

# Bond Supply and Excess Bond Returns

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## 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)

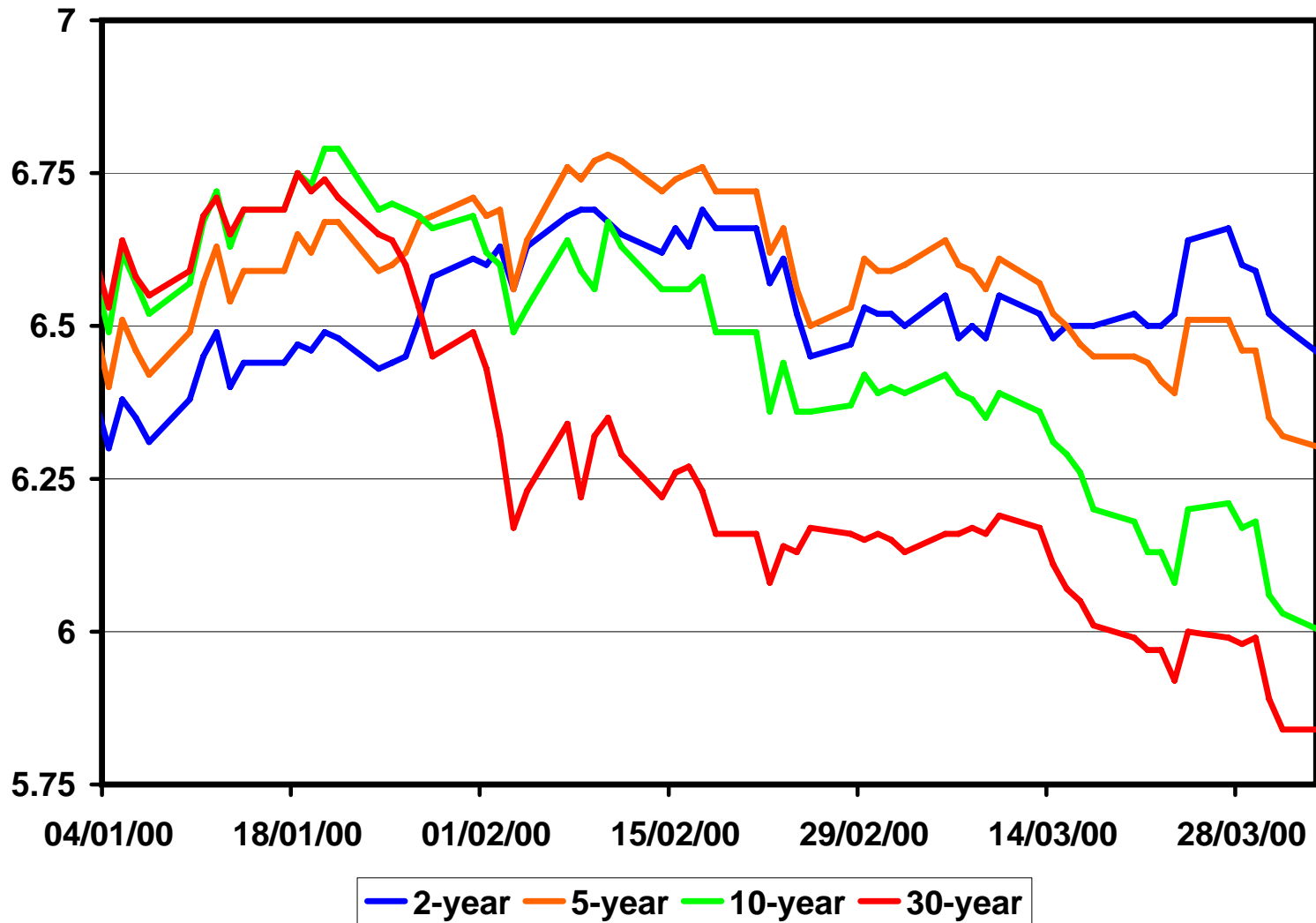
## Supply Effects: Example

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).

# 1. Introduction

## Impact on Term Structure



## 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  
⇒ 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. ✓
- 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

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

- Bond prices are endogenous.

