SWEDISH HOUSE OF FINANCE | STOCKHOLM SCHOOL OF ECONOMICS

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“Interest Rate Risk in Long-Dated Liabilities”

Peter Schotman

https://www.houseoffinance.se/valuation-hedging-long-dated-liabilities/

Interest Rate Risk in Long-Dated Liabilities

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Maastricht University

Hedging long-term liabilities

DeNederlandscheBank

EUROSYSTEEM

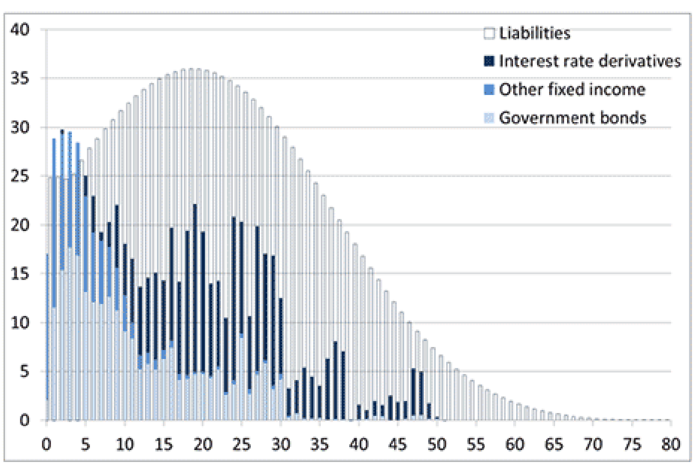


Figure 1 Cash outflows of pension benefits (liabilities) and expected cash inflows (redemptions and coupon payments) of investments in fixed-income securities (interest rate derivatives, sovereign bonds and other fixed-income securities) in EUR billion per year for the next 80 years, year-end 2012. The Figure uses the aggregate of cash inflows and outflows of pension funds.

DNBulletin (Sept 2013)

"At year-end 2012, pension funds had hedged 48% of their interest rate risk.

(…)

a **1%** fall in market interest rates would cause the average funding ratio to decline **7.8%**; without interest rate hedging, the funding ratio would drop **14.9%**."

Background

- Discount rate for pension liabilities
  - Are liabilities riskfree?
  - Should the discount rate be market consistent?
  - What if a market rate is not available?
  - Can long-term interest rate risk be hedged?
  - Should it be hedged?
  - Who bears the risk?
  - Does regulation have an impact on market rates?

- Some of these are similar for life insurance liabilities

- Supervision
  - Pensions: central bank (DNB) in Netherlands
  - Insurance industry: Solvency II, EIOPA (European Insurance and Occupational Pensions Authority)

Overview

- Behavior of very long-term interest rates
  - not much evidence beyond 10 year maturity

- **Valuation**
  - discount rates for maturities beyond 20 years

- **Hedging**
  - liquid short-maturity instruments for long-dated liabilities
  - regulatory and economic hedging

- Bonds in a strategic portfolio
  - covariance with other asset classes
  - optimal interest rate risk exposure

Market segmentation

- Market consistent valuation, but maybe prices at long maturities not reliable (or not available)
  ⇒ regulatory adjustment of discount rates

- Supply effects: maturities of government debt (Greenwood and Vayanos, RFS 2014)

- Demand pressure (Domanski, Shin and Sushko, IMF 2017)
  - Duration gap of insurers and pension funds puts downward pressure on long-term interest rates

- Regulation may affect yield spreads (Greenwood and Vissing-Jorgensen, 2018)
  - Demand from pension and insurance negatively correlated with 30-10 spread

