barrie+hibbert

Calibration of Economic Scenario Generators

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Meeting the Challenges of Change

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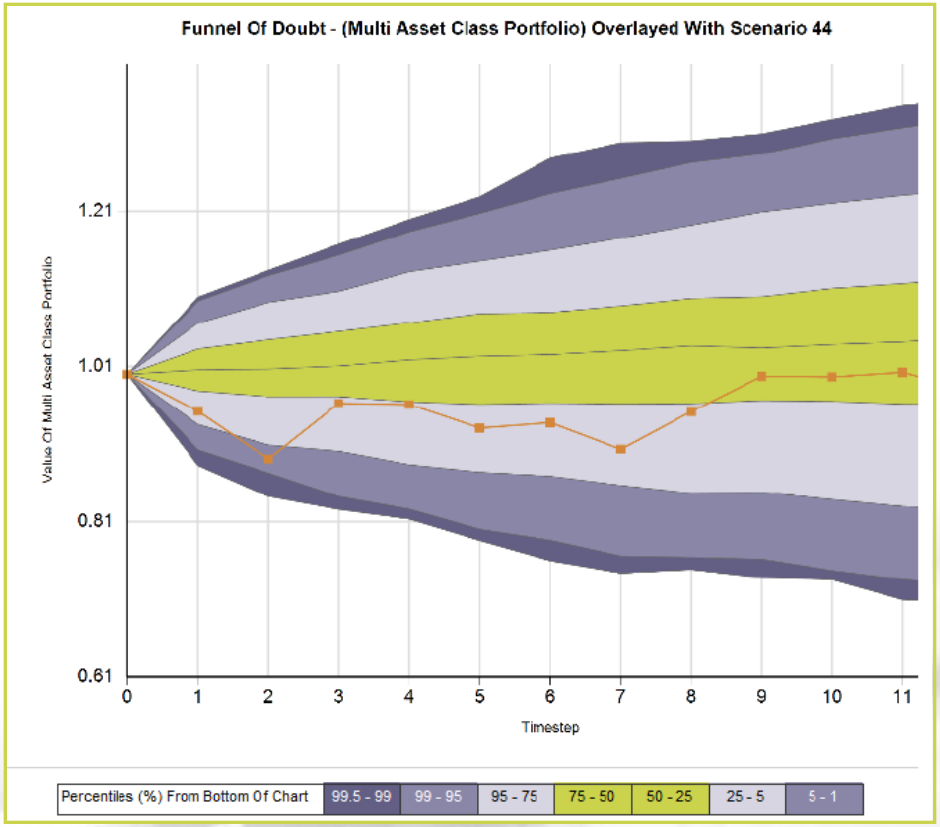
Agenda

- Recap of ESG
- Overview of the India financial markets
- Some practical examples for MC calibration
  - Yield curve construction
  - Volatility modeling

What is ESG?

ESG is …

- Monte-Carlo simulation:
  - interest rates
  - + inflation
  - + credit
  - + equity
  - + alternative investment
  - + option implied volatility
  - + FX



Why ESG is important

Stochastic modeling for management and regulator

- How does market risk impact my financials / business?
- Stochastic reserving for guarantees / ALM framework

Calibration matters

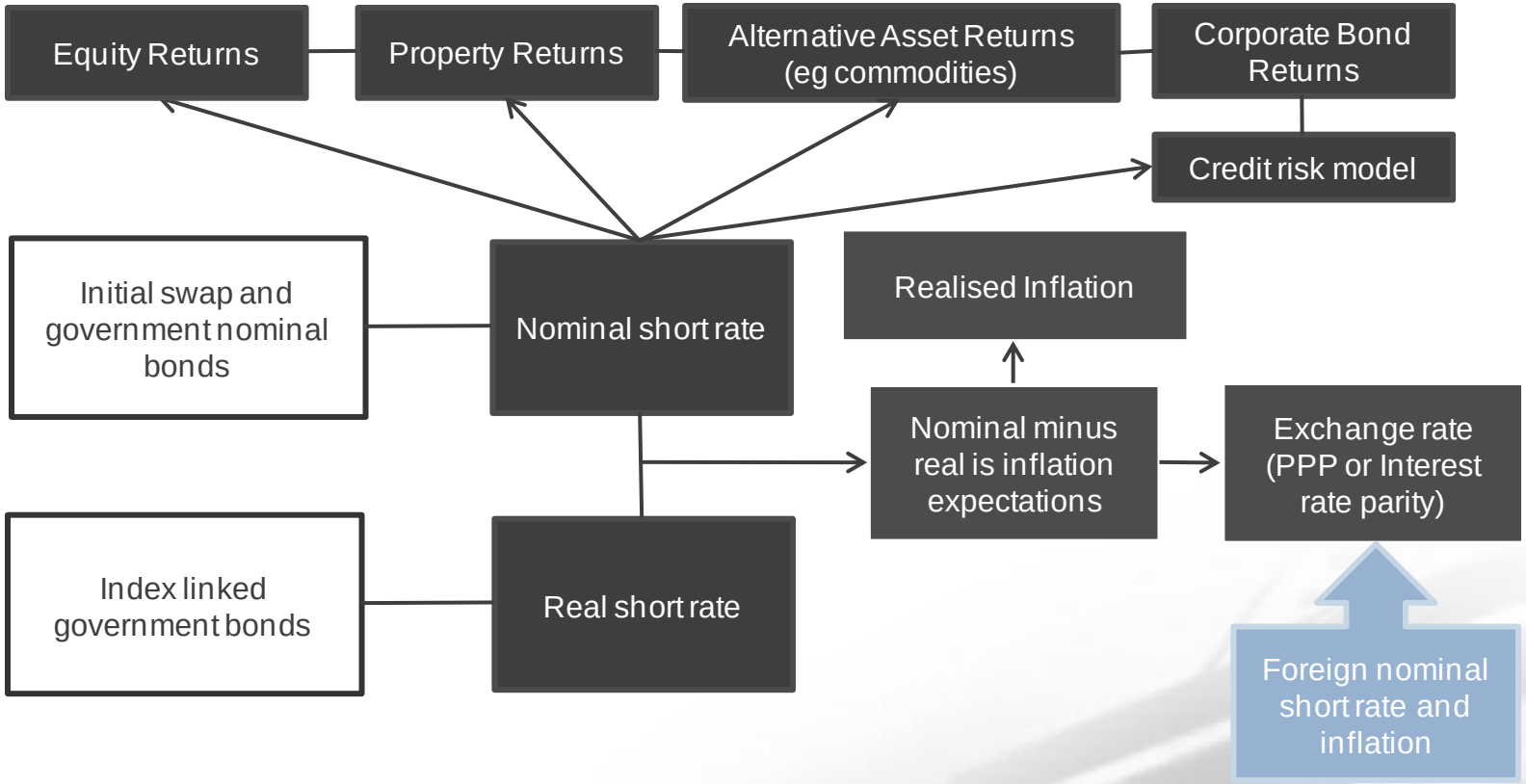
- What is the (market consistent) cost of guarantees?