- For maturity  $\tau$  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  $\tau$  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  $\tau$  is

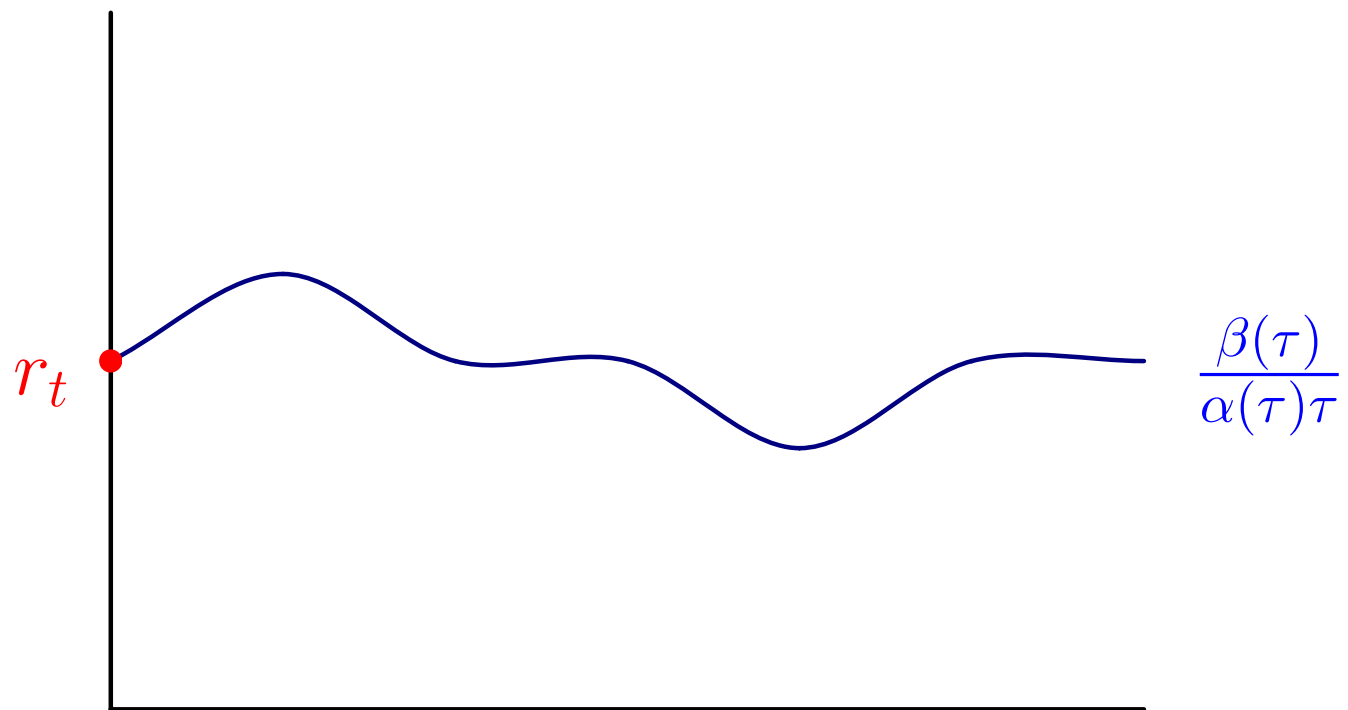
$$y_t^{(\tau)} = \frac{\beta(\tau)}{\alpha(\tau)\tau}.$$

## Arbitrageurs

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

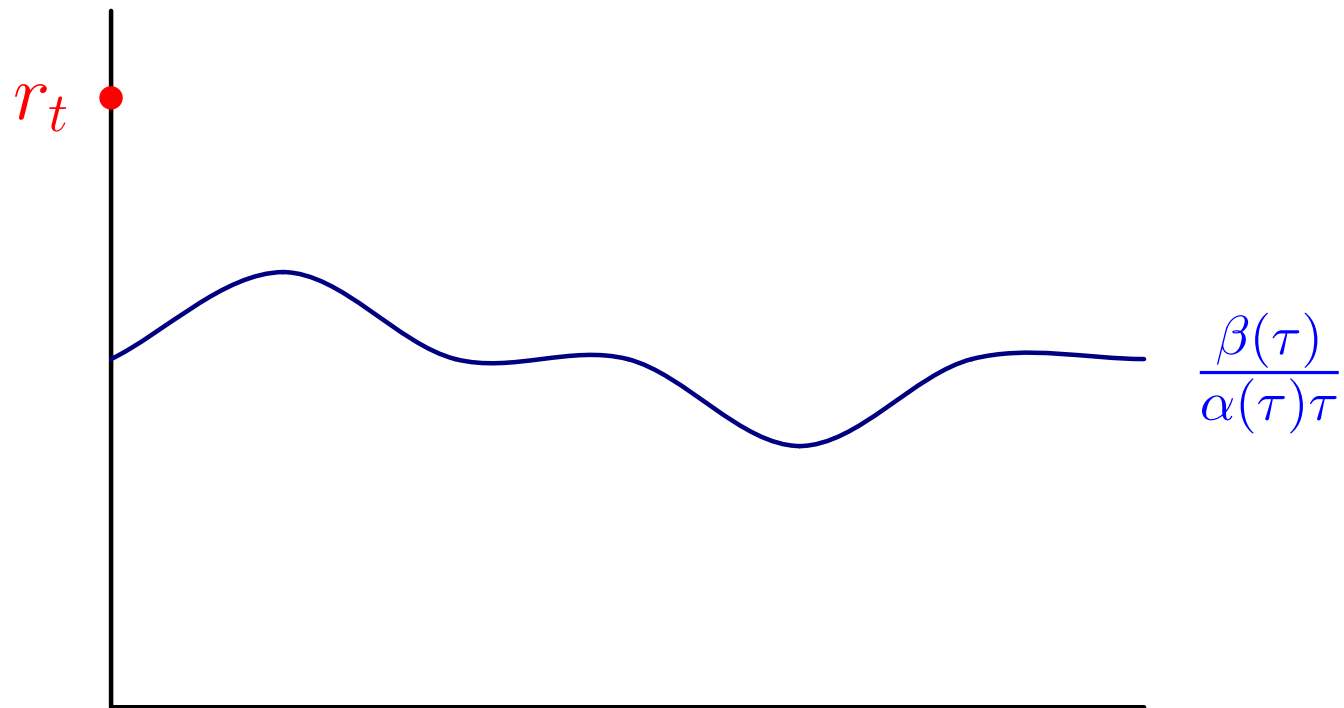
$$E_t(dW_t) - \frac{a}{2} \text{Var}_t(dW_t).$$

