Bond Supply and Excess Bond Returns

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Bank of Canada: September 2008

1. Introduction

What determines term structure of interest rates?

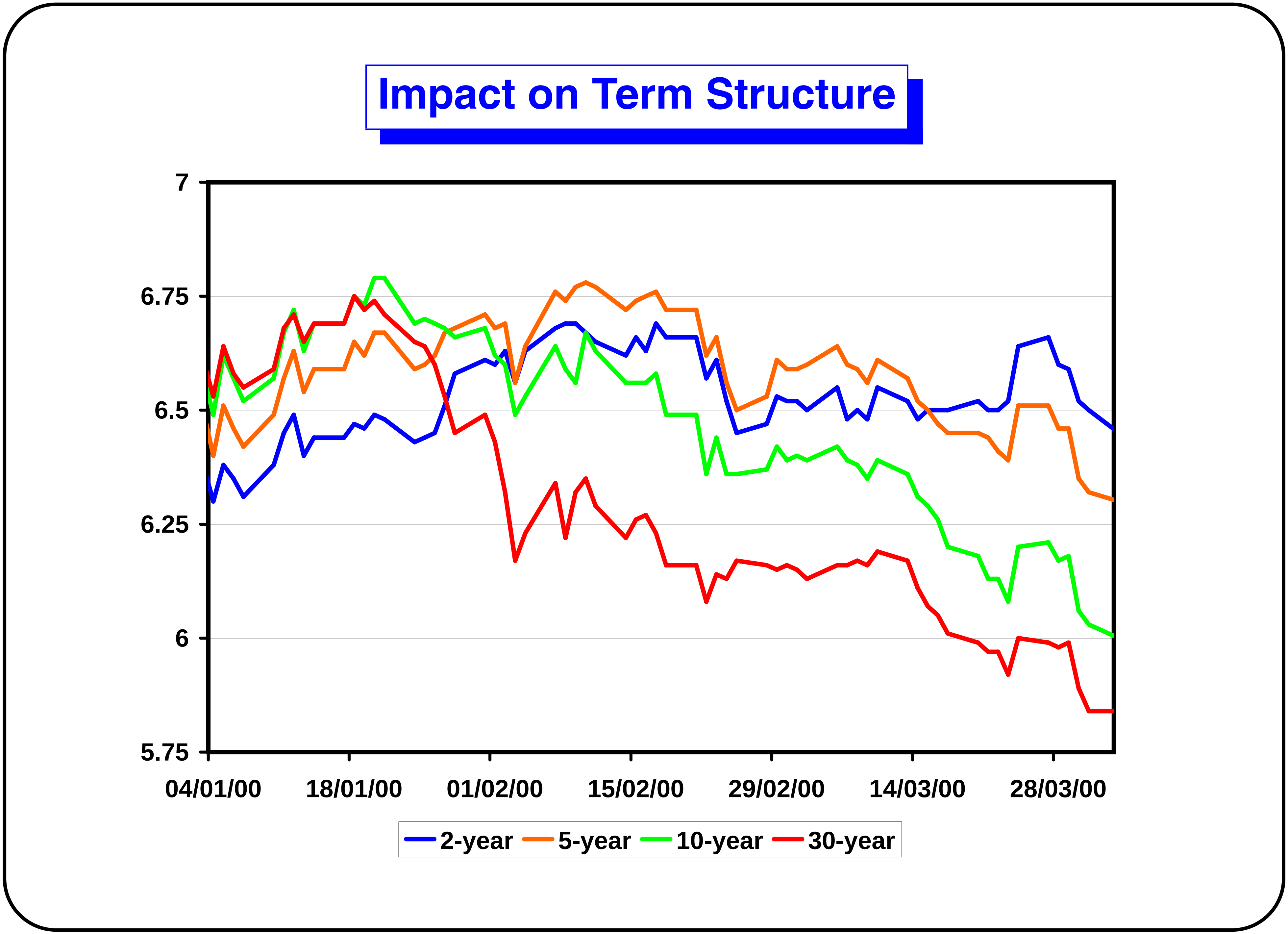
- Representative-agent model.
  - Aggregate consumption.
- Preferred-habitat view.
  - Clienteles with preferences for specific maturities.
  - Local demand and supply matter.

    (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 Term Structure
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 term structure.
- 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.

This Paper – Theory

- Formal model of preferred habitat. (Vayanos-Vila 2007)
- Term structure determined by
  - Preferred-habitat demand. (Clienteles)
  - Arbitrageurs.
- Arbitrageurs
  - Integrate markets for different maturities.
  - Are risk-averse.

This Paper – Empirics

- Test model's predictions.
- Most accessible data: government supply.
- Tests are supportive.

Roadmap

- Introduction. $\surd$
- Model.
- Theoretical predictions.
- Data.
- Empirical results.
- Conclusion.

2. 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

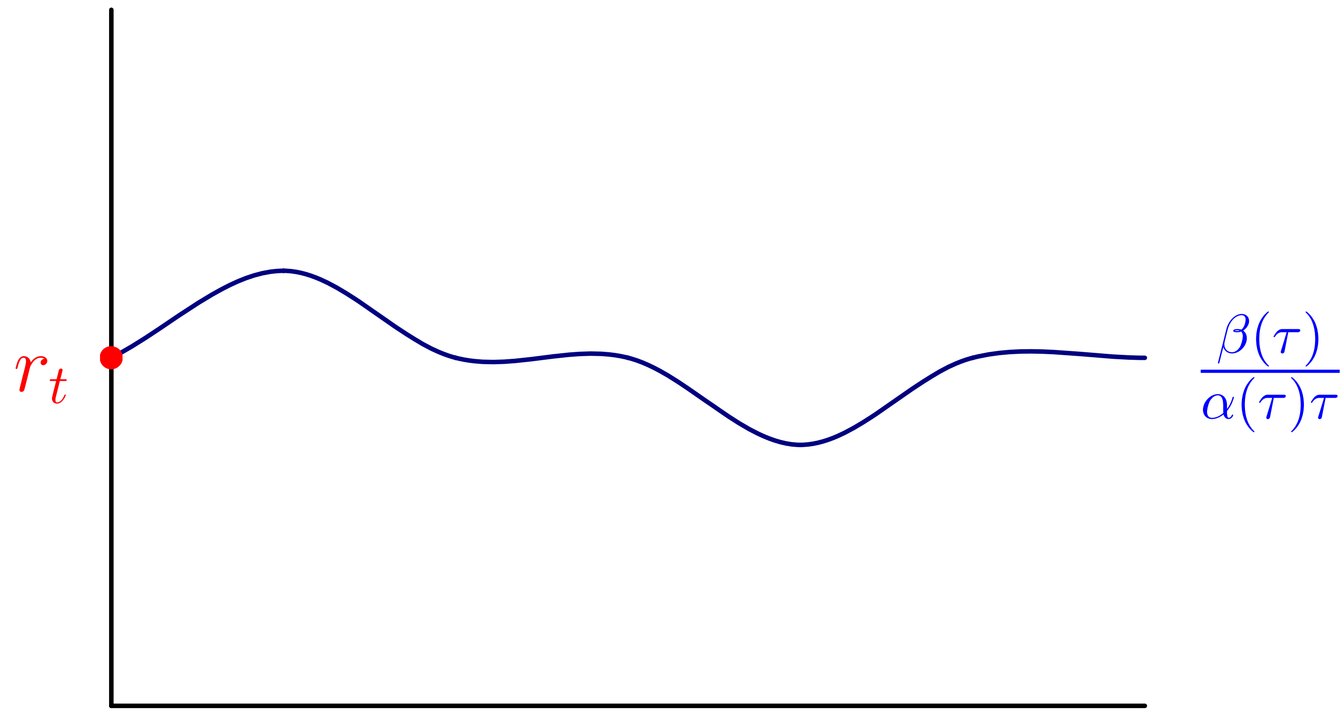
$$y_t^{(\tau)} = \frac{\beta(\tau)}{\alpha(\tau)\tau}.$$

