A Macroeconomic Model of Equities and Real, Nominal, and Defaultable Debt

Eric T. Swanson
University of California, Irvine

Workshop on Asset Pricing Theory and Computation
Stanford Institute for Theoretical Economics
August 19, 2019
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
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

Implications for Finance:

- unified framework for asset pricing puzzles
- structural model of asset prices (provides intuition, robustness to breaks and policy interventions)
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

Implications for Finance:

- unified framework for asset pricing puzzles
- structural model of asset prices (provides intuition, robustness to breaks and policy interventions)

Implications for Macro:

- show how to match risk premia in DSGE framework
- start to endogenize asset price–macroeconomy feedback
Motivation

Model has two key ingredients:
Motivation

Model has two key ingredients:

- Epstein-Zin preferences
Motivation

Model has two key ingredients:
- Epstein-Zin preferences
- nominal rigidities
Motivation

Model has two key ingredients:

- Epstein-Zin preferences
- nominal rigidities

Reduces separate puzzles in finance to a single, unifying puzzle: Why does risk aversion in model need to be so high?
Motivation

Model has two key ingredients:
- Epstein-Zin preferences
- nominal rigidities

Reduces separate puzzles in finance to a single, unifying puzzle: Why does risk aversion in model need to be so high?
Motivation

Model has two key ingredients:
- Epstein-Zin preferences
- nominal rigidities

Reduces separate puzzles in finance to a single, unifying puzzle: Why does risk aversion in model need to be so high?
- financial intermediaries: Adrian-Etula-Muir (2013)
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
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

Nominal flow budget constraint:

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

Nominal flow budget constraint:

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

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

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

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

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

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

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 $k$
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 $k$

Random walk technology: $\log A_t = \log A_{t-1} + \varepsilon_t$

- simplicity
- comparability to finance literature
- helps match equity premium
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 $k$

Random walk technology: $\log A_t = \log A_{t-1} + \varepsilon_t$

- simplicity
- comparability to finance literature
- 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:

\[ Y_t = C_t \]
Fiscal and Monetary Policy

No government purchases or investment:

\[ Y_t = C_t \]

Taylor-type monetary policy rule:

\[ i_t = r + \pi_t + \phi_\pi (\pi_t - \bar{\pi}) + \phi_y (y_t - \bar{y}_t) \]
Fiscal and Monetary Policy

No government purchases or investment:

\[ Y_t = C_t \]

Taylor-type monetary policy rule:

\[ i_t = r + \pi_t + \phi_{\pi}(\pi_t - \bar{\pi}) + \phi_y(y_t - \bar{y}_t) \]

“Output gap” \((y_t - \bar{y}_t)\) defined relative to moving average:

\[ \bar{y}_t \equiv \rho_y \bar{y}_{t-1} + (1 - \rho_y)y_t \]
Fiscal and Monetary Policy

No government purchases or investment:

\[ Y_t = C_t \]

Taylor-type monetary policy rule:

\[ i_t = r + \pi_t + \phi_\pi (\pi_t - \bar{\pi}) + \phi_y (y_t - \bar{y}_t) \]

“Output gap” \((y_t - \bar{y}_t)\) defined relative to moving average:

\[ \bar{y}_t \equiv \rho \bar{y}_{t-1} + (1 - \rho \bar{y}) y_t \]

Rule has no inertia:

- simplicity
No government purchases or investment:

\[ Y_t = C_t \]

Taylor-type monetary policy rule:

\[ i_t = r + \pi_t + \phi_\pi (\pi_t - \bar{\pi}) + \phi_y (y_t - \bar{y}_t) \]

“Output gap” \((y_t - \bar{y}_t)\) defined relative to moving average:

\[ \bar{y}_t \equiv \rho \bar{y}_{t-1} + (1 - \rho \bar{y}) y_t \]

Rule has no inertia:

- simplicity

Calibration: \(\phi_\pi = 0.5, \phi_y = 0.75, \bar{\pi} = 0.008, \rho \bar{y} = 0.9\)
Solution Method

Write equations of the model in recursive form

Divide nonstationary variables \((Y_t, C_t, w_t, \text{etc.})\) by \(A_t\)
Solution Method

Write equations of the model in recursive form

Divide nonstationary variables \((Y_t, C_t, w_t, \text{etc.})\) by \(A_t\)

