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What's Happening to Interest Rates?

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Presentation Overview

- Interest rate history: long term and the recent past
- Using diffusion models
- Interpreting prices of interest rate options
- Supply and demand arguments for lower bounds
- Conclusions

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History of Interest Rates

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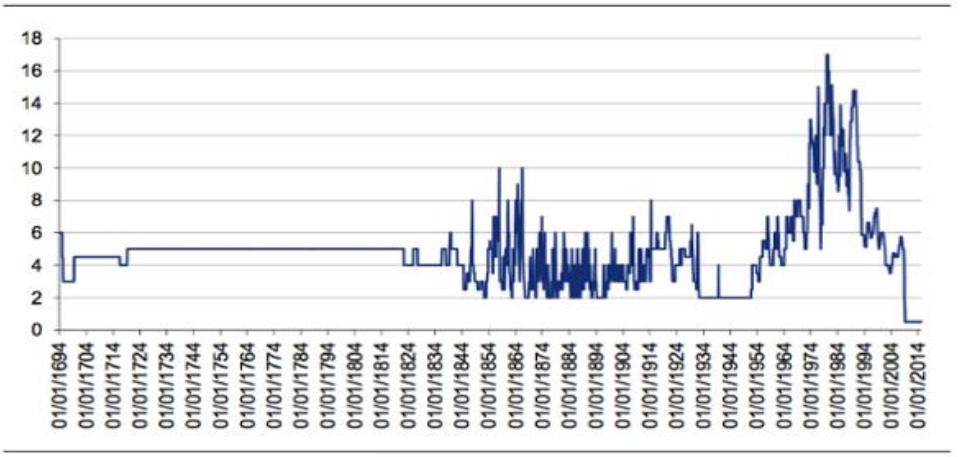
Why Interest Rates Matter for Investors

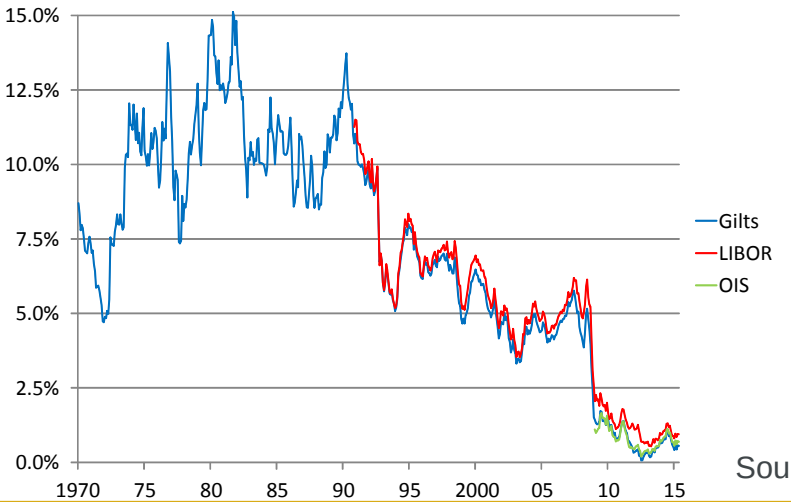
- Rates explain market prices of fixed income instruments
- Input to liability valuation calculations for insurers and pension funds
- If invested short, lower rates squeeze available balance sheet capital
- Hurdle rates for project investments
- At the apex of a dependency structure for many planning models (for example, equity returns expressed as risk-free + risk premium)
- Interest rates spreads affect profitability of carry trades (for example, rolling futures, swaps against liabilities discounted at bond yields.)
- A policy instrument that may be used to target inflation or FX rates.