Embedded option valuation on a *Market Consistent* basis

- What is the plausible distribution of outcomes?

Balance Sheet sensitivities based on a *Real World* distribution

How it works – an example



- Model specified by
  - Equations: stochastic evolution of key economic variables
  - Correlation: plausible economic relationship between asset classes

ESG modeling workflow

Calibration Content

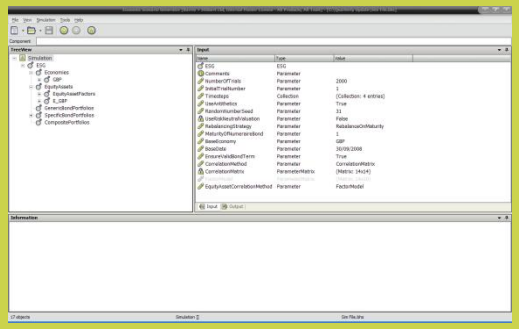
ESG - Calculation Engine

Output scenarios

Mathematical models

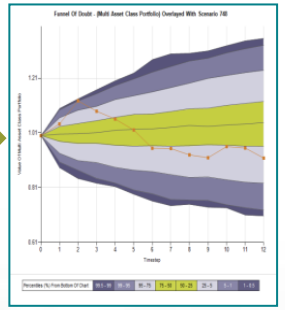
Market or historical data

Generate model parameters specific to application and market conditions



$$\Delta r = \alpha_1 (m - r(t))\Delta t + \sigma_1 \Delta Z_1(t)$$

A series of mathematical models implemented in software



$$\Delta r = \alpha_1 (m - r(t))\Delta t + \sigma_1 \Delta Z_1(t)$$

Market specific consideration

India financial markets

Government bond market

GOI bonds

- Maturities range between 1 and 30 years
- Liquidity is concentrated in the 5- to 15-year segment

Treasury bills

- Maturities range between 91 and 364 days

	Treasury Bills	Government of India Bonds	Special Government Bonds
On-the-Run			
Bid–Ask Spread (bps)	4.3	1.0	2.8
Average Trading Size (INR million)	56.3	56.3	58.3

bps = basis points, LCY = local currency.
Source: *AsianBondsOnline* 2011 LCY Bond Market Survey.

Liquidity in the region

- Among narrowest bid-ask spread in the region but small average transaction size:

		PRC	HK	IN	ID	KR	MY	PH	SG	TH	VN	Regional
Typical Bid–Ask Spread On-the-Run (bps)	Average	4.0	4.7	1.0	32.9	0.7	3.3	5.3	3.8	3.3	33.5	9.2
	Count	16	8	4	13	13	8	21	7	10	5	105
	SD	2.1	3.7	0.9	18.5	0.3	2.4	2.3	1.7	1.9	24.6	12.7
Typical Bid–Ask Spread Off-the-Run (bps)	Average	5.9	6.4	2.5	61.9	1.1	5.9	19.4	3.5	6.8	34.0	14.7
	Count	8	5	4	9	12	7	21	6	10	5	87
	SD	2.3	4.1	0.4	40.7	0.2	4.4	7.8	0.9	2.7	24.8	19.4
Accepted LCY Bond Transaction Size On-the-Run (US$ million)	Average	15.3	5.3	1.1	2.0	8.9	3.7	3.7	18.3	1.7	3.0	6.3
	Count	16	6	4	15	12	8	21	7	10	4	103
	SD	9.6	2.5	0.3	2.1	6.4	3.8	3.4	10.3	1.8	0.7	6.0
Accepted LCY Bond Transaction Size Off-the-Run (US$ million)	Average	11.8	4.7	1.1	1.1	9.8	2.6	1.0	11.7	1.2	3.0	4.8
	Count	9	3	4	9	8	7	21	7	8	4	80
	SD	10.7	1.6	0.3	0.5	7.6	1.5	0.3	5.5	1.0	0.7	4.5

bps = basis points; HK = Hong Kong, China; ID = Indonesia; IN = India; KR = Republic of Korea; LCY = local currency; MY = Malaysia; PH = Philippines; PRC = People's Republic of China; SD = standard deviation; SG = Singapore; TH = Thailand; VN = Viet Nam.
Source: *AsianBondsOnline* 2011 LCY Bond Market Survey.

