Institute and Faculty of Actuaries

Why Do Models Have Limitations?

Dr. Matthew Lightwood

13 November 2015

Model Limitations – Why do we Care?

A great deal of focus on model limitations in Solvency II

Why does the regulator care?

- Concern that market outcomes will not be adequately captured leading to insolvency
- A desire that risks are adequately priced into businesses
- A perception that models contributed to the last/current crisis/crises
- Model risk

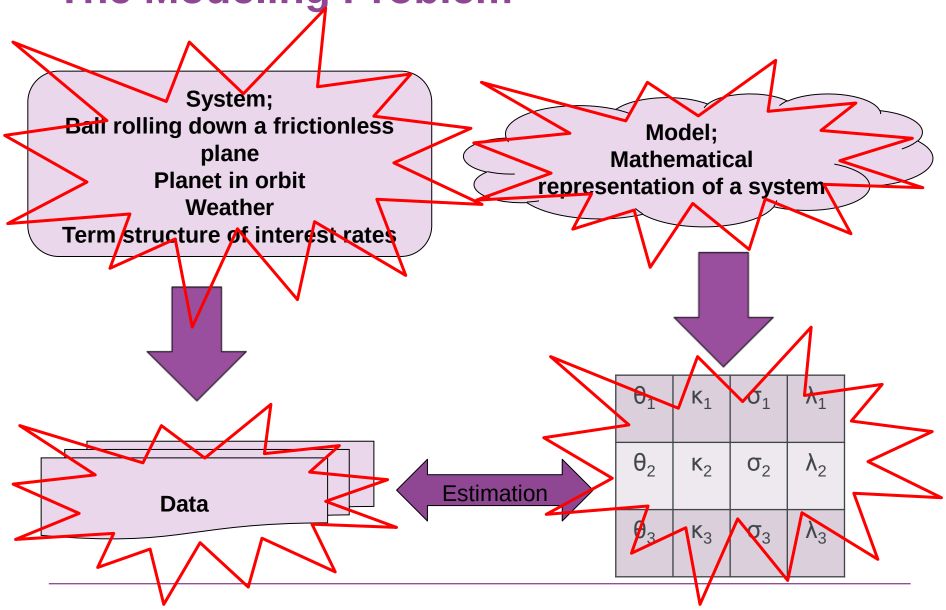
However all models have limitations – everyone always knew this

The question that needs to be addressed is what are the *material* limitations?

- The answer is likely to differ from user to user
- In most cases quantifying the model risk is only partially possible

This talk will look at why models have limitations and ask does it matter?

The Modeling Problem



Institute and Faculty of Actuaries

The System

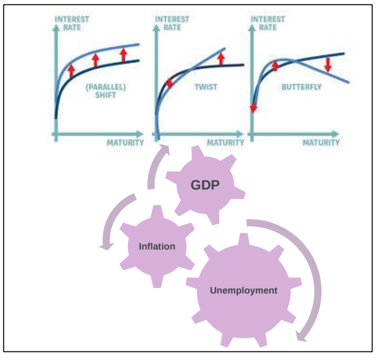
Reality is Reality and Models are Models

13 November 2015

The Extent of Limitations Depend on the System

- Most systems are highly complex
- In building models we substitute this complexity for something tractable
- Most financial models are a representation of effect rather than cause
  - Even “fundamentals” are not really fundamental

A Model of Interest Rates



Interest Rates the Reality

The Limitations on the Model Depend on the State of System

- Models are best suited to modeling markets which are “free” and liquid
- Models cannot be expected to perform as well and may fail when “structural” change occurs
- Models cannot easily capture a range of “artificial” effects
  - Quantitative easing
  - Geo political effects (e.g. Break up of the Eurozone)
  - Economic restructuring
- A failure of a model does not (automatically) make it misspecified

