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

Eric T. Swanson

University of California, Irvine

Bank of Canada/Federal Reserve Bank of San Francisco
Conference on Fixed Income Markets
San Francisco
November 5, 2015

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

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

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

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

- uncertainty: Weitzman (2007), Barillas-Hansen-Sargent (2010), et al.
- rare disasters: Rietz (1988), Barro (2006), et al.
- long-run risks: Bansal-Yaron (2004) et al.

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

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

- uncertainty: Weitzman (2007), Barillas-Hansen-Sargent (2010), et al.
- rare disasters: Rietz (1988), Barro (2006), et al.
- long-run risks: Bansal-Yaron (2004) et al.
- heterogeneous agents: Mankiw-Zeldes (1991), Guvenen (2009), Schmidt (2015), et al.
- financial intermediaries: Adrian-Etula-Muir (2013)

Motivation

Implications for Finance:

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

Motivation

Implications for Finance:

- unifying explanation 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

Implications for Finance:

- unifying explanation 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

Secondary theme: Keep the model as simple as possible

Motivation

Implications for Finance:

- unifying explanation 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

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

Flow budget constraint:

$$a_{t+1} = e^{i_t} a_t + w_t l_t + d_t - c_t$$

Calibration: (IES $= 1$), $\chi = 3$, $l = 1$ ($\eta = .54$)

Generalized Recursive Preferences

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

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

Calibration: $\beta = .992$, RRA (R^c) $= 60$ $\quad$ ($\alpha = 59.15$)

Firms

Firms are very standard:

- continuum of monopolistic firms (gross markup λ)
- 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:

$$Y_t = C_t$$

Taylor-type monetary policy rule:

$$i_t = r + \pi_t + \phi_\pi(\pi_t - \overline{\pi}) + \phi_y(y_t - \overline{y}_t)$$

"Output gap" $(y_t - \overline{y}_t)$ defined relative to moving average:

$$\overline{y}_t \equiv \rho_{\bar{y}}\overline{y}_{t-1} + (1 - \rho_{\bar{y}})y_t$$

Rule has no inertia:

- simplicity
- Rudebusch (2002, 2006)

Calibration: $\phi_\pi = 0.5$, $\phi_y = 0.75$, $\overline{\pi} = .008$, $\rho_{\bar{y}} = 0.9$

Solution Method

Write equations of the model in recursive form

Solution Method

Write equations of the model in recursive form

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

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

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
- third-order: time-varying risk premia
- higher-order: more accurate over larger region

Solution Method

Write equations of the model in recursive form

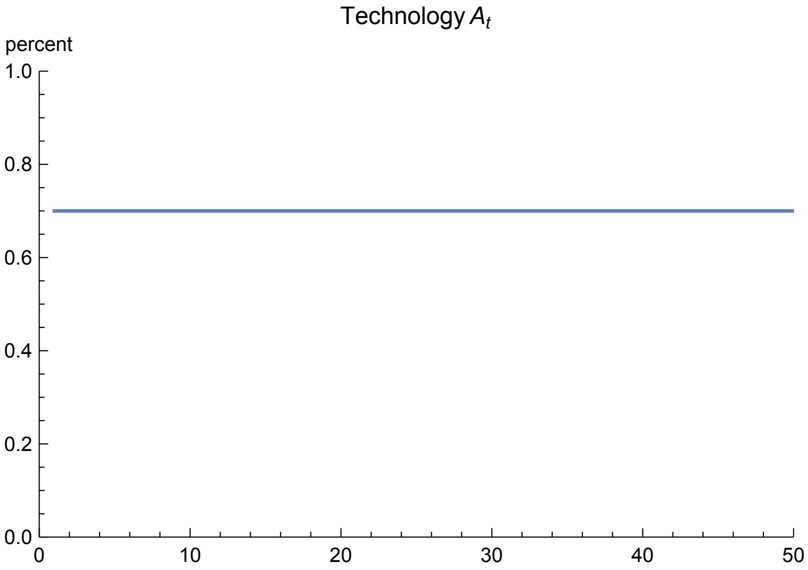
Divide nonstationary variables (Y_t, C_t, w_t, etc.) by A_t