Solve using perturbation methods around nonstoch. steady state
Solution Method

Write equations of the model in recursive form

Divide nonstationary variables ($Y_t$, $C_t$, $w_t$, etc.) by $A_t$

Solve using perturbation methods around nonstoch. steady state

- first-order: no risk premia
Solution Method

Write equations of the model in recursive form

Divide nonstationary variables ($Y_t$, $C_t$, $w_t$, etc.) by $A_t$

Solve using perturbation methods around nonstoch. steady state

- first-order: no risk premia
- second-order: risk premia are constant
Solution Method

Write equations of the model in recursive form

Divide nonstationary variables \((Y_t, C_t, w_t, \text{etc.})\) by \(A_t\)

Solve using perturbation methods around nonstoch. steady state

- first-order: no risk premia
- second-order: risk premia are constant
- third-order: time-varying risk premia
Solution Method

Write equations of the model in recursive form

Divide nonstationary variables \((Y_t, C_t, w_t, \text{etc.})\) by \(A_t\)

Solve using perturbation methods around nonstoch. steady state

- first-order: no risk premia
- second-order: risk premia are constant
- third-order: time-varying risk premia
- higher-order: more accurate over larger region
Solution Method

Write equations of the model in recursive form

Divide nonstationary variables \((Y_t, C_t, w_t, \text{etc.})\) by \(A_t\)

Solve using perturbation methods around nonstoch. steady state

- first-order: no risk premia
- second-order: risk premia are constant
- third-order: time-varying risk premia
- higher-order: more accurate over larger region

Model has 2 endogenous state variables \((\bar{y}_t, \Delta_t)\), one shock \((\varepsilon_t)\)
Impulse Responses

Technology $A_t$
Impulse Responses

Consumption $C_t$
Impulse Responses

Inflation $\pi_t$

- $\pi_t$ represents inflation.
- The graph shows the impulse response of inflation over time, with time increases on the x-axis and inflation percentage changes on the y-axis.
- The curve indicates a gradual increase in inflation over time, with percentage changes ranging from 0 to approximately -1.
Impulse Responses

Short-term nominal interest rate $i_t$

Graph showing the short-term nominal interest rate $i_t$ with time on the x-axis ranging from 10 to 50 and annual percentage change on the y-axis ranging from -0.5 to 0.0.
Impulse Responses

Short-term real interest rate $r_t$
Impulse 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
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

Realized gross return:

\[ R_{t+1}^e \equiv \frac{C_{t+1}^\nu + p_{t+1}^e}{p_t^e} \]
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

Realized gross return:

\[ R_{t+1}^e \equiv \frac{C_{t+1}^\nu + p_{t+1}^e}{p_t^e} \]

Equity premium

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

Realized gross return:

\[ R_{t+1}^e \equiv \frac{C_{t+1}^\nu + p_{t+1}^e}{p_t^e} \]

Equity premium

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

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

In the data: 3–6.5 percent per year (e.g., Campbell, 1999, Fama-French, 2002)
Table 2: Equity Premium

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

<table>
<thead>
<tr>
<th>Risk aversion $R^c$</th>
<th>Shock persistence $\rho_A$</th>
<th>Equity premium $\psi^e$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1</td>
<td>0.62</td>
</tr>
<tr>
<td>30</td>
<td>1</td>
<td>1.96</td>
</tr>
<tr>
<td>60</td>
<td>1</td>
<td>4.19</td>
</tr>
<tr>
<td>90</td>
<td>1</td>
<td>6.70</td>
</tr>
</tbody>
</table>
Table 2: Equity Premium

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

<table>
<thead>
<tr>
<th>Risk aversion $R^c$</th>
<th>Shock persistence $\rho_A$</th>
<th>Equity premium $\psi^e$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1</td>
<td>0.62</td>
</tr>
<tr>
<td>30</td>
<td>1</td>
<td>1.96</td>
</tr>
<tr>
<td>60</td>
<td>1</td>
<td>4.19</td>
</tr>
<tr>
<td>90</td>
<td>1</td>
<td>6.70</td>
</tr>
</tbody>
</table>
In the data: 3–6.5 percent per year (e.g., Campbell, 1999, Fama-French, 2002)

