



Delme Pritchard

A market-consistent calibration for India?

There has been an increasing demand for calibrations and scenario sets for Asian economies from companies in the region looking to value their insurance liabilities on a market consistent basis. Some regional offices of European companies (or even local firms in Japan), for instance, have approached Barrie & Hibbert for help with market consistent embedded value compliance, while others tell us that they require tools and models for pricing variable annuity guarantees, or help with managing the guarantees embedded within more traditional participating products.

To meet this demand, Barrie & Hibbert are extending their calibration services to include market consistent calibrations for an increasing number of Asian economies – the latest of which is the Indian economy. Whilst the basics are the same, developing economies present greater challenges for market consistent valuation techniques – since, generally speaking, there is less market information available. In this note we examine what we mean by the term 'market consistent', then, using the Indian economy as an example, we look at:

- What market data is available?
- What principles can be used to guide us in developing market consistent calibrations in the absence of market data?
- What might this mean in practice for performing market-consistent calibrations?

Market-consistent valuation

So what do we mean when we talk about market-consistent valuation? It is the process of putting a value on insurance liabilities consistent with how they would be valued if they were traded and also consistent with financial instruments with similar characteristics for which we can observe market prices. For example, an obligation to pay a fixed amount to policyholders at a fixed future date might be valued consistently with a discount bond; and a guarantee on an equity fund might be valued consistently with a traded equity index option. However, as there are no active markets in most insurance liabilities, traded assets that are closest in nature to the insurance liabilities being valued would typically be used. In theory, the process is straightforward:

- + Choose relevant financial instruments and find the price at which they are exchanged in the market
- + Select a model (or set of models combined in an economically coherent manner) to describe the price process(es)
- + Choose the model(s) parameters that give the 'best-fit' to the market prices
- + The models and parameters can then be used to value projected insurance liability cash flows consistently with those observed in the market

This is simple in principle, but there are a number of challenges that need to be overcome in practice. For example, market prices may not be available in the market e.g. long-term equity and property option prices, long-term nominal/real yield curves, correlations etc. In addition, there may be inconsistencies in the market data that is available. Before looking in more detail at the challenges, let us first look at what market data is available for the Indian financial markets.

Market data for India

There are two questions to consider when looking for market data:

1. *What data is available for a market?*
2. *How reliable is the data?*

The first question can be addressed by performing a systematic search of direct and indirect market data providers – exchanges, dealers, investment banks and 3rd party data providers. Answering the second question can provide more of a challenge. Looking at these in turn:

We make use of a variety of data providers to ensure wide coverage including Bloomberg, Thomas Reuters, SuperDerivatives and Markit. Investment banks are also surveyed to obtain over-the-counter quotes directly. These can help to fill gaps and validate data derived from other sources. Table 1 summarises the market instruments that and market price sources as of end-December 2009 for India:

	Financial Instrument	Comments
Initial yield curve	Swap rates: out to 10 years Government rates: out to 30 years	Source: Bloomberg. Short swap rates means the extrapolation method is particularly important when constructing swap curves. Many Government bonds in issue, but low liquidity means there can be relatively few active prices to use in calibration.
Interest rate volatility	Swaption implied volatilities out to 10 year options into 10 year swaps	Source: Bloomberg.
Real rates	Inflation forecasts	Source: Barrie & Hibbert estimates (5, 10 year) and Consensus Economics. No index linked bonds available.
Equity implied volatility	Options out to 10 years on NIFTY 50 index with a range of strike prices	Source: Markit.

As the above table shows, there is only limited market data available for the Indian market. Beyond 10 years there are no implied volatilities for equities or swap rates; beyond 20 years no implied volatilities for interest rate; and beyond 30 years no government bonds. This will be the case, to a greater or lesser extent, for all economies. The challenge in developing economies like India is that the methods used to interpolate or extrapolate market prices to create 'pseudo prices' will have a relatively greater impact on the final valuation and its stability through time.

