Motivation

Goal: Show that a simple macroeconomic model (with Epstein-Zin preferences) is consistent with a wide variety of asset pricing facts

- equity premium puzzle
- long-term bond premium puzzle (nominal and real)
- credit spread puzzle
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- financial intermediaries: Adrian-Etula-Muir (2013)
Implications for Finance:

- unifying explanation for asset pricing puzzles
- structural model of asset prices (provides intuition, robustness to breaks and policy interventions)
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- show how to match risk premia in DSGE framework
- start to endogenize asset price–macroeconomy feedback
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Secondary theme: Keep the model as simple as possible

Two key ingredients:
- Epstein-Zin preferences
- nominal rigidities
Households

Period utility function:

\[ u(c_t, l_t) \equiv \log c_t - \eta \frac{l_t^{1+\chi}}{1+\chi} \]

- additive separability between \( c \) and \( l \)
- SDF comparable to finance literature
- log preferences for balanced growth, simplicity
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Flow budget constraint:

\[ a_{t+1} = e^t a_t + w_t l_t + d_t - c_t \]
Households

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Flow budget constraint:

\[ a_{t+1} = e^t a_t + w_t l_t + d_t - c_t \]

Calibration: (IES = 1), \( \chi = 3 \), \( l = 1 \) (\( \eta = .54 \))
Generalized Recursive Preferences

Household chooses state-contingent \( \{(c_t, l_t)\} \) to maximize

\[
V(a_t; \theta_t) = \max_{(c_t, l_t)} u(c_t, l_t) - \beta \alpha^{-1} \log [E_t \exp(-\alpha V(a_{t+1}; \theta_{t+1}))]
\]
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\]

Calibration: \(\beta = .992\), RRA \((R^c) = 60\) \((\alpha = 59.15)\)
Firms are very standard:
- continuum of monopolistic firms (gross markup $\lambda$)
- Calvo price setting (probability $1 - \xi$)
- Cobb-Douglas production functions, $y_t(f) = A_t k^{1-\theta} l_t(f)^\theta$
- fixed firm-specific capital stocks $k$
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- simplicity
- comparability to finance literature
- helps match equity premium
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- helps match equity premium

Calibration: $\lambda = 1.1$, $\xi = 0.8$, $\theta = 0.6$, $\sigma_A = .007$, $(\rho_A = 1)$, $\frac{k}{4Y} = 2.5$
Fiscal and Monetary Policy

No government purchases or investment:

\[ Y_t = C_t \]
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Taylor-type monetary policy rule:

\[ i_t = r + \pi_t + \phi_\pi (\pi_t - \bar{\pi}) + \phi_y (y_t - \bar{y}_t) \]
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Rule has no inertia:

- simplicity

Calibration: \(\phi_\pi = 0.5, \phi_y = 0.75, \bar{\pi} = .008, \rho_y = 0.9\)
Solution Method

Write equations of the model in recursive form
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Divide nonstationary variables \((Y_t, C_t, w_t, \text{etc.})\) by \(A_t\)
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- first-order: no risk premia
- second-order: risk premia are constant
- third-order: time-varying risk premia
- higher-order: more accurate over larger region
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Model has 2 state variables \((\tilde{y}_t, \Delta_t)\), one shock \((\varepsilon_t)\)
Impulse Responses

Technology $A_t$

percent

0.0
0.2
0.4
0.6
0.8
1.0

0 10 20 30 40 50

percent

0.0
0.2
0.4
0.6
0.8
1.0

0 10 20 30 40 50
Impulse Responses

Inflation $\pi_t$

ann. pct.

