Interest Rate Conundrums in the Twenty-First Century

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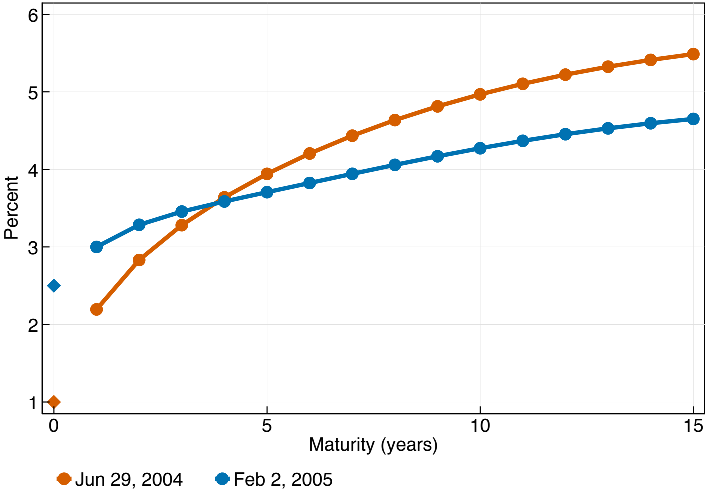
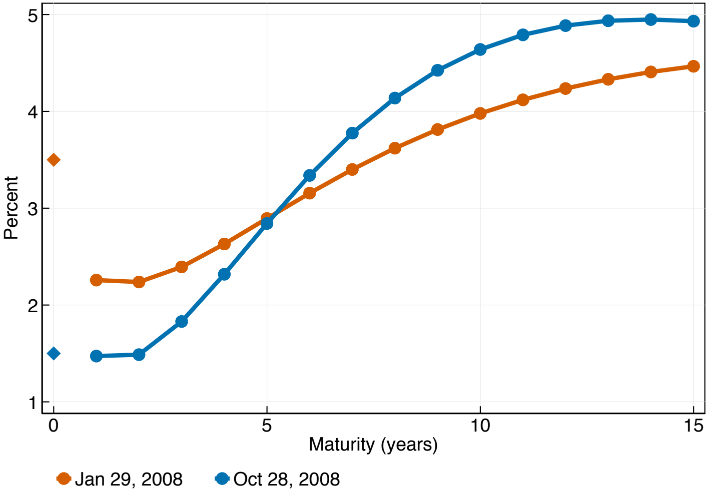
The 2004 Interest Rate Conundrum

- FOMC raised the target FFR (diamond) 150bps
- Short end of the Treasury yield curve (dotted line) rose, long end declined



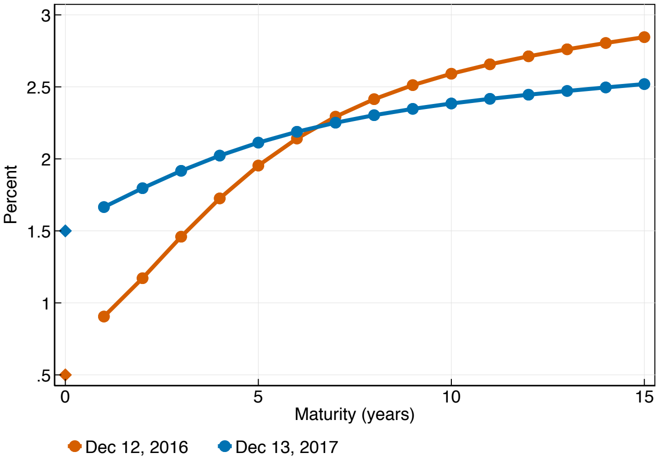
2008 "Conundrum in reverse"

- FOMC cut the target FFR (diamond) 1.5%
- Short end of the Treasury yield curve (dotted line) rose, long end declined



2017 (Yet Another) Conundrum

- FOMC raised the target FFR (diamond) 1%
- Short end of the Treasury yield curve (dotted line) rose, long end declined



This paper

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- Not just 2004, 2008 and 2017—post-2000 many more conundrums, or ST/LT moving in opposite direction over 6/12-months
  - **Old fact:** High sensitivity
  - **New fact #1:** Post-2000, sensitivity even greater at high frequencies
  - **New fact #2:** Post-2000, low frequency (semi-annual, yearly) decoupling between LT and ST
- A simple **model** to explain facts:
  - Term-premia (TP) on LT bonds rise with shocks to ST rates; arbitrage capital is slow-moving
- **Implications** for event studies, bond return predictability and monetary policy transmission