Also, just because a quoted price is available, it does not necessarily mean that any significant quantity of assets can be traded at that price without adversely moving it. Thus, the depth and liquidity of the market will also be important – i.e. how fast can one execute a trade and how much volume can be traded without significantly moving the price. The Financial Accounting Standard (FAS) 157 defines the following valuation categories for assets:

- + Level one. Deep and liquid markets, where market prices should be used.
- + Level two. Quoted prices don't exist – infer prices using observable prices on other similar assets.
- + Level three. Unobservable market prices.

As ever, the challenge to the practitioner is in translating these (or other) high level definitions to practical and objective criteria for assessing the reliability of market data, and hence determining how it should be used in a market consistent valuation. Madden (2009)¹, who looked at exactly this challenge for the Asian bond market and a number of individual Japanese bonds, concluded that while it is unlikely to be an exact science it was possible to derive:

"a system of quantitative measures and qualitative principles that allows us, given the right information, to calculate a level of relative liquidity for a market or security."

The remaining challenge is to then map the level of relative liquidity to the reliability of the market data to help assess how much information is being provided about current market levels. Barrie & Hibbert do not currently incorporate such assessments in to their calibration process, but as these issues become more important to regulators and (hence) our clients, it seems likely that there will be more focus on grading and validating market data in such a way.

Before we look at the how we might approach the task of deriving pseudo prices, let us first take a step back to look at the purpose of market consistent valuations.

The purpose of market consistent valuation

Market consistent valuation is an economically coherent framework for valuing contingent claims. It promotes better understanding of the risks that a company is exposed to which should encourage good risk management thinking. This in turn, and combined with appropriate alignment of management interests, should promote sound risk management action. Ultimately, stakeholders will judge the success of the market consistent framework by the outcomes of risk management actions taken by the organisation. Bearing in mind this end-game for market consistent valuation, what principles might guide us in deriving pseudo prices?

¹ Madden, R. (2009). *Deep and Liquid Markets*. MSc Financial Mathematics dissertation. Heriot-Watt University / University of Edinburgh.

- + **Consistency.** With the market prices we can observe at a point in time. Consistency through time to avoid spurious volatility in pseudo-prices. (i.e. extrapolated prices should be stable over time unless there is clear a clear economic rationale to change them.) There should also be consistency: with economic principles; across asset classes; across asset models; and across economies.
- + **Transparency.** The methods employed should not be a 'black-box'. They should be clearly documented and peer reviewed to ensure best practice². They should also be communicated so that the user understands the strengths and limitations of the approach(es) used.
- + **Parsimony.** The methods should be no more complex than necessary to achieve the objectives.

The next section looks at some of the details of how Barrie + Hibbert approach setting pseudo prices for two of the key risk drivers, interest rates and equities, as applied to a market consistent calibration for the Indian market.

A Market Consistent Calibration for India

This section looks at how Barrie & Hibbert approach setting pseudo prices for two of the key risk drivers, and across three aspects in turn:

- + The initial risk-free yield curve;
- + Interest rate implied volatility; and
- + Equity implied volatility

These are illustrated with extracts from the year-end 2009 market consistent calibration for India.

Initial risk-free yield curve

Barrie & Hibbert use a macro-economic style methodology³ for fitting nominal yield curves. The methodology consists of the following steps:

1. A cubic spline is fitted to market data. The spline provides the flexibility to achieve a good fit to market data where available.
2. A target for the ultra long-term forward rate is set (in practice about 120 years depending on the speed of mean reversion). This is constructed from estimates of the components that make up the forward rate: the real short-rate; inflation; a term premium; and finally a technical convexity adjustment.
3. An economically sensible functional form is then used to interpolate from the end of the market data to the ultra long-term target. This is done in such way to be consistent with the term structure of volatility observed in the market and with economic rationale – mean reversion in interest rates necessitates that the volatility of the forward rates should decrease with term.

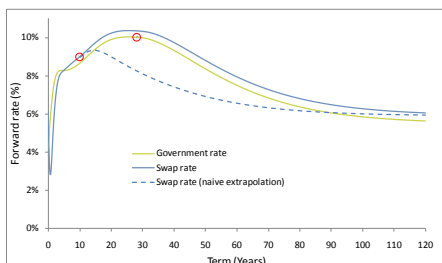
For the period from September 2009 to August 2010, the forward rate targets are 5.5% for Government rates and 5.9% for swap rates. Exhibit 1 illustrates the yield curve fit for the year-end 2009 for swap rates and government

² Barrie + Hibbert have a technical advisory panel of internal and external experts (auditors, academics, representatives from our largest clients) whose purpose it is to provide this transparency and review function.