<table>
<thead>
<tr>
<th>Risk aversion $R^c$</th>
<th>Shock persistence $\rho_A$</th>
<th>Equity premium $\psi^e$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1</td>
<td>0.62</td>
</tr>
<tr>
<td>30</td>
<td>1</td>
<td>1.96</td>
</tr>
<tr>
<td>60</td>
<td>1</td>
<td>4.19</td>
</tr>
<tr>
<td>90</td>
<td>1</td>
<td>6.70</td>
</tr>
<tr>
<td>60</td>
<td>.995</td>
<td>1.86</td>
</tr>
<tr>
<td>60</td>
<td>.99</td>
<td>1.08</td>
</tr>
<tr>
<td>60</td>
<td>.98</td>
<td>0.53</td>
</tr>
<tr>
<td>60</td>
<td>.95</td>
<td>0.17</td>
</tr>
</tbody>
</table>
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

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

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

$$p_t^{(0)} = 1, \quad p_t^{(1)} = e^{-r_t}$$
Real $n$-period zero-coupon bond price:

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

$$p_t^{(0)} = 1, \quad p_t^{(1)} = e^{-r_t}$$

Real yield:

$$r_t^{(n)} = -\frac{1}{n} \log p_t^{(n)}$$
Real Government Debt

Real \( n \)-period zero-coupon bond price:

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

\[
 p_t^{(0)} = 1, \quad p_t^{(1)} = e^{-r_t}
\]

Real yield:

\[
 r_t^{(n)} = -\frac{1}{n} \log p_t^{(n)}
\]

Real term premium:

\[
 \psi_t^{(n)} = r_t^{(n)} - \hat{r}_t^{(n)}
\]
Real Government Debt

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

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

\[ p_t^{(0)} = 1, \quad p_t^{(1)} = e^{-r_t} \]

Real yield:

\[ r_t^{(n)} = -\frac{1}{n} \log p_t^{(n)} \]

Real term premium:

\[ \psi_t^{(n)} = r_t^{(n)} - \hat{r}_t^{(n)} \]

where

\[ \hat{r}_t^{(n)} = -\frac{1}{n} \log \hat{p}_t^{(n)} \]

\[ \hat{p}_t^{(n)} = e^{-r_t} E_t \hat{p}_{t+1}^{(n-1)} \]
Nominal Government Debt

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

$$p_t^{(n)} = E_t \, m_{t+1} e^{-\pi_{t+1}} p_{t+1}^{(n-1)},$$
Nominal Government Debt

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

$$p_t^{*(n)} = E_t m_{t+1} e^{-\pi_{t+1}} p_{t+1}^{*(n-1)},$$

$$p_t^{*(0)} = 1, \quad p_t^{*(1)} = e^{-i_t}$$

Nominal yield:

$$i_t^{(n)} = -\frac{1}{n} \log p_t^{*(n)}$$

Nominal term premium:

$$\psi_t^{*(n)} = i_t^{(n)} - \hat{i}_t^{(n)}$$

where

$$\hat{i}_t^{(n)} = -\frac{1}{n} \log \hat{p}_t^{*(n)}$$

$$\hat{p}_t^{*(n)} = e^{-i_t} E_t \hat{p}_{t+1}^{*(n-1)}$$
# Real Yield Curve

## Table 3: Real Zero-Coupon Bond Yields

<table>
<thead>
<tr>
<th></th>
<th>2-yr.</th>
<th>3-yr.</th>
<th>5-yr.</th>
<th>7-yr.</th>
<th>10-yr.</th>
<th>(10y) – (3y)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>US TIPS, 1999–2018</strong>&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.12</td>
<td>0.25</td>
<td>0.54</td>
<td>0.80</td>
<td>1.10</td>
<td>0.85</td>
</tr>
<tr>
<td><strong>US TIPS, 2004–2018</strong>&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.42</td>
<td>1.53</td>
<td>1.75</td>
<td>1.92</td>
<td>2.10</td>
<td>0.57</td>
</tr>
<tr>
<td><strong>UK indexed gilts, 1983–1995</strong>&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.12</td>
<td>5.29</td>
<td>4.34</td>
<td></td>
<td>4.12</td>
<td>–1.17</td>
</tr>
<tr>
<td><strong>UK indexed gilts, 1985–2018</strong>&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.53</td>
<td>1.69</td>
<td>1.80</td>
<td>1.90</td>
<td>0.37</td>
<td></td>
</tr>
<tr>
<td><strong>UK indexed gilts, 1990–2007</strong>&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.79</td>
<td>2.78</td>
<td>2.79</td>
<td>2.80</td>
<td>0.01</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Gürkaynak, Sack, and Wright (2010) online dataset  
<sup>b</sup> Evans (1999)  
<sup>c</sup> Bank of England web site
## Real Yield Curve

