Preferred Habitat and the Term Structure of Interest Rates

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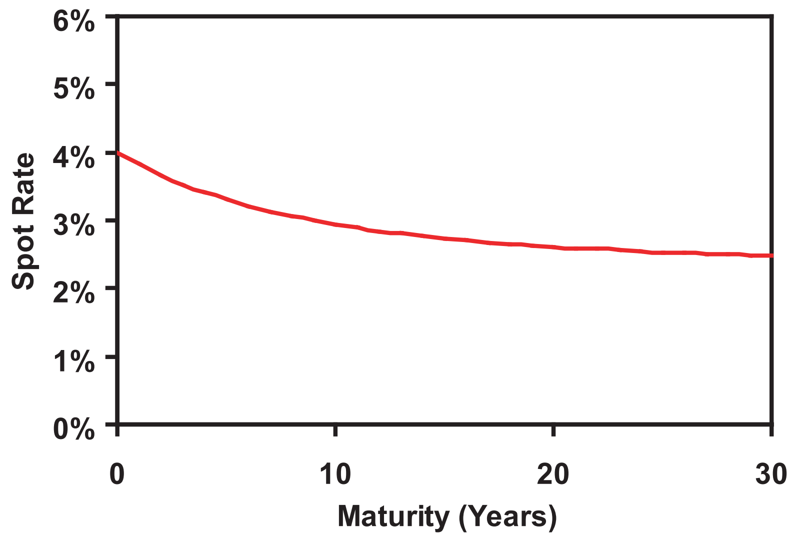
1. Introduction

- Term structure (TS) of interest rates.



- Driven by
  - Short rates. (Current and future)
  - Risk premia.

Representative-Agent Model

- Prices determined by representative agent. (Lucas 1979)
  - Prices must render aggregate consumption optimal.
- Implications for TS: (Cox-Ingersoll-Ross 1985)
  - Interest rate for maturity T depends on consumption at $t = 0$ and $t = T$.
  - Bond risk premia depend on covariance with consumption.

Preferred-Habitat View

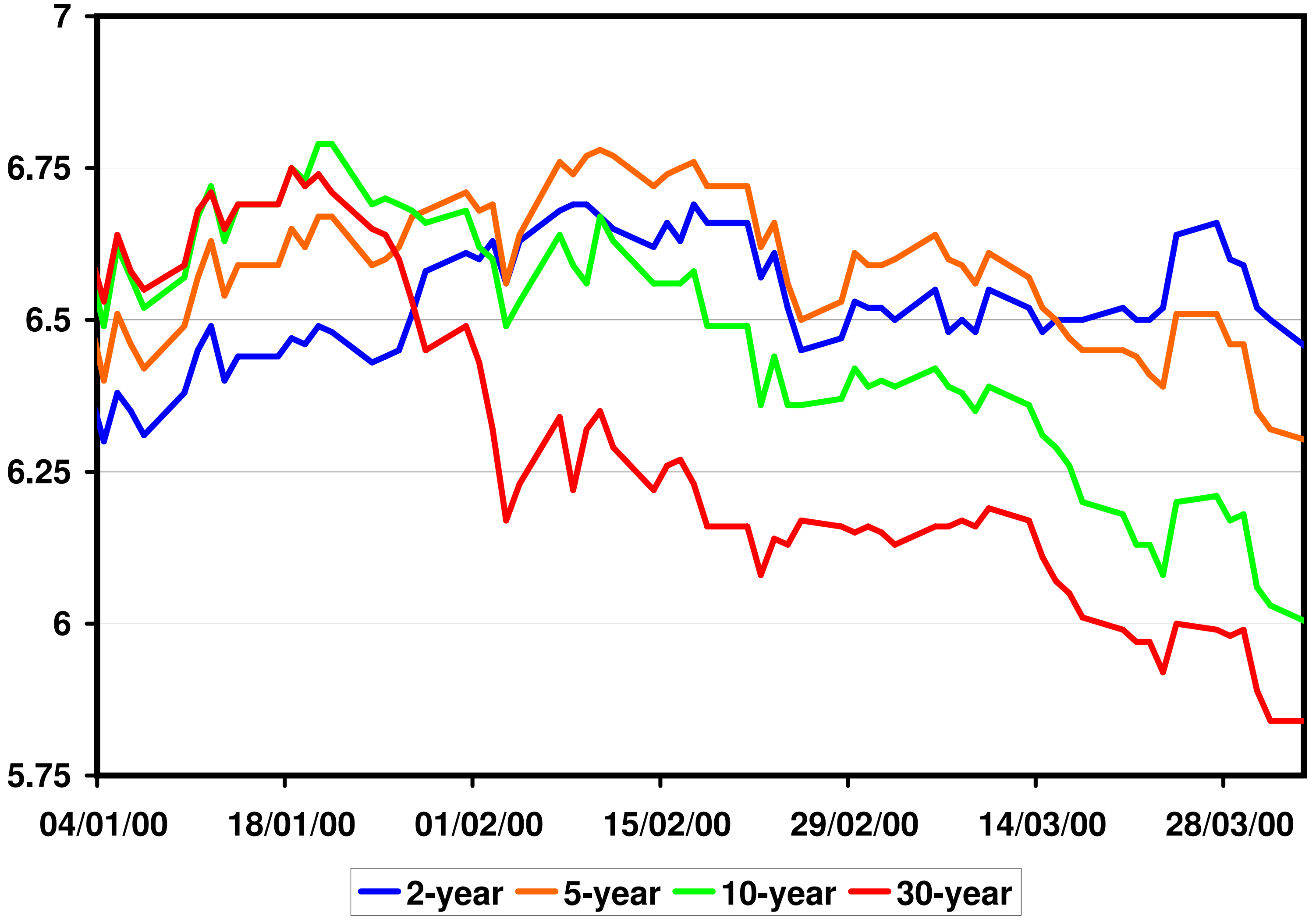
- TS involves clienteles with preferences for specific maturities.
  - Pension funds, life-insurance: Long-term.
  - Asset managers, banks' treasuries: Short-term.
- Local demand and supply matter.
- Culbertson (1957), Modigliani-Sutch (1966), Wall Street

Supply Effects: Example

US Treasury buyback program, 2000-2002.

- Announced on January 13, 2000.
- 45 reverse auctions between March 2000 and April 2002.
- Targeted issues: Maturities between 10 and 27 years.
- Total: $67.5b (on average 14% of each targeted issue).