Arbitrageurs

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

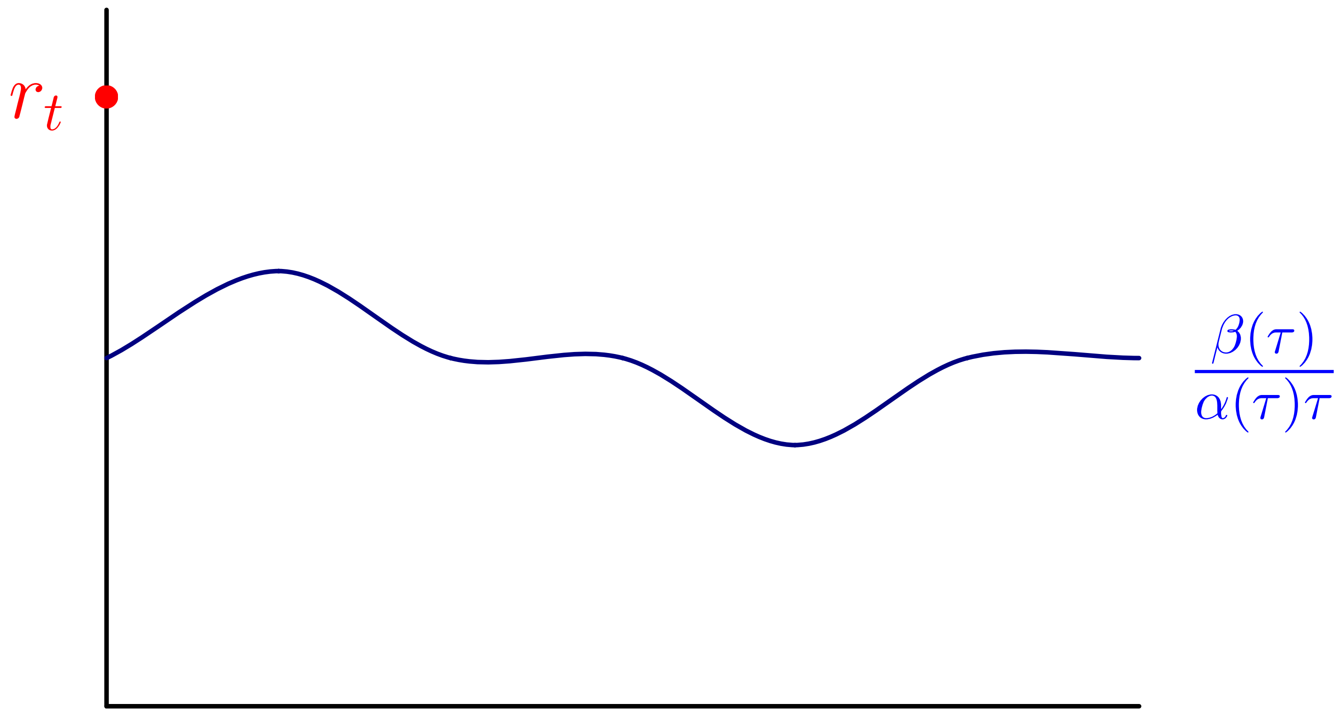
$$E_t(dW_t) - \frac{a}{2} Var_t(dW_t).$$

3. Theoretical Predictions



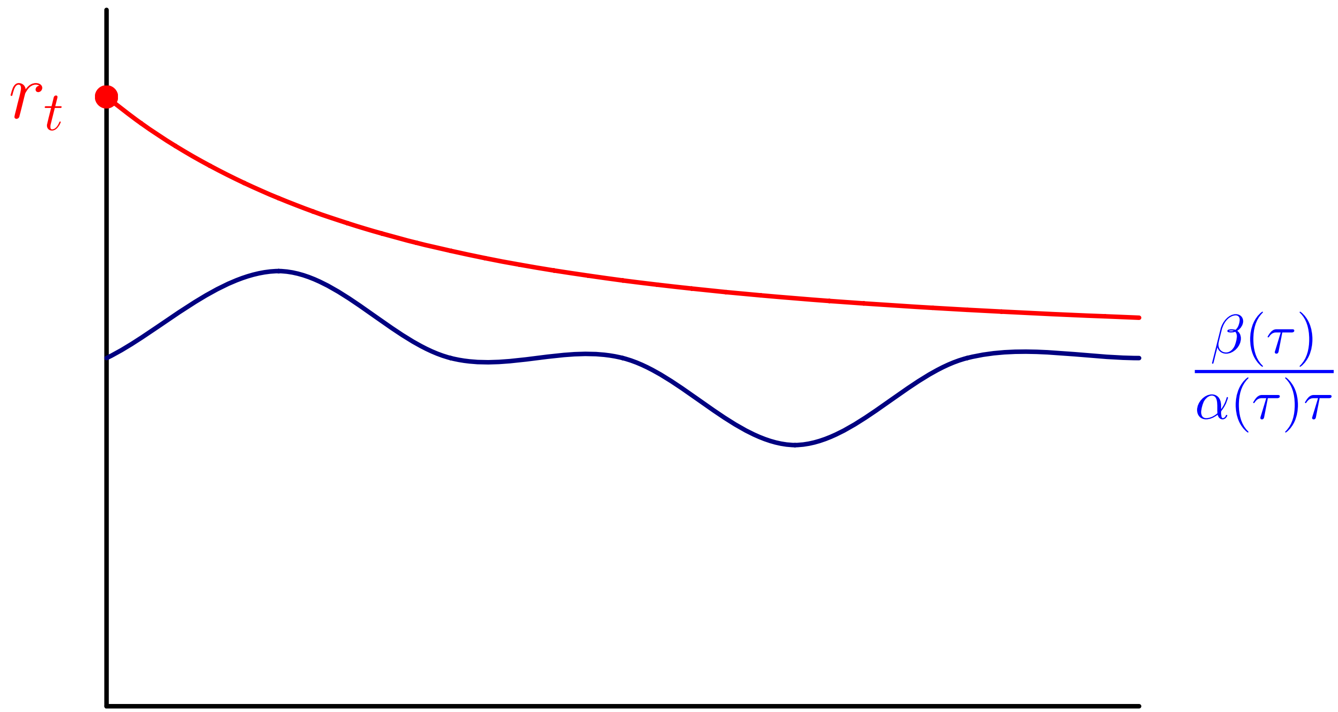
- Absent arbitrageurs, TS can have arbitrary shape ...