Interest rate derivative market

- OTC derivatives
  - lack of transparent data
  - volume and trade data seen as sensitive
- Actual trade quotes from data provider

Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity in 2010 by Bank for International Settlements (BIS) (showing selected countries only):

OTC single currency interest rate derivatives turnover by country and instrument in April 2007 and 2010[1]

Daily averages, in millions of US dollars

	April 2007					April 2010				
	Total	Forward rate agreements	Swaps	Options	Other products[2]	Total	Forward rate agreements	Swaps	Options	Other products[2]
China	...	...	...	...	...	1,521	...	206	1,315	...
Hong Kong SAR	17,292	721	15,991	561	18	18,457	1,341	15,828	1,265	23
India	**3,395**	**...**	**3,395**	**...**	**...**	**3,498**	**15**	**2,334**	**1,149**	**...**
Japan	76,357	3,424	49,082	23,851	...	89,923	1,962	82,300	5,651	11
Korea	5,386	438	4,508	441	...	10,691	433	9,855	403	...
Singapore	57,410	1,610	54,240	1,543	17	34,579	4,695	28,570	1,313	...
United States	525,011	92,120	317,826	115,064	...	641,834	268,438	309,275	64,121	...
Total	**2,173,209**	**343,320**	**1,556,024**	**271,959**	**1,906**	**2,653,656**	**790,971**	**1,633,496**	**227,860**	**1,328**

[1] Forward rate agreements, swaps, options and other products. Data may differ slightly from national survey data owing to differences in aggregation procedures and rounding. Adjusted for local inter-dealer double-counting (ie "net-gross" basis). [2] Data on a net basis have been calculated by adjusting the gross data proportionally.

Market consistent valuation

- MC calibration: fit to market prices
- MC liability valuation…
  - Unobservable inputs
  - Inactive / illiquid prices
- No definitive answer, but requires
  - Transparency
  - Reasonable and justifiable approach
  - Stability? (insurance is a long term business)

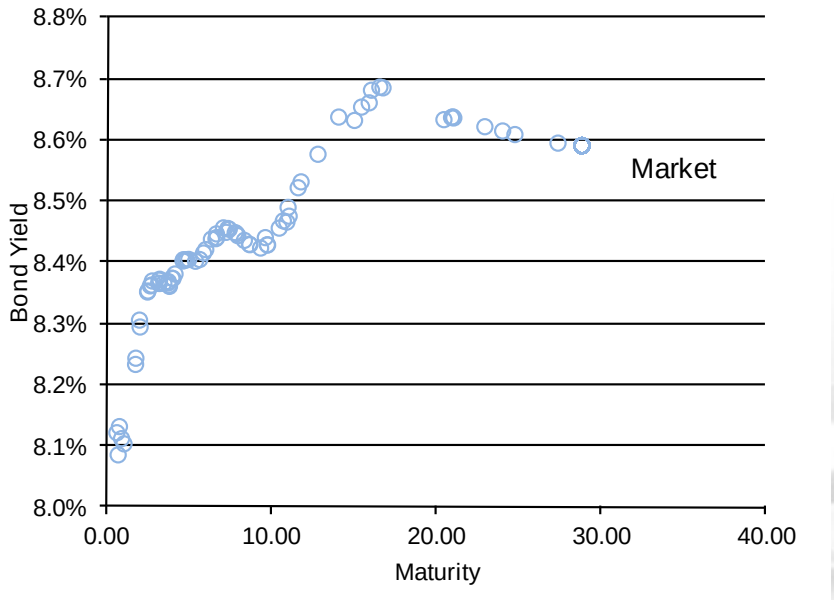
Market consistent valuation

- Desirable features of MC calibration
  - Fitting to observable market prices
  - Robust estimates for unobservable prices
  - Continuity and consistency between observables and unobservables
  - Stability for valuation of long term options?

Yield curve construction

Why it is challenging

- A few practical challenges:
  - A bumpy raw market yield curve
  - Incomplete terms (1-10, 15, 20, 25, 30)
  - No long term data, usually no more that 30 years
- Example:



Source: B&H Sep 2011 India calibration

Potential methodologies

Approach	Methodology	Advantages	Disadvantages
Bootstrap and interpolate	Choose term structure to exactly match all observed bonds	Perfectly price all bonds	Danger of over fitting Economically implausible yield curves
Standard parametric approaches	Fit a simple functional form to market data	Simple	Fails to fit complex shapes Long-term forward rate influenced by the market
Specify curve as a set of cubic splines	Define spline functions via an optimisation process	Freedom to fit complex shapes without over fitting	Expert judgment required