Rest of the talk

1. Empirical results
2. Economic model
3. Implications

Empirical Findings

Data

- Zero-coupon yields from Nelson-Siegel-Svensson yield curves
  1. Nominal and real US Treasury yields from Gürkaynak, Sack, and Wright (2007); Gürkaynak, Sack, and Wright (2010)
  2. International yields:
     - UK from the Bank of England (splines)
     - Germany from Bundesbank
     - Canada from the Bank of Canada

Main empirical specification

- Main empirical specification:

$$y^{(10)}_{t+h} - y^{(10)}_t = \alpha_h + \beta_h (y^{(1)}_{t+h} - y^{(1)}_t) + \varepsilon_{t,t+h}$$

  - $y^{(n)}_t$ is the n-year yield at time t
  - β_h is "sensitivity" of LT yield where $h = \{\text{day,month,..,year}\}$
- In simple expectations hypothesis world:
  - β_h should be fairly small: movements in ST rates transient
  - β_h should be similar across horizons h
- Even if EH fails β_h should be similar across horizons h

β_h of 10y Treas. yield on 1y yield

	(1) Nominal	(2) Nominal	(3) Real	(4) IC
Daily	0.56^{***}	0.86^{***}	0.55^{***}	0.31^{***}
	[0.02]	[0.03]	[0.03]	[0.02]
Monthly	0.46^{***}	0.64^{***}	0.37^{***}	0.26^{***}
	[0.04]	[0.12]	[0.10]	[0.10]
Quarterly	0.48^{***}	0.42^{***}	0.21^{*}	0.22
	[0.04]	[0.07]	[0.11]	[0.13]
Semi-annual	0.50^{***}	0.31^{***}	0.20^{**}	0.12
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Yearly	0.56^{***}	0.20^{***}	0.13^{*}	0.07^{*}
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- Pre-2000 β_h similar across h; post-2000 $\beta_{d,1m} \uparrow$ while $\beta_{6m,1y} \downarrow$
  - Post-2000: High-frequency "excess sensitivity" and low-frequency "decoupling"
- Most of post-2000 β_h drop in the real yield but IC drops too

β_h of 10y instantaneous fwd on 1y yield

	(1) Nominal	(2) Nominal	(3) Real	(4) IC
Daily	0.39***	0.48***	0.31***	0.17***
	[0.03]	[0.04]	[0.03]	[0.03]
Monthly	0.29***	0.22	0.17**	0.06
	[0.04]	[0.14]	[0.08]	[0.09]
Quarterly	0.31***	0.03	0.08	-0.04
	[0.05]	[0.09]	[0.05]	[0.05]
Semi-annual	0.33***	-0.06	0.03	-0.09**
	[0.06]	[0.07]	[0.04]	[0.04]
Yearly	0.39***	-0.17***	-0.03	-0.14***
	[0.07]	[0.05]	[0.05]	[0.03]
Sample	1971-1999	2000-2017	2000-2017	2000-2017

- Similar picture when looking at 10y instantaneous forwards
- Not specific to 10- and 1-year points on curve
    - Similar for other long-term US yields: Aaa and Baa corporates, swaps, and MBS