### 3. Theoretical Predictions



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

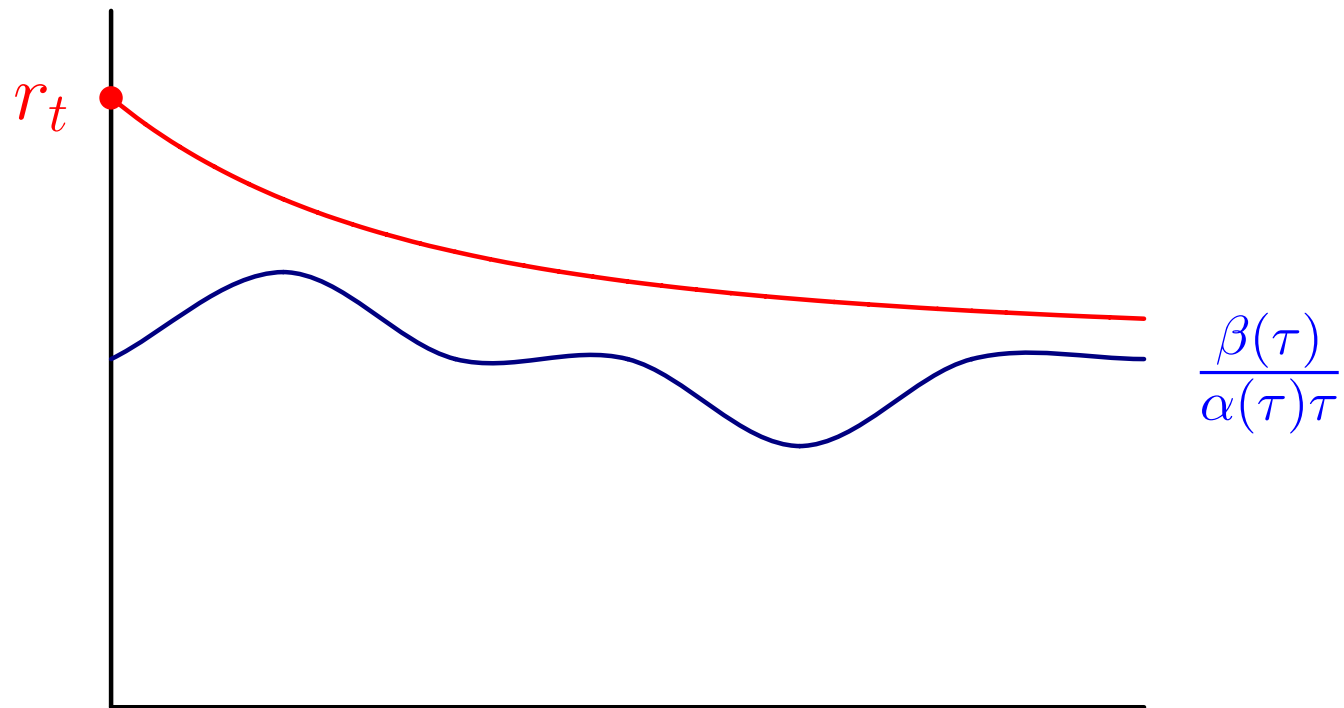
### 3. Theoretical Predictions



