

Interest Rate Conundrums in the Twenty-First Century

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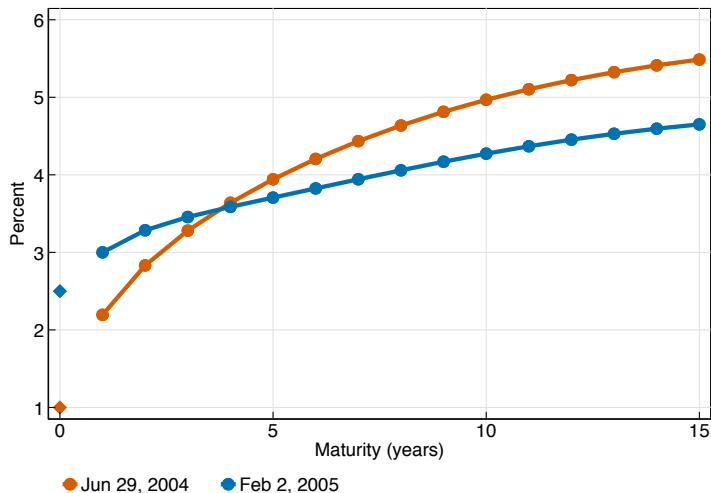
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The 2004 Interest Rate Conundrum

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



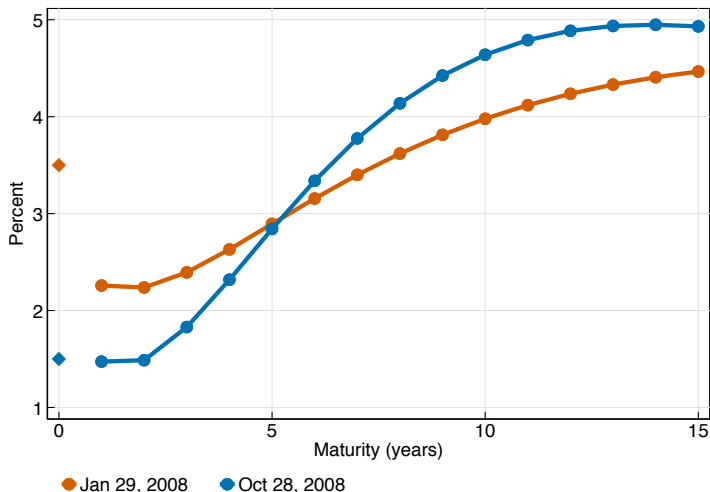
The 2004 Interest Rate Conundrum (contd)

- **Greenspan February 2005 Humphrey Hawkins Testimony:**

“This development contrasts with most experience, which suggests that . . . increasing short-term interest rates are normally accompanied by a rise in longer-term yields. Historically, even . . . distant forward rates have tended to rise in association with monetary policy tightening. . . . For the moment, **the broadly unanticipated behavior of world bond markets remains a conundrum.**”

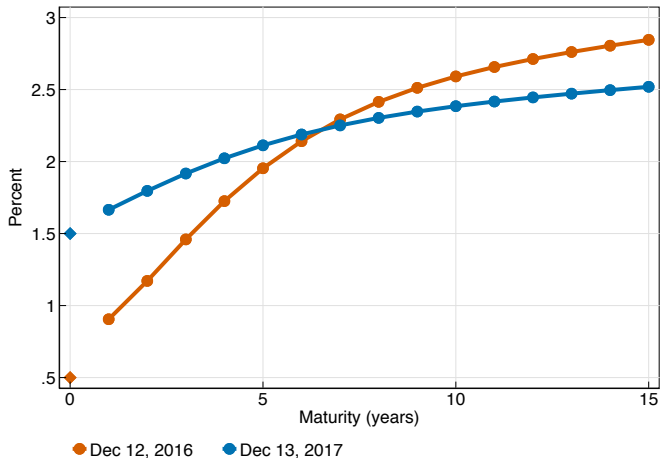
2008 “Conundrum in reverse”