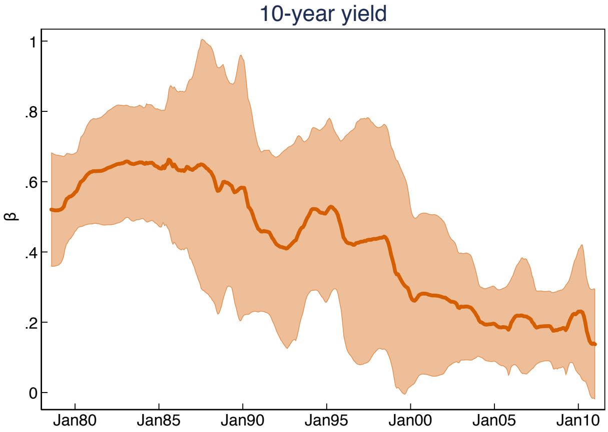
β_h of 10y UK yield on 1y UK yield

	(1)	(2)	(3)	(4)	(5)	(6)
	Nominal	Nominal	Real	Real	IC	IC
Daily	0.44***	0.86***	0.14***	0.63***	0.29***	0.23***
	[0.04]	[0.03]	[0.01]	[0.03]	[0.04]	[0.02]
Monthly	0.47***	0.55***	0.19***	0.12	0.28***	0.43***
	[0.06]	[0.14]	[0.05]	[0.26]	[0.09]	[0.13]
Quarterly	0.49***	0.43***	0.23***	0.04	0.26***	0.39***
	[0.08]	[0.10]	[0.04]	[0.18]	[0.10]	[0.10]
Semi-annual	0.45***	0.39***	0.22***	0.07	0.23**	0.32***
	[0.09]	[0.08]	[0.05]	[0.11]	[0.11]	[0.06]
Yearly	0.38***	0.29***	0.16**	0.05	0.22**	0.24***
	[0.06]	[0.06]	[0.06]	[0.08]	[0.08]	[0.03]
Sample	1985-1999	2000-2017	1985-1999	2000-2017	1985-1999	2000-2017

- UK: post-2000 $\beta_{day} \uparrow$ increases; $\beta_{year} \downarrow$
    - Most action in real yields
- Similar evidence for Germany and Canada

Dating Break for β_{year}

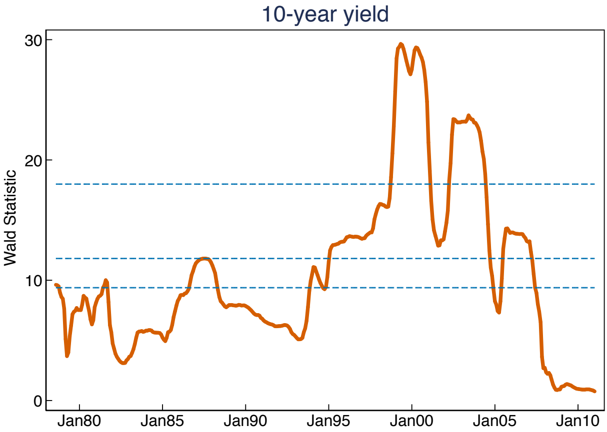
- Estimate β_{year} over 10-year rolling windows.
- Coefficient declines throughout the 1990s



Note: Coefficient plotted at mid-point of 10-year window

Dating Break for β_{year}

- Andrews (1993) test suggests a break in β_{year} around 2000



Note: Conduct a Wald test for a break at all possible dates and take max Wald

Note: Dotted lines are 1, 5, 10% critical values for max Wald

Predicting future yields

- Standard models of the term structure are **memoryless**
  - To forecast future yields/returns, only need to know **current** position of curve; don't need to know how we got there
  - Yield curve factor evolution is **Markovian**: $Y_{t+1} = A_1 Y_t + \epsilon_{t+1}$
  - Work with level $L_t \equiv y_t^{(1)}$ and slope $S_t \equiv y_t^{(10)} - y_t^{(1)}$ factors

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- Horizon dependence of β_h suggests non-Markovian evolution: $Y_{t+1} = A_1 Y_t + A_2 Y_{t-h} + \epsilon_{t+1}$
  - Duffee (2013); Feunou and Fontaine (2014); Cochrane and Piazzesi (2005); Joslin et al. (2013) all use lags but do not study implications for sensitivity
- Estimate VAR(1) and VAR(1,h=6) pre-/post-2000: AIC/BIC selects VAR(1,6) post-2000 but not before

VAR(1,6) estimates for level and slope

	(1) L_{t+1}	(2) L_{t+1}	(3) S_{t+1}	(4) S_{t+1}
L_t	0.96***	0.98***	0.01	-0.01
	[0.02]	[0.01]	[0.01]	[0.01]
S_t	-0.02	-0.00	0.97***	0.94***
	[0.04]	[0.02]	[0.03]	[0.02]
$L_t - L_{t-6}$	0.05	0.06*	-0.03	-0.13***
	[0.05]	[0.03]	[0.03]	[0.03]
$S_t - S_{t-6}$	0.13*	-0.04	-0.08	-0.01
	[0.07]	[0.02]	[0.05]	[0.03]
Sample	Pre-2000	Post-2000	Pre-2000	Post-2000

- Post-2000: Past rise in ST rates → Flattening of yield curve
- β_1
  - Actual : Pre-2000: 0.46, Post-2000: 0.64.
  - Implied: Pre-2000: 0.46, Post-2010: 0.67.
- β_{12}
  - Actual : Pre-2000: 0.56, Post-2000: 0.20.
  - Implied : Pre-2000: 0.55, Post-2000: 0.28.