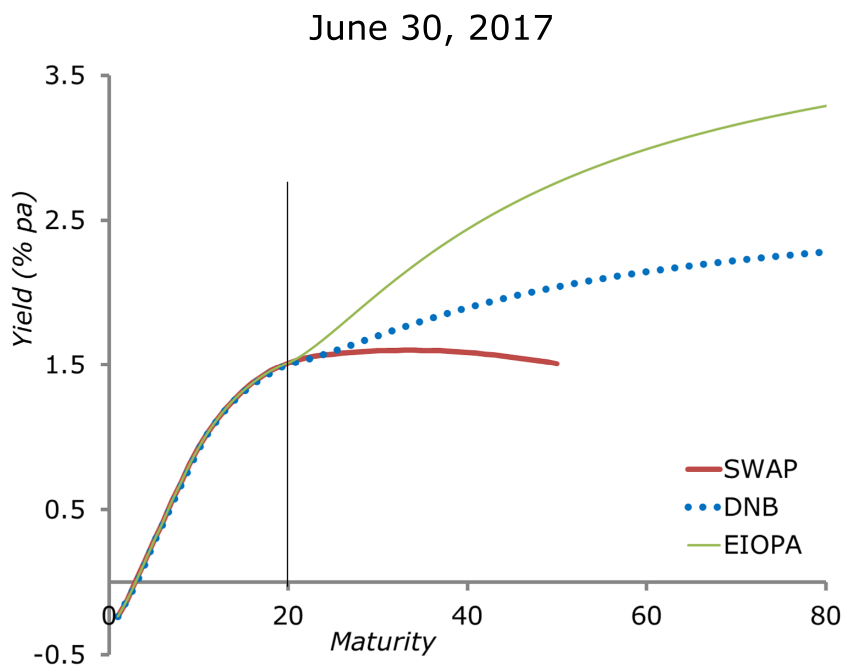
Extrapolation

- Market data for maturities up to **L**ast **L**iquid **P**oint
  - LLP = 20 years for euro curve

- EIOPA:
  - Numerical algorithm to extend to longer maturities
  - Important parameters
    - Ultimate forward rate (**UFR**)
    - Initially constant at 4.2% (but going down from 2018 onwards: 4.05, 3.90, …)
    - Speed of convergence towards UFR: 40 years

- DNB for Dutch pensions funds:
  - Slower convergence
  - UFR as average 20-year forward from last 10 years

Impact of UFR on yield curve



What about using a formal term structure model?

EUROPEAN INSURANCE AND OCCUPATIONAL PENSIONS AUTHORITY

Technical Specifications part II on the Long-Term Guarantee Assessment

The most important economic factors explaining long term forward rates are long-term expected inflation and expected real interest rates. From a theoretical point of view it can be argued that there are at least two more components: the expected long-term nominal term premium and the long-term nominal convexity effect.

The long end of the yield curve

- Empirical study
  - data on euro swap rates 1999 – 2017
  - maturities 1-10, 12, 15, 20, 25, 30, 40, 50 years
  - longest maturities (40, 50 years) avaliable since 2005

Hypotheses

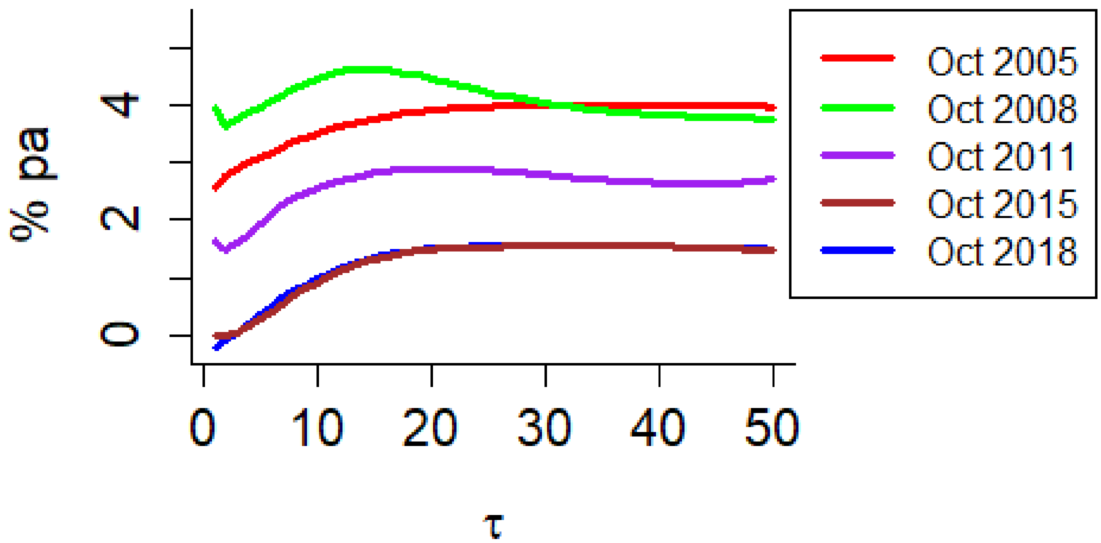
1. Yield curves show mean reversion towards a common infinite horizon rate (UFR)
   - *alternative*: mean reversion too low to be meaningful

2. The average level of ultra long rates is consistent with predictions from an arbitrage-free term structure model
   - *alternative*: observed rates rates are lower