Impact on TS


7
6.75
6.5
6.25
6
5.75
04/01/00
18/01/00
01/02/00
15/02/00
29/02/00
14/03/00
28/03/00
2-year
5-year
10-year
30-year

Summary and Implications

- Strong inversion of TS.
- Hard to rationalize within representative-agent model.
  - Ricardian equivalence.
  - Is buyback program informative about aggregate consumption in 30 years?
- Consistent with preferred-habitat view.

Preferred Habitat: Criticisms

- No formal model.
- Bonds with nearby maturities are close substitutes

  $\Rightarrow$ No-arbitrage should impose restrictions.

Plan of the Talk

- Model of preferred habitat.
- Empirical testing.
- Implications for bond issuance.
  - Government.
  - Corporations.
- Preferred habitat in other markets.
  - Government vs. corporate bonds.
  - Options.

2. Model of Preferred Habitat

- Vayanos-Vila (2007).
- TS determined by
  - Preferred-habitat demand. (Clienteles)
  - Arbitrageurs.
- Arbitrageurs
  - Integrate markets for different maturities.
  - Are risk-averse.

Main Results

- Bond risk premia are positively related to TS slope.
- Demand/supply vs. short-rate expectations:
  - Effects of demand/supply are stronger for long maturities.
  - Arbitrageurs anchor short maturities to short-rate expectations.

Model

- Continuous time $t \in [0, \infty)$.
- Continuum of zero-coupon bonds.
  - Maturities $\tau \in (0, T]$.
  - Face value $1.

Prices and Rates

- Short rate is exogenous and follows OU process

$$dr_t = \kappa_r(\overline{r} - r_t)dt + \sigma_r dB_t.$$

- Bond prices are endogenous.

- For maturity τ at time t,
  - Price is $P_t^{(\tau)}$.
  - Yield is defined by $y_t^{(\tau)} \equiv -\frac{\log P_t^{(\tau)}}{\tau}$.

Agents

- Preferred-habitat demand.
  - Specific to each maturity.
  - Can depend only on corresponding spot rate.
  - Investor clienteles, government.
- Arbitrageurs.
  - Integrate markets for different maturities.

Preferred-Habitat Demand

- Demand for maturity τ is linear and increasing in spot rate:

$$\alpha(\tau)\tau y_t^{(\tau)} - \beta(\tau) \equiv -s_t^{(\tau)},$$

where $\alpha(\tau) > 0$.

- Absent arbitrageurs, spot rate for maturity τ is

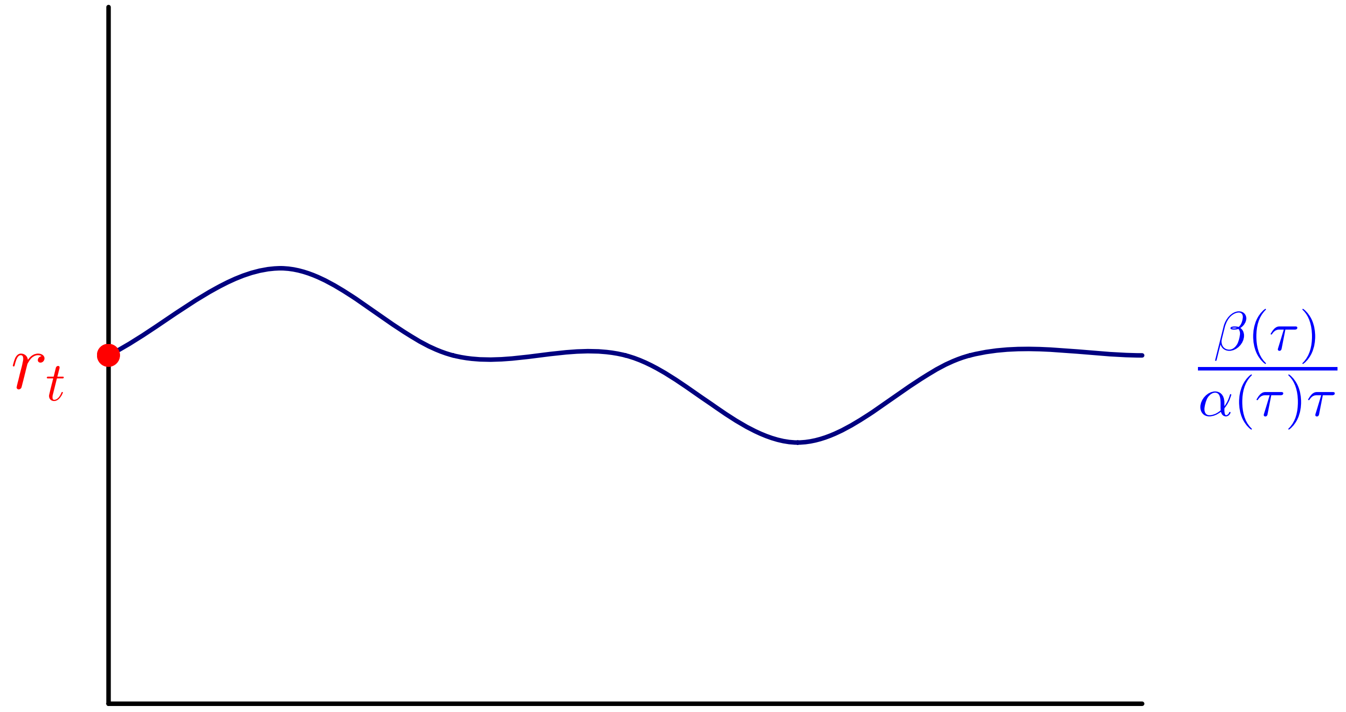
$$y_t^{(\tau)} = \frac{\beta(\tau)}{\alpha(\tau)\tau}.$$