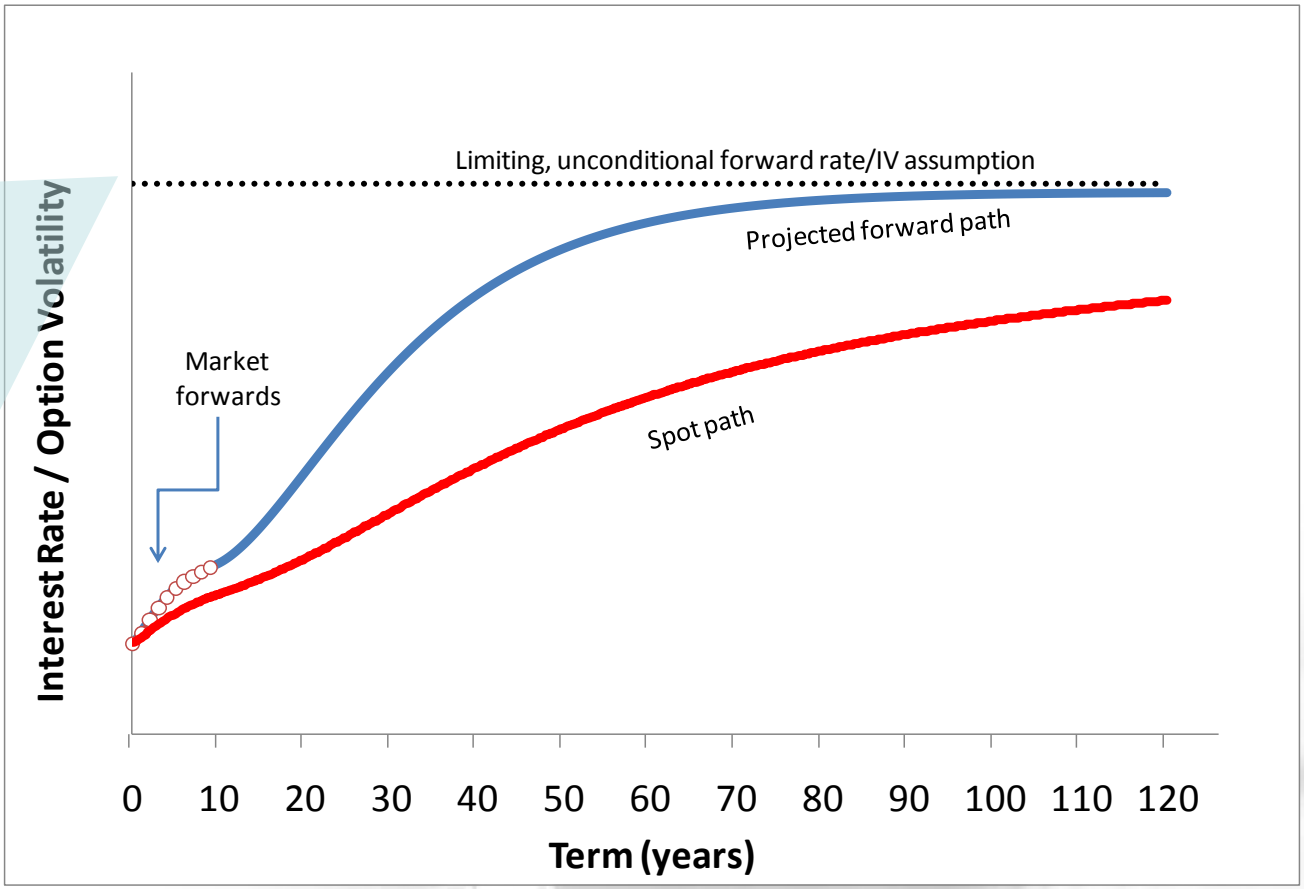
Extrapolation

Extrapolation requires us to face three questions:

1)What is the longest market data that we can observe?

2)What is an appropriate assumption for the 'unconditional' long-term forward rate?

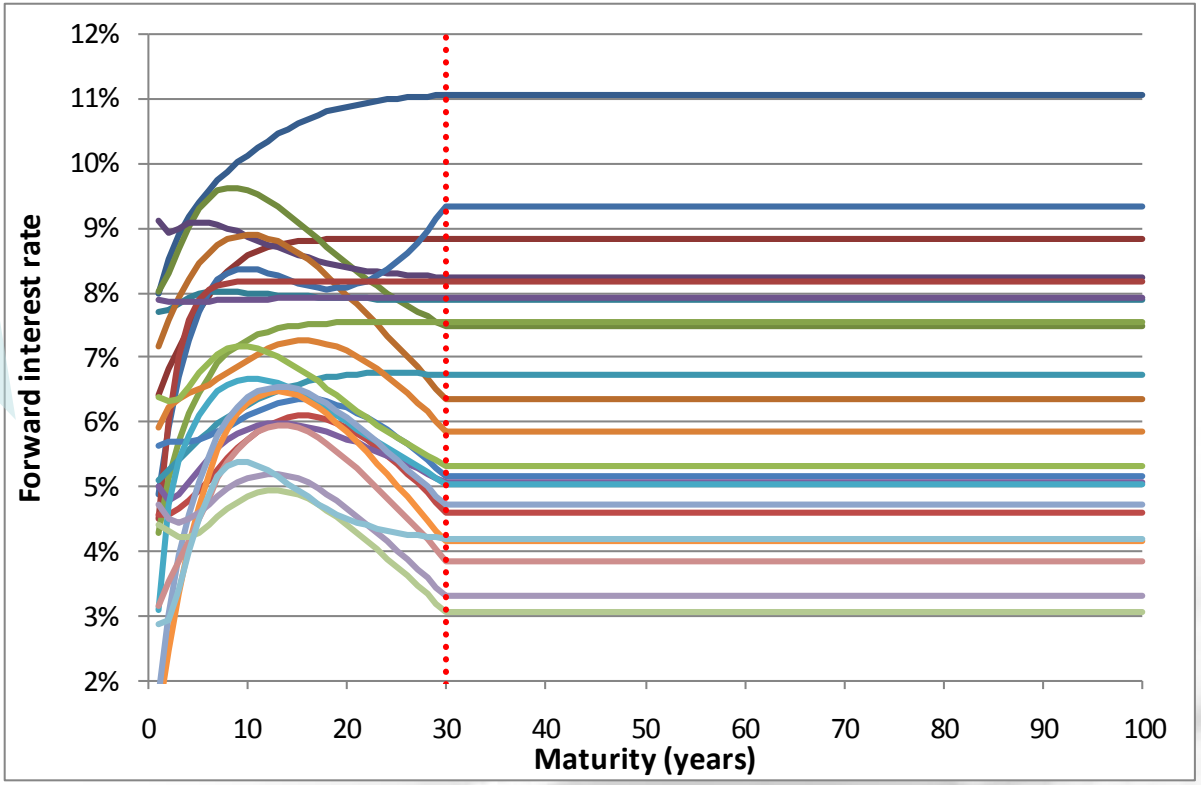
3)What path should be set between the longest market rate and the unconditional forward rate/IV?



