Session 68, Scenario Generators – What Do We Do With So Many Choices?

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What Makes a Good ESG?

◆ The previous speakers have addressed the question of what makes a good ESG and discussed the example of the AAA generator.

◆ Is the AAA generator a good ESG? It is not a comprehensive ESG in that it does not include a wide range of economic variables. The validation of the AAA generator depends on the application you have in mind.

◆ Answering the question of whether a specific ESG is any good depends on understanding the specific application of that ESG, establishing general validation principles and subjecting the ESG to a stringent validation routine.

◆ ESG’s are a critical part of actuarial practice. All actuaries need to have some basic understanding of what ESGs are and how to validate them.
What Makes a Good ESG?

- An ESG simulates future paths of economies and financial markets and illuminates the nature of risk elements within the economy that drive financial variability. A well designed ESG is critical for insurers to identify and manage the internal and external risks to their organizations.

- A good ESG has a sound, economically logical foundation on the way models are built, produces simulations that reflect a view that is relevant to the needs of the insurer; produces some extreme but plausible results; and generates scenarios that embed realistic market dynamics. Additionally, a good ESG meets the requirements of regulators and auditing firms and has capabilities for real-world and risk-neutral simulations and uses consistent models across both modes.
What Makes a Good ESG?

- There is a certain amount of expert judgement that is unavoidable in assessing the quality of an ESG. For example, no one knows how long ultra-low interest rates will persist. Modeling professionals may have difficulty agreeing on the percentage of simulated paths that should exhibit extended periods of zero interest rates or on how many years constitute an extended period. We are all likely to agree that a good ESG should generate paths with ultra-low interest rates and that these should recur along some paths throughout the simulation.

- The Society of Actuaries has recently published: “Economic Scenario Generators – A Practical Guide”

Why Are There So Many Different ESG Models?

- An ESG is based on a collection of financial and economic models.
- There are many types of models available for each type of financial or economic variable.
- Some classes of models are well-suited to real-world applications where richer model dynamics can be applied.
- Other classes of models were developed for ease of calibration in trading applications.
- Some models are easier to estimate and calibrate than others. Model performance and ease of use often involve trade-offs.
- These reasons alone account for much of the proliferation of ESG models.
Why Are There So Many Different ESG Models?

- The economic experience of recent years is driving a lot of interesting development and innovation in ESG modeling.

- Classical interest rate models were developed prior to the recent global ultra-low interest rate experience.

- The financial crisis produced credit spreads that widened to levels that were inconsistent with the ratings that the bonds carried.

- Central bank intervention, like quantitative easing and negative interest rate policies, are producing unprecedented yield curve behavior.

- Let us take a look at a few examples in this brave new world.
US Corporate Bond Spreads

Prepared by Conning, Inc. Source: ©2016 Bloomberg, L.P.
US Corporate Bond Spreads

Prepared by Conning, Inc. Source: ©2016 Bloomberg, L.P.
US Corporate Bond Spreads

Moody's US AAA and BBB Spreads (Jan1925 - Jul2015)

US Corporate Bond Spreads (10-15yr minus 5-7yr OAS Spreads)

BAML US Corporate OAS Spreads: 10-15yr over 5-7yr

Relative to the recent past, corporate bond spreads were extreme during the financial crisis.

Longer term history shows that spreads have been wider than what was experienced during the financial crisis. However, default rates during the Great Depression were significantly higher than default rates during the financial crisis.

Indications from financial crisis data are that liquidity effects may have played an important role in spread movements. The inclusion of liquidity effects in credit models is an important innovation and yet another ESG model choice.

Credit models that can accommodate spread blow-outs are a must-have for sound economic capital modeling.
Extensive interest rate data is available for major economies for the recent past decades.

Long time series of interest rate data is available for some economies.

It is natural to look to history for some guidance on what the very low interest rates of today may portend.

Unfortunately, even when long histories are available, very little of that history is similar to the interest rate levels that we are experiencing today.