UK Base Rates since 1694



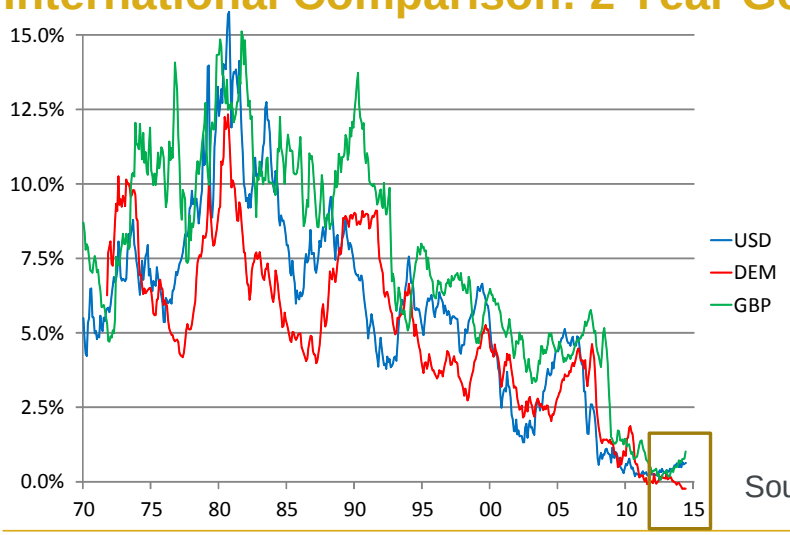
Source Bank of England, Guardian, Macrobond

UK Market Rates (2 Year Term)



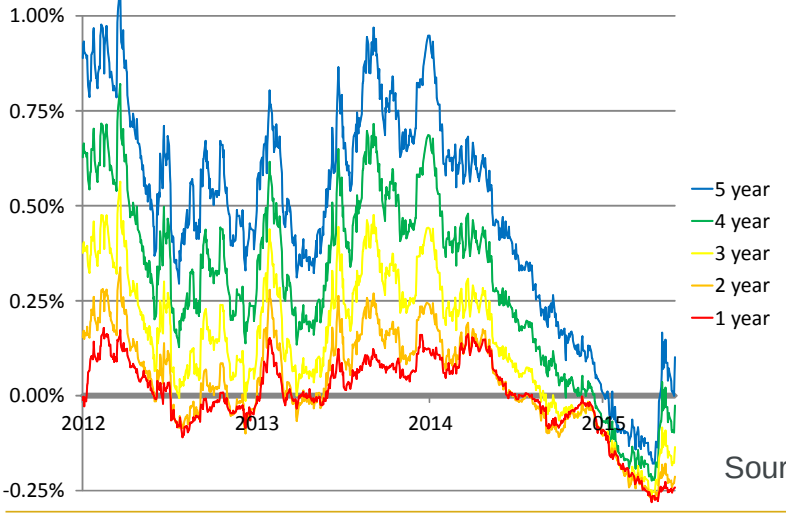
Source: Bank of England

International Comparison: 2 Year Gov Yields



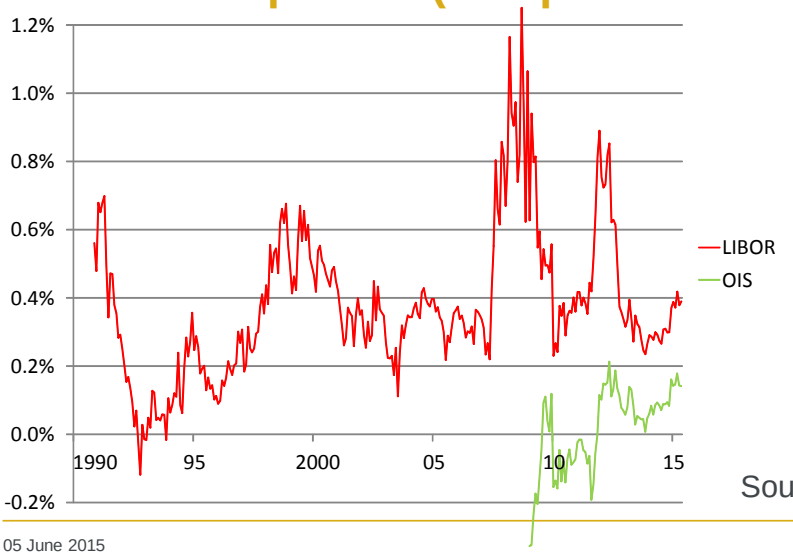
Source: Fed, BoE, Buba

Recent Yields on German Bonds



Source: Buba

UK 2-Year Spreads (Swaps over Gilts)