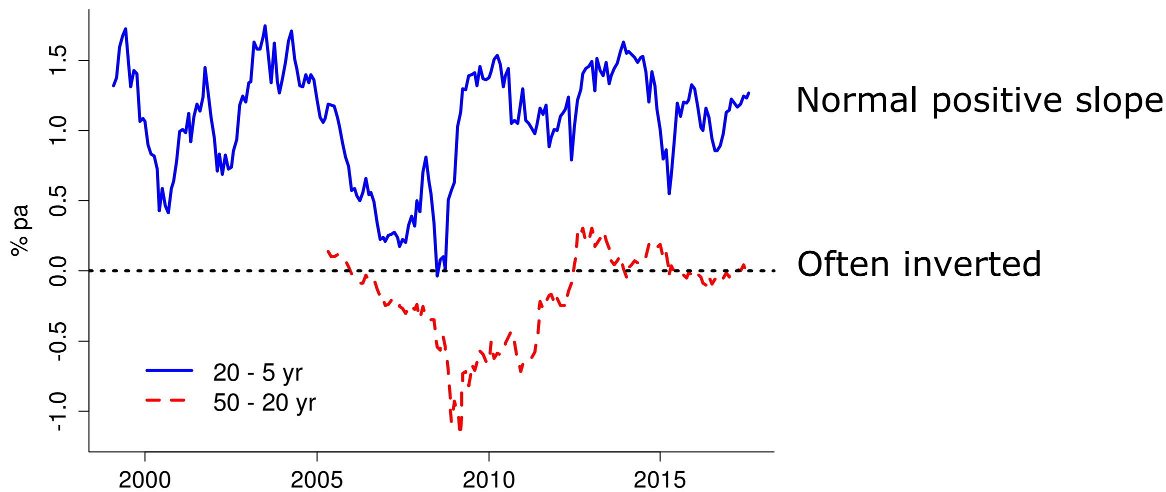
3. The volatility of ultra long rates is as predicted by term structure models commonly used for liquid maturities
   - *alternative*: excess volatility

4. Factor models for liquid maturities lead to an effective hedge for long-term interest rate risk
   - *alternative*: very long end disconnected from liquid maturities