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

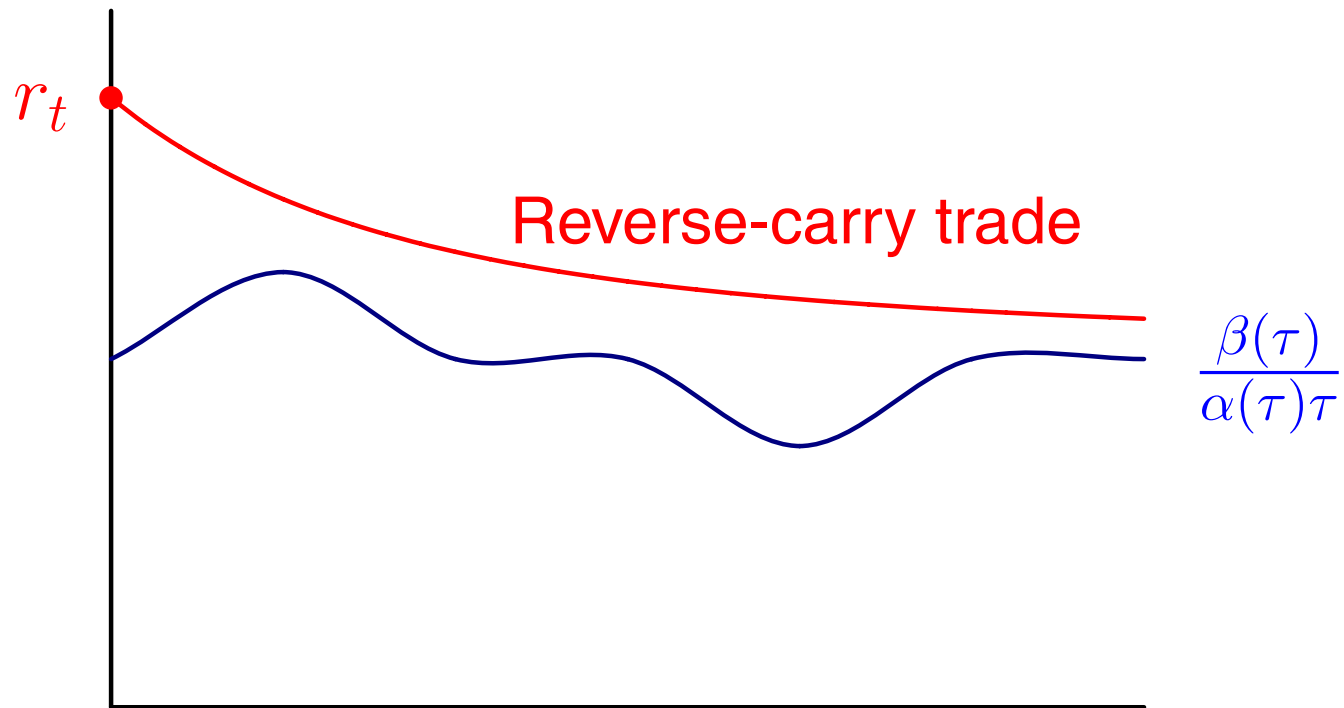


### 3. Theoretical Predictions



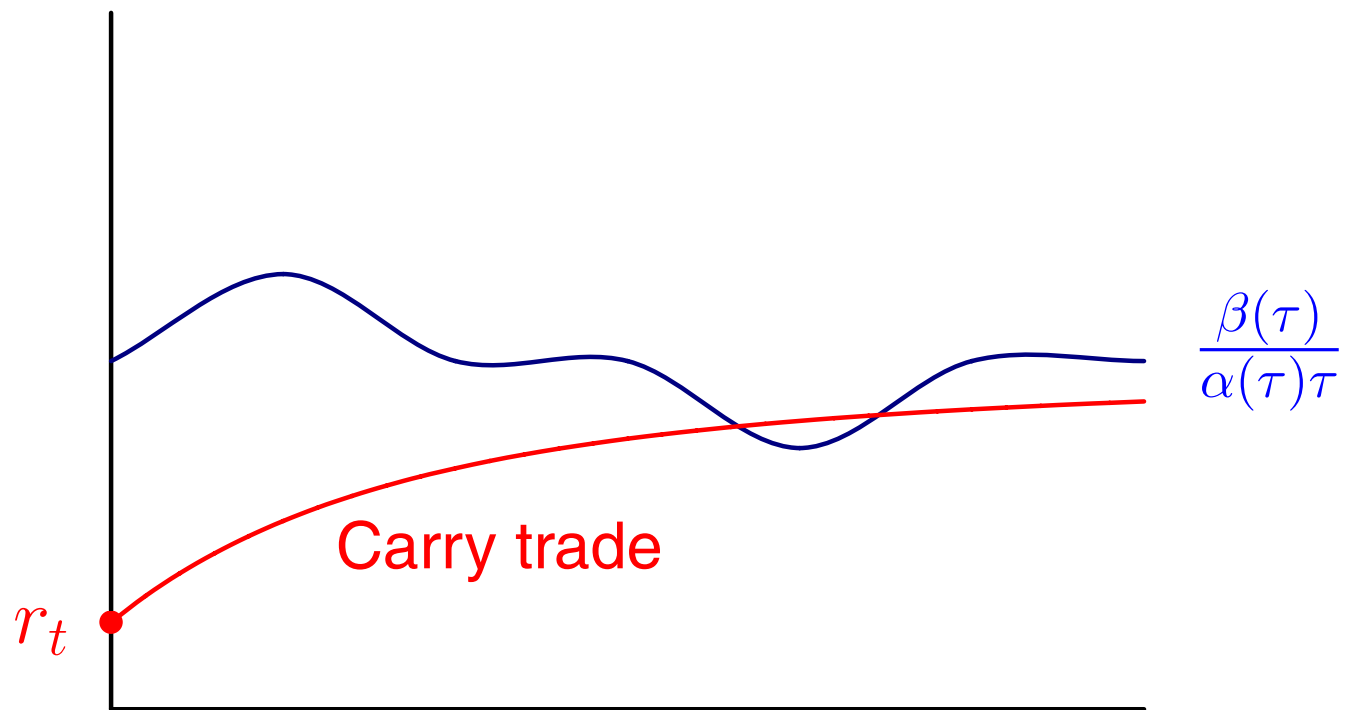
- Arbitrageurs bring information about short rates into TS.