Furthermore, there are many challenges in making comparisons across widely different periods of time. For example, the period of very low interest rates we are experiencing now in the United States is numerically similar to the data for parts of the 1930s and 1940s, but the overall economic conditions in the US are not comparable between these two epochs. Changes in tax law, government policies, and socio-political circumstances can make comparisons across epochs difficult.
The all-time lows were primarily due to tax effects.
US Interest Rates – Recent History (20 Years – Mean Reversion?)

Prepared by Conning, Inc.  Source: Federal Reserve Bank of St. Louis (2016)
It is not surprising that when the 1 year rate is pinned at zero it hardly moves. It is notable the 10 year rate is changing a lot in recent years and comparable to the 1990s.
“‘The rate of interest has fallen.’ ‘The rate of interest is falling.’ ‘The rate of interest will probably continue to fall.’ These sentences, and others of a similar nature, we have read so often, that I fear it is quite possible ‘familiarity’ may, to some extent, have had its usual effect. The fact remains, however that any further fall in the interest yield is of vital importance to insurance companies with large funds to invest, and bound by contracts, the fulfillment of which depends, to a large extent, on the rate of interest obtainable.”

There is nothing surprising about the stress that very low interest rates can have on insurance company operations. However, what may be surprising is that these words are the opening words of the article by Joseph Burn in Some Considerations in Reference to the Fall in the Rate of Interest Experienced in the Past, and the Probability of its Continuance, published in the Journal of the Institute of Actuaries in April 1899 (Vol. 34, pp. 474-509).

According to the U.K. Debt Management Office, the interest rate experience at that time looked like the following chart.
U.K. Gilt Market 2.5% Consolidated Stock Average Yield (1727–1899)
With the benefit of more than 100 years of additional data we can put this chart in a longer-term perspective.

**U.K. Gilt Market 2.5% Consolidated Stock Average Yield (1727–2012)**
While the observations of Mr. Burn are understandable, it is instructive that they were made very near to the 300-year bottom of British interest rates.

The lesson for the user of an ESG is that while an ESG must produce extreme but plausible scenarios, one cannot permit the concerns of the day to unduly influence the behavior of the simulated scenarios if these scenarios are to be used for long-term risk management.

A good ESG in 1899 would have had the capability of producing the record low interest rates that were observed at that time while also producing scenarios in line with longer-term historical levels. The imposed calibration view for such a good ESG would have generated some rate scenarios that stayed low, returned to more normal levels, and moved to even higher levels.
UK Interest Rates – Long Run History (2.5% Consol. Yield)

Low for the series is 2.25% in 1897.

Prepared by Conning, Inc.  Source: UK Debt Management Office
German Interest Rates (18 Years – Mean Reversion?)

Prepared by Conning, Inc. Source: ©2016 Bloomberg, L.P.
Japanese Interest Rates – Recent History


Summary of Yield Data

- Long-term interest rates for developed economies are at or near all-time historical lows.
- Short-term interest rates for developed economies are zero or even negative.
- Corporate bond yields and spreads, are typical by historical standards, and are not at all-time historical lows. [Recent ECB intervention in corporate bond markets is having an effect on this.]
- The Japanese experience shows that ultra-low interest rate environments can persist for extended periods of time.
- It is remarkable that German 10-year government bond yields have gone negative.
- It is incredible that the Swiss yields are deeply negative out to long tenors.
- All this is happening while it seems that the world is sitting on large amounts of debt.
Dynamics Are Different in Recent Years (PCA Jan1998 – Dec2008)

- Principal components analysis on monthly changes in US Yields.
- Normalized eigenvectors corresponding to largest eigenvalues.
Dynamics Are Different in Recent Years (PCA Jan2009 – Jul2015)

- Principal components analysis on monthly changes in US Yields.
- Normalized eigenvectors corresponding to largest eigenvalues.

Graph showing the dynamics of principal components analysis on monthly changes in US Yields, with normalized eigenvectors corresponding to largest eigenvalues.
Models for Low Interest Rate Environments (DNS Structure)

\[ y_t(\tau) = L_t + S_t \left( \frac{1 - e^{-\lambda \tau}}{\lambda \tau} \right) + C_t \left( \frac{1 - e^{-\lambda \tau}}{\lambda \tau} - e^{-\lambda \tau} \right) \]
The model can capture ultra-low interest rates and “hockey stick” yield curves.