Arbitrageurs

- Can invest in all bonds.
- Preferences over instantaneous mean and variance

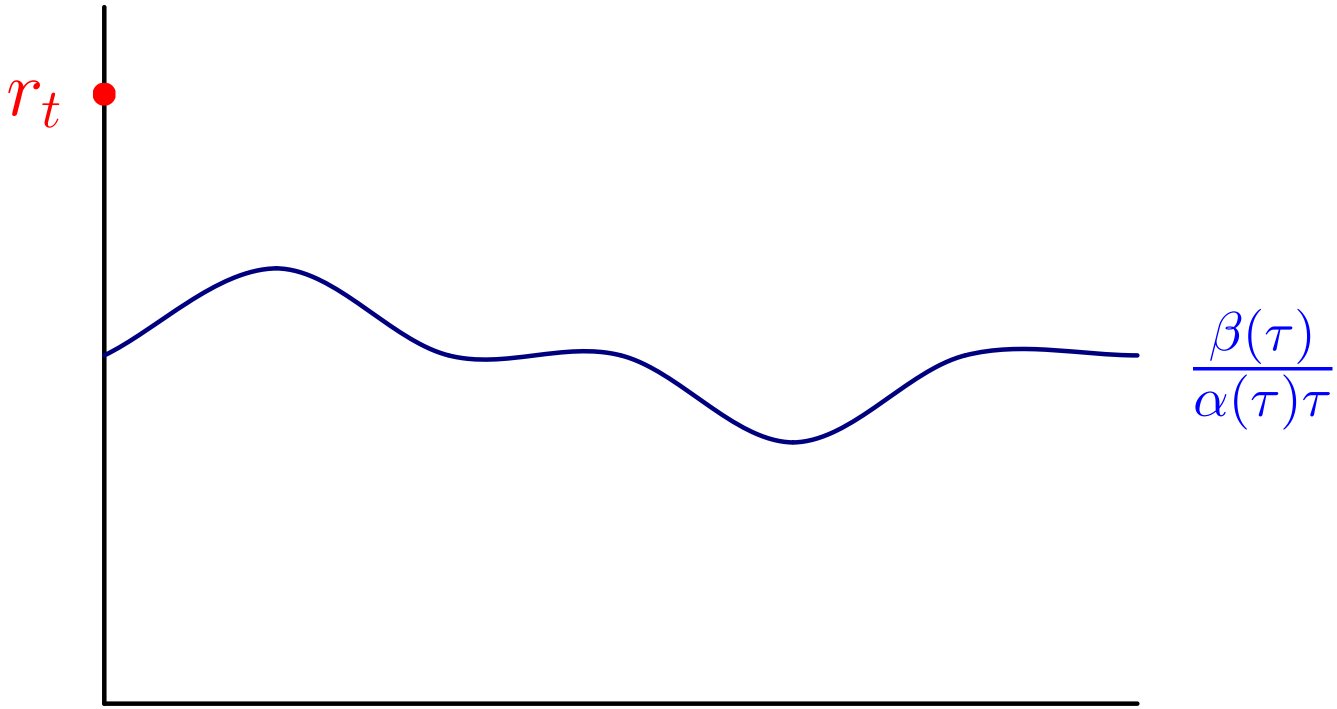
$$E_t(dW_t) - \frac{a}{2} Var_t(dW_t).$$

Equilibrium



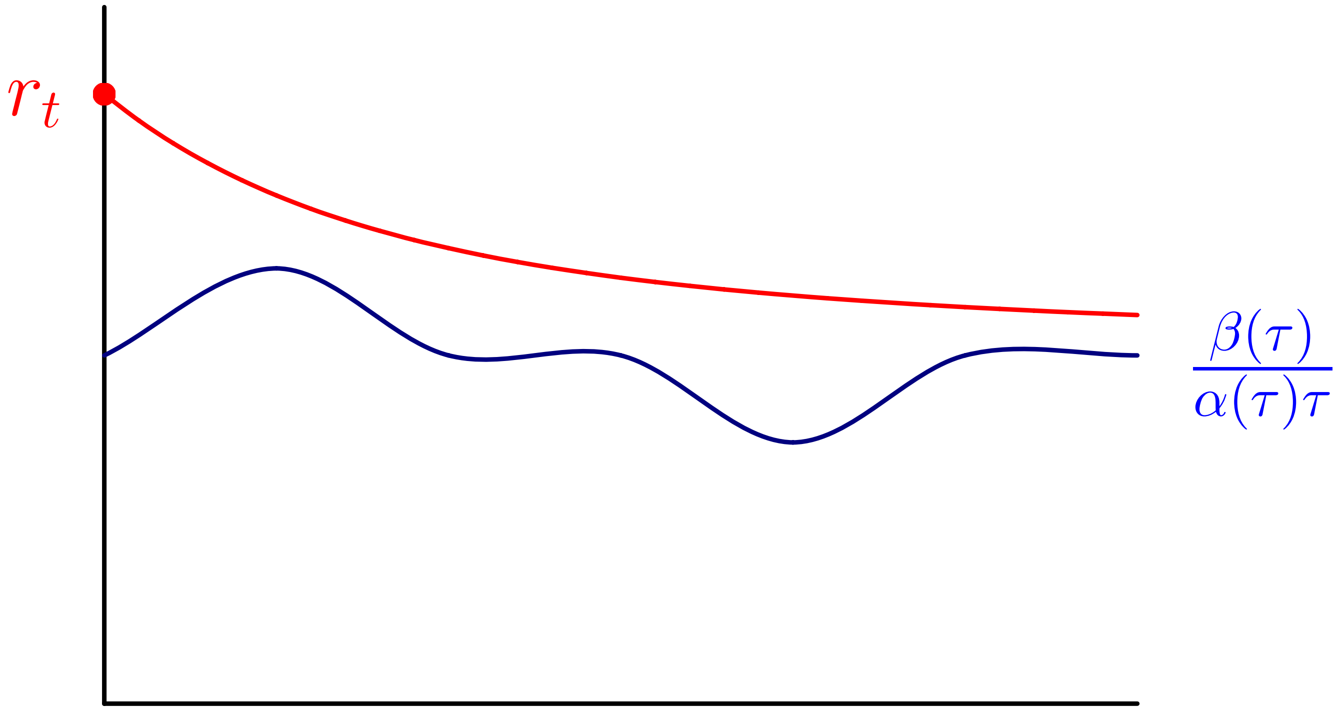
- Absent arbitrageurs, TS can have arbitrary shape ...