3. Theoretical Predictions



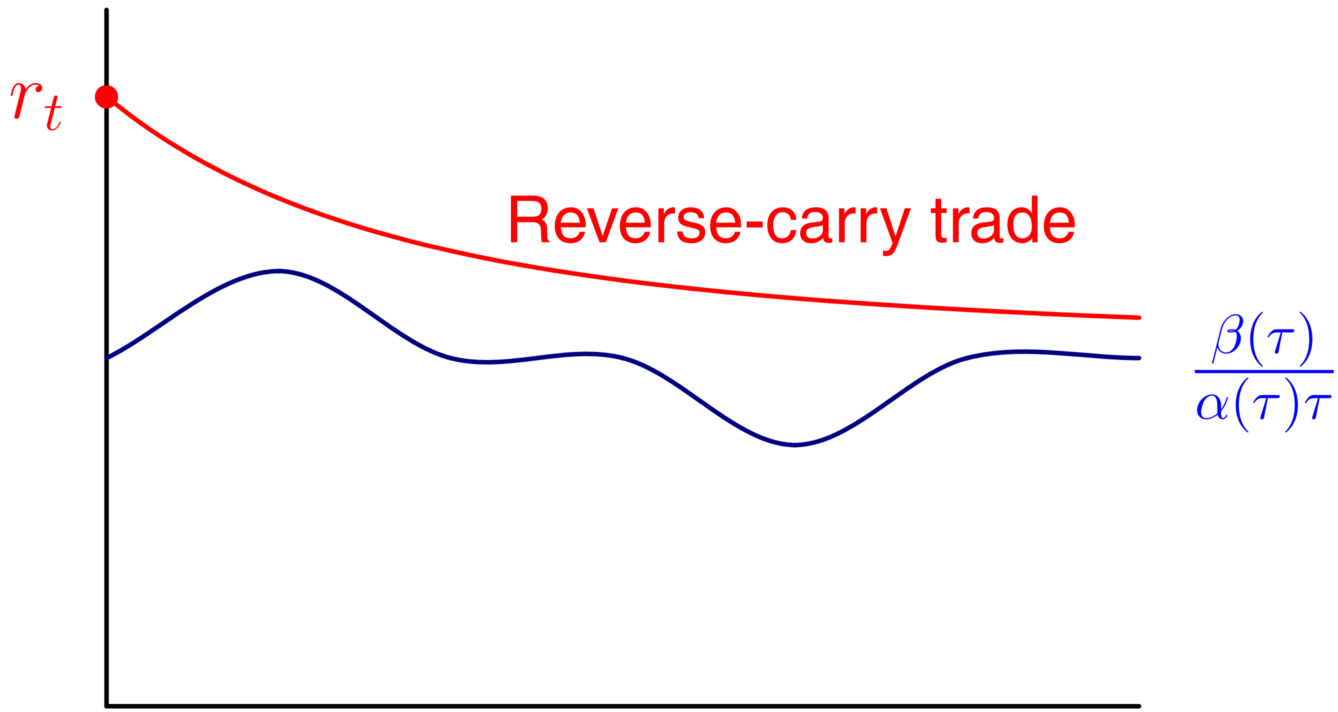
- ... and is disconnected from short-rate process.

3. Theoretical Predictions



- Arbitrageurs bring information about short rates into TS.

3. Theoretical Predictions



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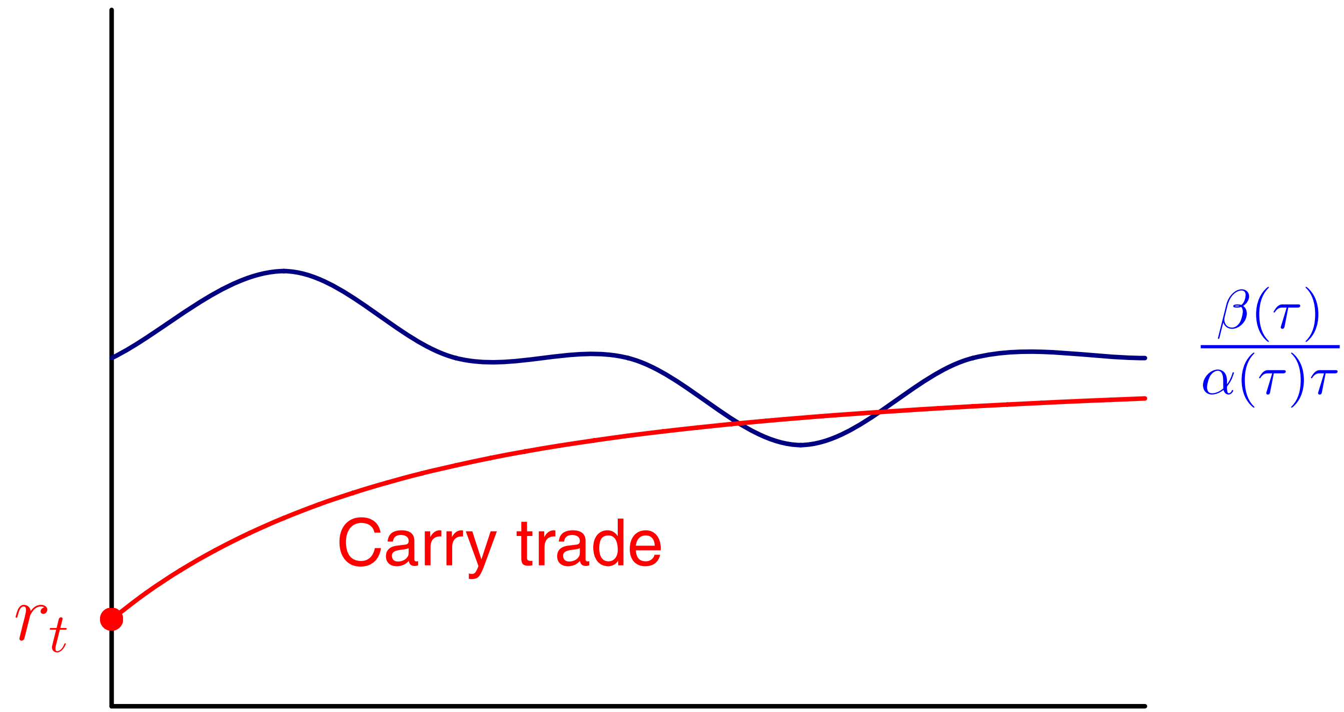