Solve using perturbation methods around nonstoch. steady state

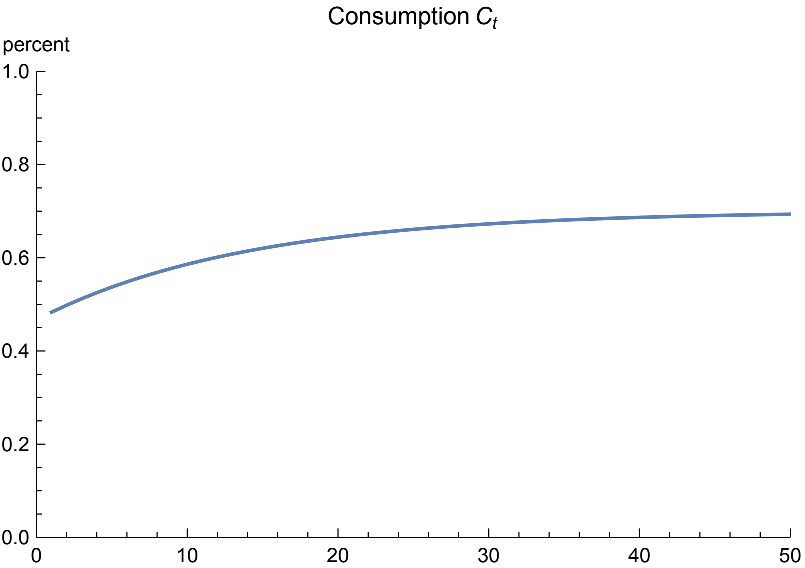
- first-order: no risk premia
- second-order: risk premia are constant
- third-order: time-varying risk premia
- higher-order: more accurate over larger region

Model has 2 state variables ($\bar{y}_t$, Δ_t), one shock (ε_t)