### 3. Theoretical Predictions



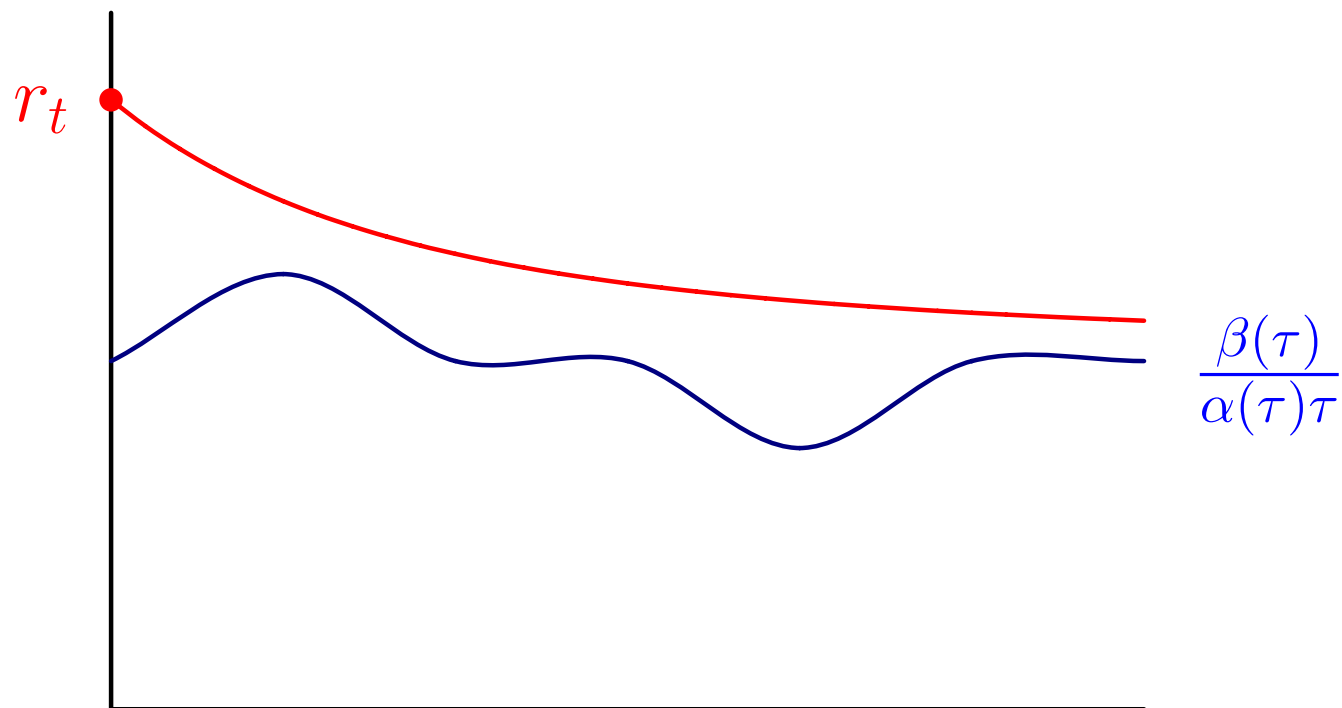
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### 3. Theoretical Predictions