Source: Bank of England

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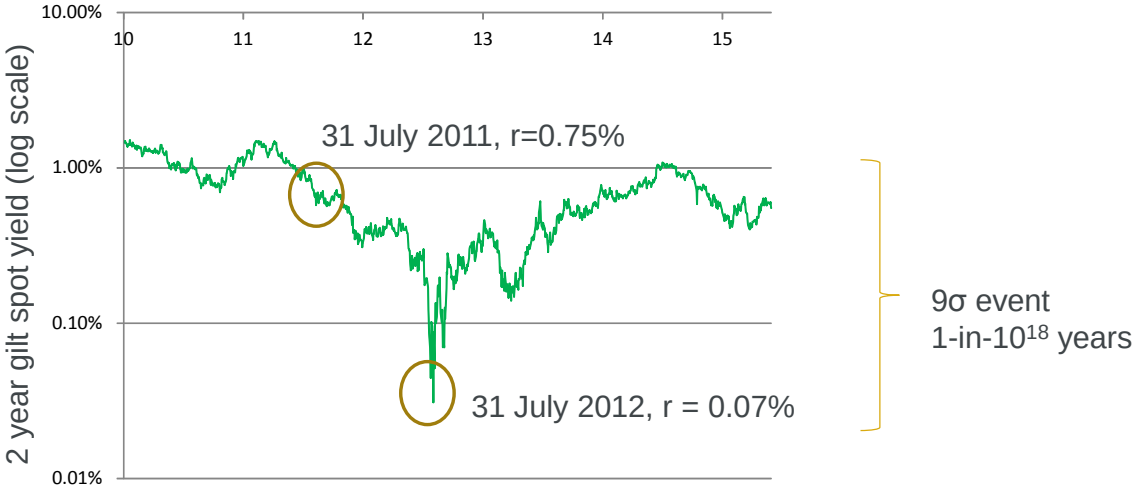
Local Volatility Diffusion Models

Calibrating Drift and Volatility Terms

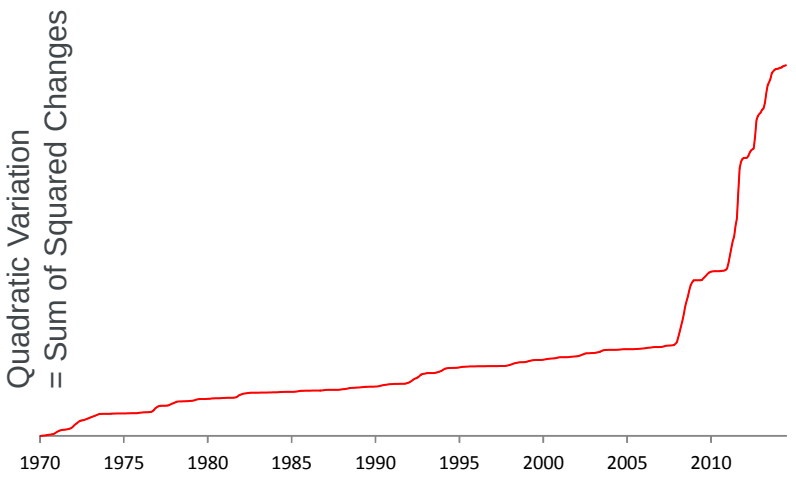
Geometric Random Walk Models

- The default model for positive economic series (such as share prices or foreign exchange rates)
- The absolute size of an extreme percentile stress is proportional to the current level
- This is consistent with Solvency II standard formula approach for equities, property and the risk-free curve.