Equilibrium



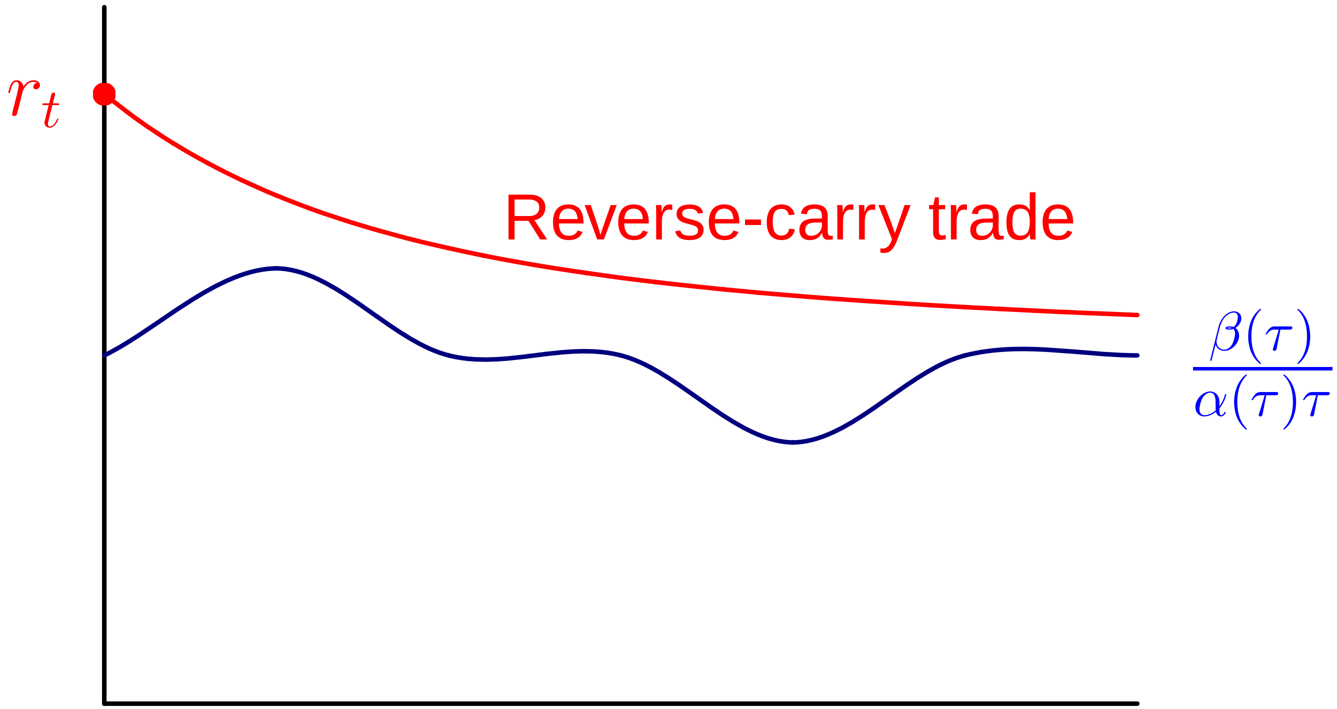
- ... and is disconnected from short-rate process.

Equilibrium



- Arbitrageurs bring information about short rates into TS.

Equilibrium



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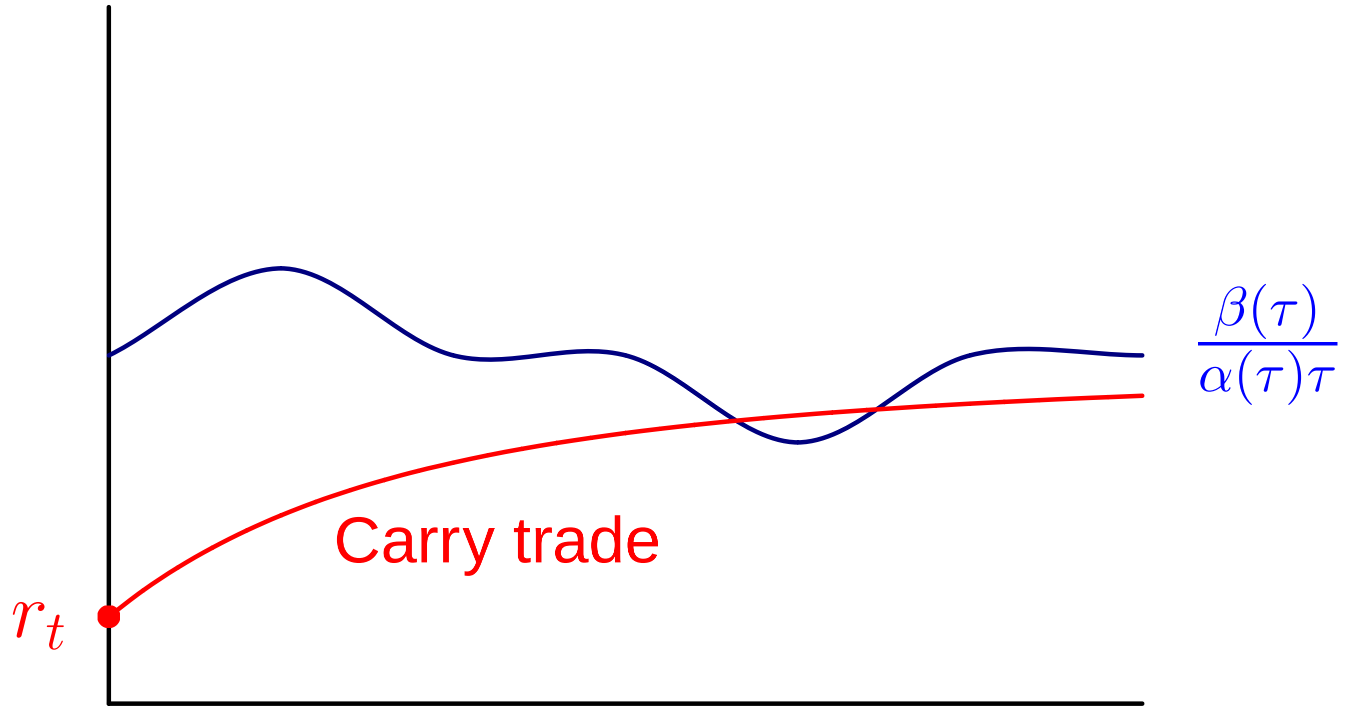