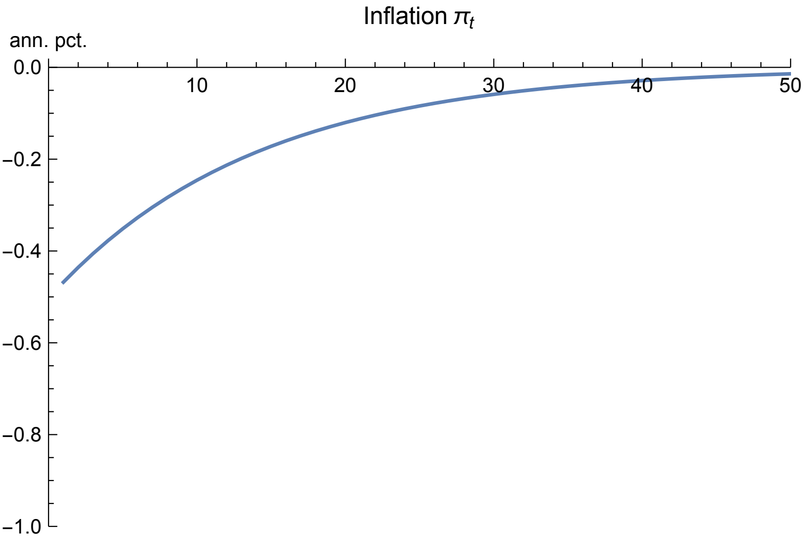
Impulse Responses



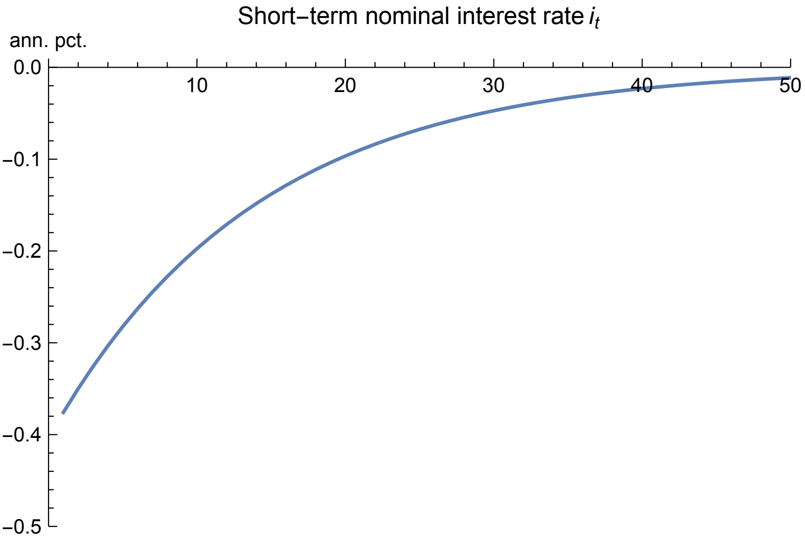
Impulse Responses



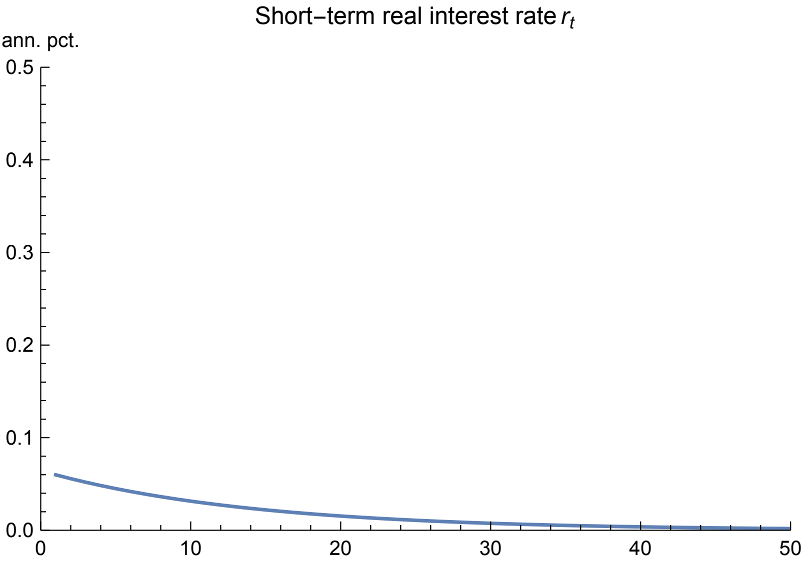
Impulse Responses



Impulse Responses



Impulse Responses



Equity: Levered Consumption Claim

Equity price

$$p_t^e = E_t m_{t+1} (C_{t+1}^{\nu} + p_{t+1}^e)$$

where ν 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 ν 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 ν 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 ν 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)

Risk aversion R^c	Shock persistence ρ_A	Equity premium ψ^e
10	1	0.62
30	1	1.96
60	1	4.19
90	1	6.70

Table 2: Equity Premium

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

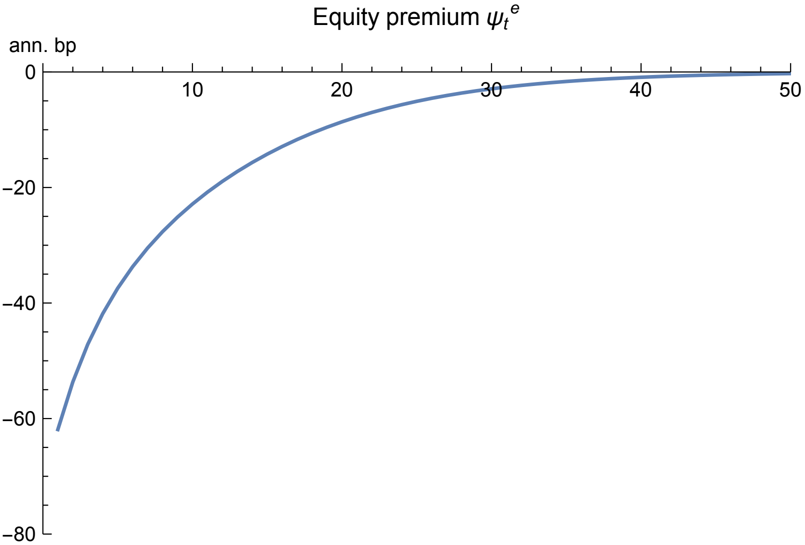
Risk aversion R^c	Shock persistence ρ_A	Equity premium ψ^e
10	1	0.62
30	1	1.96
60	1	4.19
90	1	6.70

Table 2: Equity Premium

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

Risk aversion R^c	Shock persistence ρ_A	Equity premium ψ^e
10	1	0.62
30	1	1.96
60	1	4.19
90	1	6.70
60	.995	1.86
60	.99	1.08
60	.98	0.53
60	.95	0.17

Equity Premium



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 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 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 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 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:

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

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

	2-yr.	3-yr.	5-yr.	7-yr.	10-yr.	(10y)−(3y)
US TIPS, 1999–2014[a]			1.37	1.63	1.90	
US TIPS, 2004–2014[a]	0.19	0.32	0.65	0.95	1.28	0.96
US TIPS, 2004–2007[a]	1.39	1.52	1.74	1.91	2.09	0.57
UK indexed gilts, 1983–1995[b]	6.12	5.29	4.34		4.12	−1.17
UK indexed gilts, 1985–2014[c]		2.02	2.16	2.26	2.35	0.33
UK indexed gilts, 1990–2007[c]		2.79	2.78	2.79	2.80	0.01

Real Yield Curve

Table 3: Real Zero-Coupon Bond Yields

	2-yr.	3-yr.	5-yr.	7-yr.	10-yr.	(10y)−(3y)
US TIPS, 1999–2014[a]			1.37	1.63	1.90	
US TIPS, 2004–2014[a]	0.19	0.32	0.65	0.95	1.28	0.96
US TIPS, 2004–2007[a]	1.39	1.52	1.74	1.91	2.09	0.57
UK indexed gilts, 1983–1995[b]	6.12	5.29	4.34		4.12	−1.17
UK indexed gilts, 1985–2014[c]		2.02	2.16	2.26	2.35	0.33
UK indexed gilts, 1990–2007[c]		2.79	2.78	2.79	2.80	0.01
macroeconomic model	1.94	1.93	1.93	1.93	1.93	0.00

[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

	1-yr.	2-yr.	3-yr.	5-yr.	7-yr.	10-yr.	(10y)−(1y)
US Treasuries, 1961–2014[a]	5.36	5.59	5.77	6.05	6.26		
US Treasuries, 1971–2014[a]	5.53	5.77	5.97	6.29	6.54	6.81	1.28
US Treasuries, 1990–2007[a]	4.56	4.84	5.06	5.41	5.68	5.98	1.42
UK gilts, 1970–2014[b]	7.07	7.25	7.41	7.65	7.84	8.02	0.95
UK gilts, 1990–2007[b]	6.20	6.29	6.38	6.47	6.50	6.48	0.28

Nominal Yield Curve

Table 4: Nominal Zero-Coupon Bond Yields

	1-yr.	2-yr.	3-yr.	5-yr.	7-yr.	10-yr.	(10y)−(1y)
US Treasuries, 1961–2014[a]	5.36	5.59	5.77	6.05	6.26		
US Treasuries, 1971–2014[a]	5.53	5.77	5.97	6.29	6.54	6.81	1.28
US Treasuries, 1990–2007[a]	4.56	4.84	5.06	5.41	5.68	5.98	1.42
UK gilts, 1970–2014[b]	7.07	7.25	7.41	7.65	7.84	8.02	0.95
UK gilts, 1990–2007[b]	6.20	6.29	6.38	6.47	6.50	6.48	0.28
macroeconomic model	5.35	5.59	5.80	6.09	6.27	6.44	1.09

[a]Gürkaynak, Sack, and Wright (2007) online dataset
[b]Bank of England web site

Nominal Yield Curve

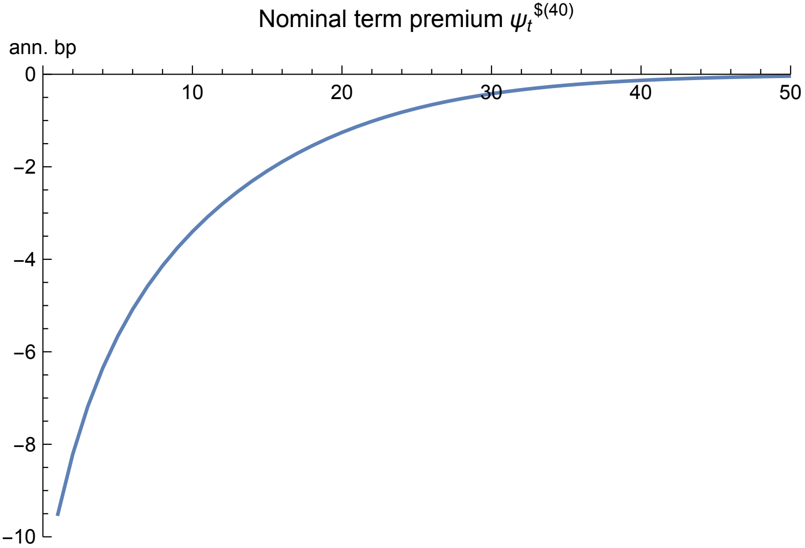
Table 4: Nominal Zero-Coupon Bond Yields