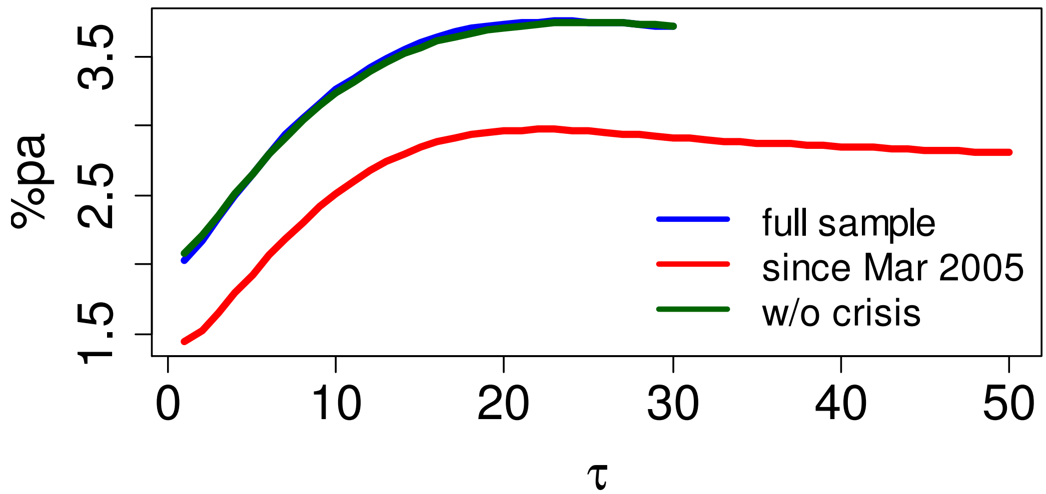
Yield curves do not converge



Yield spread



Average yield curve



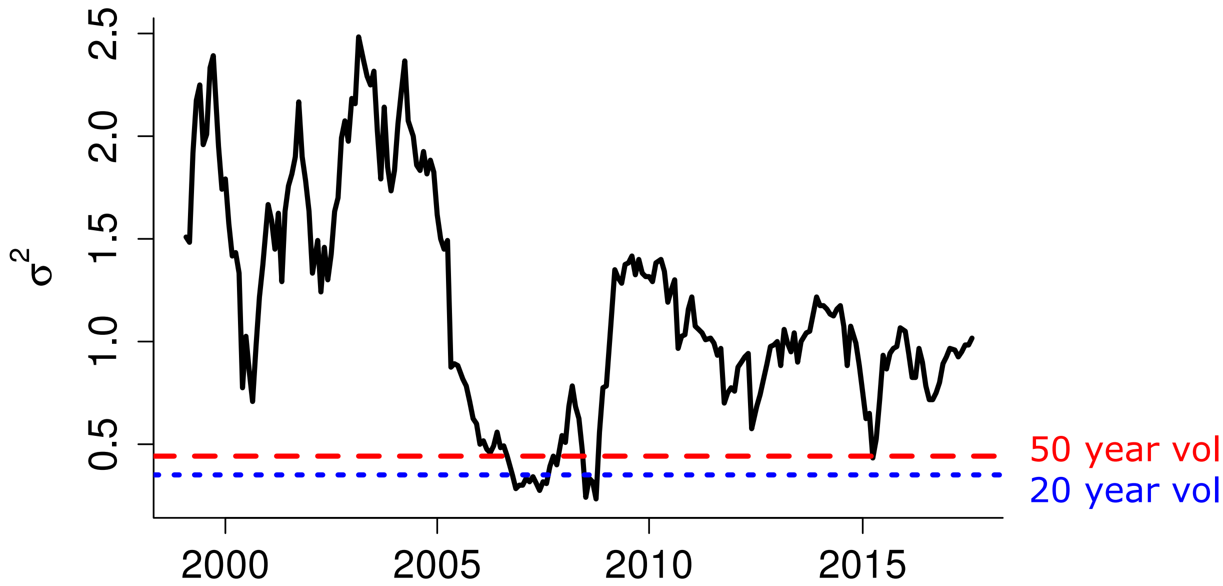
If anything, downward sloping at the long end
$\Rightarrow$ Convexity

Convexity

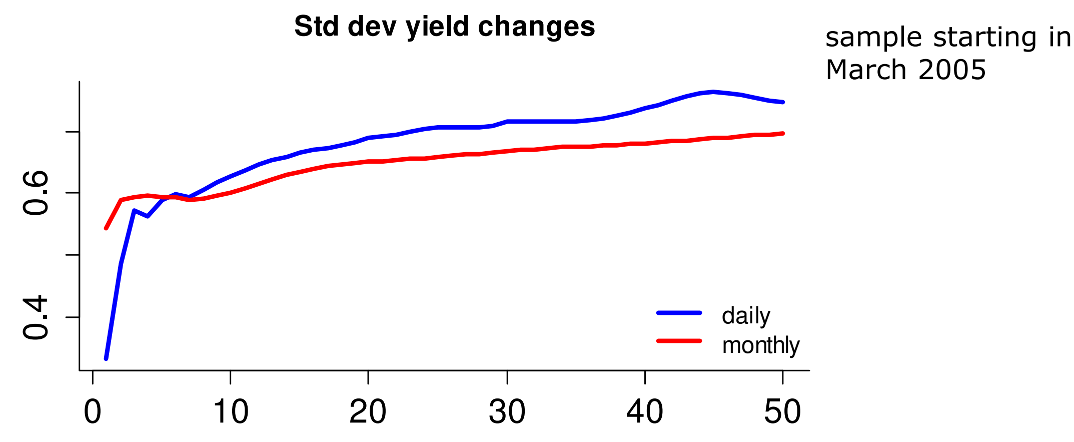
- If level factor is Gaussian random walk, then long end of the yield curve is quadratic in maturity (Merton, MS 1973)
  - negative quadratic term $-\frac{1}{6}\sigma^2\tau^2$
- Run cross-sectional regressions of
  - long-maturity spread, $y_t(\tau) - y_t(\tau^*)$, with 20-years rate
  - on maturity (τ) and maturity² to estimate σ^2
- Implied volatility much larger than time series volatility

σ^2 = 1.16
(0.27)