Institute and Faculty of Actuaries

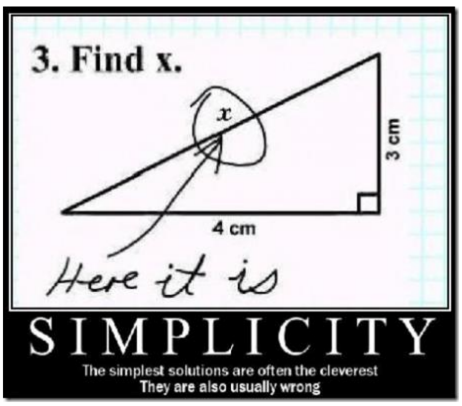
Model Specification

The Search for Parsimony

13 November 2015

Ockham's Razor

- “Simple models are better models”
- This is actually not an accepted definition
  - Entities must not be multiplied beyond necessity
  - We consider it a good principle to explain the phenomena by the simplest hypothesis possible (Ptolemy b. AD90)
  - We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances (b. I. Newton 1642)
- What Ockham's Razor is really talking about is parsimony
  - Smallest number of factors to explain the maximum amount of variance



Source: Google Images

What is Parsimony and why is it important?

Under-specified

↓

Too Simple
Large Model Risk
Unrealistic

↓

Important Risks
Not Captured

Parsimonious

Over-specified

↓

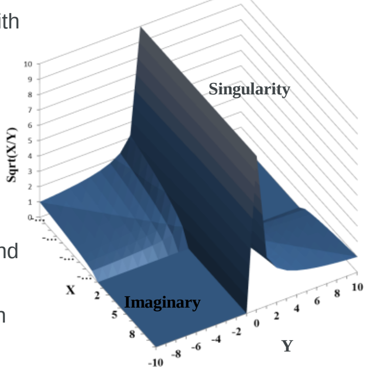
Too Complex
Estimation Errors
“Cosmetic” Models

↓

Poor Out of
Sample
Performance

The Limitations of Parsimony

- Parsimony reduces the complexity of the system with the minimum loss of information
- Models must be mathematically tractable as well
- Restricting ourselves to the tractable parsimonious models however engenders limitations
  - They tend to produce smooth continuous distributions
  - The model may contain boundary conditions and singularities
  - We may want the model to do something which is outside of the parameter space
- Why not just add more factors then?
  - We may solve one problem for others to appear
  - A model that can do everything probably will
  - The additional factors cannot be estimated – they are just noise (False Precision)



Source: Conning RCMS

Institute and Faculty of Actuaries

Data Limitations

13 November 2015

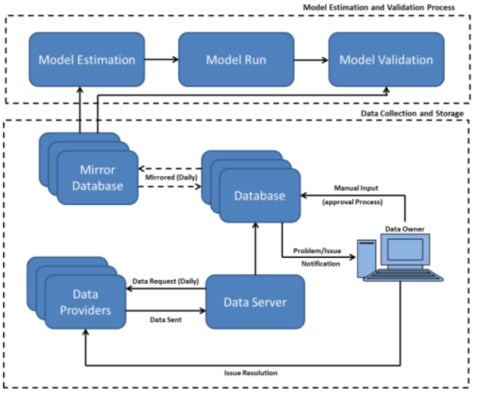
Data Issues

- Accuracy
  - How noisy is the data
  - Accuracy of the data is often difficult to assess
  - Using multiple sources does not solve the issue
  - Data corruption
- Completeness
  - Often time series data is too short for valuing long term risks robustly
  - Data granularity
- Appropriateness
  - Expost vs. Exante
  - End of day data biases
  - Selection bias particularly within index data is also a key consideration

Tackling Limitations in Data

Data limitations can be tackled on several fronts

- Accuracy
  - Using long histories of data can limit the effect of a small number of spurious points
  - Using noise reduction techniques to estimate the model from the data
  - Reduce manual processes
- Completeness
  - Consider augmenting/splicing multiple data sets
  - Extrapolation and interpolation
- Appropriateness
  - Ensure that data used is specific to the asset class/local being modeled
  - Have a consistent approach for when data is not available
  - Expert judgment