	1-yr.	2-yr.	3-yr.	5-yr.	7-yr.	10-yr.	(10y)−(1y)
US Treasuries, 1961–2014[a]	5.36	5.59	5.77	6.05	6.26		
US Treasuries, 1971–2014[a]	5.53	5.77	5.97	6.29	6.54	6.81	1.28
US Treasuries, 1990–2007[a]	4.56	4.84	5.06	5.41	5.68	5.98	1.42
UK gilts, 1970–2014[b]	7.07	7.25	7.41	7.65	7.84	8.02	0.95
UK gilts, 1990–2007[b]	6.20	6.29	6.38	6.47	6.50	6.48	0.28
macroeconomic model	5.35	5.59	5.80	6.09	6.27	6.44	1.09

[a]Gürkaynak, Sack, and Wright (2007) online dataset
[b]Bank of England web site

Supply shocks make nominal long-term bonds risky: inflation risk

Nominal Term Premium



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:

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

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:

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

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:

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

Yield to maturity:

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

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:

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

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

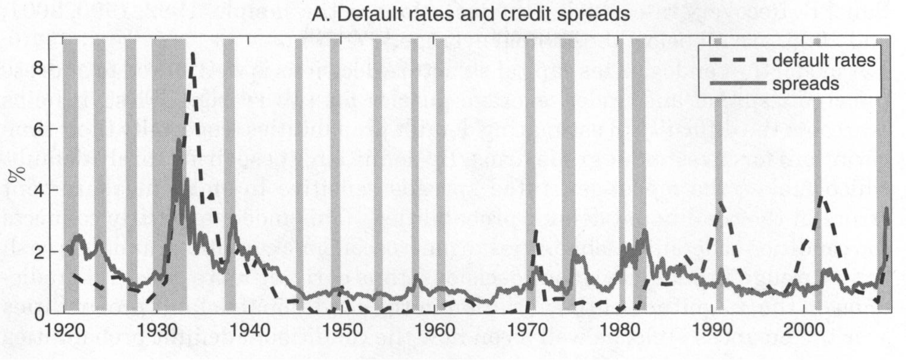
average ann. default prob.	cyclicality of default prob.	average recovery rate	cyclicality of recovery rate	credit spread (bp)
.006	0	.42	0	34.0

Table 5: Credit Spread

average ann. default prob.	cyclicality of default prob.	average recovery rate	cyclicality of recovery rate	credit spread (bp)
.006	0	.42	0	34.0

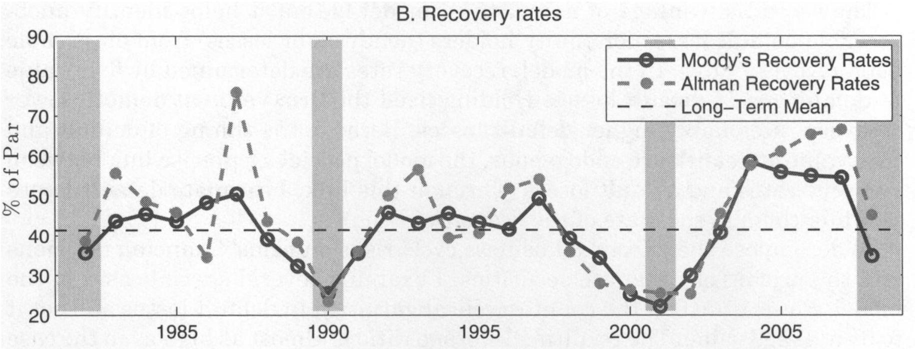
If default isn't cyclical, then it's not risky

Default Rate is Countercyclical



source: Chen (2010)

Recovery Rate is Procyclical



source: Chen (2010)

Table 5: Credit Spread

average ann. default prob.	cyclicality of default prob.	average recovery rate	cyclicality of recovery rate	credit spread (bp)
.006	0	.42	0	34.0
.006	-0.3	.42	0	130.9

Table 5: Credit Spread

average ann. default prob.	cyclicality of default prob.	average recovery rate	cyclicality of recovery rate	credit spread (bp)
.006	0	.42	0	34.0
.006	-0.3	.42	0	130.9
.006	-0.3	.42	2.5	143.1

Discussion

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

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

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

Monetary and Fiscal Policy Shocks

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 $m_{t+1} \Rightarrow$ 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

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

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