Convexity may not be enough

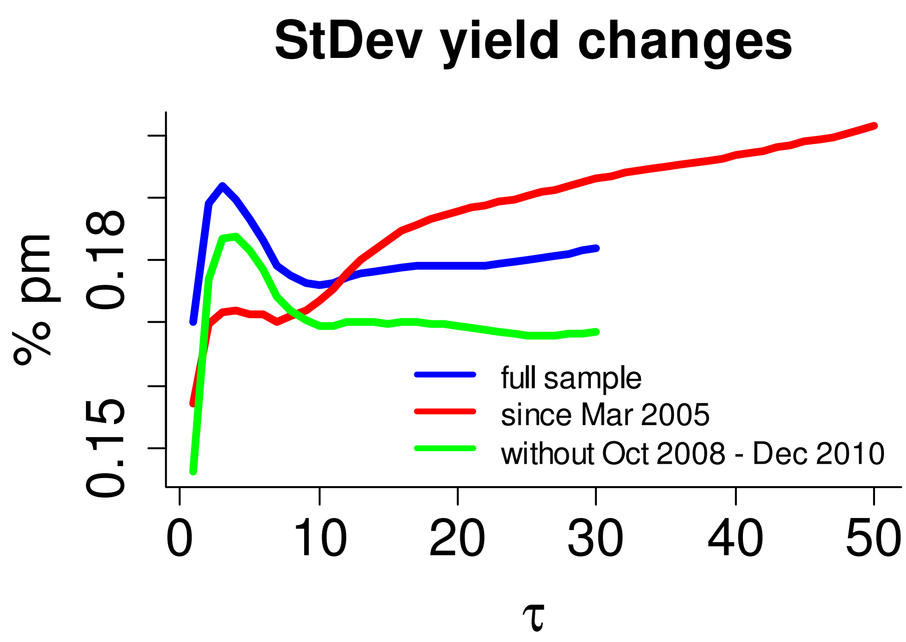


Volatility puzzles



- How to explain upward volatility slope?
- Much transitory noise at very long end
- Persistent changes at short end

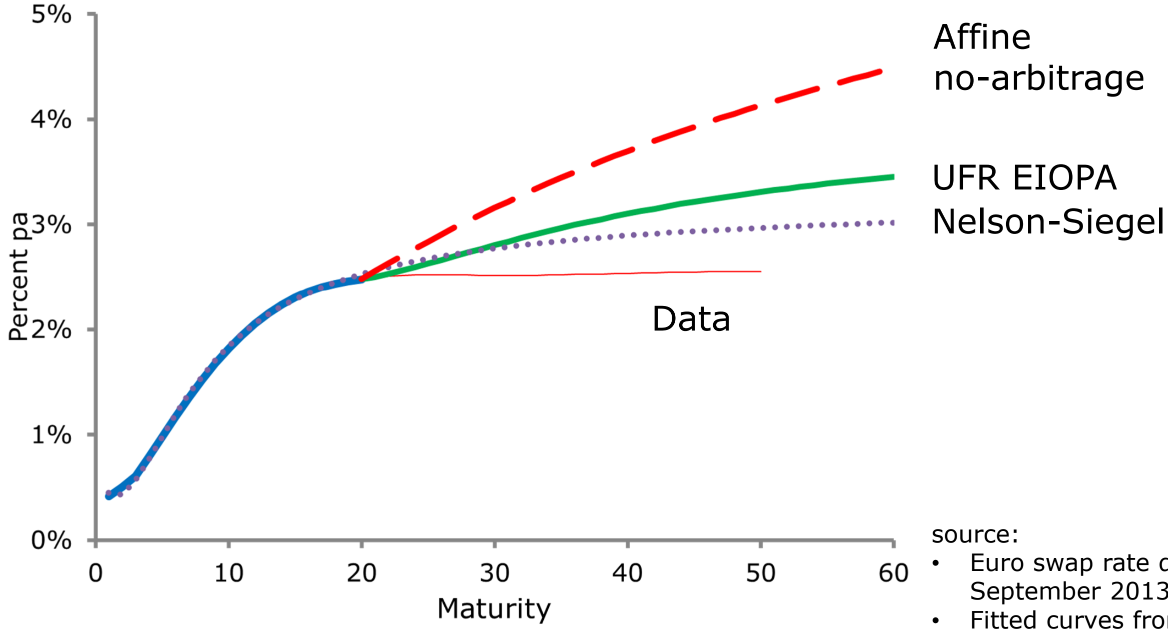
… with different samples



Term structure models

- Gaussian essentially affine
  - implies constant UFR
  - explicitly accounts for term premium and convexity
- Nelson-Siegel
  - fit entire term structure using 3 time-varying factors: level, slope, curvature
  - ⇒ yield curve converges to time-varying level factor
  - (can be adapted to belong to Gaussian affine)