0.0

-1.0

-0.8

-0.6

-0.4

-0.2

0.0

ann. pct.
Impulse Responses

Short-term nominal interest rate $i_t$

Ann. pct.
Impulse Responses

Short-term real interest rate $r_t$
Nonlinear vs. Linear Impulse Response Responses

Consumption $C_t$

1st-order solution
5th-order solution

percent

0.0
0.2
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percent

0 10 20 30 40 50

1st-order solution
5th-order solution

0.0 0.2 0.4 0.6 0.8 1.0

percent

0 10 20 30 40 50 50

Nonlinear vs. Linear Impulse Response Responses

Price Dispersion $\Delta_t$
Nonlinear vs. Linear Impulse Response Responses

Labor $L_t$
Equity: Levered Consumption Claim

Equity price

\[ p_t^e = E_{t} m_{t+1} (C_{t+1}^{\nu} + p_{t+1}^e) \]

where \( \nu \) is degree of leverage
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Equity premium

$$\psi_t^e \equiv E_t R_{t+1}^e - e^{rt}$$
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Equity premium

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Calibration: \( \nu = 3 \)
Table 2: Equity Premium

In the data: 3–6.5 percent per year (e.g., Campbell, 1999, Fama-French, 2002)
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Equity Premium

Equity premium $\psi_t^e$
Real Government Debt

Real $n$-period zero-coupon bond price:

$$p_t^{(n)} = E_t m_{t+1} p_{t+1}^{(n-1)},$$
Real Government Debt

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where

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### Table 3: Real Zero-Coupon Bond Yields

<table>
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<td>0.33</td>
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<td>2.79</td>
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<td>2.80</td>
<td>0.01</td>
<td></td>
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*a* Gürkaynak, Sack, and Wright (2010) online dataset  
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<td>6.12</td>
<td>5.29</td>
<td>4.34</td>
<td>4.12</td>
<td>−1.17</td>
<td></td>
</tr>
<tr>
<td>UK indexed gilts, 1985–2014&lt;sup&gt;c&lt;/sup&gt;</td>
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Table 4: Nominal Zero-Coupon Bond Yields

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## Nominal Yield Curve

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<sup>a</sup>Gürkaynak, Sack, and Wright (2007) online dataset

<sup>b</sup>Bank of England web site
# Nominal Yield Curve

## Table 4: Nominal Zero-Coupon Bond Yields

<table>
<thead>
<tr>
<th>Bond Type</th>
<th>1-yr.</th>
<th>2-yr.</th>
<th>3-yr.</th>
<th>5-yr.</th>
<th>7-yr.</th>
<th>10-yr.</th>
<th>(10y) – (1y)</th>
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Supply shocks make nominal long-term bonds risky: inflation risk
Nominal Term Premium

Nominal term premium $\psi_t^{(40)}$
Defaultable Debt

Default-free depreciating nominal consol:

\[ p_t^c = E_t \, m_{t+1} \, e^{-\pi_{t+1}} \, (1 + \delta p_{t+1}^c) \]
Defaultable Debt

Default-free depreciating nominal consol:

\[ p_t^c = E_t m_{t+1} e^{-\pi_{t+1}} (1 + \delta p_{t+1}^c) \]

Yield to maturity:

\[ i_t^c = \log \left( \frac{1}{p_t^c} + \delta \right) \]
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Default-free depreciating nominal consol:

\[ p^c_t = E_t m_{t+1} e^{-\pi_{t+1}} (1 + \delta p^c_{t+1}) \]

Yield to maturity:

\[ i^c_t = \log \left( \frac{1}{p^c_t} + \delta \right) \]

Nominal consol with default:

\[ p^d_t = E_t m_{t+1} e^{-\pi_{t+1}} \left[ (1 - 1^d_{t+1})(1 + \delta p^d_{t+1}) + 1^d_{t+1} \omega_{t+1} p^d_t \right] \]
Defaultable Debt

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\[ p^C_t = E_t m_{t+1} e^{-\pi t+1} (1 + \delta p^C_{t+1}) \]

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Yield to maturity:

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The credit spread is \( i^d_t - i^c_t \)
## Table 5: Credit Spread

<table>
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<tr>
<th>average ann. default prob.</th>
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<th>average recovery rate</th>
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If default is not cyclical, then it's not risky
Default Rate is Countercyclical

A. Default rates and credit spreads

- Moody's Recovery Rates
- Altman Recovery Rates

1985–2005

1990–1995

2000

Figure 1. Default rates, credit spreads, and recovery rates over the business cycle.