The Rate Fall in 2012

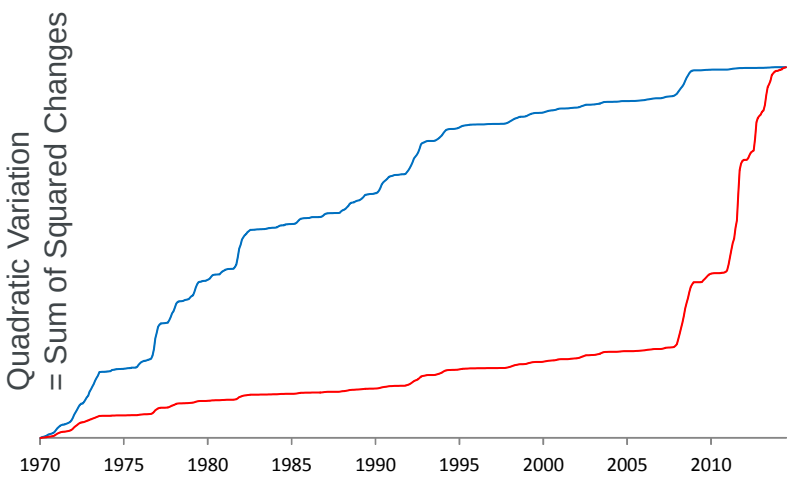


Test for Constant Volatility



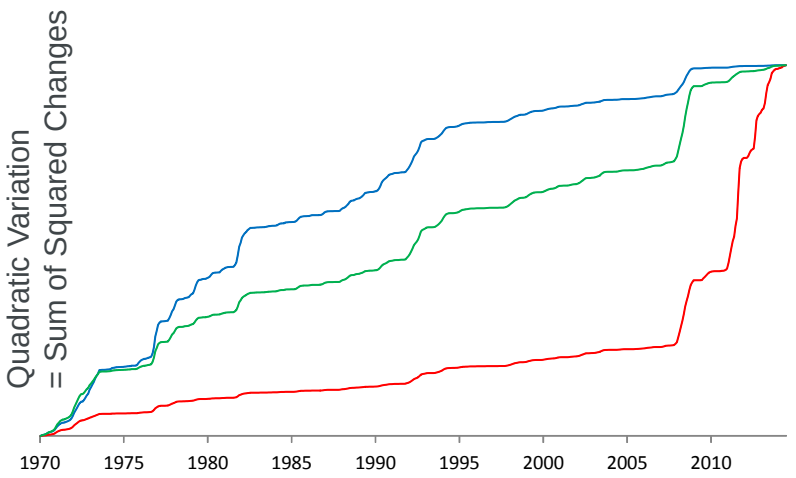
The red line shows the cumulative sum of squared log changes. The abrupt change of direction in the financial crisis shows that an increase in (relative) volatility accompanied falling rates.

What if We Don't Take Logs?



The blue line shows the cumulative sum of squared changes in absolute rates. Here the slope is decreasing; the absolute level of volatility has reduced as rates have fallen.

Displaced Random Walk Model



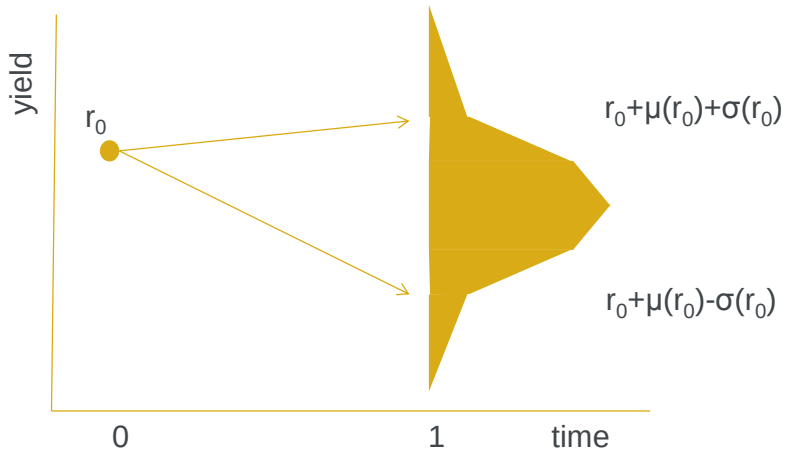
The green line shows the cumulative sum of squared changes in log(r+3.48%). This is closer to a constant slope, or equivalently, the green line is as close as we can get to a straight line.