<table>
<thead>
<tr>
<th></th>
<th>2-yr.</th>
<th>3-yr.</th>
<th>5-yr.</th>
<th>7-yr.</th>
<th>10-yr.</th>
<th>(10y) – (3y)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>US TIPS, 1999–2018</strong>(^a)</td>
<td>1.15</td>
<td>1.39</td>
<td>1.65</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>US TIPS, 2004–2018</strong>(^a)</td>
<td>0.12</td>
<td>0.25</td>
<td>0.54</td>
<td>0.80</td>
<td>1.10</td>
<td>0.85</td>
</tr>
<tr>
<td><strong>US TIPS, 2004–2007</strong>(^a)</td>
<td>1.42</td>
<td>1.53</td>
<td>1.75</td>
<td>1.92</td>
<td>2.10</td>
<td>0.57</td>
</tr>
<tr>
<td><strong>UK indexed gilts, 1983–1995</strong>(^b)</td>
<td>6.12</td>
<td>5.29</td>
<td>4.34</td>
<td></td>
<td>4.12</td>
<td>–1.17</td>
</tr>
<tr>
<td><strong>UK indexed gilts, 1985–2018</strong>(^c)</td>
<td>1.53</td>
<td>1.69</td>
<td>1.80</td>
<td>1.90</td>
<td></td>
<td>0.37</td>
</tr>
<tr>
<td><strong>UK indexed gilts, 1990–2007</strong>(^c)</td>
<td>2.79</td>
<td>2.78</td>
<td>2.79</td>
<td>2.80</td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td><strong>macroeconomic model</strong></td>
<td>1.94</td>
<td>1.93</td>
<td>1.93</td>
<td>1.93</td>
<td>1.93</td>
<td>0.00</td>
</tr>
</tbody>
</table>

\(^a\)Gürkaynak, Sack, and Wright (2010) online dataset

\(^b\)Evans (1999)

\(^c\)Bank of England web site
### Nominal Yield Curve

**Table 4: Nominal Zero-Coupon Bond Yields**

<table>
<thead>
<tr>
<th></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>
</tr>
</thead>
<tbody>
<tr>
<td>US Treasuries, 1961–2018	extsuperscript{a}</td>
<td>5.07</td>
<td>5.29</td>
<td>5.48</td>
<td>5.76</td>
<td>5.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US Treasuries, 1971–2018	extsuperscript{a}</td>
<td>5.16</td>
<td>5.40</td>
<td>5.60</td>
<td>5.92</td>
<td>6.17</td>
<td>6.44</td>
<td>1.28</td>
</tr>
<tr>
<td>US Treasuries, 1990–2007	extsuperscript{a}</td>
<td>4.56</td>
<td>4.84</td>
<td>5.06</td>
<td>5.41</td>
<td>5.68</td>
<td>5.98</td>
<td>1.42</td>
</tr>
<tr>
<td>UK gilts, 1970–2018	extsuperscript{b}</td>
<td>6.52</td>
<td>6.69</td>
<td>6.85</td>
<td>7.10</td>
<td>7.29</td>
<td>7.49</td>
<td>0.97</td>
</tr>
<tr>
<td>UK gilts, 1990–2007	extsuperscript{b}</td>
<td>6.20</td>
<td>6.29</td>
<td>6.38</td>
<td>6.47</td>
<td>6.50</td>
<td>6.48</td>
<td>0.28</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Gürkaynak, Sack, and Wright (2007) online dataset

\textsuperscript{b}Bank of England web site

Supply shocks make nominal long-term bonds risky: inflation risk.
## Nominal Yield Curve