Panel A plots the Moody's annual corporate default rates during 1920 to 2008 and the monthly Baa-Aaa credit spreads during 1920/01 to 2009/02. Panel B plots the average recovery rates during 1982 to 2008. The "Long-Term Mean" recovery rate is 41.4%, based on Moody's data. Shaded areas are NBER-dated recessions. For annual data, any calendar year with at least 5 months being in a recession as defined by NBER is treated as a recession year.

default component of the average 10-year Baa-Treasury spread in this model rises from 57 to 105 bps, whereas the average optimal market leverage of a Baa-rated firm drops from 50% to 37%, both consistent with the U.S. data.

Figure 1 provides some empirical evidence on the business cycle movements in default rates, credit spreads, and recovery rates. The dashed line in Panel A plots the annual default rates over 1920 to 2008. There are several spikes in the default rates, each coinciding with an NBER recession. The solid line plots the monthly Baa-Aaa credit spreads from January 1920 to February 2009. The spreads shoot up in most recessions, most visibly during the Great Depression, the savings and loan crisis in the early 1980s, and the recent financial crisis in 2008. However, they do not always move in lock-step with default rates (the correlation at an annual frequency is 0.65), which suggests that other factors, such as recovery rates and risk premia, also affect the movements in spreads.

Next, business cycle variation in the recovery rates is evident in

source: Chen (2010)
Recovery Rate is Procyclical

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Discussion

1. Endogenous conditional heteroskedasticity
2. IES $\leq 1$ vs. IES $> 1$
3. Volatility shocks
4. Monetary and fiscal policy shocks
5. Financial accelerator
Endogenous Conditional Heteroskedasticity

Note that

\[ \psi_t^e \equiv E_t R_{t+1}^e - e_{r_t} \]
Endogenous Conditional Heteroskedasticity

Note that

\[ \psi_t^e \equiv E_t R_{t+1}^e - e_{r,t} \]

\[ = \frac{E_t (C_{t+1}^e + p_{t+1}^e)}{p_t^e} - e_{r,t} \]
Note that

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\[ = \frac{E_t (C_{t+1}^\nu + p_{t+1}^e)}{p_t^e} - e_{r_t} \]

\[ = \frac{E_t (C_{t+1}^\nu + p_{t+1}^e)}{E_t m_{t+1} (C_{t+1}^\nu + p_{t+1}^e)} - \frac{1}{E_t m_{t+1}} \]
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= \frac{E_t m_{t+1} E_t (C_{t+1}^\nu + p_{t+1}^e) - E_t m_{t+1}(C_{t+1}^\nu + p_{t+1}^e)}{E_t m_{t+1} p_t^e}
\]
Endogenous Conditional Heteroskedasticity

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\[
\psi_t^e \equiv E_t R_{t+1}^e - e_{t+1}^e = \frac{E_t (C_{t+1}^e + p_{t+1}^e)}{p_t^e} - e_{t+1}^e = \frac{E_t (C_{t+1}^e + p_{t+1}^e)}{E_t m_{t+1} (C_{t+1}^e + p_{t+1}^e)} - \frac{1}{E_t m_{t+1}} = \frac{E_t m_{t+1} E_t (C_{t+1}^e + p_{t+1}^e) - E_t m_{t+1} (C_{t+1}^e + p_{t+1}^e)}{E_t m_{t+1} p_t^e} = -\text{Cov}_t (m_{t+1}, R_{t+1}^e) \frac{1}{E_t m_{t+1}}
\]
Note that

\[ \psi^e_t \equiv E_t R^e_{t+1} - e^r_t \]

\[ = \frac{E_t(C^{\nu}_{t+1} + p^e_{t+1})}{p^e_t} - e^r_t \]

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\[ = -\text{Cov}_t(m_{t+1}, R^e_{t+1}) \]

\[ = -\text{Cov}_t\left(\frac{m_{t+1}}{E_t m_{t+1}}, r^e_{t+1}\right) \]
Endogenous Conditional Heteroskedasticity

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$$\psi_t^e = -\text{Cov}_t\left(\frac{m_{t+1}}{E_t m_{t+1}}, r_{t+1}^e\right)$$

Risk premium can only vary over time if SDF or asset return is conditionally heteroskedastic
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Risk premium can only vary over time if SDF or asset return is conditionally heteroskedastic.