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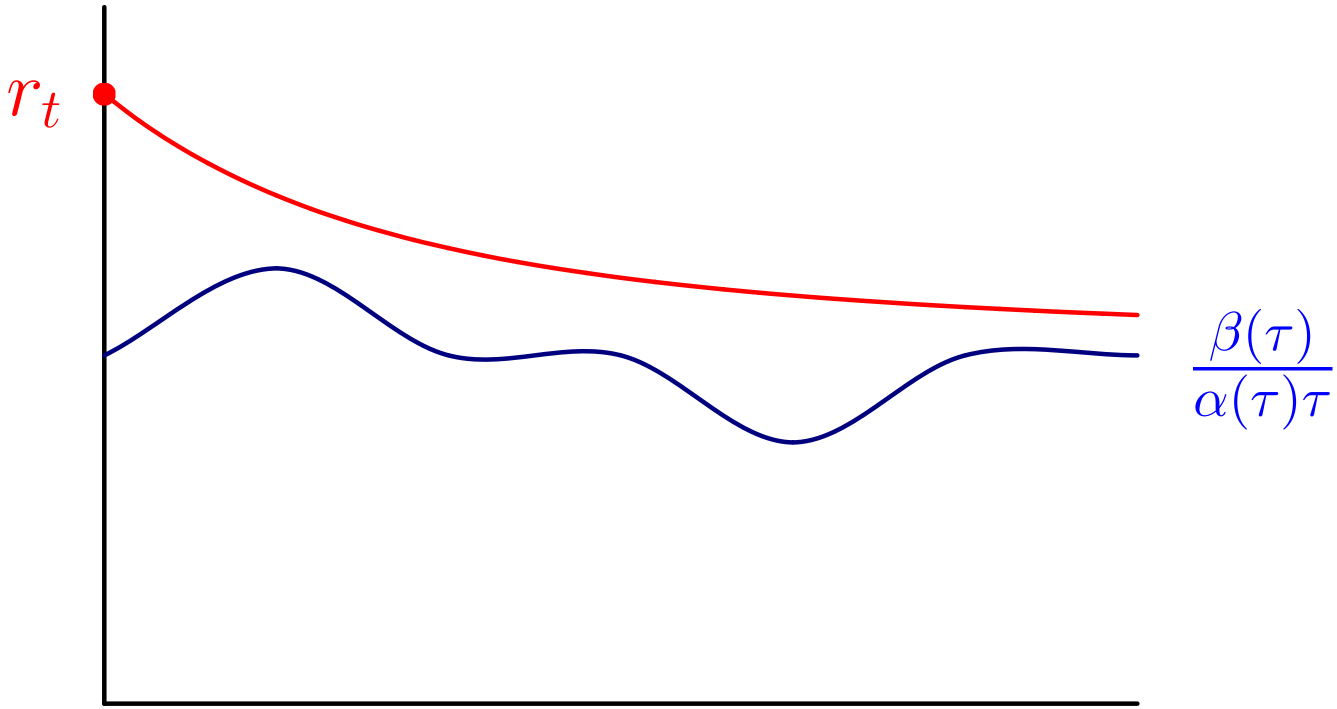


- Arbitrageurs smooth local demand and supply pressures.

Bond Risk Premia

- Fama-Bliss (1987):
  - Bond risk premia are strongly time-varying.
  - Positively related to term-structure slope.
- Suppose that slope is negative.
  - Expectations hypothesis: Short rates should decrease.
  - FB: Short rates do not decrease enough $\Rightarrow$ Premia are negative.

Bond Risk Premia (cont'd)

- Positive premia-slope relationship arises naturally in our model.
- Suppose that r_t is high.
  - Slope is negative.
  - Arbitrageurs short bonds and invest at short rate.
  - Premia are negative.

Solving for Equilibrium

- Conjecture affine bond yields

$$P_t^{(\tau)} = \exp\left[-\left[A_r(\tau)r_t + C(\tau)\right]\right].$$

- Bond returns are

$$\frac{dP_t^{(\tau)}}{P_t^{(\tau)}} = \mu_t^{(\tau)}dt - A_r(\tau)\sigma_r dB_t,$$

where

$$\mu_t^{(\tau)} \equiv A_r'(\tau)r_t + C'(\tau) - A_r(\tau)\kappa_r(\overline{r} - r_t) + \frac{1}{2}A_r(\tau)^2\sigma_r^2.$$

No-Arbitrage Pricing

- No-arbitrage implies

$$\underbrace{\mu_t^{(\tau)} - r_t}_{\text{Bond's expected excess return}} = \underbrace{A_r(\tau)}_{\text{Bond's loading on short rate}} \times \underbrace{\lambda_r.}_{\text{Market price of short-rate risk}}$$

- But what determines λ_r?

Equilibrium Pricing

- No-arbitrage equation

$$\mu_t^{(\tau)} - r_t = A_r(\tau)\lambda_r$$

is also arbitrageurs' first-order condition.

- Implication:

$$\lambda_r = a\sigma_r^2 \times \underbrace{\int_0^T x_t^{(\tau)} A_r(\tau) d\tau.}_{\text{Loading of arbitrageurs' portfolio on short rate}}$$

Loading of arbitrageurs' portfolio on short rate

Solving for λ_r

- Use market clearing.

$$\begin{aligned}\lambda_r &= a\sigma_r^2 \int_0^T s_t^{(\tau)} A_r(\tau) d\tau \\ &= a\sigma_r^2 \int_0^T \left[\beta(\tau) - \alpha(\tau)\tau y_t^{(\tau)}\right] A_r(\tau) d\tau.\end{aligned}$$

- Since

$$y_t^{(\tau)} = \frac{A_r(\tau) r_t + C(\tau)}{\tau},$$

λ_r is affine in r_t.

Market Price of Short-Rate Risk λ_r

- Changes sign with r_t.
  - Negative when r_t is high.
  - Positive when r_t is low.
- Essentially affine model.

  (Dai-Singleton 2002, Duffee 2002)
- Equilibrium model $\Rightarrow$ Can link λ_r to economic primitives:
  - Demand/supply.
  - Arbitrageur risk aversion.