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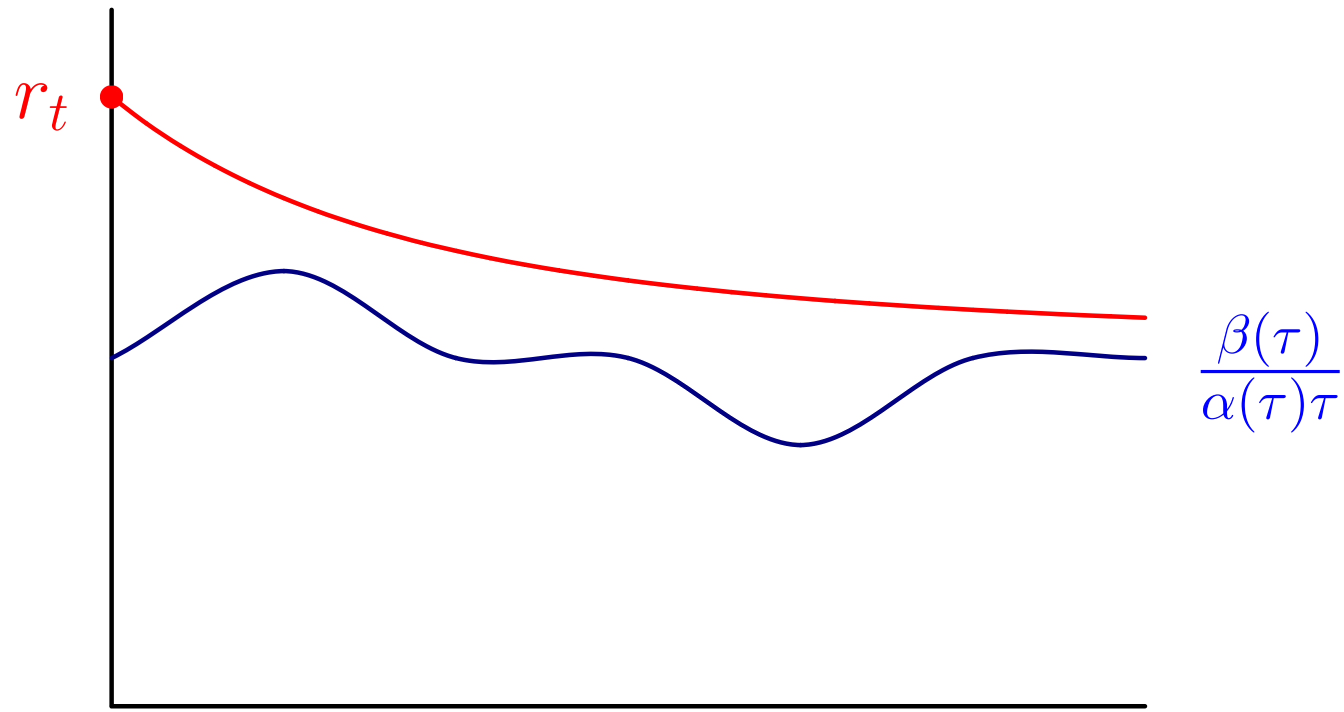


- Arbitrageurs smooth local demand and supply pressures.

Summary

- Arbitrageurs
  - Bring information about short rates into TS.
  - Smooth local demand and supply pressures.
- Monetary policy transmitted through arbitrageurs' carry trades.

Bond Risk Premia

- Negative when r_t is high.
  - Arbitrageurs do reverse-carry trade $\Rightarrow$ Short bonds.
- Positive when r_t is low.
  - Arbitrageurs do carry trade $\Rightarrow$ Long bonds.
- Positive relationship between premia and TS slope.

  (Fama-Bliss 1987)

Effects of 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 ($\int_0^T \beta(\tau)d\tau$).

Yields and Risk Premia

- Arbitrageurs buy LT bonds $\Rightarrow$ Bear more short-rate risk.
- Bond risk premia increase, especially for longer maturities.
  - LT bonds are more sensitive to short-rate risk.
- Bond yields increase, especially for longer maturities.
  - Arbitrageurs tie yields of ST bonds to short rate.

Arbitrageur Risk Aversion

- When arbitrageurs are more risk-averse (large a):
  - Maturity structure has stronger effects on yields and risk premia.
  - Stronger relationship between premia and TS slope.

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.

