Why Do Models Have Limitations

A Broader View.
A Sharper Focus.SM

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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 new 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

θ_1	κ_1	σ_1	λ_1
θ_2	κ_2	σ_2	λ_2
θ_3	κ_3	σ_3	λ_3

The System: Reality is Reality and Models are Models

The Extent of Limitations Depend on the System

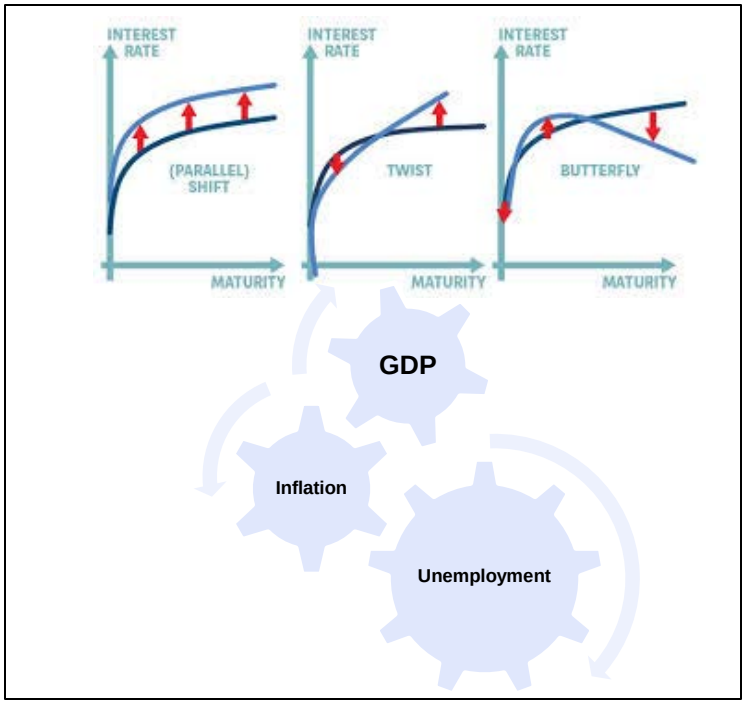
Most systems are highly complex

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

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

Model Specification

Ockhams Razor

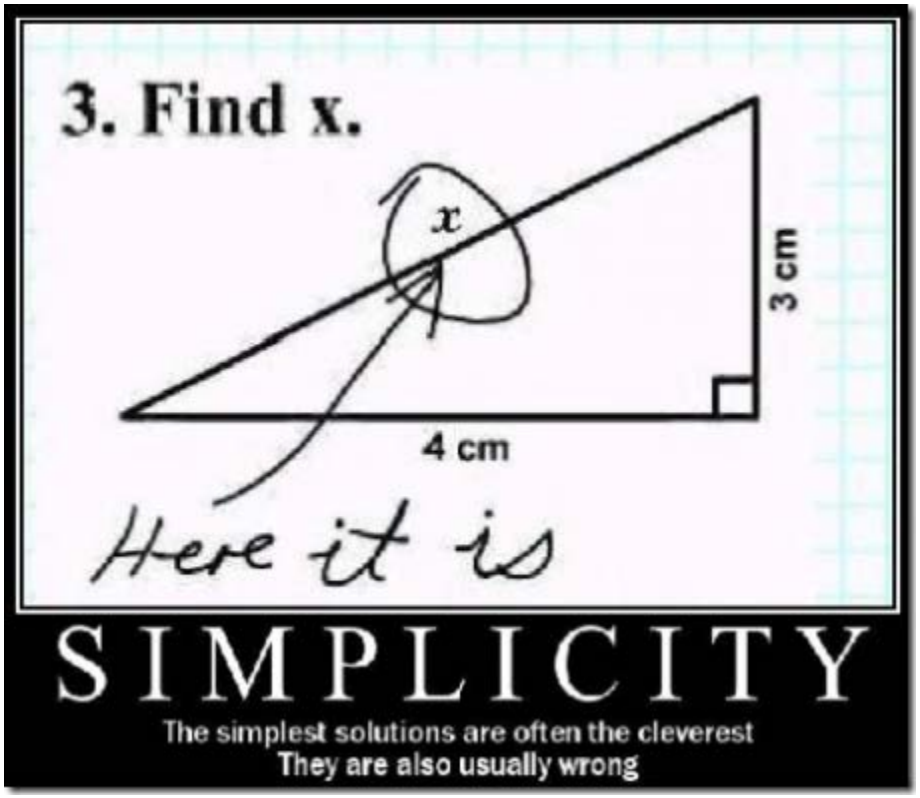
“Simple models are better models”