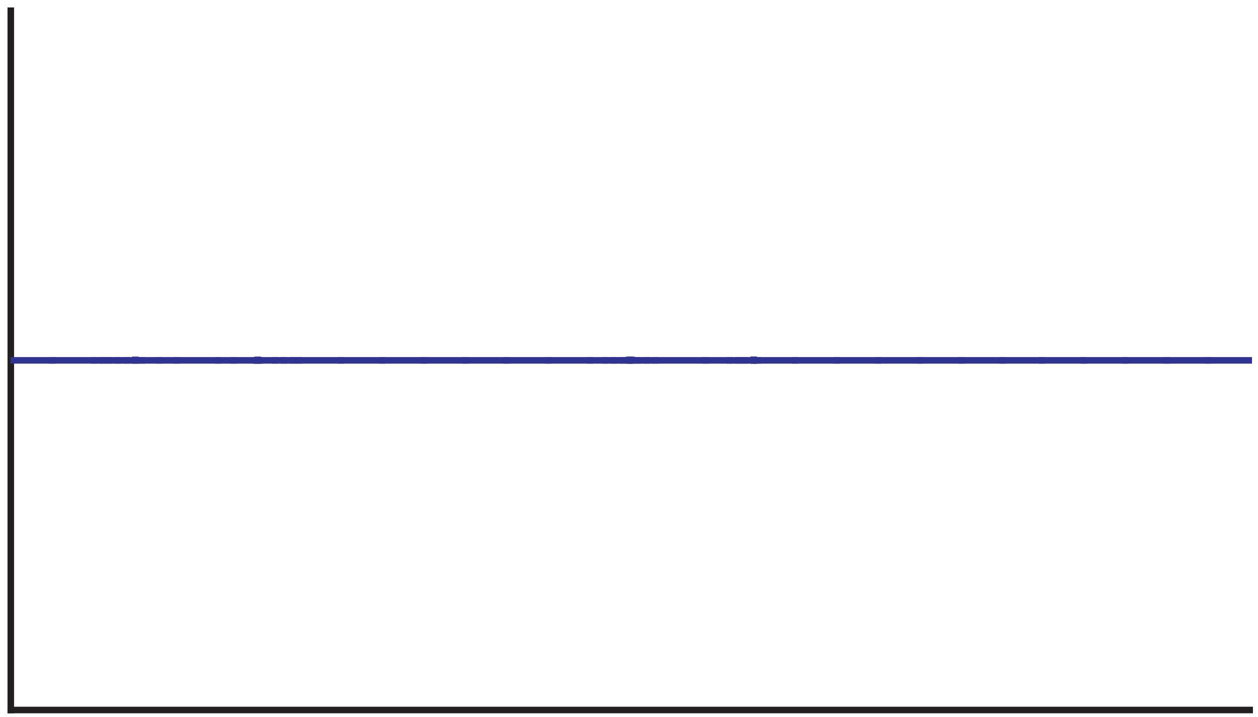
Effects of Demand/Supply

- Demand/supply shocks: Changes in $\beta(\tau)$.
- Empirical counterparts:
  - Changes in maturity structure of government debt.
  - Changes in foreign ownership.
  - Demographical changes.
  - Regulatory reform (e.g., pensions).

Changes in Maturity Structure

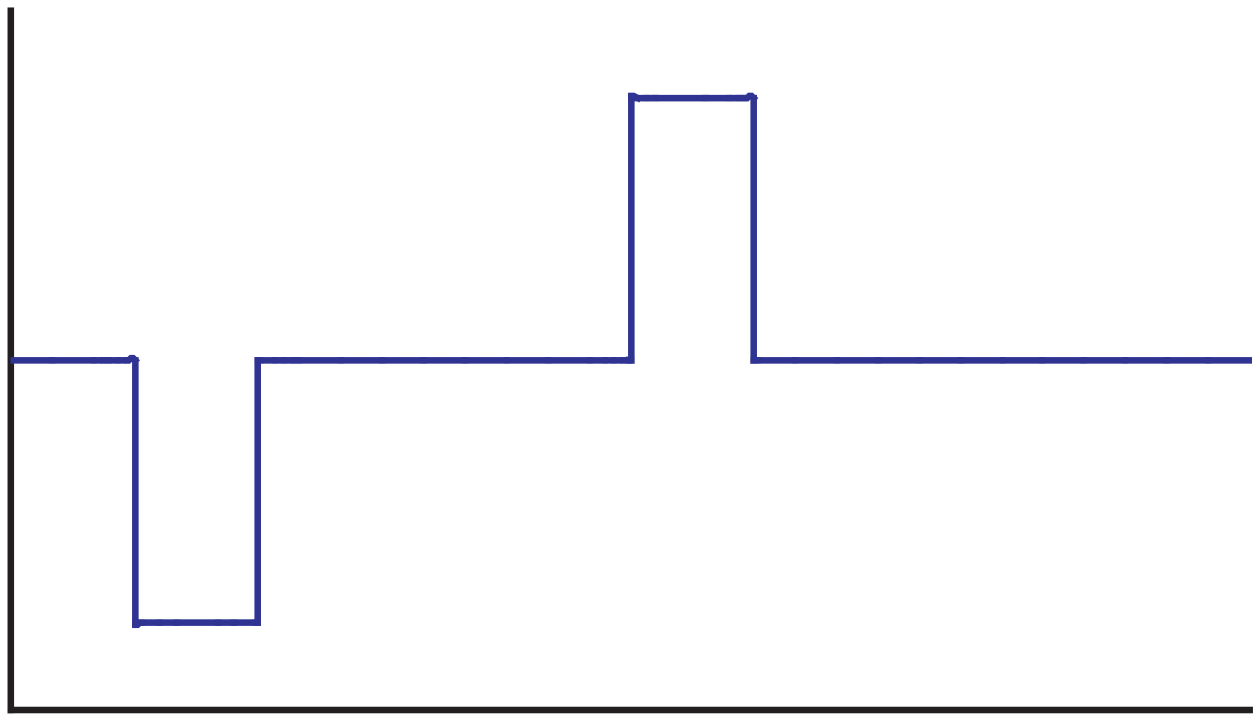
- Suppose that government
  - Issues LT bonds ($\beta(\tau)$ increases for large τ).
  - Buys back ST bonds ($\beta(\tau)$ decreases for small τ).
  - Keeping total value of debt constant ($\int_0^T \beta(\tau) d\tau$).

Effects of Maturity Structure



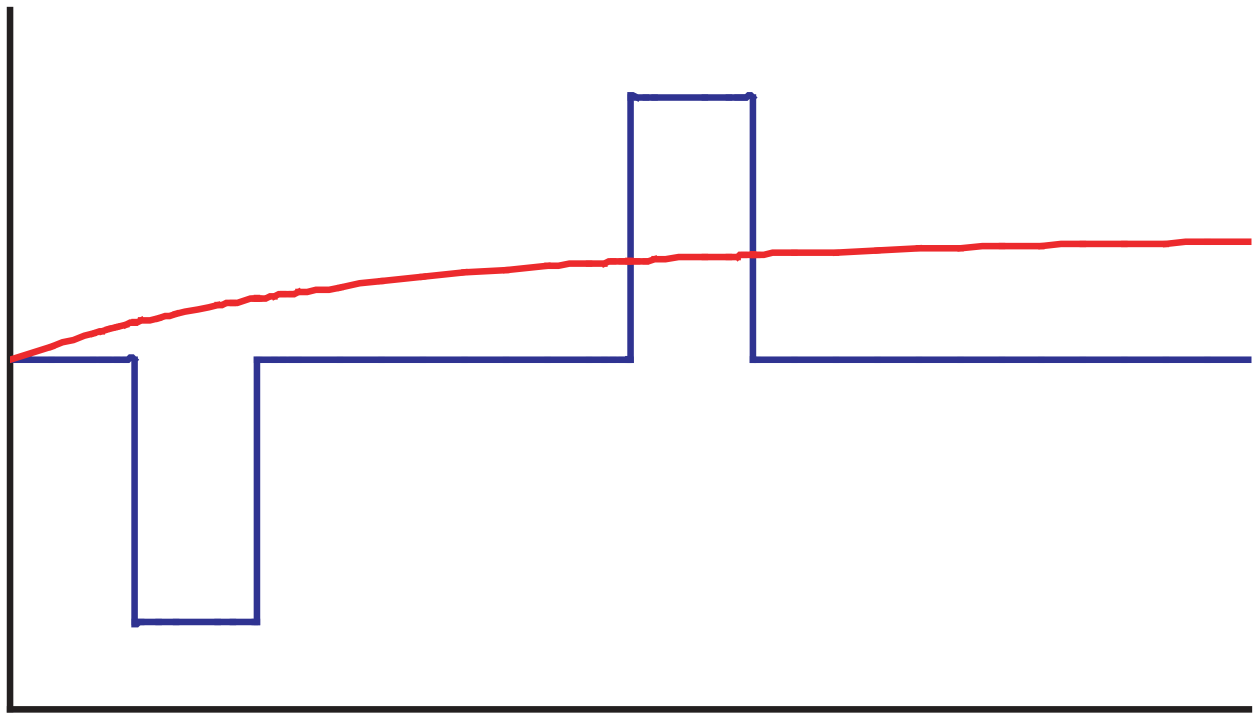
- Suppose that TS is flat, and government
  - Issues LT bonds.
  - Buys back ST bonds.