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### 3. Theoretical Predictions



- 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  $\tau$ ).
  - Buys back ST bonds ( $\beta(\tau)$  decreases for small  $\tau$ ).
  - 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

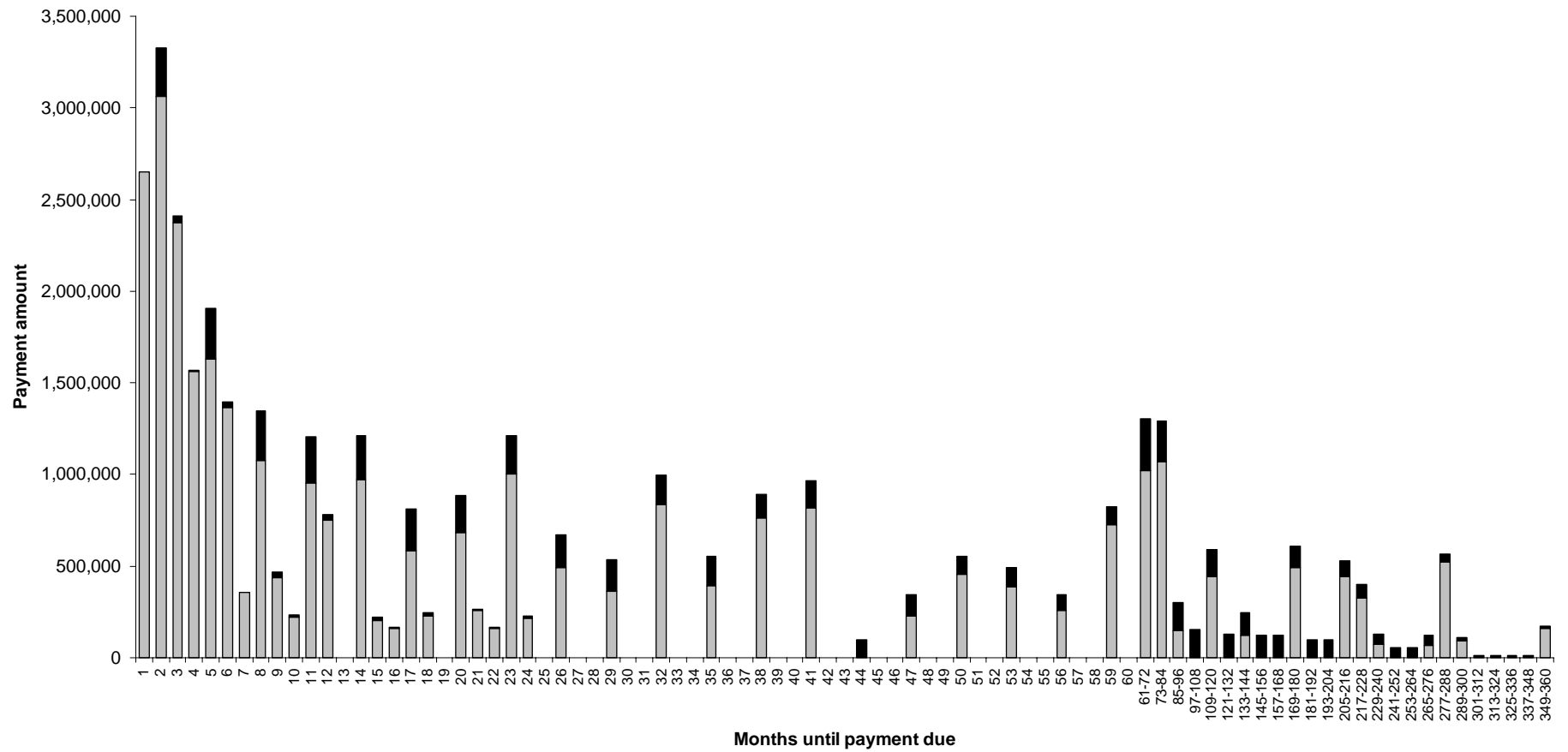
- CRSP bond database.
- Face values, issue dates, coupon schedules.
  - Bills, notes, bonds.
  - 1950-present.

## 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



## Measures of Debt Maturity

- Payments due in  $\tau$  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:  $M_t$ .