Economic Model

Model setup

- **Three groups:** Fast arbs, slow arbs and preferred habitat.
- **Two kinds of bonds:**
  1. ST bonds w/ yield i_t: riskless return i_t from t to $t+1$;
  2. LT bonds w/ yield y_t: risky excess return rx_{t+1} from t to $t+1$
     - Perpetuity
- i_t set by monetary policy: ST bond in fully elastic supply.
- LT bond available in a given net supply s_t = gross supply less inelastic demands of preferred-habitat investors

Assumption 1: Slow-moving arbitrage capital

- Formulation follows Duffie 2010
- Fast arbs (fraction q) trade every period. Demand for LT bonds is:

$$b_t = \tau \frac{E_t\left[rx_{t+1}\right]}{Var_t\left[rx_{t+1}\right]}$$

- Slow arbs (fraction $1-q$) only trade every k periods. If active at time t, their demand for LT bonds is:

$$d_t = \tau \frac{E_t\left[\sum_{i=1}^{k} rx_{t+i}\right]}{Var_t\left[\sum_{i=1}^{k} rx_{t+i}\right]}$$

Assumption 2: Shocks to i_t affect s_t

- ST rates set by policy and evolves as sum of two AR(1)s:
  - Transitory (T) = Cyclical movements in real rate
  - Persistent (P) = Expected inflation

$$i_t = i_{P,t} + i_{T,t}$$

$$i_{T,t+1} = \rho_T i_{T,t} + \varepsilon_{T,t+1} \text{ and } i_{P,t+1} = \bar{i} + \rho_P \left(i_{P,t} - \bar{i} \right) + \varepsilon_{P,t+1}$$

- Net supply of LT bonds depends on shocks to ST rates

$$s_{t+1} = \bar{s} + \rho_s \left(s_t - \bar{s} \right) + \varepsilon_{s,t+1} + C\varepsilon_{P,t+1} + C\varepsilon_{T,t+1},$$

where $C > 0$

Why is C > 0?

1. Reaching for yield (Rajan13, Hanson-Stein15):
   $i_t \downarrow \Rightarrow$ yield-oriented demand LT bonds $\uparrow \Rightarrow s_t \downarrow$
2. Shifts in asset/liability duration and convexity hedging:
   - Hanson 14 for mortgages:
     $i_t \downarrow \Rightarrow$ mortgage refi activity $\uparrow \Rightarrow$ mortgage duration $\downarrow$
     $\Rightarrow$ effective supply LT bonds $\downarrow \Rightarrow s_t \downarrow$
   - Shin 17 for insurers and pensions:
     $i_t \downarrow \Rightarrow$ asset duration $\uparrow$ but liability duration $\uparrow\uparrow$
     $\Rightarrow$ demand LT bonds $\uparrow \Rightarrow s_t \downarrow$
3. Over-extrapolative investors (Cieslak 18, Giglio-Kelly 18)
   $i_t \downarrow \Rightarrow$ extrapolative demand LT bonds $\uparrow \Rightarrow s_t \downarrow$
4. Financial crises: $s_t \downarrow$ and $i_t \downarrow$.

Short-run versus long-run equilibrium

- y_t set by matching supply and demand
- Arb demand curve is steeper in short-run than long-run:
  - In the short run, only fraction $1/k$ of slow arbs are active
  - In the long run, all slow arbs accommodate shifts in s_t

Model-implied behavior of β_h

- If $C = 0$, expectations hypothesis (EH) holds and β_h rises slightly with h.

- If $C > 0$, there is “excess sensitivity” :
  Relative to EH benchmark, LT yields over-react to ST rates
  - Over-reaction more pronounced in short-run if:
    - Associated net supply shifts are transitory ($\rho_S < \rho_T \leq \rho_P$)
    - Slow-moving capital: Demand curve steeper in short-run