Theoretical Predictions: Summary

- Increase in relative supply of LT bonds
  - Raises their yields. Hypothesis 1
  - Raises their expected excess returns. Hypothesis 2
- Effects are stronger
  - For longer maturities. Hypothesis 3
  - Following times when arbs. lose money. Hypothesis 4a

    At those times, TS slope is stronger predictor of excess returns. Hypothesis 4b

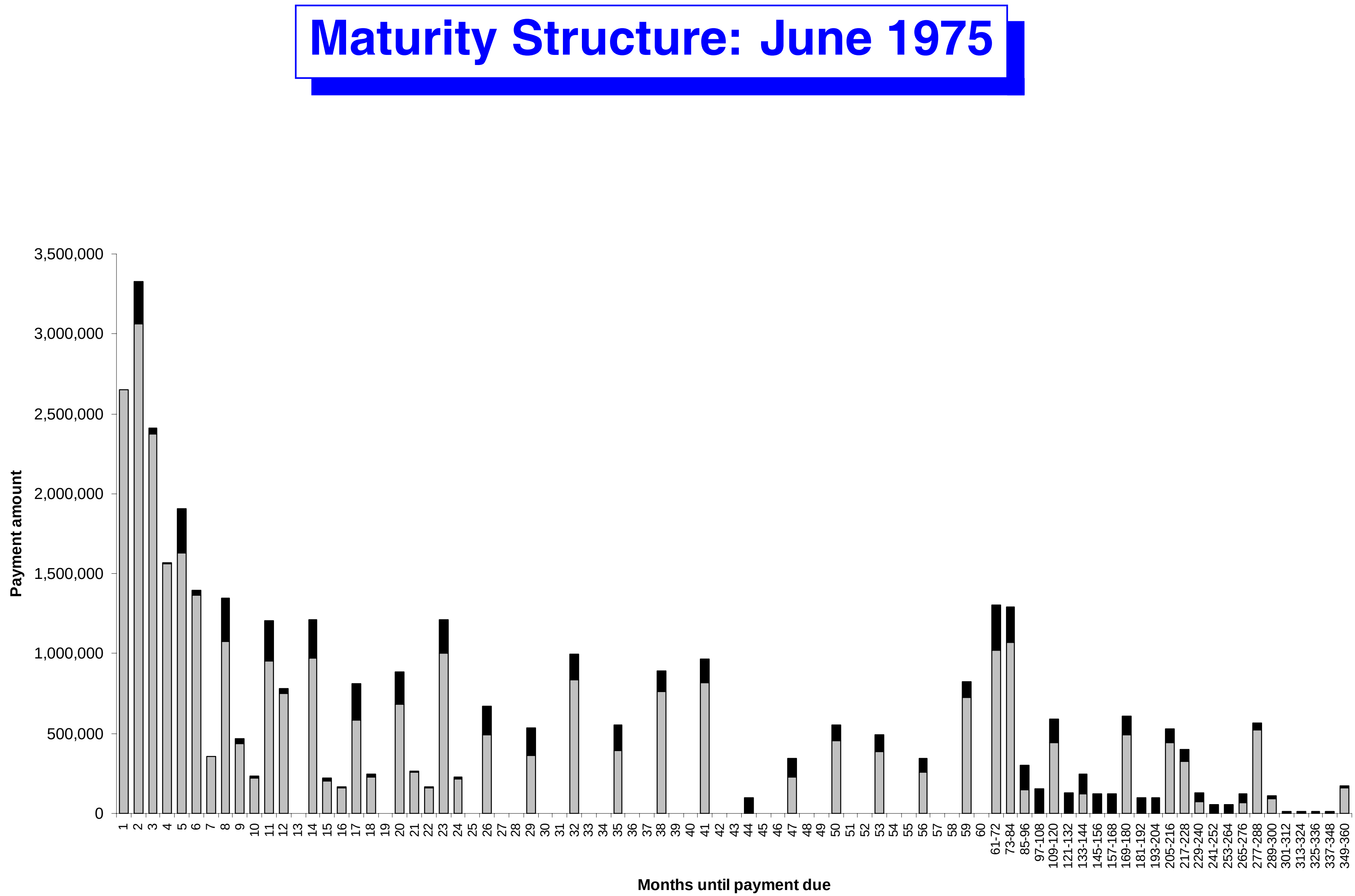
4. Data

- CRSP bond database.
- Face values, issue dates, coupon schedules.
  - Bills, notes, bonds.
  - 1950-present.

Data (cont'd)

- Snapshot: CRSP ID 19760215.206250.
  - Face value $882M, issued Feb 1969, coupon rate 6.25%.
  - As of March 1972:
    - 8 coupon payments of $27.5 million.
    - 1 principal payment of $882 million.
- Perform this exercise at the end of each month, aggregating payments over all bonds.

4. Data

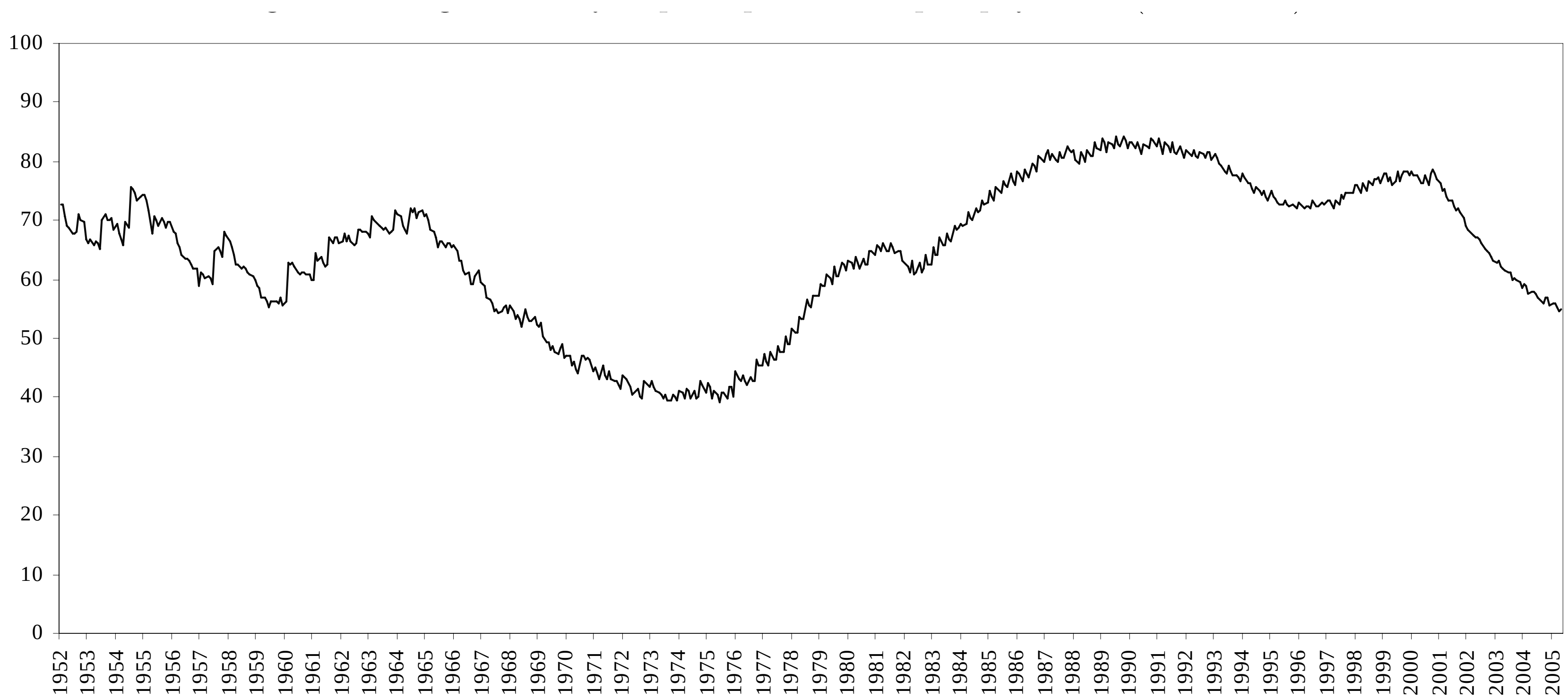


Maturity Structure: June 1975
Payment amount
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Months until payment due