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)

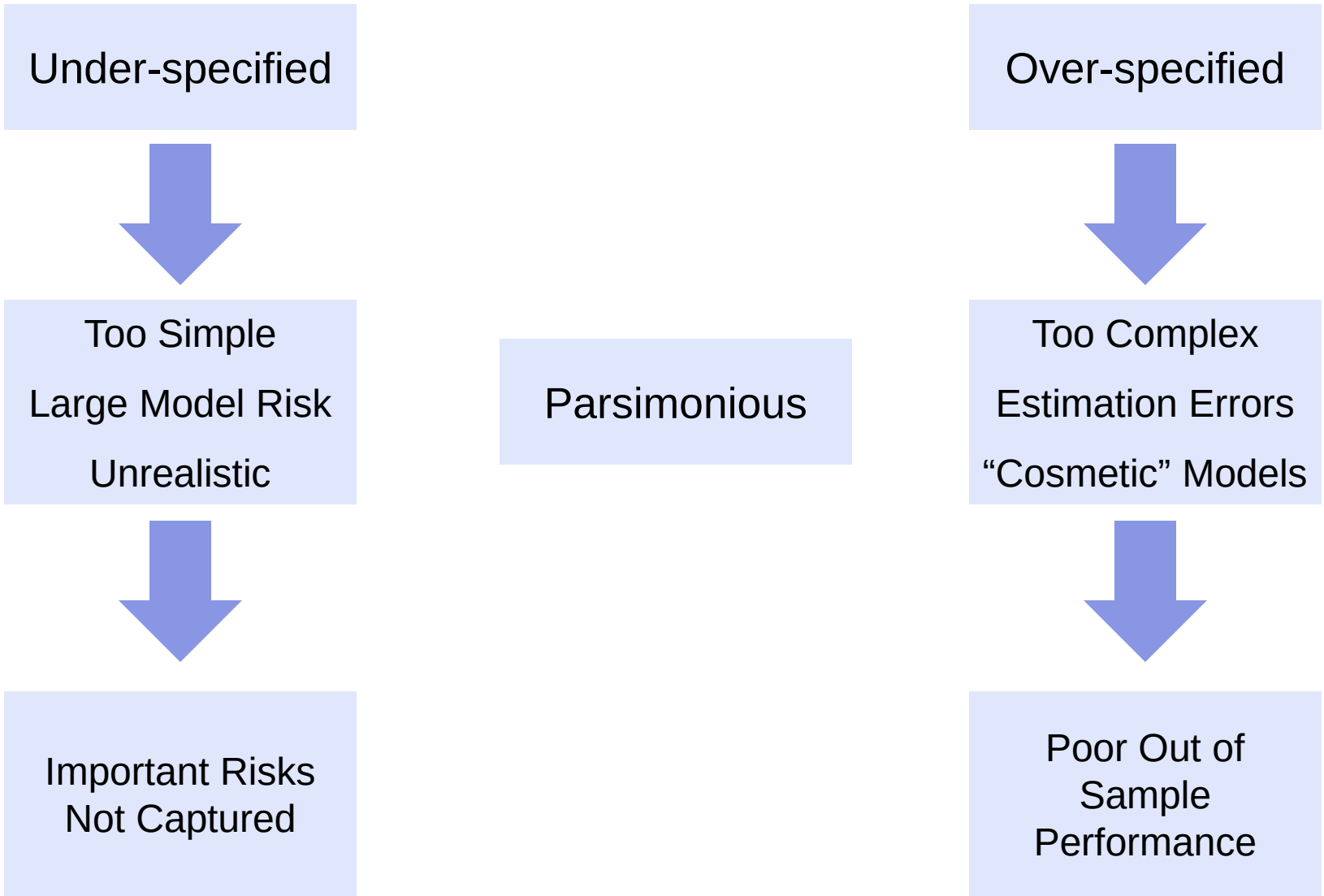
What Ockhams Razor is really talking about is parsimony

- Smallest number of factor to explain the maximum amount of variance



Source: Google Images

What is Parsimony and why is it Important?