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Here, conditional heteroskedasticity is endogenous.

Nonlinear solution contains terms of form

\[ x_{t+1} \]

so covariance Cov$_t$ depends on state $x_t$. 
Impulse Responses for Conditional Variance

Conditional Variance $Var_t[(C_{t+1}/C_t)^{-1}]$
Conditional Variance $\text{Var}_t[\exp(-\alpha V_{t+1})/E_t\exp(-\alpha V_{t+1})]$
Impulse Responses to Pos. and Neg. Tech. Shocks

- Price Dispersion $\Delta_t$
- Consumption $C_t$

- No previous shock in period 0
- Previous shock of .007 in period 0
Intertemporal Elasticity of Substitution

Long-run risks literature typically assumes IES > 1, for two reasons:

- ensures equity prices rise in response to an increase in technology
- ensures equity prices fall in response to an increase in volatility
Intertemporal Elasticity of Substitution

Long-run risks literature typically assumes $\theta > 1$, for two reasons:

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Model here satisfies both criteria with IES = 1 (or even < 1).
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Extend model above to include volatility shocks:

$$\log \sigma_{A,t} = (1 - \rho_{\sigma}) \log \bar{\sigma}_A + \rho_{\sigma} \log \sigma_{A,t-1} + \varepsilon_t^\sigma$$
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\[ \log \sigma_{A,t} = (1 - \rho_{\sigma}) \log \bar{\sigma}_A + \rho_{\sigma} \log \sigma_{A,t-1} + \varepsilon_t^\sigma \]

Calibration: \( \rho_{\sigma} = .98, \ Var(\varepsilon_t^\sigma) = (0.1)^2 \)
Impulse Responses to Volatility Shock

Volatility $\sigma_{A,t}$
Impulse Responses to Volatility Shock

Consumption $C_t$

percent

-0.5
-0.4
-0.3
-0.2
-0.1
0.0

percent

10 20 30 40 50

-0.5
-0.4
-0.3
-0.2
-0.1
0.0

percent

Introduction
Model
Asset Prices
Discussion
Conclusions
Impulse Responses to Volatility Shock

Inflation $\pi_t$

ann. pct.
Impulse Responses to Volatility Shock

Equity premium $\psi_t^e$
Impulse Responses to Volatility Shock

Equity price $p_t^e$
Impulse Responses to Volatility Shock

Nominal term premium $\psi_t^{(40)}$
Monetary and Fiscal Policy Shocks

Rudebusch and Swanson (2012) consider similar model with

- technology shock
- government purchases shock
- monetary policy shock
Monetary and Fiscal Policy Shocks

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All three shocks help the model fit macroeconomic variables
Rudebusch and Swanson (2012) consider similar model with
- technology shock
- government purchases shock
- monetary policy shock

All three shocks help the model fit macroeconomic variables

But technology shock is most important (by far) for fitting asset prices:
- technology shock is more persistent
- technology shock makes nominal assets risky
No Financial Accelerator

With model-implied stochastic discount factor $m_{t+1}$, we can price any asset.

Economy affects $m_{t+1}$ $\Rightarrow$ economy affects asset prices.

However, asset prices have no effect on economy.
No Financial Accelerator

With model-implied stochastic discount factor $m_{t+1}$, we can price any asset

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Clearly at odds with financial crisis

To generate feedback, want financial intermediaries whose net worth depends on assets
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However, asset prices have no effect on economy.

Clearly at odds with financial crisis.

To generate feedback, want financial intermediaries whose net worth depends on assets.

...but not in this paper.
Conclusions

1. The standard textbook New Keynesian model (with Epstein-Zin preferences) is consistent with a wide variety of asset pricing facts/puzzles.

2. Unifies asset pricing puzzles into a single puzzle—Why does risk aversion in macro models need to be so high? (Literature provides good answers to this question).

3. Provides a structural framework for intuition about risk premia.

4. Suggests a way to model feedback from risk premia to macroeconomy.