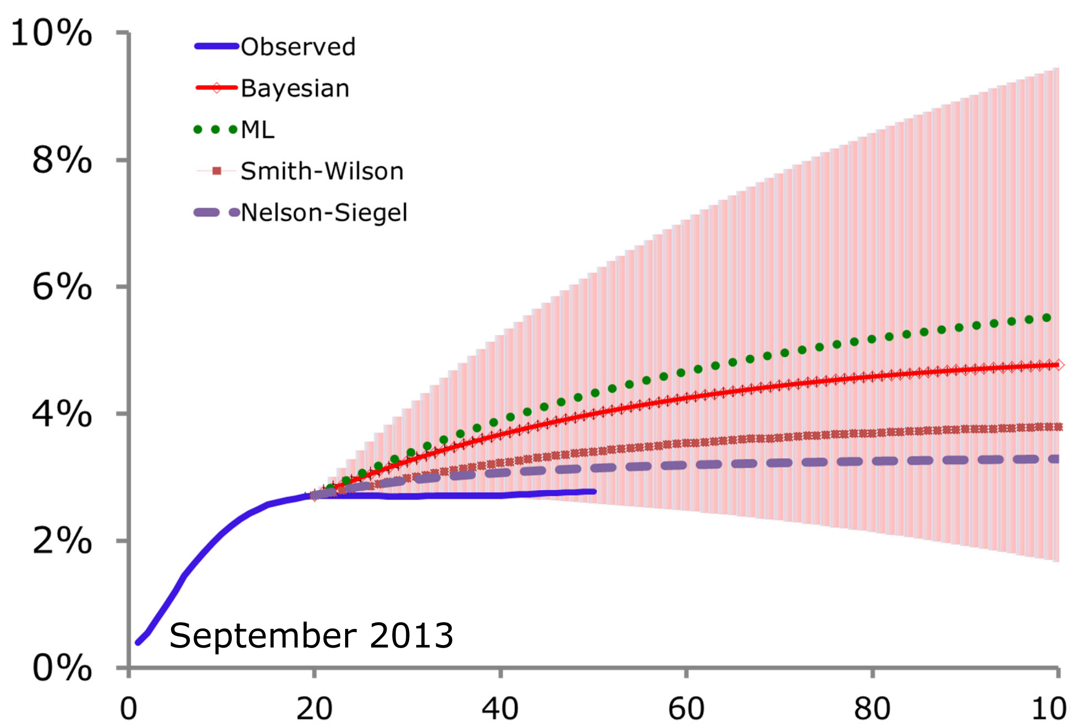
It is difficult to fit the very long end of the yield curve



source:

- Euro swap rate data September 2013,
- Fitted curves from Balter *et al* (2018)

Extrapolated curves with a credibility interval



Hedging interest rate risk

- Nelson-Siegel
  - parsimonious 3-factor term structure model
  - level, slope and curvature factors
  - also holds for bond **excess returns**

- Hedging:
  - invest in factor mimicking portfolios
  - with weights equal to factor exposure of the liability

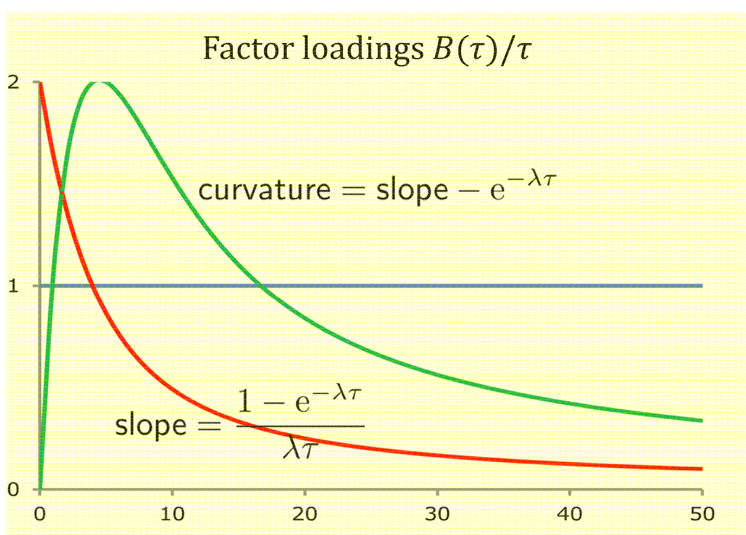
- **Liabilities are longer than liquid instruments**
  $\Rightarrow$ leveraged position in longest liquid bonds

Duration plus …

- 1st factor in Nelson-Siegel is a parallel shift in the yield curve
  - level factor ➔ corresponds to duration hedging
  - bond prices move proportional to duration τ

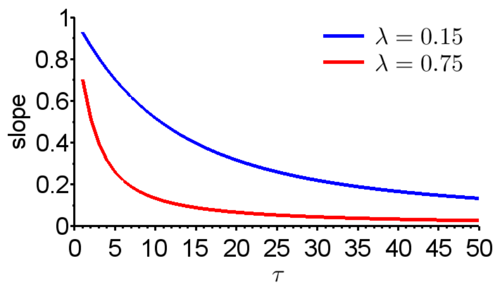
- Other two factors are slope and curvature, both governed by a single parameter λ

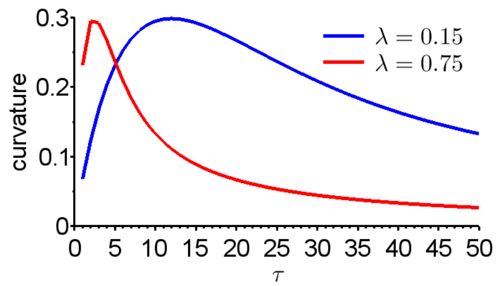
- How stable are factor loadings?
  - after 2008?