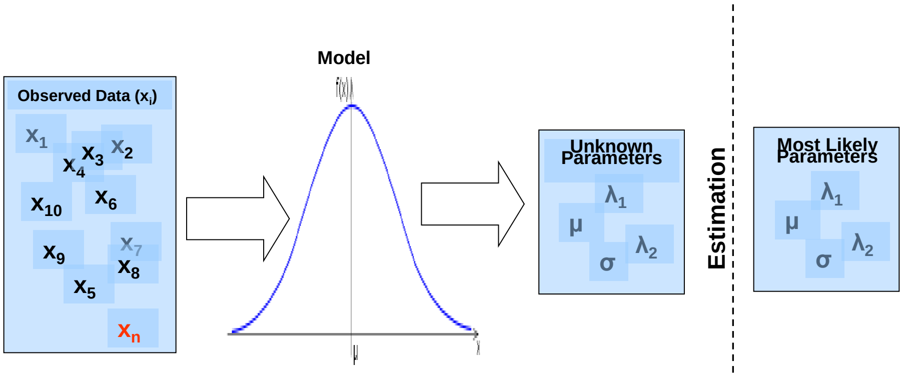
Source: Conning RCMS

Institute and Faculty of Actuaries

Model Estimation

Estimation

- Even with good data how the model is estimated may introduce limitations
- Often the most useful models do not have parameters and factors which are directly observable (short rate models, stochastic volatility, jumps)
  - What's more the models are often "continuous time"
- Analytical techniques must be used to link the model world to the real world



Source: Conning RCMS

Kalman Filter and MLE – Robustness of estimates

- We can quantify how good these methods are
- Method:
  - Fix the model parameters to some known values
  - Simulate yield curves for 10 years at monthly frequency
  - Take 250 simulations and run KF + MLE on each one to recover estimates of the model parameters
  - Compare the parameter vector distributions to the input parameters
- The results are good although they will be biased to an extent by:
  - The optimizer used
  - Discretization error

$$dy_1(t) = \kappa_i(\theta_1 - y_1(t))dt + \sigma_1\sqrt{y_1(t)}dW_1(t),$$
$$\vdots$$
$$dy_n(t) = \kappa_n(\theta_n - y_n(t))dt + \sigma_n\sqrt{y_n(t)}dW_n(t),$$

	CIR		
Parameters	Actual values	Mean estimate	Standard deviation
κ	0.10	0.141	0.053
θ	0.05	0.041	0.013
σ	0.075	0.075	0.005
λ	-0.40	-0.437	0.042

Parameters	Actual values	Mean estimate	Standard deviation
λ_1	-0.15	-0.193	0.078
λ_2	-0.10	-0.125	0.067
λ_3	-0.05	-0.074	0.051

Source: J. Bolder, Affine Term-Structure Models Theory and Implementation

Institute and Faculty of Actuaries

Model Usage

Behavioral Aspects

13 November 2015

Choice of Metric

- In many cases statistical models are used to produce a single or limited number of metrics to describe risk
- Which metric is chosen will carry its own limitations
  - Volatility
  - VaR
  - cVaR, TVaR, Expected Shortfall
- As does the quantile
  - 99%, 99.5%
- Depending on the distribution this may give quite different views of risk
- In Insurance we exist within a regulatory framework with a "single metric" definition of risk

Paradigms – Why do we repeatedly mis-apply models?

- In many areas paradigms develop which become entrenched
- The physicist Thomas Kuhn suggested how such paradigms develop
- Inauguration
  - An event occurs or a new concept is introduced which gives rise to a paradigm shift
- Vigor
  - The paradigm shift gives rise to whole new areas of research, new disciplines and practical applications
- Dominance
  - The paradigm comes to dominate activity in the area in which it occurred
- Revolution/Evolution
  - An event occurs which shows the limitations of the paradigm and new ideas develop to replace it