Some combinations of parameters do not produce realistic yield curves.
DNS Structure – Illustrative Simulation for 10-year Yield

DNS Structure – Illustrative Sample Path for 10-year Yield

DNS Structure – Illustrative Simulation for Short-Rate

Models for Low Interest Rate Environments

- Dynamic Nelson-Siegel models (DNS).
- Macro finance (DNS with VAR macro variables, other)
- Quadratic interest rate models. Shadow rate models. Krippner zero lower bound (ZLB) models.
- There is a rich collection of models that are being actively researched for low interest rate environments.
- Ideally, the models should capture prolonged periods of low rates and be capable of returning to “normal” interest rate dynamics later in the simulation.
- Limited data (historical experience) means that there is a considerable amount of expert judgment involved.
- For better or worse, the choice of ESGs is going to get even wider!
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Academy Generator

- Real World Generator
- Equity indices projection: Stochastic Log Volatility (SLV) model
  - Static correlation matrix
- Yield curve projection: Stochastic Variance with Mean Reversion
- 3 random variables generated per period
  - Long and short rates (1 & 20 Yr)
    - Floors of 1bp and 1.15% respectively
  - Shock to log volatility
- Uses a mutating Sbox random number generator
- Fits Long & Short rate to curve using Nelson-Siegel interpolation factors
- Uses Mean Reversion Parameter (MRP) to set final long term rate destination
Academy's Interest Rate Generator (AIRG) (Version 7.1.201604)

Starting date: 201608  Use YYYYMM form for the starting date. Example: December 31, 2008 = 200812

Yield curve on starting date:
- 3 Month 0.29%
- 6 Month 0.40%
- 1 Year 0.50%
- 2 Years 0.67%
- 3 Years 0.78%
- 5 Years 1.06%
- 7 Years 1.33%
- 10 Years 1.51%
- 20 Years 1.84%
- 30 Years 2.24%

Press button above to generate the scenarios selected at right.

Generate Scenarios:
- Full set of 10,000 scenarios
- Subset with 1,000 scenarios
- Subset with 500 scenarios
- Subset with 200 scenarios
- Subset with 50 scenarios
- Stochastic Exclusion Test Scenarios

Mean reversion to: 3.75%  The 20-yr rate tends towards this mean, which depends on the start date (go to the Parameters tab to override this)

Years to project: 30  Maximum digits to retain after the decimal: 5

Output folder: Select  W:\General\Economic Scenario Generator\1603 Release\Run\10000

Optional suffix to append to output file names:  (Suffix can be blank)

Output files:
- Separate *.csv file for each term to maturity
- Single *.csv file
- EconSML file (*.xml)
- Random numbers in *.csv format

Time step:
- Monthly
- Quarterly
- Semi-annual
- Annual

Output rates:
- Bond Rates (bond-equivalent)
- Spot Rates (annual effective)
8/1 UST Rates based on UST history through 05/16.

2 each of pop-up, pop-down, down-up, up-down deterministic & short volatility rate scenarios.

Starting date: 201608

Yield curve on starting date:
- 3 Month: 0.29%
- 6 Month: 0.40%
- 1 Year: 0.50%
- 2 Years: 0.67%
- 3 Years: 0.78%
- 5 Years: 1.06%
- 7 Years: 1.33%
- 10 Years: 1.51%
- 20 Years: 1.84%
- 30 Years: 2.24%

Mean reversion to: 3.75%

Years to project: 30

Generate Scenarios:
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- Subset with 50 scenarios
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- Random numbers in *.csv format

Time step:
- Monthly
- Quarterly
- Semi-annual
- Annual

Output rates:
- Bond Rates (bond-equivalent)
- Spot Rates (annual effective)
## Generated Outputs