The Limitations of Parsimony

Parsimony reduces the complexity of the system with the minimum loss of information

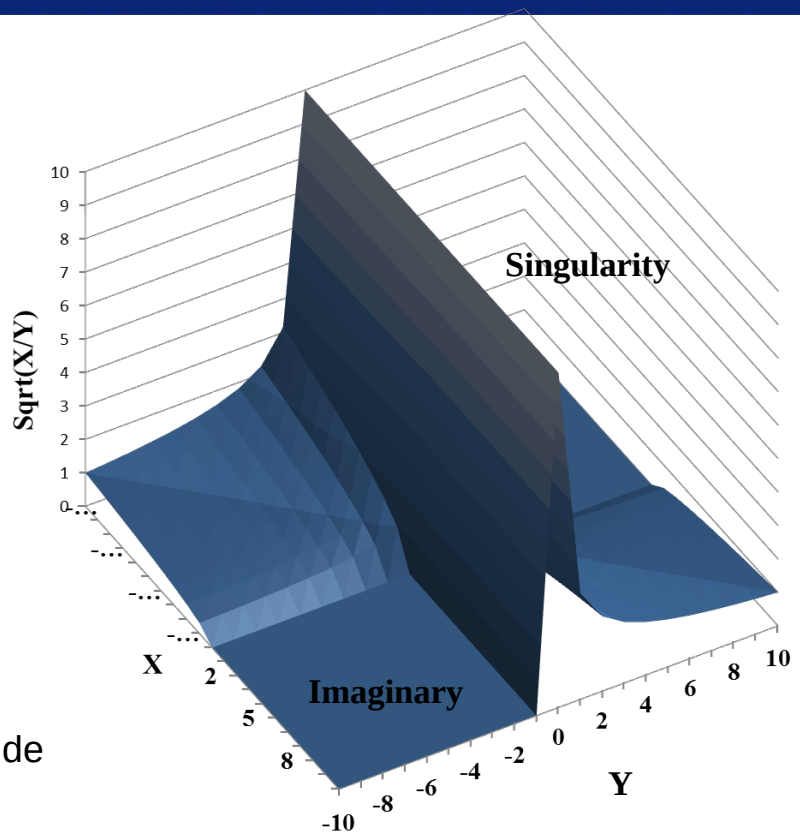
Models must then be constructed so as to be mathematically tractable as well

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

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

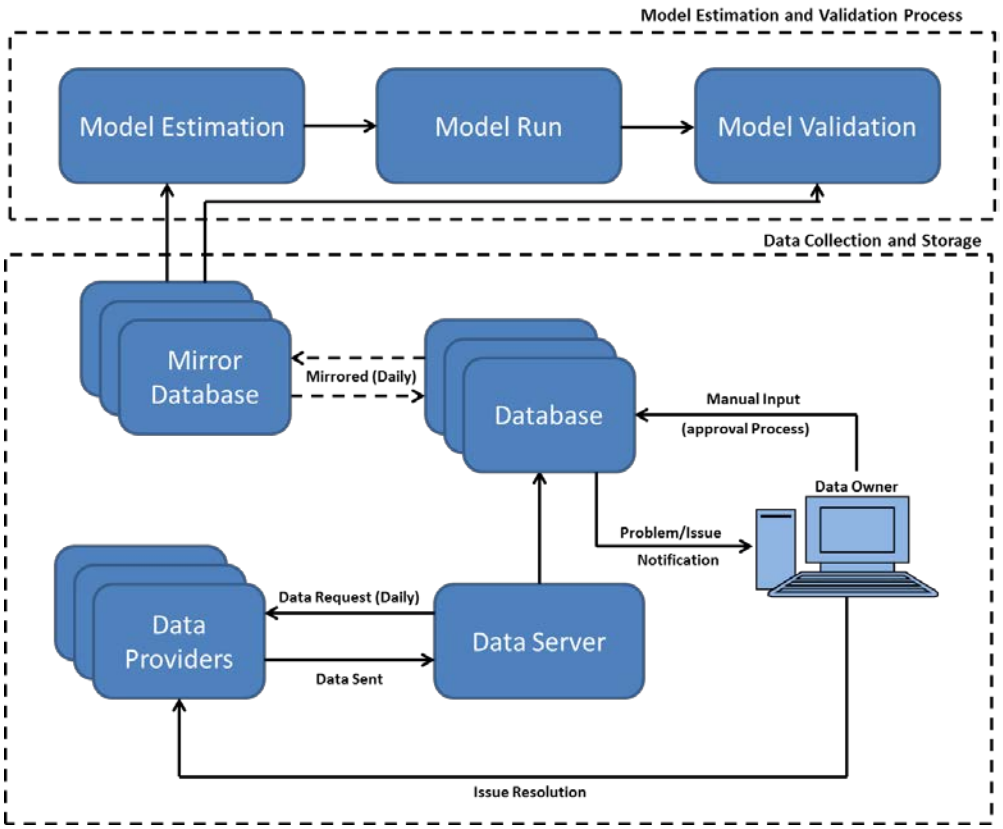
Data limitations can be tackled on several fronts

