Incorporating Liquidity Risk and Machine Learning within ERM and ALM to drive Risk-aware Business Decision-Making

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SS&C Algorithmics
Agenda

• New challenges for risk management in the insurance sector

• 5-step journey to a sophisticated ERM solution

• Liquidity risk management at L&G: a case study

• Machine Learning for Replicating Portfolios: a case study
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A challenging market landscape
Low to negative yields

Market challenges
• Low interest rates across core developed markets
• High long term guarantees in life or retirement products
• Limited premium rise due to client pressure and competition

10Y Government rate history across G7 countries (OECD)

Need to rethink investments and ERM in the insurance sector
New challenges call for new strategies
Markets, regulations, IT

Market and regulatory challenges...
- Complex and credit-intensive securities considered because of low market yields
- Options and guarantees are often met with dynamic hedging strategies
- Risk management under scrutiny of regulatory authorities and stakeholders
- Demand for trustworthy data, renewed skill sets and IT infrastructures

...drive new business requirements
- Native asset modelling accounting for consistent market and credit risk management
- Improved ALM with liability proxying, risk-aware investment strategies, liquidity risk management
- Compliance must be accompanied by business benefits and improved ALM
- Reduce TCO with cured data, cloud computing, managed services and cognitive technologies
Global shift to sophisticated ERM

Regulations and business needs drive the change

- How the business is evolving
- Actuarial funding
  - Long-term guarantees
  - Prescriptive models
- Market-consistent balance sheet
- Stochastic projections
- Solvency II, Principles-based approaches
- ORSA
- Internal models

Integrated modelling of market and credit risks
- Liquidity risk management
- Liability Driven Investment
- Innovation: Machine Learning and Cloud
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5 Step journey to a sophisticated ERM solution

1. Devise a three step process: scenario generation, simulation of assets and liabilities, risk aggregation

2. Calibrate proxies for liabilities (loss functions or Replicating Portfolios) using sample data sets

3. Integrated Monte-Carlo analysis of market and credit risks

4. Expand ERM solution to include Liquidity risk, as well as ALM and LDI processes

5. Improve process with cloud and cognitive technologies
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Market-Consistent Modelling of the Balance Sheet

**Historical Time Series**
- Interest rates
- Exchange rates
- Equity indexes
- Commodities
- Individual securities

**Risk Factor Scenarios**
- Consistent paths of risk factor changes
- Copula codependent structures widely used

**Instrument Scenarios**
- Consistent paths of instrument values
- Mark-to-Future cube

**Simulation Methods**
- Historical sampling
- Stochastic models
- Calibration
- Codependence
- Transformations (PCA)

**Valuation Methods**
- Linear factor models
- Analytic
- Numerical methods
- Proxies
Portfolio level aggregation
Mark-To-Future decouples the simulation and aggregation

A portfolio is a set of positions, \( \mathbf{x} \), where \( x_j \) is the number of units of instrument \( j, j = 1, \ldots, N \).

From the instrument values in the MtF cube, the portfolio value at time \( t \) in scenario \( i \) is

\[
V_{it}(\mathbf{x}) = \sum_{j=1}^{N} v_{ijt} \cdot x_j
\]

Given the initial portfolio value, it is straightforward to compute changes in value (profits and losses) and returns in each scenario

\[
\ell_{it}(\mathbf{x}) = V_0(\mathbf{x}) - V_{it}(\mathbf{x})
\]

An MtF cube can be used to value portfolios that hold any subset of its instruments

- No need to re-simulate when positions change
- \( x \) are decision variables in portfolio optimization
Full Monte Carlo Simulation
Mark-To-Future For A Multiple Horizon Risk Perspective

Risk/Reward Statistics
- VaR, Marginal VaR, Credit VaR, ETL
- Stress testing, sensitivity analysis

Relative Risk Indicators
- Tracking error, Marginal TE, Attribution
- LDI, ALM, capital projections
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How to proxy liability portfolios

Enhance the ALM process

Why do we need liability proxying?

- Actuarial projection systems unable to handle large simulation runs
- Leverage cash flows generated from existing actuarial solutions
- Consistent valuation and simulation of assets and liabilities
- Replicating Portfolios allows to generate cash-flows projecting at any horizon

Main techniques to proxy the liabilities

<table>
<thead>
<tr>
<th>Zero bonds</th>
<th>Distributions</th>
<th>LSMC/Curve Fitting</th>
<th>Portfolio Replication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replicate static cash-flows with zero bonds (or sensitivity instruments.)</td>
<td>The actuarial ALM system outputs the entire marginal distribution (analytical or empirical.) This can be interpolated and re-sampled in the calculation engine from a correlated risk driver.</td>
<td>The actuarial ALM system outputs a sample of values, using a nested real-world + risk neutral scenario set. A (linear) regression is run to find the best fitting polynomial.</td>
<td>The actuarial ALM system outputs a sample of cash-flows. Find a portfolio of securities (real or synthetic) that matches liability cash-flows over time and scenarios.</td>
</tr>
</tbody>
</table>
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Manage market and credit risk
An integrated view of all risk types

Integrated modeling of market and credit risk allows to decompose loss distributions by
- spread,
- default and
- migration risk

Credit events are correlated to market movements
- Each issuer is mapped to an equity risk driver
- Equity level drives issue Credit Worthiness Index (CWI)
- CWI level determines rating

Simulate credit loss distributions
- Joint default, migration and spread
- Spread only

Analyze risk contributions
- Default
- Migration
- Spread

Scenarios are generated simultaneously for market factors and credit drivers
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Advantages of an integrated ALM platform

- Consistent modeling of assets and liabilities, simulated under a joint scenario set
- Link together enterprise risk management, asset liability management and investment management
- Use what-if and optimization for strategic asset allocation, with liabilities as a benchmark
- Adopt risk-based limits to monitor portfolio managers relative to asset allocations
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Move to Cloud
Manage simulation bursts and reduce TCO
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Liquidity Management and Planning
How it is becoming a regulatory requirement

‘Liquidity risk’ means the risk that insurance and reinsurance undertakings are unable to realise investments and other assets in order to settle their financial obligations when they fall due.