³ For a more detailed overview see: *Market-consistent valuation of ultra long-term cash flows* by John Hibbert. (http://www.barrhibb.com/knowledge_base/article/market_consistent_valuation_of_ultra_long_term_cash_flows/)

Exhibit 1

Initial risk-free forward rate curves for the Indian Rupee at 31 December 2009. The red circles indicate the terms of longest market instruments available.



bonds. As this chart illustrates, applying the extrapolation methodology to swap rates and Government rates naively (independently) can lead to somewhat unrealistic implications for the swap spread. For example, it is far more likely that the swap spread of -200 bps in year 35 as forecast in the naive extrapolation is an artefact of there being shorter term swap data and the extrapolation methodology rather than being a genuine feature. If we assume swap rates beyond the longest available maturity fall in to a FAS level 2 classification as discussed above, market data on similar instruments can be used to do the extrapolation – in this case Government securities.

There are a number of ways this data could be incorporated into the calibration process. One approach⁴, as illustrated in the exhibit 1, is to assume that the forward swap spread is constant between the longest swap and the longest Government security. Beyond the longest dated Government security, the swap rates are then extrapolated as per the standard methodology described above. This approach helps ensure consistency between the risk-free curves and, we would argue, produces a more reasonable term structure of swap spreads.

Interest rate volatility

Although interest rate volatility can be calibrated using more than one type of financial instrument, Barrie & Hibbert choose to calibrate to swaptions where market data is available, as these most closely resemble insurance liabilities and provide information on the correlation structure of interest rate volatility. Unfortunately, there is relatively little swaption data available (by providers and through time) for the Indian Rupee and so we have less confidence in the data than we would have for USD or GBP, for example. Where there is less data and/or the data available is questionable, it will be more important to have a standard structure imposed on the model fits as well as imposing long-term targets. This will help ensure that data error (if unreliable) or gaps in the data don't have an undue influence on the overall fit – especially at longer horizons.

The method of extrapolation of swaption implied volatility varies according to the interest rate model used. However, the Barrie & Hibbert calibration approach ensures a degree of consistency across model types and consistency with our *a priori* belief that very long-term interest rate volatility will be relatively stable:

- + When performing the initial fit as well as fitting to market data, we also target a real world volatility term structure at an ultra long term horizon. Exhibit 2 illustrates the target term structure and the fit achieved when fitting a 2-factor Libor Market Model to the available swaptions data together with the unconditional volatility term structure.
- + During the fitting process we impose a standard structure to forward rate volatilities (a humped exponential form). This approach gives enough freedom to obtain reasonably accurate fits to market data while resulting in relatively stable long term swaption volatilities.

From this initial fit, the model is used to create a swaption implied volatility surface of pseudo prices out to long-term horizons. These pseudo prices together with the market data are used for calibrating the other models – which helps ensure consistency between extrapolations.

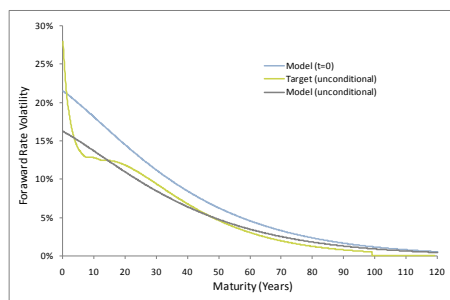
Equity volatility

As for interest rates and swaption volatilities, we have argued that very long-term equity implied volatilities will be relatively stable. However, given the complexity and range of the model choices fixing the long-term implied

⁴ See TAP discussion paper by D. Antonio: Yield curve extrapolation consistency between swap and government curves.

Exhibit 2

Targeting the unconditional term structure of forward rates in the calibration of a 2 factor Libor Market Model of interest rates for the Indian Rupee at year-end 2009



volatility can often result in achieving a poor fit to market data. Even still, we impose a target 'window' for the very long-term implied volatility based on long-term historical analysis after allowing for known estimation biases⁵.