What is a Diffusion Process?

- Generalise the arithmetic / geometric random walk
- Write down a plausible equation for interest rates and then fit parameters.
- Fix a rate term, and consider r_t as a Markov process
- Diffusion process – no discontinuities
- Characterised by conditional mean per unit time (drift) and conditional variance per unit time (volatility squared)

Diffusion Formula

$$dr_t = \mu(r_t)dt + \sigma(r_t)dZ_t$$



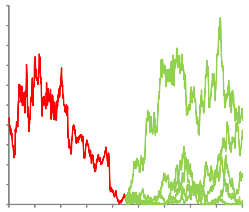
The Cox-Ingersoll-Ross Model

Mean reversion

Change in yield

Ergodic Mean

Change in Brownian Motion



$$dr_t = \alpha(\mu - r_t)dt + \eta r_t^{1/2}\, dZ_t$$

Possible parameters:
μ = 5%
α = 0.02
η = 0.20

Volatility

Avoids zero (without the $r_t^{1/2}$ term, we have the Vasiček model)

What is the Lower Bound for Interest Rates?

- The lower bound is an artefact of the model we choose.

Model	Interest Rate Lower Bound
Geometric random walk	Zero
Cox-Ingersoll-Ross	Zero (instant rate) Strictly positive (positive terms)
Arithmetic random walk	Unbounded
Vasiček	Unbounded
Displaced geometric random walk	-3.48%

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Interest Rate Option Pricing Models

Black, Bachelier and Related Models

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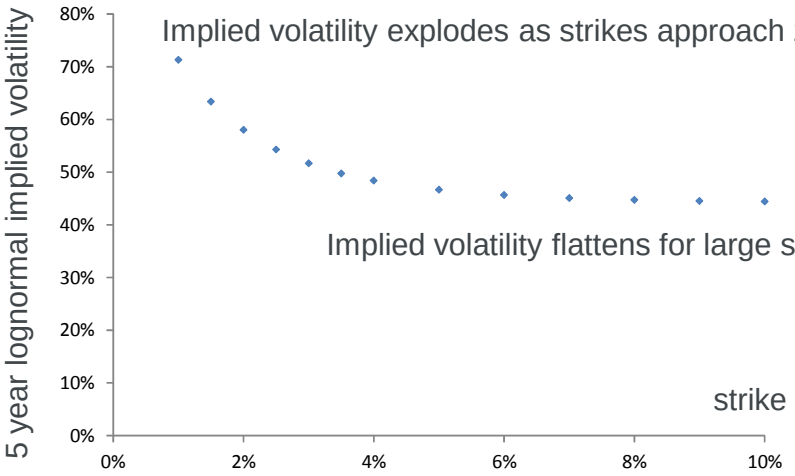
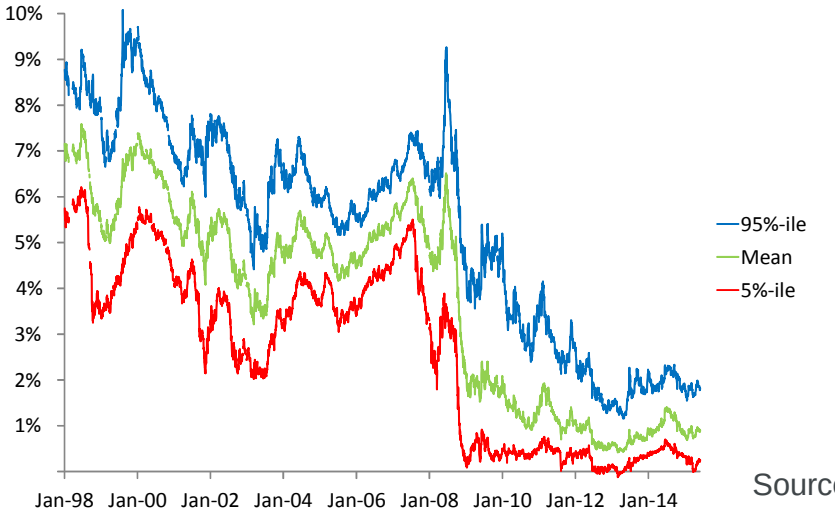
Implied Volatility of Interest Caps and Floors