Measures of Debt Maturity

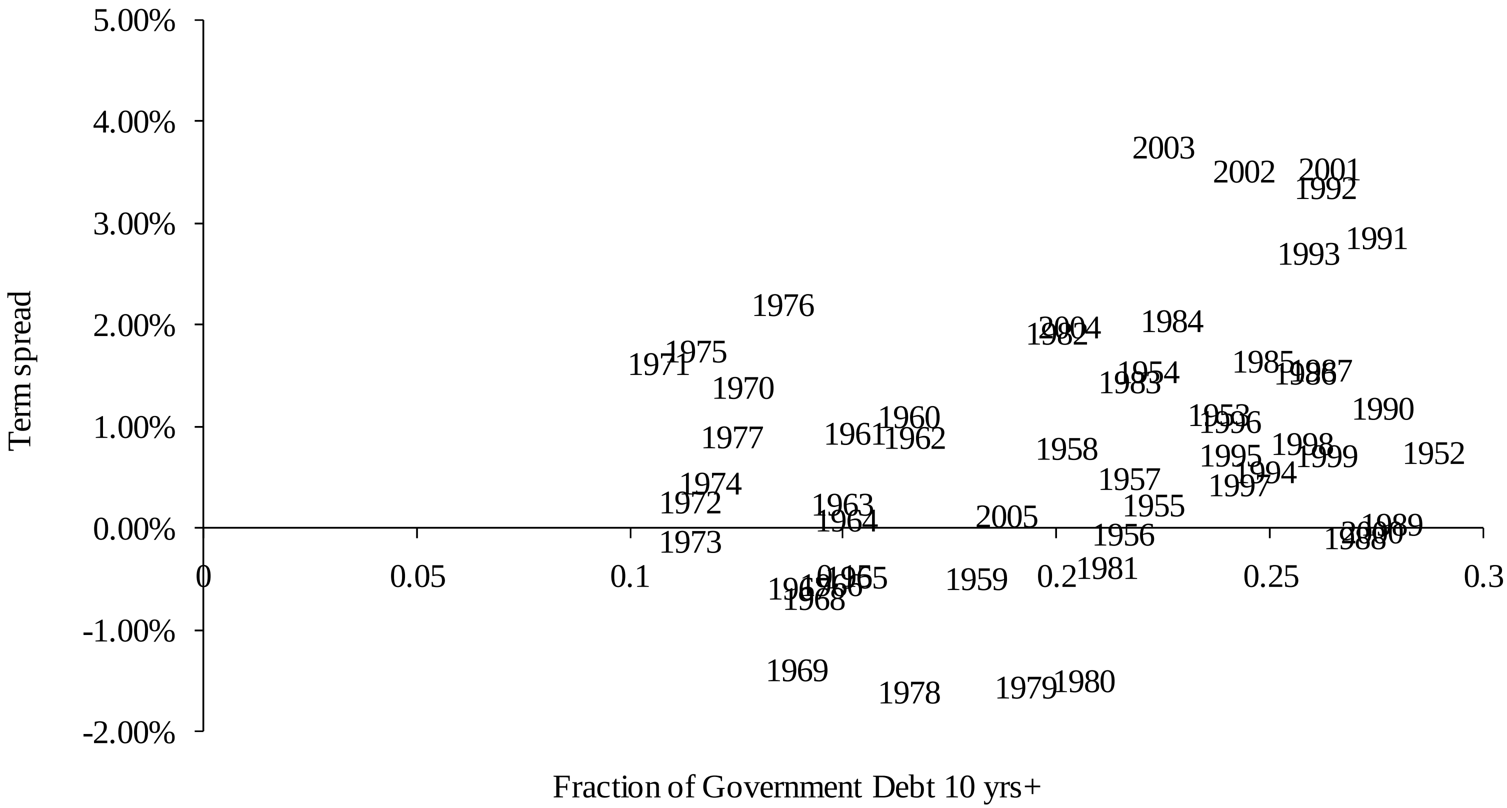
- Payments due in τ years: $D_t^{(\tau)} = PR_t^{(\tau)} + C_t^{(\tau)}$.
- Total payments: $D_t = \sum_{\tau=0}^{30} D_t^{\tau}$.
- Total payments due in T years or later: $D_t^{(T+)} = \sum_{\tau=T}^{30} D_t^{\tau}$.
- Two measures.
  - Long-term debt share: $D_t^{(10+)}/D_t$.
  - Dollar-weighted average maturity: M_t.