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



Source: Conning RCMS

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

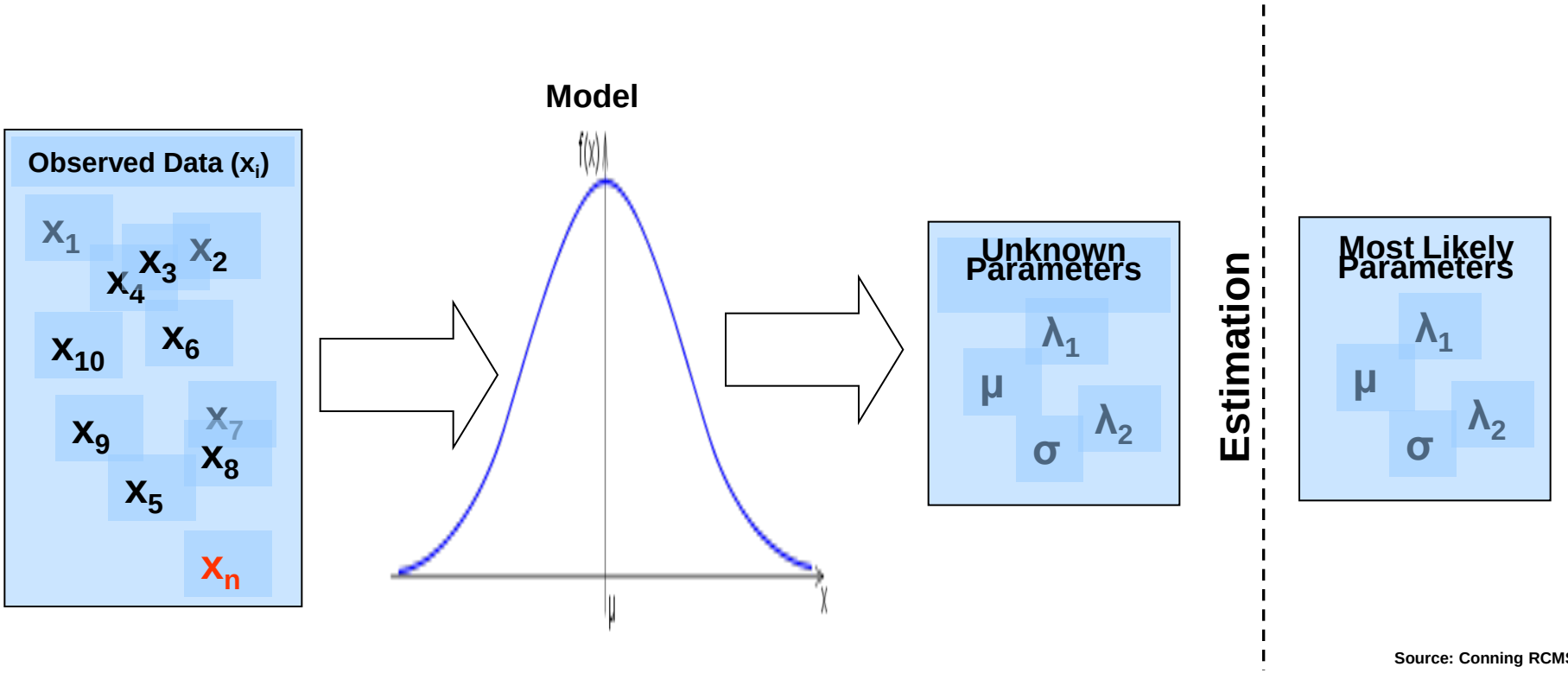
Estimation

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 – How good are the 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_1	0.25	0.296	0.100
κ_2	0.45	0.514	0.158
κ_3	0.80	0.797	0.152
θ_1	0.05	0.042	0.019
θ_2	0.03	0.034	0.019
θ_3	0.01	0.014	0.014
σ_1	0.05	0.057	0.018
σ_2	0.075	0.078	0.031
σ_3	0.15	0.137	0.022
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