The first step is to perform an extrapolation of forward at-the-money implied volatilities independently of model choice. Similar to the approach for interest rate volatilities, we impose a structural form for the volatility (forward variances) term structure. The set of pseudo prices so created is then used in the calibration of all of the equity volatility models – thus ensuring consistency in extrapolation. We use the Time Varying Deterministic Volatility (TVDV) model as an illustration because it is easier to describe and visualise since it is a fit in one dimension (option term). The same principles hold when looking at fitting more sophisticated models.

Exhibit 3

Time varying deterministic equity implied volatility fit for at-the-money European style put options on the S&P Nifty 50 Index for the Indian Rupee at 31 December 2009¹.

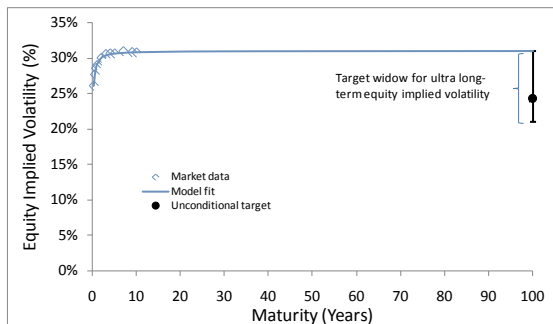


Exhibit 3 shows the equity implied volatility fit for the TVDV model illustrating the quality of fit to market data and the extrapolation 'window'. The current TVDV model is a very 'parsimonious' model (there are only three parameters to fit the term structure), so there is sometimes a balancing act between obtaining a good fit to market data, where it exists, and hitting the long-term target window. Of course, the relative importance will depend on the application and time horizon of interest. Typically this is more of an issue when there is more market data, which is when it may be more appropriate to use a more sophisticated model. For example, we have used the Stochastic Volatility Jump Diffusion (SVJD) model, which is capable of producing a good fit to an entire volatility surface (term structure and by strike price), since for the Indian market there is equity implied volatility data for a range of terms (1 to 10 years) and a range of strike prices (0.6 to 1.4).

Final comments

This note has looked at the challenges of producing market consistent valuations in economies that have a scarcity of market data, which caused us to consider the underlying purpose of market consistent valuations and how the effectiveness of a valuation framework will ultimately be judged. On this basis, we postulated some high level principles to help act as a guide in the creation of pseudo prices, where there is no or limited data. We finished by looking at how Barrie & Hibbert are practically addressing some of these very challenging questions using an Indian case study – looking in some detail at equity and rate modelling – leaving the reader to judge for themselves how we measure up against our own principles. There are still plenty of hard questions to answer and we look forward to working with local partners to improve and refine our data, methods and ultimately calibrations over the coming years.

⁵ For more detail, see the Barrie & Hibbert technical advisor panel's statement of practice:
http://www.barrhibb.com/documents/tap/Extrapolation_of_Equity_Implied_Volatility_.pdf

Disclaimer

Copyright 2010 Barrie & Hibbert Limited. All rights reserved. Reproduction in whole or in part is prohibited except by prior written permission of Barrie & Hibbert Limited (SC157210) registered in Scotland at 7 Exchange Crescent, Conference Square, Edinburgh EH3 8RD.

The information in this document is believed to be correct but cannot be guaranteed. All opinions and estimates included in this document constitute our judgment as of the date indicated and are subject to change without notice. Any opinions expressed do not constitute any form of advice (including legal, tax and/or investment advice).

This document is intended for information purposes only and is not intended as an offer or recommendation to buy or sell securities. The Barrie & Hibbert group excludes all liability howsoever arising (other than liability which may not be limited or excluded at law) to any party for any loss resulting from any action taken as a result of the information provided in this document. The Barrie & Hibbert group, its clients and officers may have a position or engage in transactions in any of the securities mentioned.

Barrie & Hibbert Inc. and Barrie & Hibbert Asia Limited (company number 1240846) are both wholly owned subsidiaries of Barrie & Hibbert Limited.