Dollar-Weighted Average Maturity



5. Empirical Results

Supply and Bond Yields

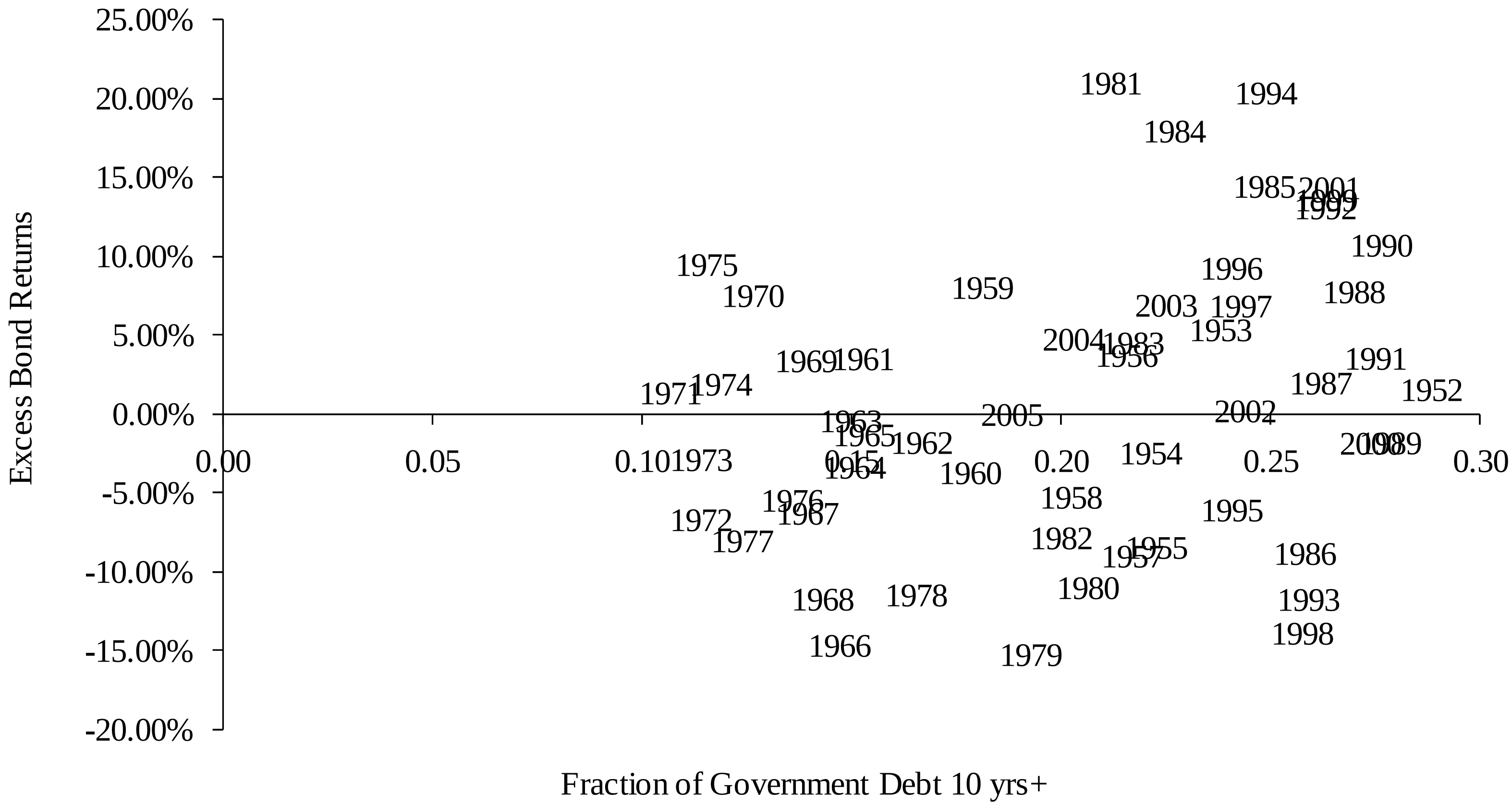


Supply and Bond Yields: Regressions

Panel A: Yield spreads $y_t^{(\tau)} - y_t^{(1)}$										
	2-year		3-year		4-year		5-year		20-year	
$D_t^{(10+)} / D_t$	0.016		0.025		0.034		0.040		0.077	
	(2.593)		(2.564)		(2.742)		(2.799)		(3.677)	
M_t		0.006		0.010		0.013		0.015		0.028
		(2.105)		(2.246)		(2.442)		(2.384)		(3.096)
R-squared	0.057	0.045	0.055	0.049	0.062	0.056	0.065	0.053	0.097	0.074

- Support for Hypotheses 1 and 3.

Supply and Bond Returns



Supply and Bond Returns: Univariate 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

- Support for Hypotheses 2 and 3.

Supply and Bond Returns: Multivariate Regressions

	Excess 1-yr return						Excess 3-yr return		Excess 5-yr return	
	2-yr bond		3-yr bond		20-yr bond		20-yr bond		20-yr bond	
$D_t^{(10+)} / D_t$	0.081	0.076	0.133	0.123	0.359	0.301	1.453	1.446	2.543	2.802
	(2.298)	(2.074)	(2.228)	(2.050)	(2.622)	(2.141)	(3.800)	(3.768)	(4.847)	(4.529)
	(2.017)	(1.816)	(1.962)	(1.806)	(2.362)	(1.921)	(3.301)	(3.316)	(5.216)	(4.250)
γf_t	0.310		0.603		1.677		2.146		3.078	
	(4.883)		(5.176)		(4.340)		(4.199)		(4.229)	
	(4.425)		(4.675)		(3.918)		(4.186)		(4.395)	
$y_t^{(\tau)} - y_t^{(1)}$		1.438		1.776		2.036		1.638		-1.330
		(3.178)		(3.355)		(2.768)		(1.535)		(-0.802)
		(2.854)		(2.982)		(2.510)		(1.813)		(-0.893)
R-squared	0.269	0.162	0.285	0.162	0.276	0.143	0.375	0.279	0.552	0.433

- Results remain significant.

Arbitrageur Wealth: Proxies

- Base case:

$$\Delta W_t^{Arb} = (y_{t-1}^{(\tau)} - y_{t-1}^{(1)})(r_t^{(\tau)} - y_{t-1}^{(1)}).$$

- General lookback period:

$$\Delta W_{k,t}^{Arb} = \sum_{j=1}^{k}(y_{t-j}^{(\tau)} - y_{t-j}^{(1)})(r_{t-j+1}^{(\tau)} - y_{t-j}^{(1)}).$$

Arbitrageur Wealth and Bond Returns

	(1)	(2)	(3)	(4)	(5)	(6)
$y_t^{(\tau)} - y_t^{(1)}$	3.222	2.822	3.367			
	(3.623)	(3.682)	(3.739)			
	(3.219)	(3.291)	(3.337)			
$D_t^{(10+)} / D_t$				0.572	0.524	0.543
				(3.282)	(3.077)	(3.175)
				(2.893)	(2.719)	(2.802)
ΔW_t^{Arb}	-8.038	-14.571		25.857	-11.604	
	(-1.354)	(-2.818)		(1.004)	(-2.359)	
	(-1.189)	(-2.614)		(0.978)	(-2.219)	
$\Delta W_t^{Arb}(y_t^{(\tau)} - y_t^{(1)})$	-441.940		-721.280			
	(-1.844)		(-3.332)			
	(-1.605)		(-3.154)			
$\Delta W_t^{Arb}(D_t^{(10+)} / D_t)$				-189.270		-61.900
				(-1.488)		(-2.639)
				(-1.463)		(-2.506)
R-squared	0.183	0.173	0.175	0.117	0.107	0.113

- Support for Hypothesis 4.