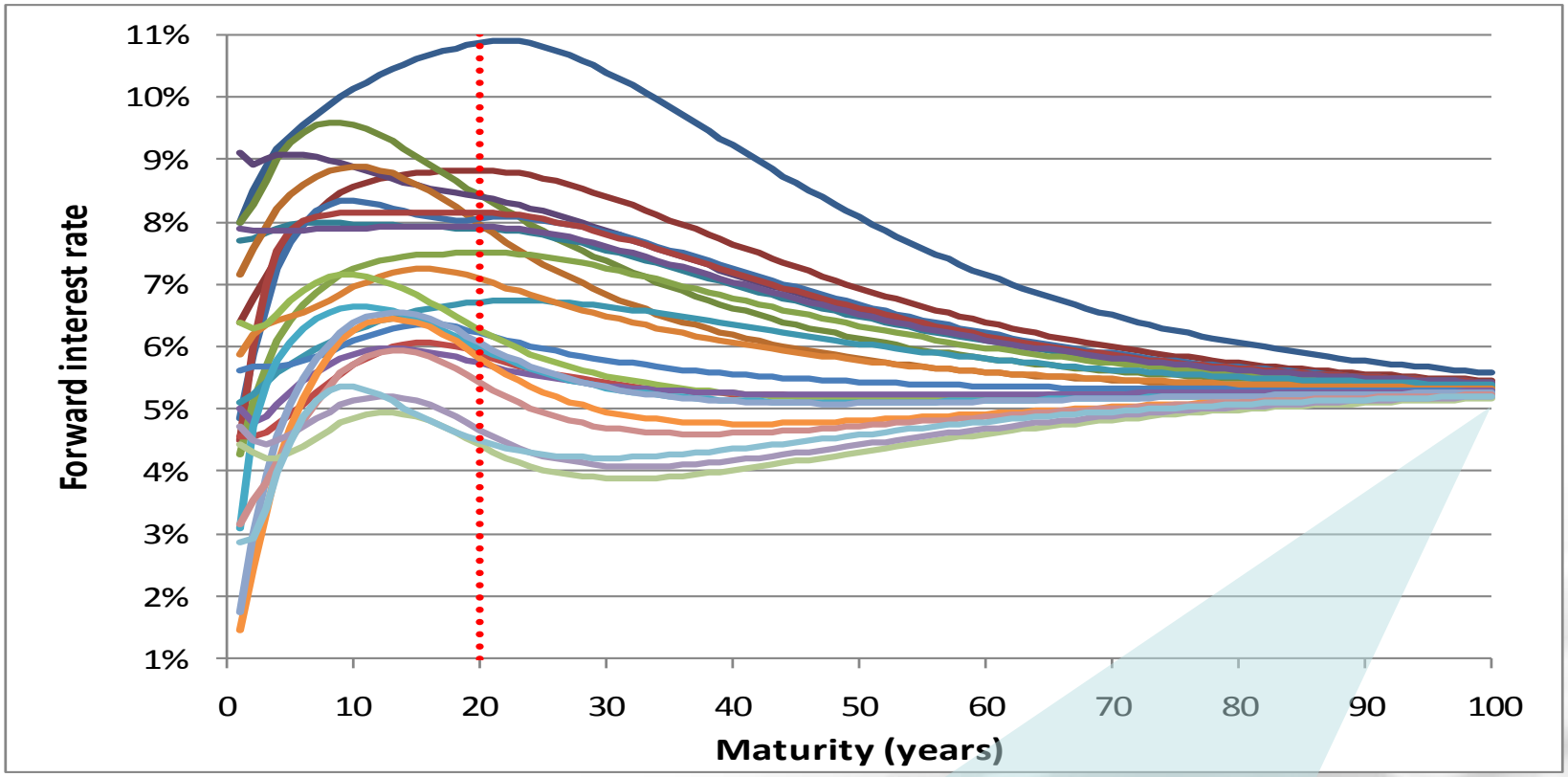
What is the problem?