Econometrics

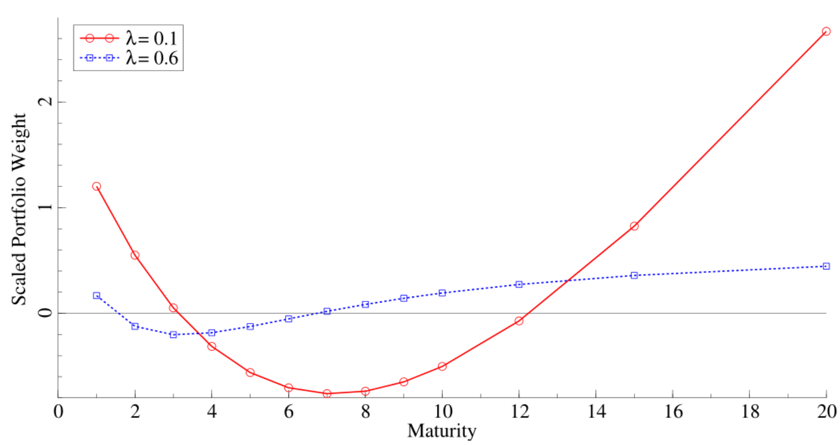
- Time-varying factor loadings
  - reflect time-varying volatility and covariances,
  - before, during and after financial crisis
- In recent data slope and curvature factors become more important at long end
  - decrease in λ from 0.75 to 0.15 (and lower)
  - need more than one factor at very long end





Hedge portfolio: 50-year liability

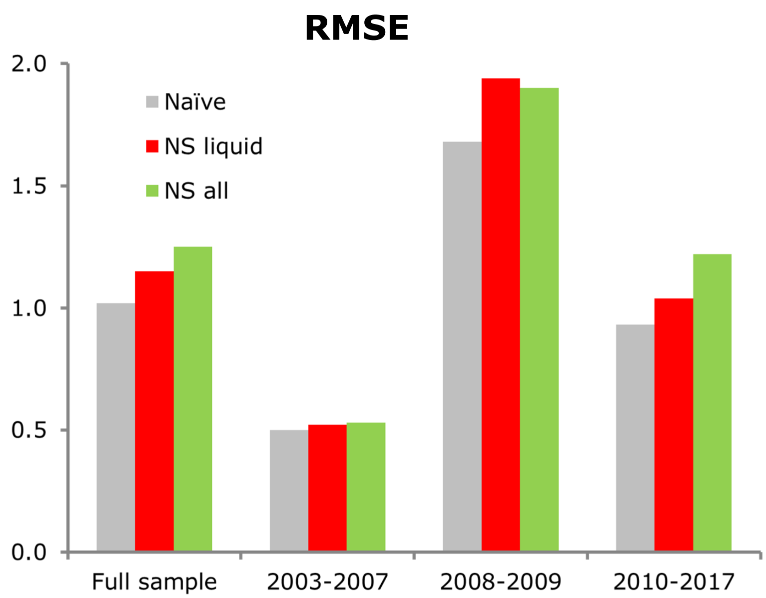
Figure 1: Factor-Mimicking hedge portfolio composition



Factor hedge: mimicking factors from NS model

Naïve hedge: 250% in 20Y bond, financed by short position in riskfree rate

Out-of-sample hedging results



50 years liability
Daily rebalancing

Naïve = leveraged position in 20 yr rate

NS LIQ = Optimal hedge with NS model estimated on liquid maturities

NS ALL = Optimal hedge with NS model estimated on liquid maturities

Regulatory hedging

- With an artificial curve with UFR the 50 year rate becomes a function of shorter maturities
- Subject to discrete changes in methodology
- In some cases strong dependence on 20-year rate