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

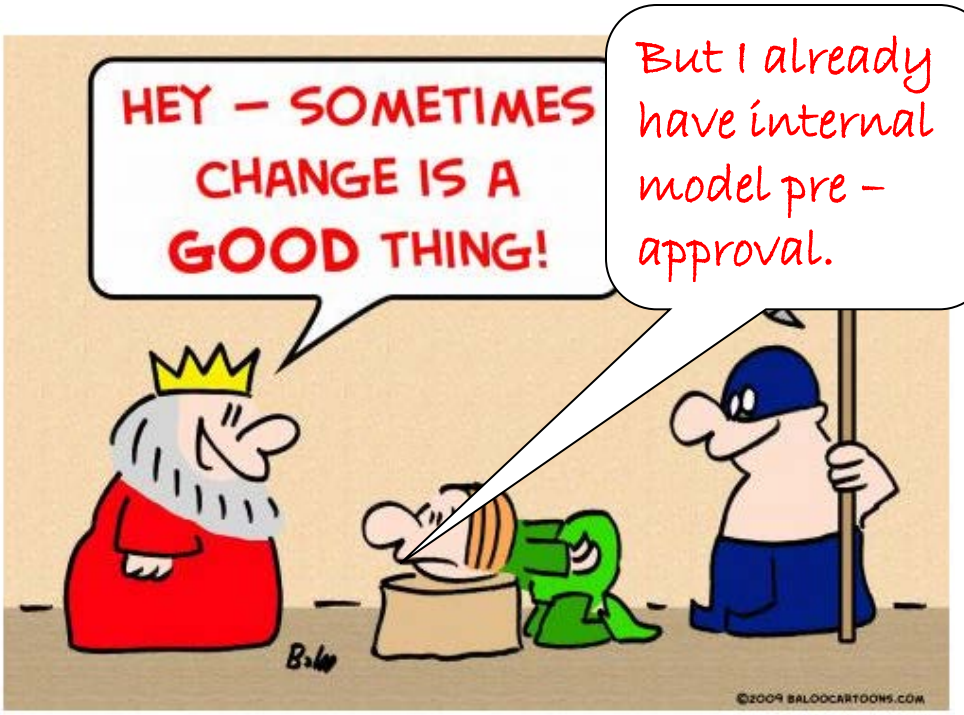
Solvency II aims to ensure the appropriateness of internal models

But introduces its own significant model risk

Insurers may wish to take advantage of new models or improved modelling approaches but there are significant impediments

- The model change procedure
- Documentation
- The effect on regulatory capital
- The effect on embedded value
- New model, new limitations

Is Solvency II a dangerous paradigm?



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: 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