USD government forward rates assuming constant rate beyond 30 years (1985-2007)

Very conservative and will generate very high volatility in the MTM value of ultra long-term cash flows



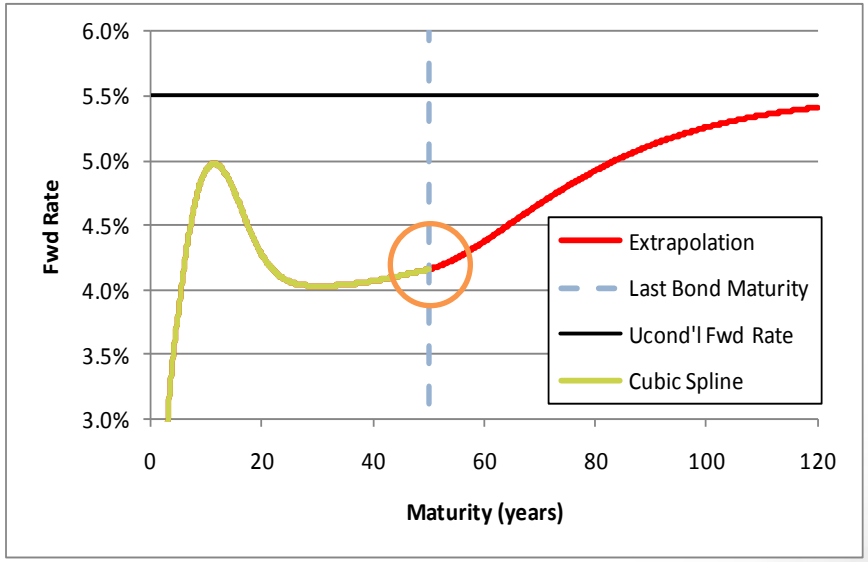
Example: USD (1985-2007)



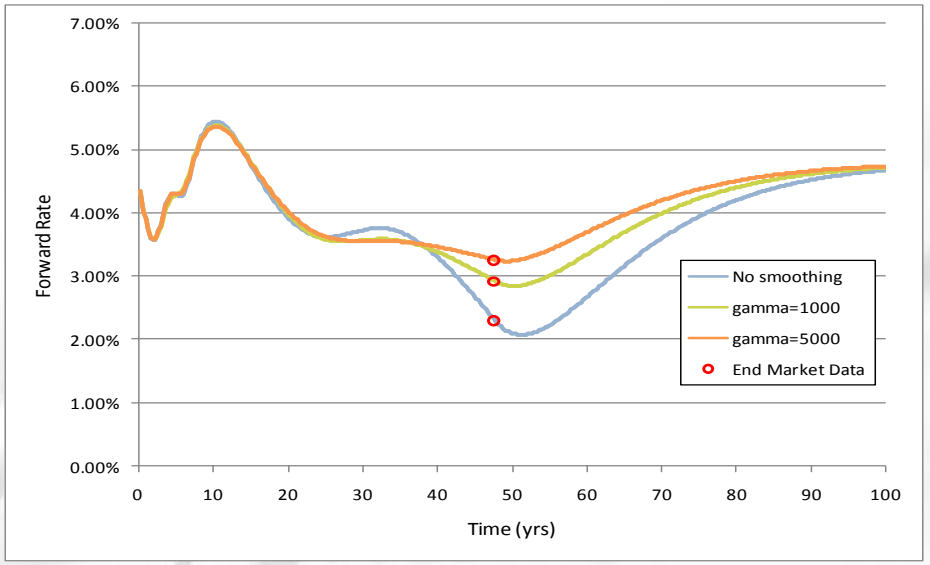
Unconditional ‘anchor’ produces greater stability in mark-to-model (‘level-3’) valuations.

Importance of smoothness

- Extrapolate smoothly and continuously towards forward rate target



- Small changes in long-dated market yields impact extrapolation
- Minimise gradient at end of market data



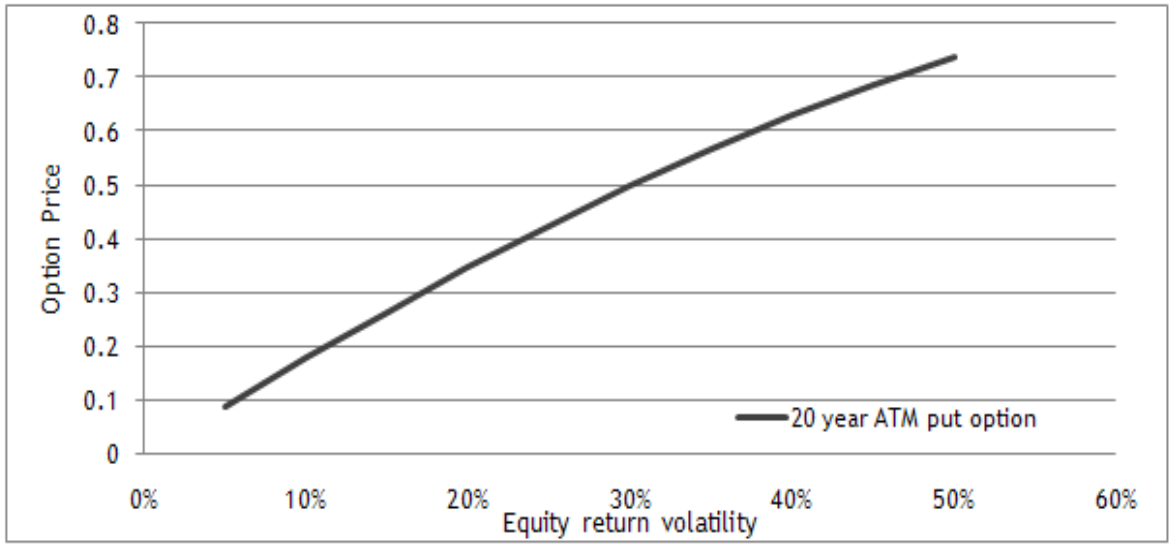
Volatilities

Introducing implied volatility

- MC equity calibration targets market implied volatilities
- Example: Black-Scholes Formula:

$$P(S,T) = N(-d_2)Ke^{-RT} - N(-d_1)S$$

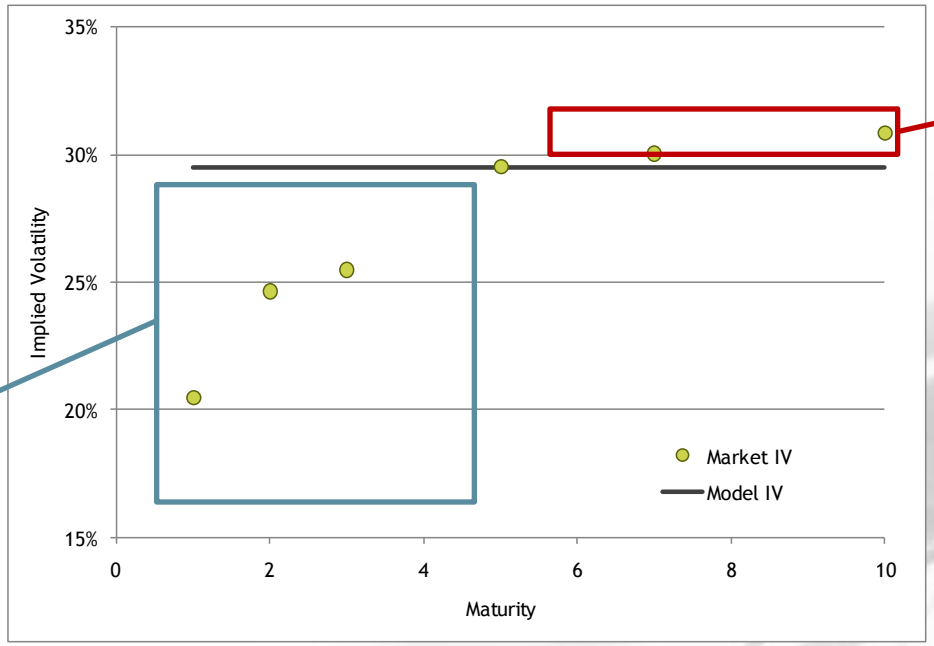
$$d_1 = \frac{\ln\left(\frac{S}{K}\right) + \left(R + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}, \qquad d_2 = d_1 - \sigma\sqrt{T}$$



- Implied volatility correctly prices an option according to the BS model: not necessarily actual volatility

Application to valuation

- MC valuation (or CoG) depends on implied volatilities
- Practical consideration
  - Only short tenor options available
  - Term structure / vol surface
- A first attempt using constant volatility assumption:

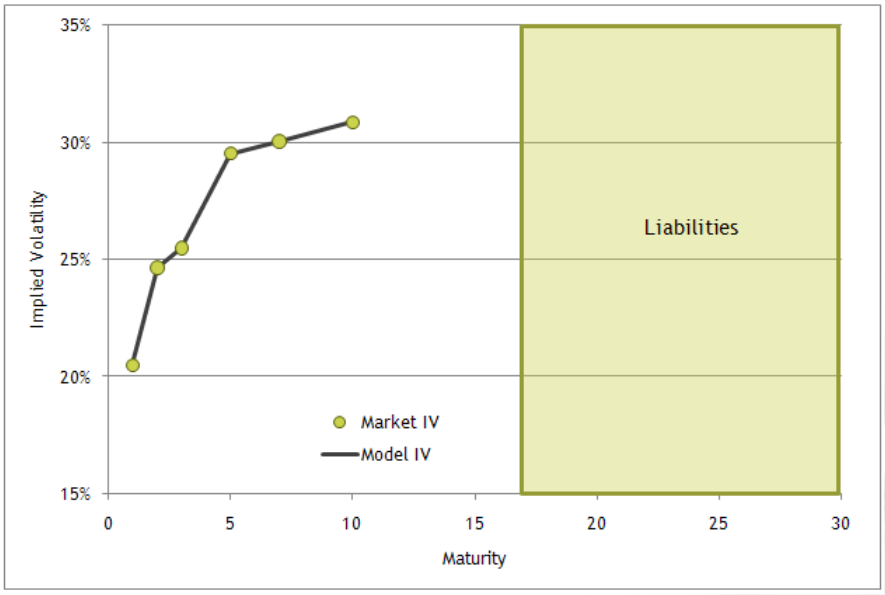


Under-valued for long dated options

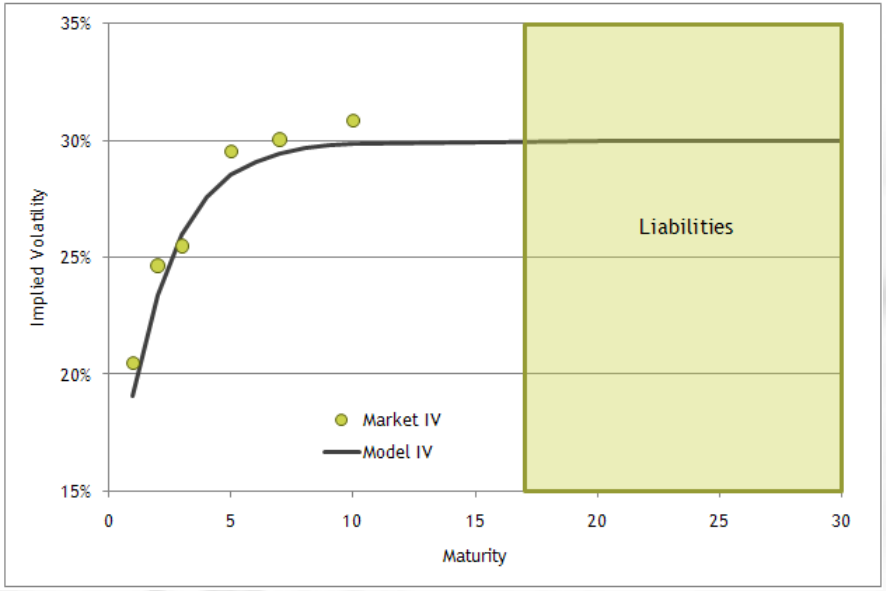
Over-valued for short dated options

Application to valuation

- A perfect fit to market data?
- Example: deterministic volatility modeling

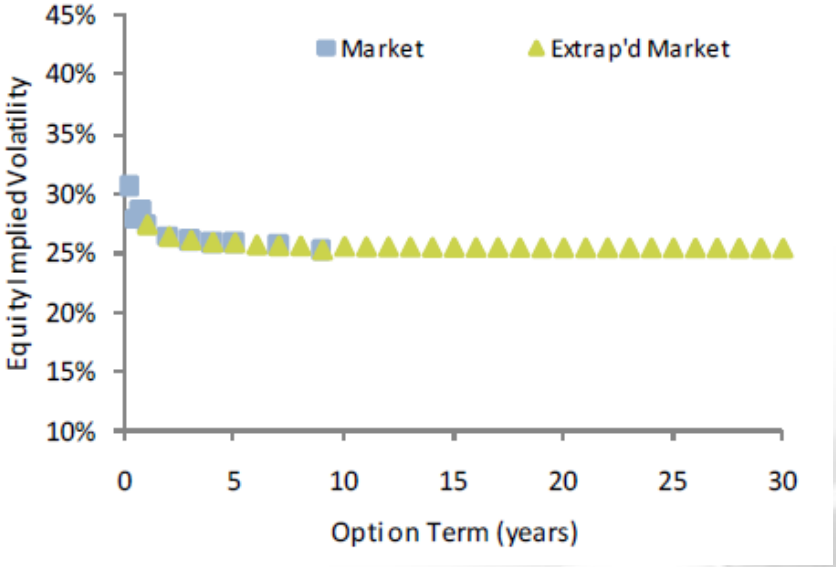


- Economically robust, stable extrapolation lead to stable, sensible valuation
- Example: functional form



Equity implied volatilities

- Implied volatility from market but no long term data
- Impose functional form for the entire IV term structure
  - Interpolate (observable market data)
  - extrapolate (unobservable / untraded)



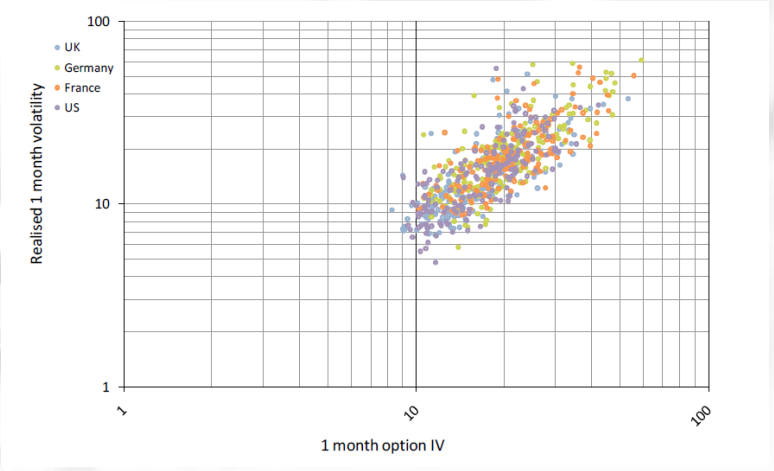
Source: B&H Sep 2011 India calibration (NIFTY 50)

- How about IV surface (varying by strike)?

Long term target

- Why need a long term volatility target?
  - Stability for liability valuation
  - Does market expectation of equity performance in say 50 years time change from month to month?

- Long term volatility target:
  - Unconditional realized vol and spread of IV over it
  - Use relative value of IVs from other developed economy



Concluding remarks

- Challenges in MC calibration:
  - Yield curve interpolation and extrapolation
  - Volatilities extrapolation beyond last market data point
  - …

- Desirable features of MC calibration
  - Fitting to observable market prices
  - Robust estimates for unobservable prices
  - Continuity and consistency between observables and unobservables
  - Stability for valuation of long term options?

Thank you!

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