^{(10)} - i$]	(long - short rate, annualized p.p.)
mean[$x^{(10)}$]	Quarterly excess holding period return
sd[$x^{(10)}$]	(10-year bond, annualized p.p.)

*deviations from HP trend in percentage points

Table 2: Empirical and Model-Based Moments

Variable	U.S. Data 1961-2007	EU Preferences	EZ Preferences	"best fit" EZ Preferences
sd[C]	1.19	1.42	1.45	2.53
sd[L]	1.71	2.56	2.50	2.21
sd[w^r]	0.82	2.08	2.02	1.52
sd[π]	2.52	2.25	2.30	2.71
sd[i]	2.71	1.90	1.93	2.27
sd[r]	2.30	1.89	1.95	1.62
sd[$i^{(10)}$]	2.41	0.54	0.57	1.03
mean[$\psi^{(10)}$]	1.06	.010	.438	1.05
sd[$\psi^{(10)}$]	0.54	.000	.053	.184
mean[$i^{(10)} - i$]	1.43	$-$.047	.390	0.99
sd[$i^{(10)} - i$]	1.33	1.43	1.43	1.33
mean[$x^{(10)}$]	1.76	.015	.431	1.04
sd[$x^{(10)}$]	23.43	6.56	6.87	9.02
memo: IES		.5	.5	1.3
quasi-CRRA		2	75	75

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Coefficient of Relative Risk Aversion

In a standard DSGE model:

- additive labor implies utility kernel is nonhomothetic
- shocks are not multiplicative with respect to wealth
- wealth includes human capital as well as physical capital

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This is the CRRA *if* labor were held fixed and *if* all shocks were multiplicative with respect to wealth

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This is the CRRA *if* labor were held fixed and *if* all shocks were multiplicative with respect to wealth

Better measures of risk aversion (e.g., thought experiments) are likely to look less risk-averse than the quasi-CRRA would suggest

- households can self-insure risk by varying labor supply

Long-Run Risks

3. Long-Run Risks
   - Long-Run Real Risk
   - Long-Run Inflation Risk

Long-Run Productivity Risk

Following Bansal and Yaron (2004), introduce long-run real risk to make the economy more risky:

Assume productivity follows:

$$\log A_t^* = \rho_{A^*} \log A_{t-1}^* + \varepsilon_t^{A^*}$$

$$\log A_t = \log A_t^* + \varepsilon_t^A$$

where $\rho_{A^*} = .98$, $\sigma_{A^*} = .002$, and $\sigma_A = .005$.

- makes the economy much riskier to agents
- increases volatility of stochastic discount factor

Table 3: Moments with Long-Run Productivity Risk

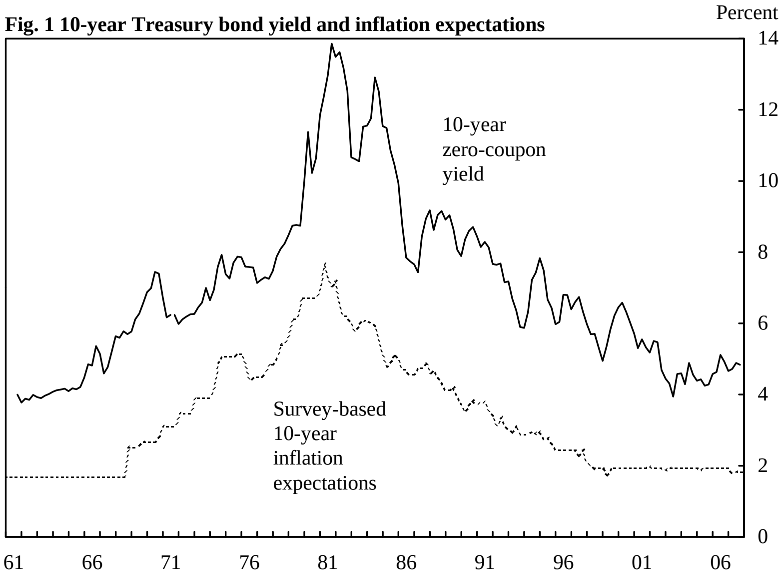
Variable	U.S. Data 1961-2007	EU Preferences	Best Fit EZ Prefs
sd[C]	1.19	0.92	2.95
sd[L]	1.71	1.03	1.32
sd[w^r]	0.82	1.43	1.90
sd[π]	2.52	1.12	3.14
sd[i]	2.71	1.17	2.88
sd[r]	2.30	0.66	1.35
sd[$i^{(10)}$]	2.41	0.65	1.84
mean[$\psi^{(10)}$]	1.06	.005	.872
sd[$\psi^{(10)}$]	0.54	.000	.183
mean[$i^{(10)} - i$]	1.43	$-$.018	.758
sd[$i^{(10)} - i$]	1.33	0.64	1.15
mean[$x^{(10)}$]	1.76	.005	.859
sd[$x^{(10)}$]	23.43	4.39	11.59
memo: quasi-CRRA		2	35

