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

System:
- Ball rolling down a frictionless plane
- Planet in orbit
- Weather
- Term structure of interest rates

Model:
- Mathematical representation of a system

Data

Estimation

The System

Reality is Reality and Models are Models
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

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
Model Specification
The Search for Parsimony

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
What is Parsimony and why is it important?

Under-specified
Too Simple
Large Model Risk
Unrealistic
Important Risks
Not Captured

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)
Data Limitations

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

---

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

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

Source: J. Bolder, Affine Term-Structure Models Theory and Implementation
Model Usage
Behavioral Aspects

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

Case Study
Multifactor Interest Rate Models
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.*
The views expressed in this [publication/presentation] are those of invited contributors and not necessarily those of the IFoA. The IFoA do not endorse any of the views stated, nor any claims or representations made in this [publication/presentation] and accept no responsibility or liability to any person for loss or damage suffered as a consequence of their placing reliance upon any view, claim or representation made in this [publication/presentation]. The information and expressions of opinion contained in this publication are not intended to be a comprehensive study, nor to provide actuarial advice or advice of any nature and should not be treated as a substitute for specific advice concerning individual situations. On no account may any part of this [publication/presentation] be reproduced without the written permission of the IFoA (or authors, in the case of non-IFoA research).