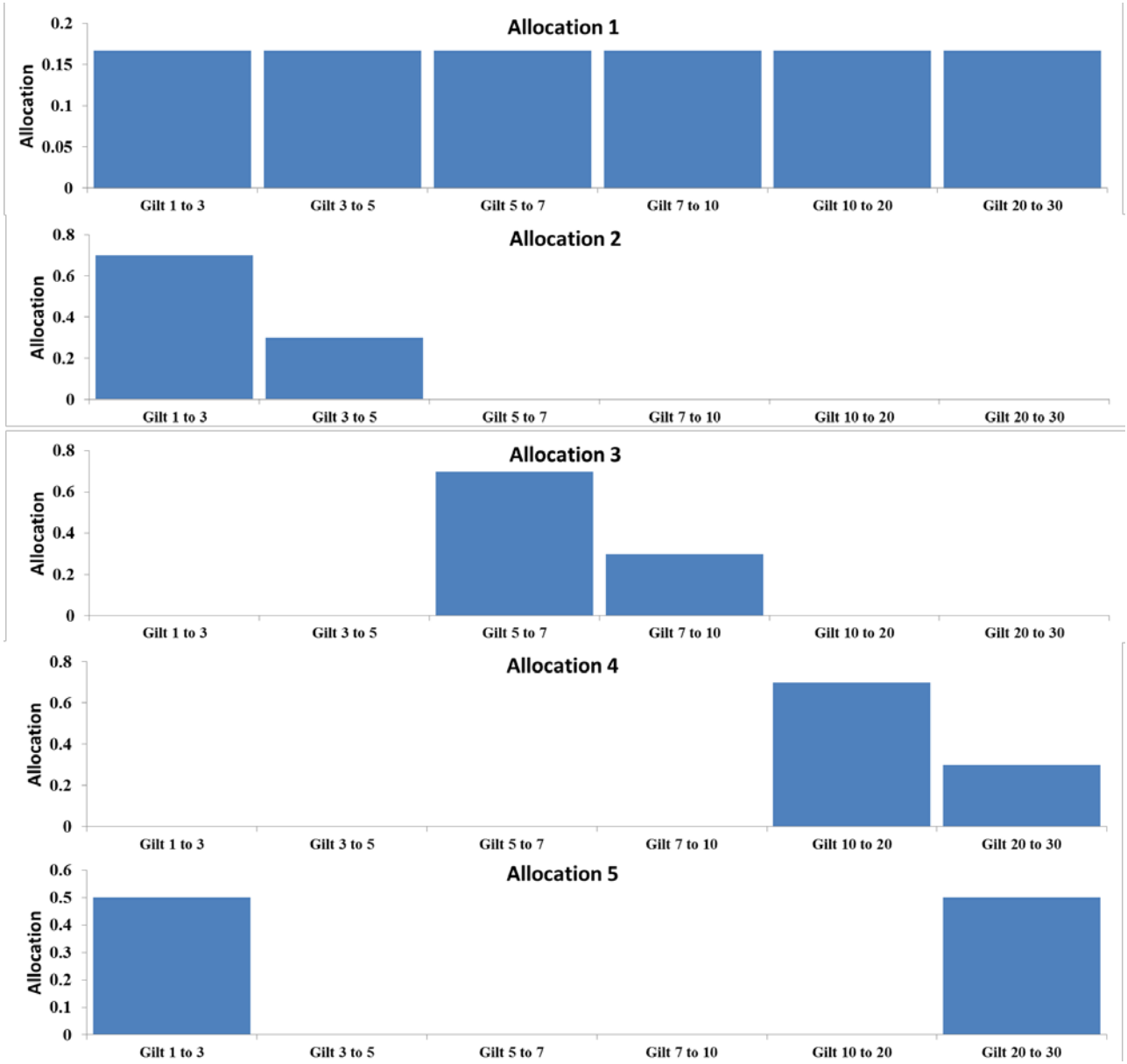
- Estimated from 55 years of data
- Starting point is the year end 2013 Gilt curve