Table 4: Nominal Zero-Coupon Bond Yields

<table>
<thead>
<tr>
<th></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>
</tr>
</thead>
<tbody>
<tr>
<td>US Treasuries, 1961–2018&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.07</td>
<td>5.29</td>
<td>5.48</td>
<td>5.76</td>
<td>5.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US Treasuries, 1971–2018&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.16</td>
<td>5.40</td>
<td>5.60</td>
<td>5.92</td>
<td>6.17</td>
<td>6.44</td>
<td>1.28</td>
</tr>
<tr>
<td>US Treasuries, 1990–2007&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.56</td>
<td>4.84</td>
<td>5.06</td>
<td>5.41</td>
<td>5.68</td>
<td>5.98</td>
<td>1.42</td>
</tr>
<tr>
<td>UK gilts, 1970–2018&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.52</td>
<td>6.69</td>
<td>6.85</td>
<td>7.10</td>
<td>7.29</td>
<td>7.49</td>
<td>0.97</td>
</tr>
<tr>
<td>UK gilts, 1990–2007&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.20</td>
<td>6.29</td>
<td>6.38</td>
<td>6.47</td>
<td>6.50</td>
<td>6.48</td>
<td>0.28</td>
</tr>
<tr>
<td>macroeconomic model</td>
<td>5.35</td>
<td>5.59</td>
<td>5.80</td>
<td>6.09</td>
<td>6.27</td>
<td>6.44</td>
<td>1.09</td>
</tr>
</tbody>
</table>

<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></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>
</tr>
</thead>
<tbody>
<tr>
<td>US Treasuries, 1961–2018&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.07</td>
<td>5.29</td>
<td>5.48</td>
<td>5.76</td>
<td>5.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US Treasuries, 1971–2018&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.16</td>
<td>5.40</td>
<td>5.60</td>
<td>5.92</td>
<td>6.17</td>
<td>6.44</td>
<td>1.28</td>
</tr>
<tr>
<td>US Treasuries, 1990–2007&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.56</td>
<td>4.84</td>
<td>5.06</td>
<td>5.41</td>
<td>5.68</td>
<td>5.98</td>
<td>1.42</td>
</tr>
<tr>
<td>UK gilts, 1970–2018&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.52</td>
<td>6.69</td>
<td>6.85</td>
<td>7.10</td>
<td>7.29</td>
<td>7.49</td>
<td>0.97</td>
</tr>
<tr>
<td>UK gilts, 1990–2007&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.20</td>
<td>6.29</td>
<td>6.38</td>
<td>6.47</td>
<td>6.50</td>
<td>6.48</td>
<td>0.28</td>
</tr>
<tr>
<td>macroeconomic model</td>
<td>5.35</td>
<td>5.59</td>
<td>5.80</td>
<td>6.09</td>
<td>6.27</td>
<td>6.44</td>
<td>1.09</td>
</tr>
</tbody>
</table>

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

<sup>b</sup>Bank of England web site

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:

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

$$i_t^c = \log \left( \frac{1}{p_t^c} + \delta \right)$$
Defaultable Debt

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

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:

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

Yield to maturity:

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

\[ i_t^c = \log \left( \frac{1}{p_t^c} + \delta \right) \]

Nominal consol with default:

\[ p_t^d = E_t m_{t+1} e^{-\pi_{t+1}} \left[ (1 - 1_{t+1}^d)(1 + \delta p_{t+1}^d) + 1_{t+1}^d \omega_{t+1} p_t^d \right] \]

Yield to maturity:

\[ i_t^d = \log \left( \frac{1}{p_t^d} + \delta \right) \]

The credit spread is \( i_t^d - i_t^c \)
### Table 5: Credit Spread

<table>
<thead>
<tr>
<th></th>
<th>Average Ann. Default Prob.</th>
<th>Cyclicality of Default Prob.</th>
<th>Average Recovery Rate</th>
<th>Cyclicality of Recovery Rate</th>
<th>Credit Spread (bp)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.006</td>
<td>0</td>
<td>.42</td>
<td>0</td>
<td>34.0</td>
</tr>
</tbody>
</table>
### Table 5: Credit Spread

<table>
<thead>
<tr>
<th>average ann. default prob.</th>
<th>cyclicality of default prob.</th>
<th>average recovery rate</th>
<th>cyclicality of recovery rate</th>
<th>credit spread (bp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>.006</td>
<td>0</td>
<td>.42</td>
<td>0</td>
<td>34.0</td>
</tr>
</tbody>
</table>

If default isn’t cyclical, then it’s not risky
Default Rate is Countercyclical

source: Chen (2010)
Recovery Rate is Procyclical

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.