- 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

- Not just 2004, 2008 and 2017—post-2000 many more conundrums, or ST/LT moving in opposite direction over 6/12-months

This paper

- 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:

$$y_{t+h}^{(10)} - y_t^{(10)} = \alpha_h + \beta_h(y_{t+h}^{(1)} - y_t^{(1)}) + \varepsilon_{t,t+h}$$

- $y_t^{(n)}$ is the n -year yield at time t
- β_h is “sensitivity” of LT yield where $h = \{\text{day, month, \dots, year}\}$
- 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*** [0.02]	0.86*** [0.03]	0.55*** [0.03]	0.31*** [0.02]
Monthly	0.46*** [0.04]	0.64*** [0.12]	0.37*** [0.10]	0.26*** [0.10]
Quarterly	0.48*** [0.04]	0.42*** [0.07]	0.21* [0.11]	0.22 [0.13]
Semi-annual	0.50*** [0.04]	0.31*** [0.07]	0.20** [0.08]	0.12 [0.10]
Yearly	0.56*** [0.05]	0.20*** [0.04]	0.13* [0.06]	0.07* [0.05]
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 - Post-2000: High-frequency “excess sensitivity” and low-frequency “decoupling”

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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*** [0.03]	0.48*** [0.04]	0.31*** [0.03]	0.17*** [0.03]
Monthly	0.29*** [0.04]	0.22 [0.14]	0.17** [0.08]	0.06 [0.09]
Quarterly	0.31*** [0.05]	0.03 [0.09]	0.08 [0.05]	-0.04 [0.05]
Semi-annual	0.33*** [0.06]	-0.06 [0.07]	0.03 [0.04]	-0.09** [0.04]
Yearly	0.39*** [0.07]	-0.17*** [0.05]	-0.03 [0.05]	-0.14*** [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

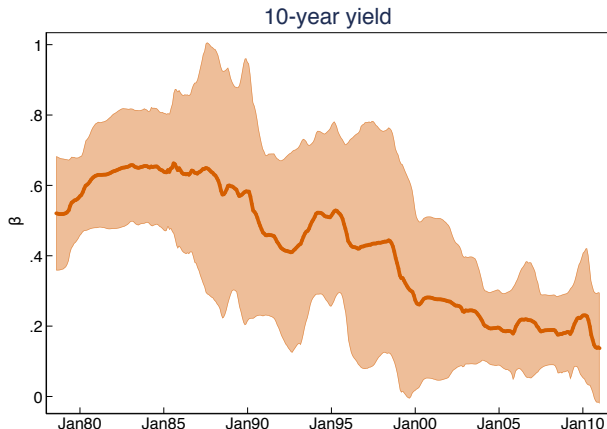
β_h of 10y UK yield on 1y UK yield

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

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

Dating Break for β_{year}

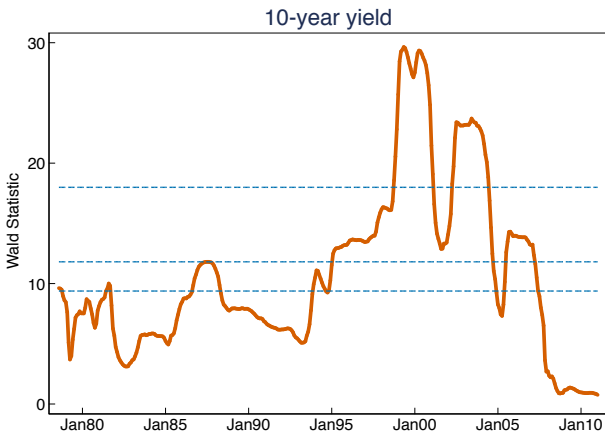
- Estimate β_{year} over 10-year rolling windows.
- Coefficient declines throughout the 1990s