Effects of Maturity Structure



- Absent arbitrageurs, effects would be local.
  - LT bonds become cheaper.
  - ST bonds become more expensive.

Effects of Maturity Structure



- In the presence of arbitrageurs,
  - All bonds become cheaper.
  - LT bonds especially so.
- Intuition: Market price of short-rate risk λ_r increases.

Arbitrageur Risk Aversion

- When arbitrageurs are more risk-averse (large a):
  - Stronger relationship between premia and TS slope.
  - Demand/supply have stronger effects on yields and risk premia.

Arbitrageur Risk Aversion (cont'd)

- In our model, arbitrageur risk aversion is constant.
- If it increases following trading losses, it is high when
  - TS slopes down and reverse-carry trade loses money.
  - TS slopes up and carry trade loses money.

Multiple Risk Factors

- So far:
  - One-factor model. (Short rate r_t)
  - Demand/supply shocks are unanticipated and one-off.
- Can model explicitly time-variation in demand/supply.

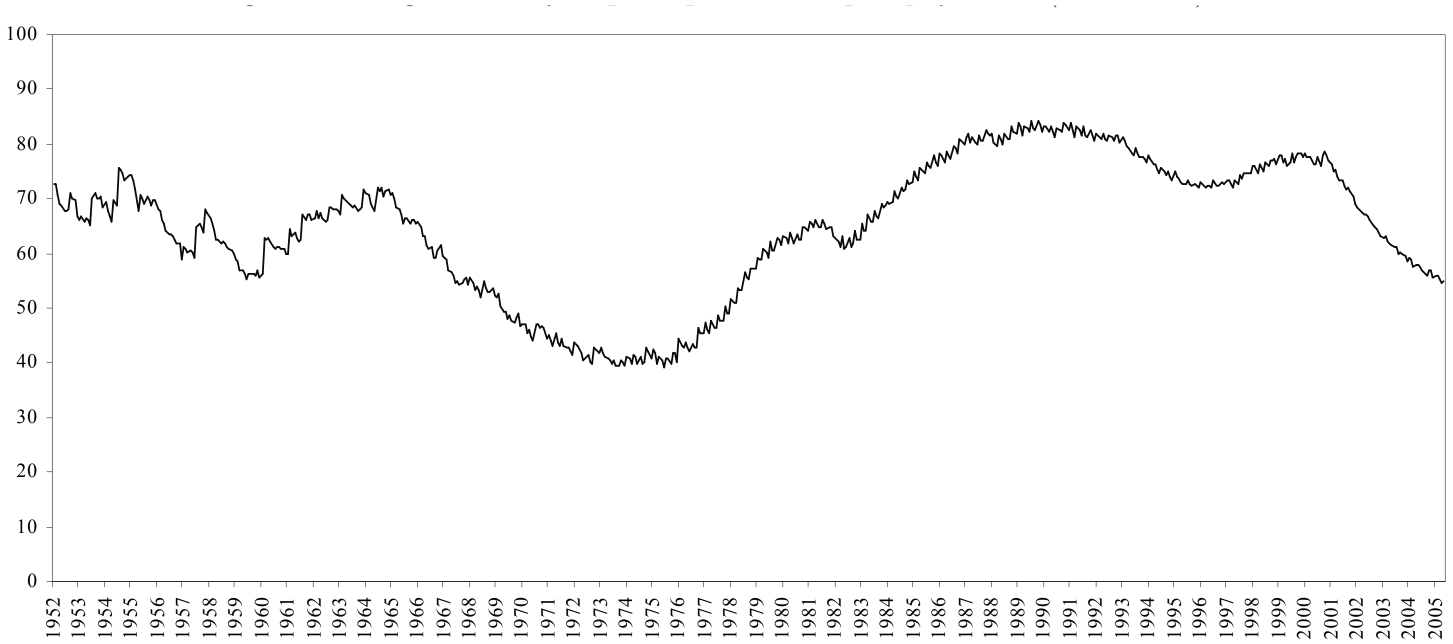
Two-Factor Model

- Demand shock β_t affecting all maturities in same direction.
- Main driver of TS movement is
  - Short-rate expectations (r_t) for short end.
  - Demand (β_t) for long end.
- Even when shocks are independent with same variance, one principal component can explain 95% of return variation!