Long-Run Inflation Risk

Introduce long-run inflation risk to make long-term bonds more risky:

- same idea as Bansal-Yaron (2004), but with nominal risk rather than real risk
- long-term inflation expectations more observable than long-term consumption growth
- other evidence (Kozicki-Tinsley, 2003, Gürkaynak, Sack, Swanson, 2005) that long-term inflation expectations in the U.S. vary

Long-Run Inflation Risk



Long-Run Inflation Risk

Suppose:

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Then:

- inflation is volatile, but not risky
- in fact, long-term bonds act like insurance: when $\pi^* \uparrow$, then $C \uparrow$ and $p^{(10)} \downarrow$
- result: term premium is *negative*

Long-Run Inflation Risk

Consider instead:

$$\pi_t^* = \rho_\pi^* \pi_{t-1}^* + (1 - \rho_\pi^*)\theta_{\pi^*}(\overline{\pi}_t - \pi_t^*) + \varepsilon_t^{\pi^*}$$

Long-Run Inflation Risk

Consider instead:

$$\pi_t^* = \rho_\pi^* \pi_{t-1}^* + (1 - \rho_\pi^*)\theta_{\pi^*}(\overline{\pi}_t - \pi_t^*) + \varepsilon_t^{\pi^*}$$

- θ_{π^*} describes pass-through from current π to long-term π^*
- Gürkaynak, Sack, and Swanson (2005) found evidence for $\theta_{\pi^*} > 0$ in U.S. bond response to macro data releases
- makes long-term bonds act less like insurance: when technology/supply shock, then $\pi \uparrow$, $C \downarrow$, and $p^{(10)} \downarrow$ supply shocks become very costly
- The term premium is *positive*, closely associated with θ_{π^*}

Table 4: Moments with Long-Run Inflation Risk

Variable	U.S. Data 1961-2007	EU Preferences	Best Fit EZ Prefs
sd[C]	1.19	1.92	1.86
sd[L]	1.71	3.33	1.73
sd[w^r]	0.82	2.55	1.45
sd[π]	2.52	5.00	3.22
sd[i]	2.71	4.74	2.99
sd[r]	2.30	2.61	1.48
sd[$i^{(10)}$]	2.41	3.32	1.94
mean[$\psi^{(10)}$]	1.06	.002	.748
sd[$\psi^{(10)}$]	0.54	.001	.431
mean[$i^{(10)} - i$]	1.43	$-$.062	.668
sd[$i^{(10)} - i$]	1.33	1.60	1.11
mean[$x^{(10)}$]	1.76	.003	.737
sd[$x^{(10)}$]	23.43	16.96	11.83
memo: quasi-CRRA		2	65

Conclusions

1. Epstein-Zin preferences appear to solve bond premium puzzle in DSGE model, as in an endowment economy:
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2. Long-run risks reduce the required quasi-CRRA, increase volatility of risk premia, help fit financial moments

3. Unresolved issues:
   - Reliance on technology shocks, not π^* shocks
   - Fitting more moments, estimation from data
   - Is quasi-CRRA appropriate measure of risk aversion?
   - Little feedback from asset prices to economy