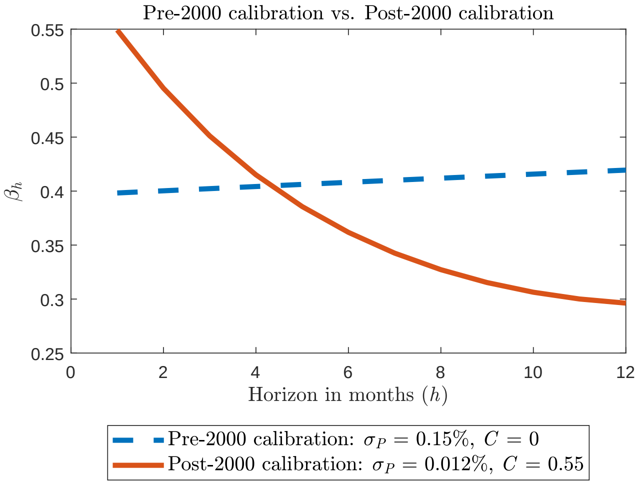
Illustrative calibration: Post-2000

- **One period:** one month
- **Persistence:** $\rho_s = 0.80$, $\rho_T = 0.96$ and $\rho_P = 0.995$.
- **Volatlity of $i_{P,t}$:** 0.012%.
- **Slow-moving capital:** $q = 0.3$ and $k = 12$: 70% of investors are slow-moving and only rebalance their portfolios every 12 months.
- **Supply process:** $C = 0.55 > 0$.
- **Duration of long bond:** 10 years.

Illustrative calibration: Pre-2000

- $C = 0$ so that the expectations hypothesis (EH) holds.
- Volatlity of $i_{P,t}$: 0.15%.
  - Consistent with Gürkaynak, Sack, and Swanson (2005)

Model-implied β_h: Pre-2000 vs Post-2000



Implications

Implications (1): Event-Studies in Macro

- Macroeconomic news comes out in a lumpy manner
- Short-run change in LT yields around news release used as unconfounded measure of longer-run impact
- But some of short-run impact on LT rates reflects changes in term premia that wear off quickly
- Macroeconomists face a bias-variance trade-off in assessing impact of news on LT yields:
  - Event studies = Precise estimates of short-run impact
  - But biased estimates of longer-run impact

Implications (1)

- Simple Illustration:

$$S_{t+3} - S_t = \beta NI_{t-1,t} + Controls + \epsilon_t$$

- $NI_{t-1,t}$ is actual or predicted news index from the end of month $t-1$ to the end of month t

Implications (1)

- Regression Results:

	Pre-2000			Post-2000		
$\text{NewsIndex}_{(t-1)\to t}$	-0.42	-0.61	-0.79***	-1.31***	-1.28***	-0.52
	[0.36]	[0.31]	[0.28]	[0.23]	[0.21]	[0.34]
L_t		0.03	0.03		-0.01	-0.00
		[0.02]	[0.03]		[0.04]	[0.03]
S_t		-0.13*	-0.12		-0.09*	-0.09**
		[0.07]	[0.06]		[0.05]	[0.04]
$L_t - L_{t-1}$			0.08			-0.63**
			[0.12]			[0.27]

Implications (2)

- Monetary policy transmission channel:
  - Bernanke(2010)/Taylor(2010) debate on effects of monetary policy on mortgage rates during the 2003
  - Stein(2013) "recruitment channel" of monetary policy: more powerful due to reach-for-yield investors (Hanson-Stein, 2015)
  - In practice, much of these TP effects are temporary; effect of monetary policy not as strong as from initial reaction.

Implications (3)

- Can form a "slope-mimicking" portfolio with excess returns similar to changes in slope
  - Weight of 1 on the 1 year bond and -0.1 on the 10-year bond
  - Trading strategy 1: go long (short) the "slope-mimicking" portfolio if $L_t < L_{t-h}$ ($L_t > L_{t-h}$).
  - Trading strategy 2: invest $-(L_t - L_{t-h})$ in the "slope-mimicking portfolio"
- Annualized Sharpe Ratios:

Strategy	$h = 1$	$h = 3$	$h = 6$	$h = 12$
1	0.52	0.62	0.68	0.64
2	0.38	0.62	0.47	0.4 5

Conclusion

- This paper:
  - Prior to 2000: Sensitivity of LT rates to changes in ST rates is high ... But similar at high and low frequencies
  - Post-2000: Sensitivity of LT rates becomes much stronger at high frequencies, weakens substantially at lower frequencies
- What explains puzzling frequency-dependent sensitivity in post-2000 data?
  - LT yields **temporarily** over-react to changes in ST rates
  - ST rates rise $\Rightarrow$ LT yields over-react $\Rightarrow$ LT yields likely to fall $\Rightarrow$ LT bonds likely to outperform ST
- Simple **limited arbitrage model** to explain post-2000 facts