3. Empirical Testing

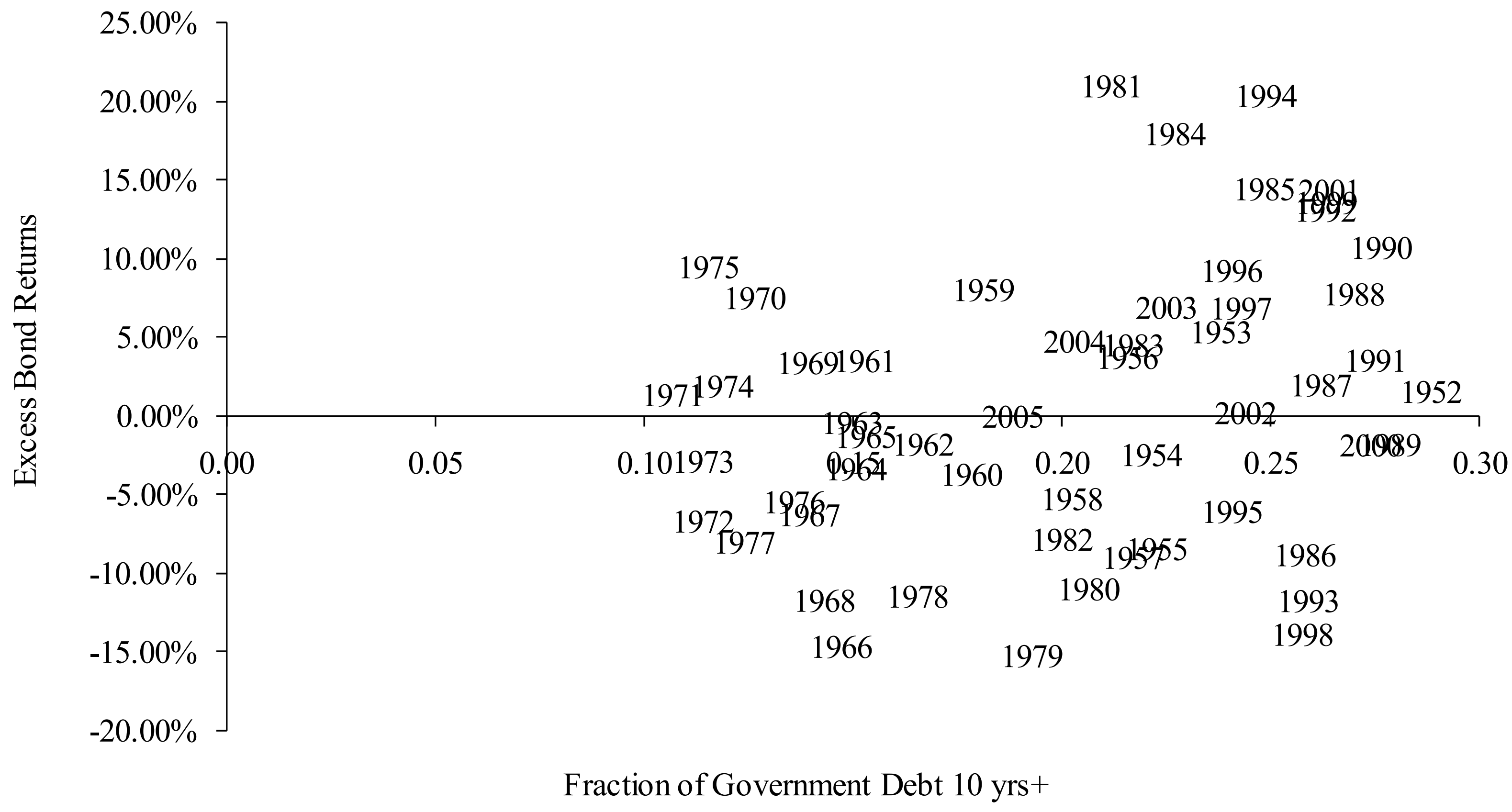
- Greenwood-Vayanos (2008).
- Variation in maturity structure of government debt.
  - Positive correlation with yields?
  - Positive correlation with expected returns?

Dollar-Weighted Average Maturity: US 1952-2005



- Significant time variation.
  - Dropped in late 60s and 70s.
  - Increased in 80s and 90s.

Supply and Bond Returns: Picture



Supply and Bond Returns: Regressions

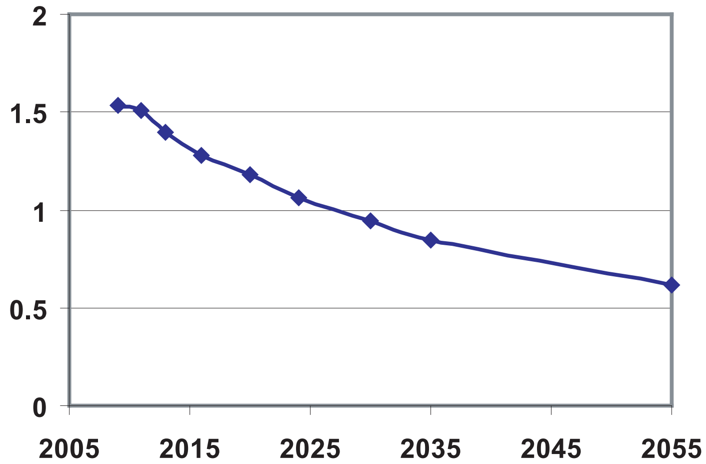
	$X = D_t^{(10+)} / D_t$			
	b	(t)	(t)	R^2
Dependent Variable:				
12-month return 2-year bond	0.100	(2.599)	(2.273)	0.084
12-month return 3-year bond	0.168	(2.566)	(2.252)	0.073
12-month return 4-year bond	0.231	(2.676)	(2.358)	0.072
12-month return 5-year bond	0.274	(2.685)	(2.373)	0.068
12-month return 20-year bond	0.458	(2.838)	(2.528)	0.068
24-month return 20-year bond	1.003	(3.508)	(3.156)	0.164
36-month return 20-year bond	1.574	(3.939)	(3.363)	0.264
60-month return 20-year bond	2.713	(5.260)	(4.372)	0.428

4. Bond Issuance

- Do issuers respond to demand pressures of clienteles?
- Relevant issuers:
  - Government.
  - Corporations.

Clienteles and Government Issuance: Example

- 2005 UK pension reform.
- Pension funds must discount liabilities at market long rates.
- Switch from stocks to long-maturity bonds.
- UK real TS, January 2006:



Issuance Response

- Tilt towards long maturities.
- Maturities of 15 years or longer constitute
  - 58% of issuance during financial year 2006-7.
  - 40% during four previous years.

Optimal Maturity Structure of Government Debt

- Main departures from Ricardian equivalence:
  - Representative agent, distortionary taxes.
  - OLG two-period lives $\Rightarrow$ No clienteles.
- Guibaud-Nosbusch-Vayanos (2008):
  - OLG three-period lives
  - How does generation mix influence maturity structure?
  - Preferred-habitat effects if CRRA$>$1.

Optimal Maturity Structure of Corporate Debt

- Mix of LT and ST debt is irrelevant in Modigliani-Miller world.
- Greenwood-Hanson-Stein (2008):
  - Corporations issue LT debt when govt. supply is small.
  - Corporations time bond market.

5. Preferred Habitat in Other Markets

- Government vs. corporate bonds.
  - Krishnamurthy-Vissing Jorgensen (2007).
- Options.
  - Bollen-Whalley (2004).
  - Garleanu-Pedersen-Poteshman (2007).

6. Conclusion

- TS determined by maturity clienteles and arbitrageurs.
  - Local demand and supply for each maturity.
  - Discipline of no-arbitrage.
- Novel implications for
  - Bond risk premia.
  - TS movements.
  - Government and corporate issuance.