Institute and Faculty of Actuaries

Case Study

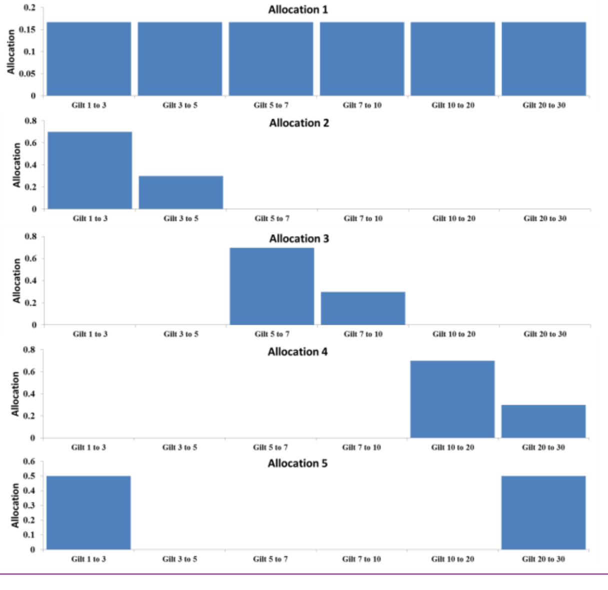
Multifactor Interest Rate Models

13 November 2015

Do Model Limitations Matter?

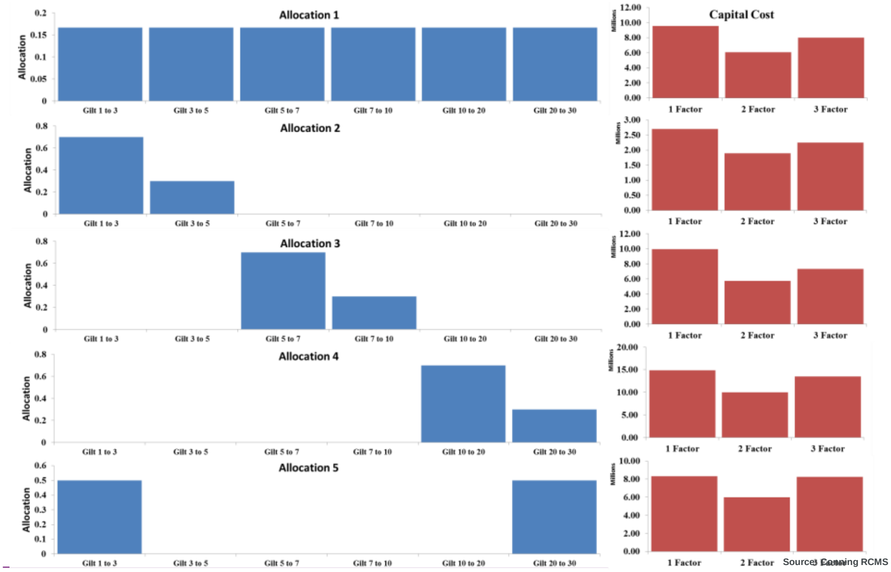
- Test using a 3 Factor, 2 Factor and 1 Factor Model of Interest Rates
- Model used is a multi factor Cox, Ingersoll, Ross Model
- A “through the cycle” parameterisation is used
  - Estimated from 55 years of data
  - Starting point is the year end 2014 Gilt curve
- The 3 Factor model is estimated first
  - The 2 and the 1 factor model are then estimated using the same data
  - An additional constraint is put on the mean and volatility of the medium horizon yields (5 Years) and returns 3F=2F=1F
- What impact does the number of factors have on capital cost?

Test Allocations



Source: Conning RCMS

Results



Summary

- There are many reasons that models have limitations some of which have been identified
- Understanding limitations are an important element of solvency II
- Often we are inclined to “solve” limitations
  - Doing so may engender new limitations
- There are other ways to assess the impact of limitations though
  - What if analysis
  - Stress testing
  - Discussion

It is the process of developing an understanding of model limitations which adds the most value to a risk management process, and identifies key risks and opens dialogue on how to mitigate those risks.

Questions

Comments