Source: Chen (2010)
Table 5: Credit Spread

<table>
<thead>
<tr>
<th>average ann. default prob.</th>
<th>cyclicality of default prob.</th>
<th>average recovery rate</th>
<th>cyclicality of recovery rate</th>
<th>credit spread (bp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.006</td>
<td>0</td>
<td>0.42</td>
<td>0</td>
<td>34.0</td>
</tr>
<tr>
<td>0.006</td>
<td>-0.3</td>
<td>0.42</td>
<td>0</td>
<td>130.9</td>
</tr>
</tbody>
</table>
## Table 5: Credit Spread

<table>
<thead>
<tr>
<th>average ann. default prob.</th>
<th>cyclicality of default prob.</th>
<th>average recovery rate</th>
<th>cyclicality of recovery rate</th>
<th>credit spread (bp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>.006</td>
<td>0</td>
<td>.42</td>
<td>0</td>
<td>34.0</td>
</tr>
<tr>
<td>.006</td>
<td>−0.3</td>
<td>.42</td>
<td>0</td>
<td>130.9</td>
</tr>
<tr>
<td>.006</td>
<td>−0.3</td>
<td>.42</td>
<td>2.5</td>
<td>143.1</td>
</tr>
</tbody>
</table>
Table 5: Credit Spread

<table>
<thead>
<tr>
<th>average ann. default prob.</th>
<th>cyclicality of default prob.</th>
<th>average recovery rate</th>
<th>cyclicality of recovery rate</th>
<th>credit spread (bp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>.006</td>
<td>0</td>
<td>.42</td>
<td>0</td>
<td>34.0</td>
</tr>
<tr>
<td>.006</td>
<td>−0.3</td>
<td>.42</td>
<td>0</td>
<td>130.9</td>
</tr>
<tr>
<td>.006</td>
<td>−0.3</td>
<td>.42</td>
<td>2.5</td>
<td>143.1</td>
</tr>
<tr>
<td>.006</td>
<td>−0.15</td>
<td>.42</td>
<td>2.5</td>
<td>78.9</td>
</tr>
<tr>
<td>.006</td>
<td>−0.6</td>
<td>.42</td>
<td>2.5</td>
<td>367.4</td>
</tr>
<tr>
<td>.006</td>
<td>−0.3</td>
<td>.42</td>
<td>1.25</td>
<td>137.0</td>
</tr>
<tr>
<td>.006</td>
<td>−0.3</td>
<td>.42</td>
<td>5</td>
<td>155.2</td>
</tr>
</tbody>
</table>
Discussion

1. IES ≤ 1 vs. IES > 1
2. Volatility shocks
3. Endogenous conditional heteroskedasticity
4. Monetary and fiscal policy shocks
5. Financial accelerator
Intertemporal Elasticity of Substitution

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

- ensures equity prices rise (by more than consumption) 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 IES > 1, for two reasons:

- ensures equity prices rise (by more than consumption) in response to an increase in technology
- ensures equity prices fall in response to an increase in volatility

However, IES > 1 is not necessary for these criteria to be satisfied, particularly when equity is a levered consumption claim.
Intertemporal Elasticity of Substitution

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

- ensures equity prices rise (by more than consumption) in response to an increase in technology
- ensures equity prices fall in response to an increase in volatility

However, IES > 1 is not necessary for these criteria to be satisfied, particularly when equity is a levered consumption claim.

Model here satisfies both criteria with IES = 1 (or even < 1).
Endogenous Conditional Heteroskedasticity

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

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

Risk premium can only vary over time if SDF or asset return is conditionally heteroskedastic
Endogenous Conditional Heteroskedasticity

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

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

Traditional finance approach: assume shocks are heteroskedastic.
Risk premium can only vary over time if SDF or asset return is conditionally heteroskedastic.

Traditional finance approach: assume shocks are heteroskedastic.

Here, conditional heteroskedasticity is endogenous.
Endogenous Conditional Heteroskedasticity

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

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

Traditional finance approach: assume shocks are heteroskedastic.

Here, conditional heteroskedasticity is \textit{endogenous}.

Nonlinear solution contains terms of form \[ x_t \epsilon_{t+1} \]

so covariance \( \text{Cov}_t \) depends on state \( x_t \).
Impulse Responses for Conditional Variance

Conditional Variance $\text{Var}_t[(C_{t+1}/C_t)^{-1}]$
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

Discussion

Conclusions
Monetary and Fiscal Policy Shocks

Rudebusch and Swanson (2012) consider similar model with
- technology shock
- government purchases shock
- monetary policy shock
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.
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.

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

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.
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.

Clearly at odds with financial crisis.

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

...but not in this paper.
The standard textbook New Keynesian model (with Epstein-Zin preferences) is consistent with a wide variety of asset pricing facts/puzzles.

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

Provides a structural framework for intuition about risk premia

Suggests a way to model feedback from risk premia to macroeconomy