Different Lookback Periods

Lookback period:	6-months		12-months		24-months		36-months		60-months	
	Return Forecasting Horizon: 12–month excess bond returns									
$y_t^{(\tau)} - y_t^{(1)}$	2.847		3.222		3.948		4.288		4.095	
	(3.633)		(3.623)		(4.106)		(4.570)		(3.789)	
	(3.236)		(3.219)		(3.645)		(4.099)		(3.391)	
$D_t^{(10+)} / D_t$		0.508		0.572		0.610		0.609		0.682
		(3.055)		(3.282)		(3.279)		(2.795)		(2.427)
		(2.703)		(2.893)		(2.912)		(2.479)		(2.175)
ΔW_t^{Arb}	1.853	30.258	-8.038	25.857	1.305	34.346	6.381	17.670	5.683	9.062
	(0.281)	(0.971)	(-1.354)	(1.004)	(0.257)	(1.588)	(1.397)	(1.140)	(1.751)	(0.675)
	(0.318)	(1.072)	(-1.189)	(0.978)	(0.278)	(1.519)	(1.595)	(1.141)	(1.877)	(0.649)
$\Delta W_t^{Arb}(y_t^{(\tau)} - y_t^{(1)})$	-523.860		-441.940		-701.800		-874.810		-687.750	
	(-2.255)		(-1.844)		(-2.725)		(-3.346)		(-2.709)	
	(-2.834)		(-1.605)		(-2.706)		(-3.378)		(-2.620)	
$\Delta W_t^{Arb}(D_t^{(10+)} / D_t)$		-164.990		-189.270		-198.850		-108.830		-66.832
		(-1.010)		(-1.488)		(-1.882)		(-1.265)		(-0.803)
		(-1.099)		(-1.463)		(-1.822)		(-1.242)		(-0.761)
R-squared	0.132	0.077	0.183	0.117	0.189	0.097	0.211	0.086	0.177	0.093

- Peak: 2-3 years.

6. Conclusion

- Formal model of preferred habitat.
  - Local demand and supply for each maturity.
  - Maturities integrated by risk-averse arbitrageurs.

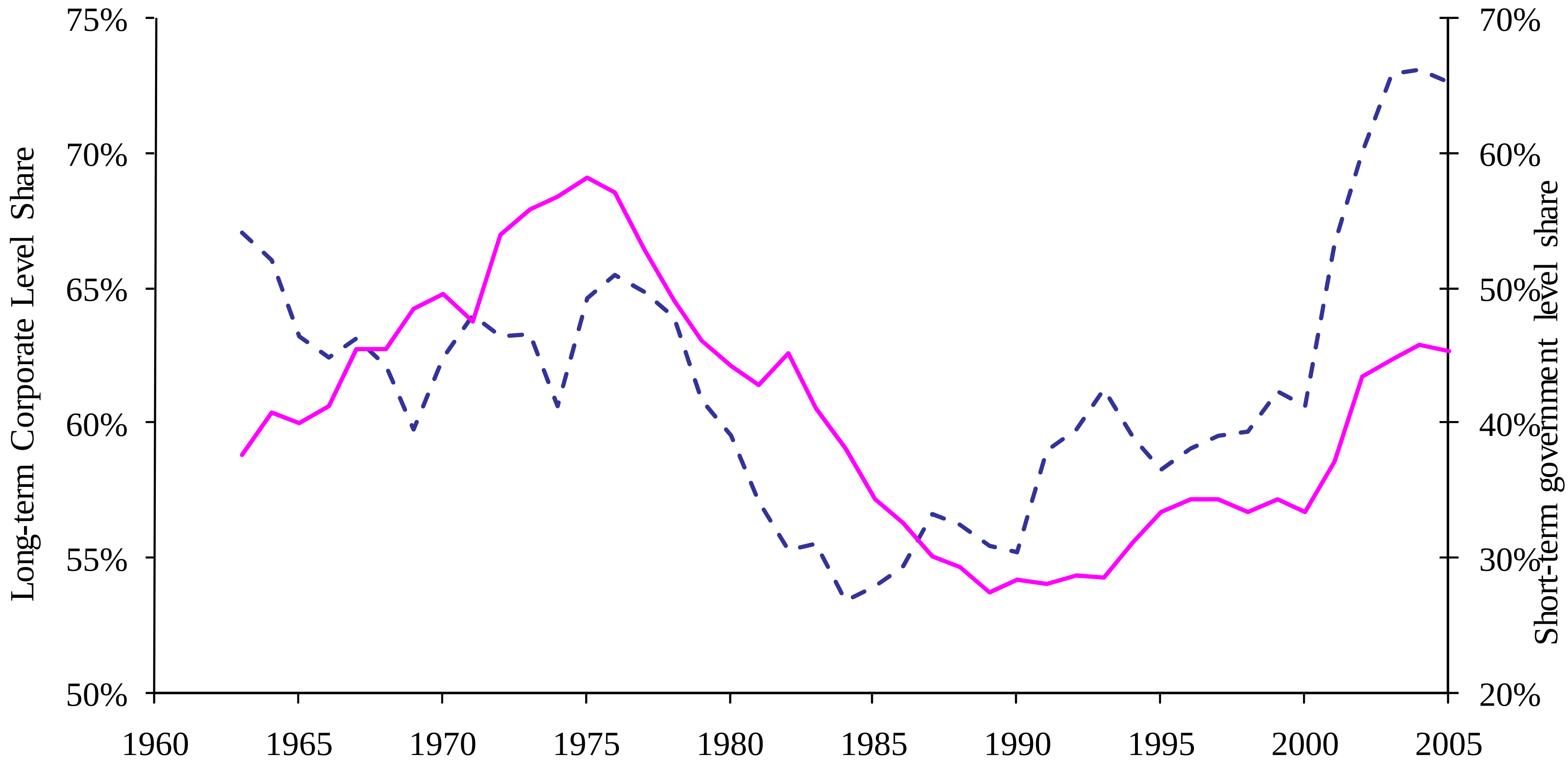
    $\Rightarrow$ Discipline of no-arbitrage.
- Test predictions concerning effects of maturity structure.
  - Positively related to yields and excess returns.
  - Effects strengthen with maturity and arb. risk aversion.

Future Work

- Connect to corporate maturity decisions

  Greenwood, Hanson, Stein (2008)

  Corporations act as arbitrageurs against shocks to gov't debt maturity.



Long-term Corporate Level Share
Short-term government level share
75%
70%
65%
60%
55%
50%
70%
60%
50%
40%
30%
20%
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005