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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 - Work with level $L_t \equiv y_t^{(1)}$ and slope $S_t \equiv y_t^{(10)} - y_t^{(1)}$ factors
- 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)	(2)	(3)	(4)
	L_{t+1}	L_{t+1}	S_{t+1}	S_{t+1}
L_t	0.96*** [0.02]	0.98*** [0.01]	0.01 [0.01]	-0.01 [0.01]
S_t	-0.02 [0.04]	-0.00 [0.02]	0.97*** [0.03]	0.94*** [0.02]
$L_t - L_{t-6}$	0.05 [0.05]	0.06* [0.03]	-0.03 [0.03]	-0.13*** [0.03]
$S_t - S_{t-6}$	0.13* [0.07]	-0.04 [0.02]	-0.08 [0.05]	-0.01 [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
- Risk averse arbs select among ST and LT bond

Assumption 1: Slow-moving arbitrage capital

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

$$b_t = \tau \frac{E_t [rX_{t+1}]}{\text{Var}_t [rX_{t+1}]}$$

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

$$d_t = \tau \frac{E_t \left[\sum_{i=1}^k rX_{t+i} \right]}{\text{Var}_t \left[\sum_{i=1}^k rX_{t+i} \right]}$$

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

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

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

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

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

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

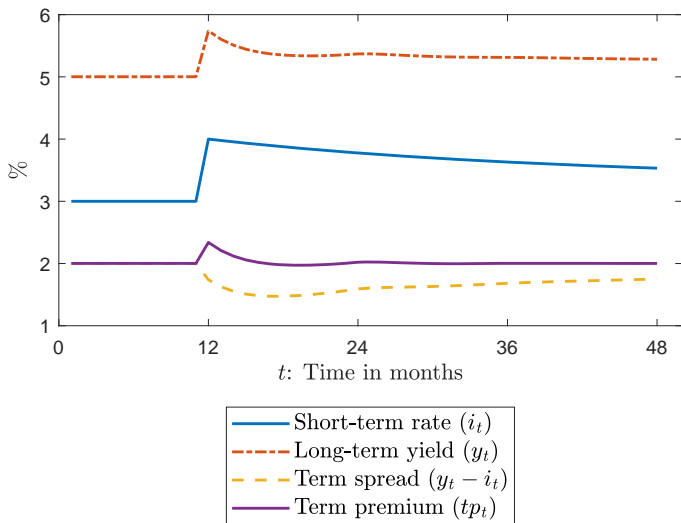
Model-implied behavior of β_h

- 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 $\rho_P = 0.995$.
- **Volatility 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.

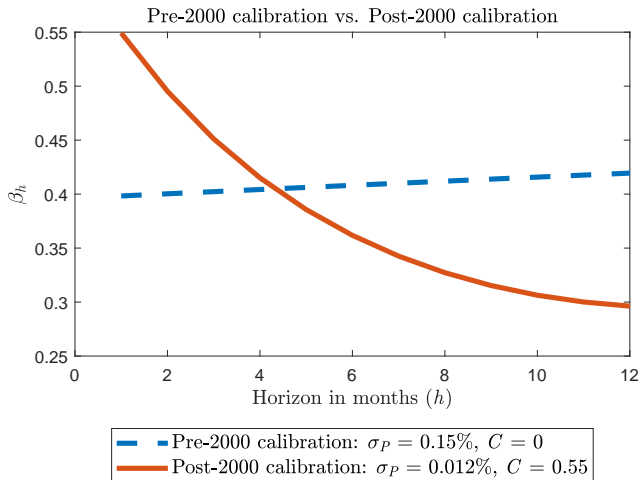
Model-implied impulse responses to a shock to SR



Illustrative calibration: Pre-2000

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

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



Why might C have risen?

- **Reaching for yield:** Non-linear relationship between reaching for yield and level of rates (Lian, Ma and Wang (2017)).
 - Weber's Law: People think in proportions, not differences
- **Mortgage refinancing:** Strength of mortgage-refi channel has grown (Hansen (2014))
- **Flight to quality episodes**

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		
$\text{NewsIndex}_{(t-1) \rightarrow t}$	-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	0.45

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