As at 29 May 2015
Source: Bloomberg

1-Year Ahead Percentiles of GBP LIBOR



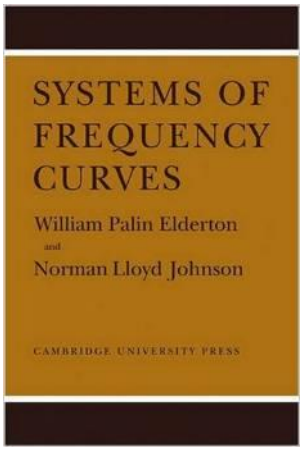
Source: Bank of England

What is the Lower Bound for Interest Rates?

- The lower bound is an artefact of the model we choose.

Model	Interest Rate Lower Bound
Bank of England (Shimko method of extrapolating Black / lognormal implied volatility)	Zero
Bachelier (normal implied volatility); Johnson curves	Unbounded
Displaced geometric random walk (Piterbarg DDSV LMM)	-3.48% or other estimated constant

Extending Displaced Geometric RW's



- First published 1906.
- Reprinted 2009.
- Norman Lloyd Johnson (1917-2004) qualified as FIA in 1949.
- William Palin Elderton (1877–1962) was President of the Institute of Actuaries 1932–1934.
- Johnson distribution family includes normal and displaced lognormal distributions.

What do the Examiners Say? (CT8, Apr 2012, Q 6)

(i) Write down a stochastic differential equation for the short rate r_t for the Vasiček model. [1]

(ii) State the type of process of which the Vasiček model is a particular example. [1]

(iii) Solve the stochastic differential equation in (i). [5]

(iv) State the distribution of r_t for t given. [1]

(v) Derive the expected value and the second moment of r_t for t given. [3]

(vi) Outline the main drawback of the Vasiček model. [1]

Examiners' Model Solution to part (vi):

"The process may become negative which is undesirable in a nominal interest rate model"

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Supply and Demand Considerations

Could Interbank Rates become Negative?

- Short government bond yields have become negative in several currencies
- LIBOR (inter-bank unsecured borrowing) has remained positive
- Typically settled as two cash flows (deposit, followed by redemption + interest)
- No particular administrative issues with the interest rate becoming negative – it would mean banks had to pay other banks to look after their money.
- Negative swap rates also theoretically feasible.
- What about negative perpetuity yields?

Are Negative Interest Rates Logical?

- Investors can choose to hold physical banknotes.
- It could be argued that the option to hold banknotes should keep market interest rates above zero.
- But this ignores:
  - Cost of storage
  - Risk of theft
  - Damage from floods, fire
  - Cost of moving cash, especially across borders
  - Legal tender issues

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Conclusions

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Lessons Learned from Recent Rate Moves

- Negative nominal rates are already here for a few economies, and could spread further.
- Model output is a function not only of input parameters but also the chosen model structure. Consider several alternative models.
- If a single model says negative rates (or rates above 100%) can't happen, this does not mean these rates can't happen.
- Think about fundamental supply and demand in the broader economy
- Interpreting derivative prices requires a whole host of subsidiary assumptions.

Questions

Comments

Expressions of individual views by members of the Institute and Faculty of Actuaries and its staff are encouraged.

The views expressed in this presentation are those of the presenter.