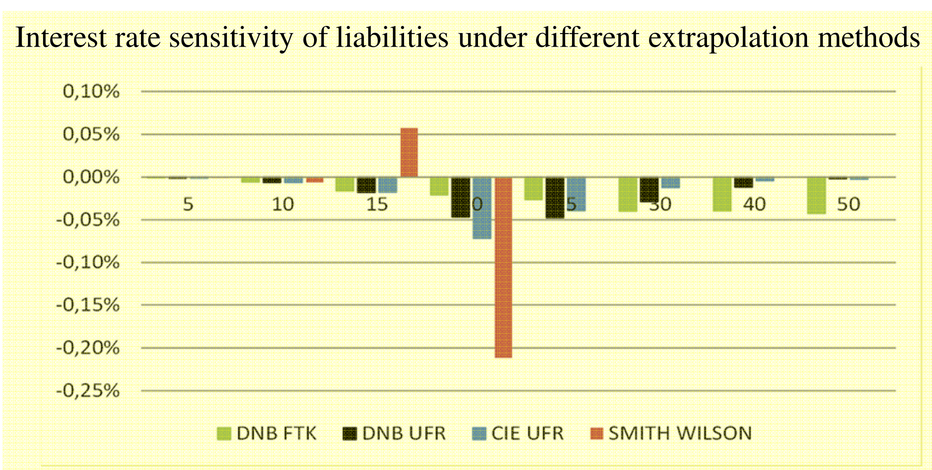
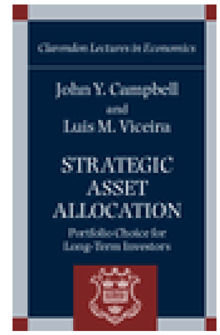


figure from commissie UFR, 2013

Strategic portfolio choice

- Interest rates are correlated with expected and unexpected returns of other asset classes
- Not always optimal to hedge all interest rate risk
  - ambition, hard guarantees
  - nominal versus real
  - buffers, funding ratio
- Optimal portfolio choice for long-term investors
  - textbook treatment: Campbell and Viceira (2002)
  - extensions to pension setting with liabilities



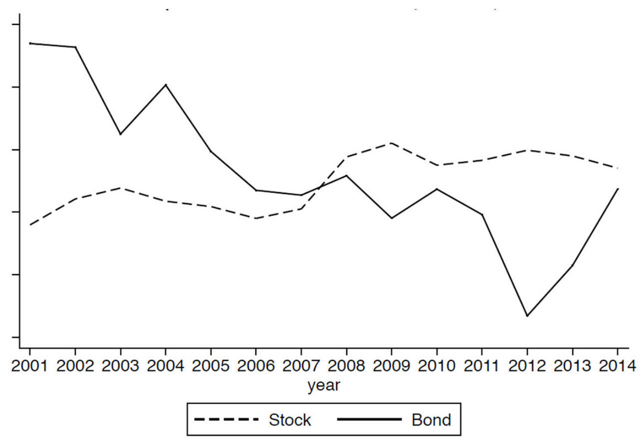
- Optimal portfolio weights change in response to changes in **investment opportunities**

Changing investment opportunities

- **Investment asset menu**: equity, long-term nominal bonds, short-term bonds, (alternatives)
- State variables predict changes in expected returns
- Expected adjustments from optimal strategic portfolios

	EQUITY		**BONDS**	
	Asset only	Asset-Liability	Asset only	Asset-Liability
Interest rate	-	-	+	+
Yield spread	-	-	+	+
Dividend yield	+	+	-	-
Credit spread	+	?	-	?

Optimized portfolio



Campbell, Chan, Viceira (JFE 2003) VAR parameters
Risk aversion γ=5, discount factor δ=0.92, intertemporal elasticity ψ=1

Actual allocation decisions

$$A_{i,j,t} = \sum_{\ell=1}^{K} \beta_{\ell,j} \Delta Y_{\ell,t-1} + \epsilon_{i,j,t}$$

- CEM Benchmarking data (Toronto)
  - Pension fund holdings
  - annual 1990-2011
- Active allocations asset class *j* by fund *i* in year *t*
- Explain using variables that signal changes in investment opportunities

	Equity	Bonds	Alternatives
Nominal yield	-1.59	1.50	0.13
	(-2.84)	(3.40)	(1.16)
log D-P ratio	11.72	-10.44	-1.68
	(3.87)	(-3.88)	(-2.03)
Credit spread	-1.16	1.55	-0.27
	(-1.46)	(2.13)	(-1.38)
Yield spread	-1.63	1.38	0.26
	(-2.81)	(2.88)	(2.05)
R^2	0.25	0.22	0.07

Summary

- Puzzling interest rate behavior at very long end of yield curve
  - hard to fit with conventional models
  - discrepancy with regulatory adjustment and extensions of yield curve
  - high volatility at very long end
- Hedging gains
  - beyond duration
  - time-varying factor loadings: more importance of level and curvature factor in recent period implies more emphasis on longer maturities
- In strategic asset allocation models persistent low interest rates imply more equity and fewer long-term nominal bonds

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