## 4. Data

# Dollar-Weighted Average Maturity

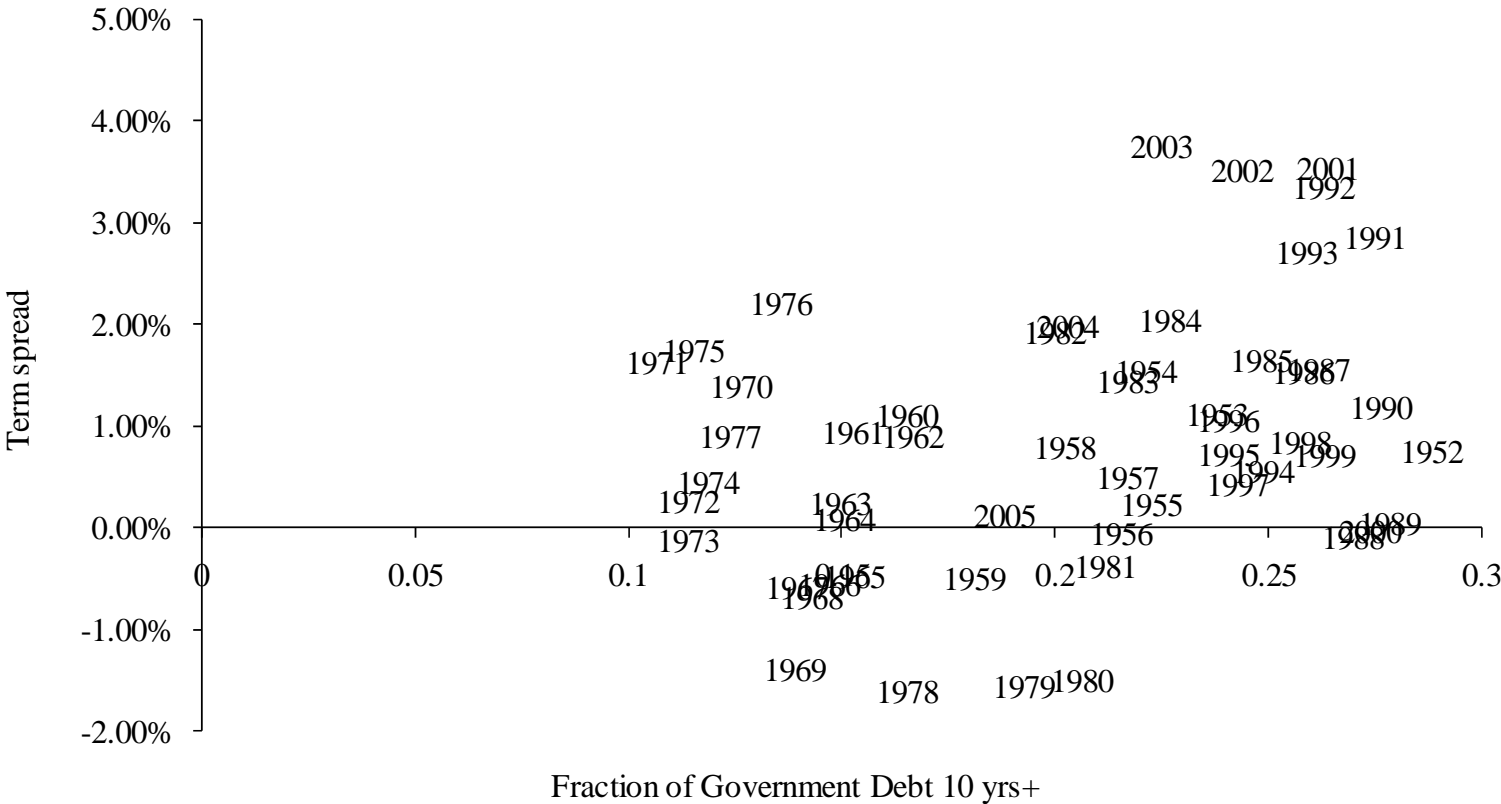




5. Empirical Results

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## Supply and Bond Yields



## 5. Empirical Results

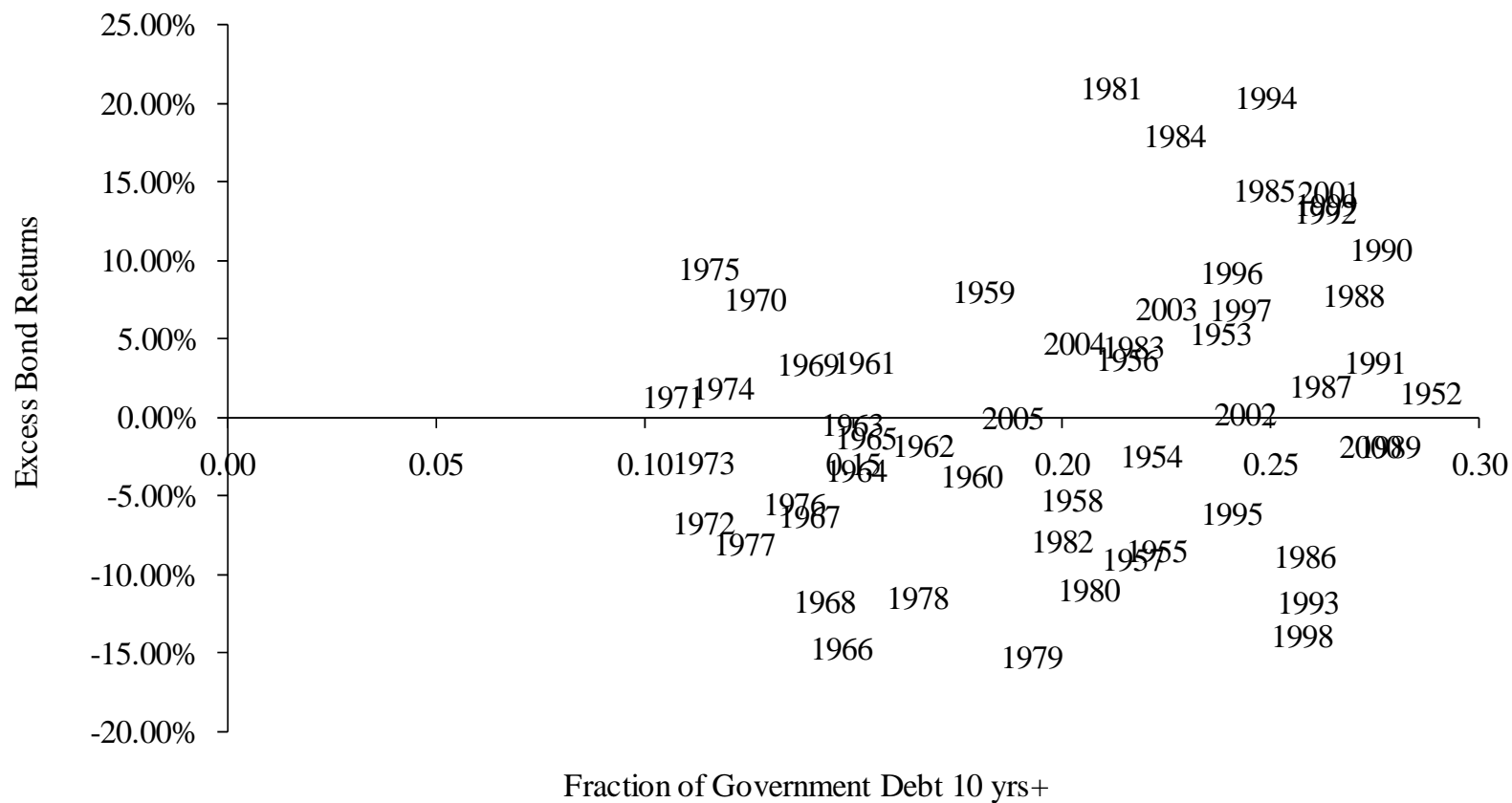
### Supply and Bond Yields: Regressions

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.

## 5. Empirical Results

### Supply and Bond Returns



## 5. Empirical Results

### Supply and Bond Returns: Univariate Regressions

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Dependent Variable:	$X = D_t^{(10+)} / D_t$			$R^2$
	b	(t)	(t)	
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.

## 5. Empirical Results

### 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 (2.298) (2.017)	0.076 (2.074) (1.816)	0.133 (2.228) (1.962)	0.123 (2.050) (1.806)	0.359 (2.622) (2.362)	0.301 (2.141) (1.921)	1.453 (3.800) (3.301)	1.446 (3.768) (3.316)	2.543 (4.847) (5.216)	2.802 (4.529) (4.250)
$\gamma_t^f$	0.310 (4.883) (4.425)	0.603 (5.176) (4.675)			1.677 (4.340) (3.918)		2.146 (4.199) (4.186)		3.078 (4.229) (4.395)	
$y_t^{(\tau)} - y_t^{(1)}$		1.438 (3.178) (2.854)		1.776 (3.355) (2.982)		2.036 (2.768) (2.510)		1.638 (1.535) (1.813)		-1.330 (-0.802) (-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:

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

## 5. Empirical Results

### Arbitrageur Wealth and Bond Returns

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

- Support for Hypothesis 4.

## 5. Empirical Results

### Different Lookback Periods

Lookback period:	Return Forecasting Horizon: 12-month excess bond returns									
	6-months		12-months		24-months		36-months		60-months	
$y_t^{(\tau)} - y_t^{(1)}$	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)
$\Delta W_t^{Arb}$	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.
    - ⇒ 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.