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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<td>AGGR</td>
<td>Aggregate real estate index</td>
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<tr>
<td>BALANCED</td>
<td>Balanced equity fund</td>
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<tr>
<td>INT</td>
<td>International equity fund</td>
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<td>LTCORP</td>
<td>Long term corporate bonds</td>
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<td>SMALL</td>
<td>Small company index</td>
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<td>FIXED</td>
<td>Intermediate Risk Equity Index</td>
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<tr>
<td>INTGOV</td>
<td>US Intermediate Government Bond Index</td>
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<td>MONEY</td>
<td>Money Market Bond Index</td>
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<tr>
<td>US</td>
<td>US Equity Index Fund</td>
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<td>1 year treasury</td>
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<td>2 year treasury</td>
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<td>3 year treasury</td>
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<td>20 year treasury</td>
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<tr>
<td>UST_30y</td>
<td>30 year treasury</td>
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### Equity Levels
- Based on a correlation matrix
- Cumulative output

### Yield Curve
- Project 1Y stochastically
- Project 20Y to MRP
- Spot output
- Annual or Bond Equivalent
MRP (Mean Reversion Parameter)

AAA ESG: SLV-1 Long Rate MRP

- 20-year yield
- 600 months median
- 36 months average
- AAA MRP Rounded
- NAIC MRP
MRP Impact On 10 Year Treasury (1,000 Scenario Average)

- MR/NonMR ...
- 3.50%
- 3.75% MRP
- 4%
- No MRP
AAA Generator Summary

- Missing some risks
  - Eg Foreign exchange, credit risk, alternative assets
- Correlation matrix assumed constant
- Interest rate & equity indices not correlated

- User friendly
- Defines regulatory expectations
- Good for simple products
AAA Generator Use - Example

• Calculate projected VM20 DR & SR at discrete points in time
Deterministic Scenario Creation - Example

- Laddering of Academy Generator’s .csv outputs
  - Row 1 = deterministic scenario projected using time 0 yield curve
  - Row 2 = 1 year of experience scenario, then deterministic scenario projected using yield curve 1 year hence
  - etc

- Deterministic = scenario 12 of SET output
- Rescaling cumulative indices (equities)

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<th>Year 0</th>
<th>Year 1</th>
<th>Year 5</th>
<th>Year 10</th>
<th>Year 30</th>
<th>Experience</th>
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AAA Generator vs In House?

Simple In House Generator

- Equity = RSLN (Regime Switching Log Normal)

- Interest Rates = Basic Multiplicative Formula
  \[ r_t = (r_{t-1} + \alpha (\mu - r_{t-1}))e^{\sigma \varepsilon - \sigma^2/2} \]
  - Modeling 1, 10, and 20 year terms
  - Spline fit remaining curve
  - 20 year mu, sigma, and alpha set to AAA defaults
  - 1 & 10 year mu, sigma, and alpha set to their 10 year averages
  - Same starting curve and correlations as AAA generator

- Mersenne Twister RNG

<table>
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<th>Transition %</th>
<th>%</th>
<th>μ</th>
<th>σ</th>
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<td>1</td>
<td>5%</td>
<td>87%</td>
<td>1.5%</td>
<td>4%</td>
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<td>2</td>
<td>35%</td>
<td>13%</td>
<td>-3%</td>
<td>10%</td>
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<tr>
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<td>0.5%</td>
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<td>0.7%</td>
<td>4.1%</td>
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10 Year Treasury Projection Comparison

- In House
- AAA 3.75MRP
Addition of Momentum

Simple In House Generator

- Addition of 12 month rolling average – MA(12)
- Interest Rates = Multiplicative Formula with MA:
  \[ r_t = (r_{t-1} + \alpha (\mu - r_{t-1}) + \beta MA(12))e^{\sigma \varepsilon - \sigma^2/2} \]
  - Strength of \( \beta \) (1%) applied to the MA(12)

<table>
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<tr>
<th></th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>4</th>
<th>3</th>
<th>2 Months Prior</th>
<th>1 Month Prior</th>
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<tr>
<td>10 Year Treasury</td>
<td>2.2%</td>
<td>2.2%</td>
<td>2.2%</td>
<td>1.8%</td>
<td>1.8%</td>
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10 Year Treasury Projection Comparison

In House

AAA 3.75MRP

In House w/MA
In House Generators Summary

- Goal is to be less conservative than AAA
- Get back to your MRP in less time
  - AAA Generator takes 15-20 years
- Don’t need to use very complicated formulas
- About half of the time companies use AAA generator
  - Mostly small companies
- About half the time companies have an In House Generator
  - Mostly big companies