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



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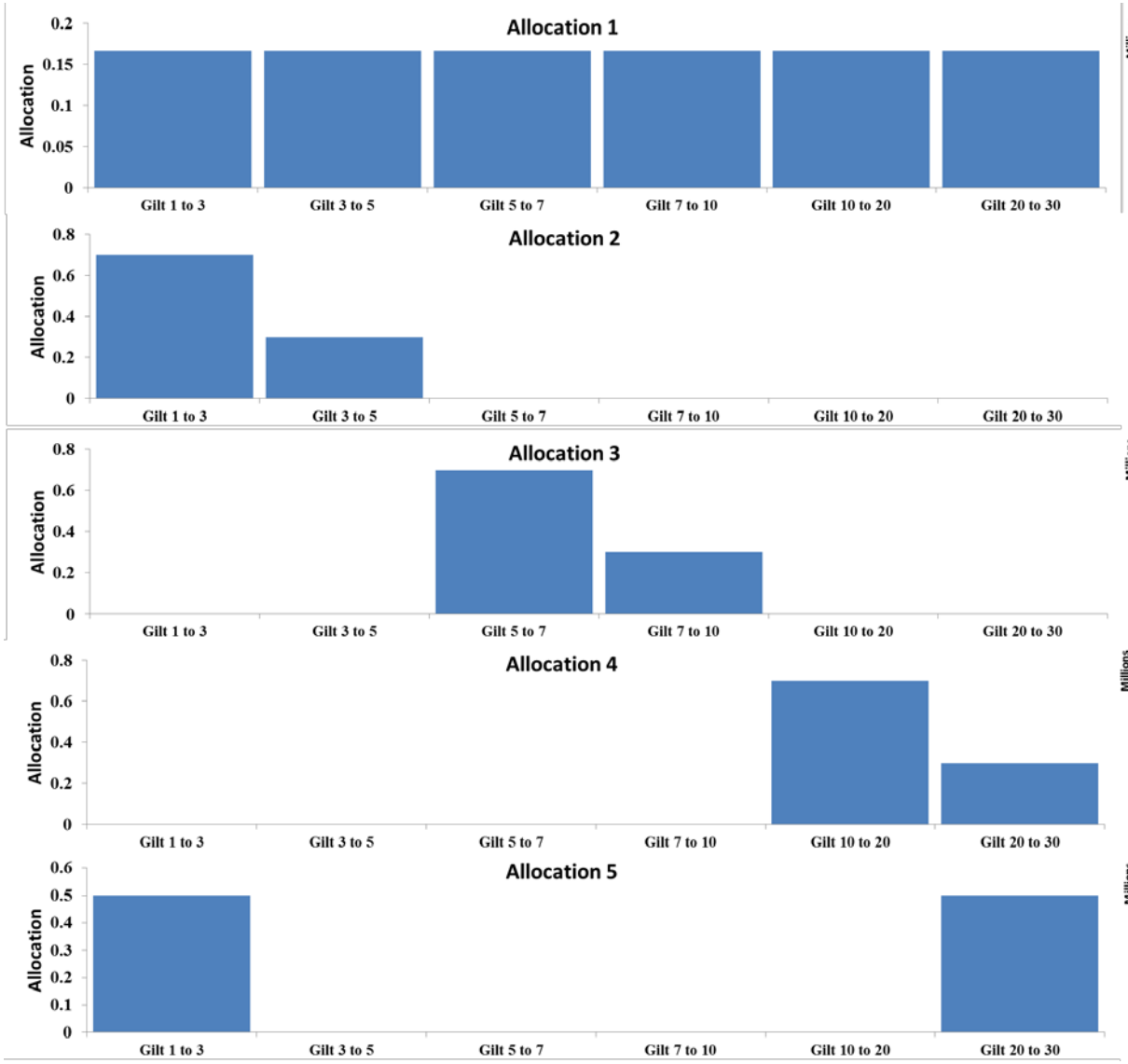
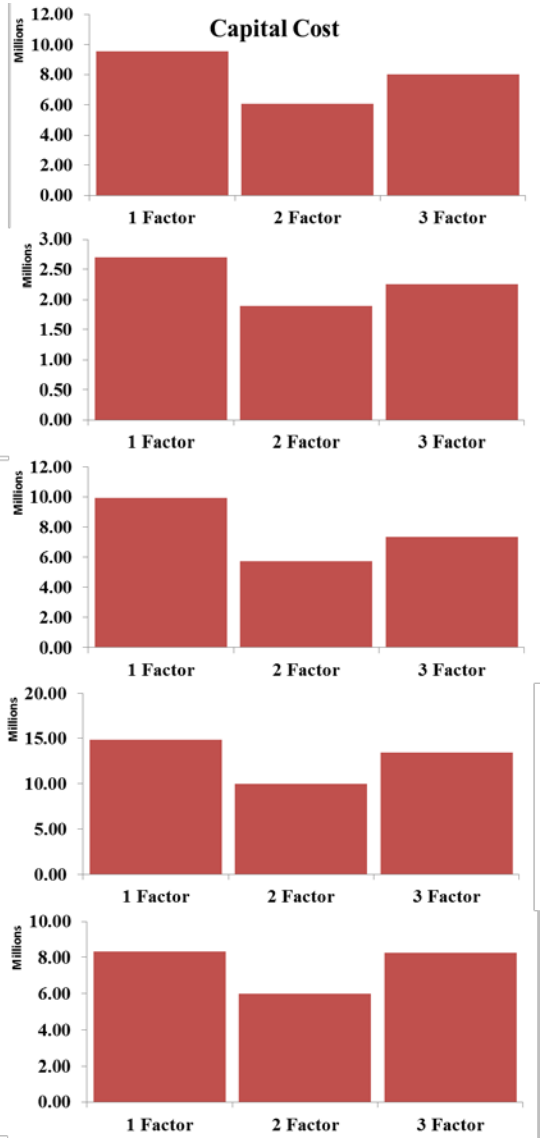
Results





Source: Conning RCMS

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.

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