*Solvency II Directive, Art. 13(34)*

Increasing regulatory pressure:

**G-SII Liquidity Management Plan** is being applied by an increasing number of local authorities.

**IAIS** issued a *holistic framework* for systemic risk to be applied in 2020 with liquidity requirements.

Local initiatives, e.g. PRA’s CP4/19
Liquidity Risk is becoming material for insurance
Insurers increasingly move market risks into liquidity risk

Why are insurance firms exposed to Liquidity Risk?

- Investments in illiquid assets
- Higher market volatility
- Surrenders (no compulsory annuitisation)
- Increased derivative hedging

Source: PRA’s CP4/19

Sources of liquidity risks incurred under stressed market conditions

**Liability Side:** Increase in lapse rates, surrender of life insurance policies.

- Some insurance products contain options to withdraw cash.

When insurers do not adequately match such liabilities with sufficiently liquid assets, this may lead to a liquidity shortage and ultimately trigger fire sales.

**Asset Side:** Monetising assets, market depth, access and size.

- Sudden demands for collateral could force the lender to sell illiquid assets.

In a stressed market, these sales could impact the insurer’s creditworthiness, triggering more collateral demands and leading to a price spiral.

**Off balance Sheet:** Collateral and margin obligations.

- When derivatives are used to hedge market risk, *margin requirements transform capital risk into liquidity risk.*

A macroeconomic shock could trigger calls for additional margin, forcing insurers to raise liquidity.
Liquidity risk solution at Legal & General
Case Study of Algorithmics solution at L&G

Business problem

– Monitor liquidity under stress in order to improve the asset allocation in an autonomous manner.

Solution

– AWA for Liquidity risk, fueled by MDS data, provides liquidity analytics to business users including VaR, what-if and biting scenarios

Highlights:

– Produce metrics used to measure liquidity requirements for derivatives hedging

– Provide business users the required self-service capabilities

– Source curated data from the Algo Market Data Service

Functional Scope:
Collateralize derivative portfolio while managing risks and ensuring:

1. To forecast liquidity impacts of market events
2. To have sufficient eligible assets to post as derivative collateral in stress scenarios
3. To hold enough cash and gilts to cover risk

Calculation Methodology:

• Monte Carlo + Historical random sampling + Deterministic scenarios
• Granularity of standalone/diversified VaR e.g. eligible assets, counterparty, product type.
• Daily MDS market data feed
L&G Algo solution reports
The ERM framework now serves liquidity and ALM departements

- Portfolio Analysis across multiple dimensions
- VaR (standalone, marginal, decomposed, contributory VaR)
- Scenario-based Sensitivities and stress test
- Scenario Viewer and Analysis
- Smoothed Biting Scenarios
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Machine Learning in Insurance
Increasing application span

- Understanding data. ML can be effectively applied across structured, semi-structured or unstructured datasets.
- Process automation, including chatbots, claims registration and settlement
- Fraud detection to identify fraudulent claims more accurately and timely
- Underwriting and credit scoring, i.e. checking datasets to understand if a person qualifies for an insurance
- Recommender systems to provide insurance advice
- Risk Management:
  - Modeling complex contracts
  - Calculating Economic Capital
  - Proxy liabilities
Advantages of Replicating Portfolios

RP’s make excellent proxies for insurance liabilities

- Replication error approaches zero (no projection error)
- Reproduces values and cash-flows of the liabilities, thus allowing ALM and AA
- Provides immediate indication of risk composition, facilitating hedging strategies
- Automatically updates with new market data and time horizons

Use Cases:
- Pricing (e.g. Black-Sholes)
- Risk and Portfolio Management (e.g. modeling a portfolio of alternatives)
- Liability Proxying for insurance asset-liability and capital management
ML makes Replicating Portfolios easy

In ML/AI terms, Portfolio Replication is a regression problem with advanced constraints, bucketing and other enhancements.

Problem: train the model precisely avoiding underfitting and overfitting.
An L1 regularized regression or LASSO can be implemented via the trading budget constraint. Efficient frontiers of objective function values vs. trading budget help solving the "bias-variance tradeoff”

To this end we shall combine two ML methodologies:
• hyperparameter tuning and
• cross validation

Note: this requires a solution and optimization architecture granting a high the level of automation and visualization functionalities
Hybrid Software Architecture for RP Automation

Machine learning can be enabled by a high performance modular approach
ML-enhanced Replicating Portfolio: a case study

1000 simulated scenarios, equal probabilities
   Risk factors include interest rates, equity indexes
   Each scenario contains annual cash flows for a 30-year time horizon
500 scenarios are used for optimization, 500 scenarios are used to evaluate the replicating portfolios out-of-sample. The optimization tries to match $500 \times 30 = 15000$ liability cash flows

- 1157 possible replicating assets, including
  - Interest rate sensitive instruments (bonds, swaps, caps and floors)
  - Equity sensitive instruments in 3 markets (forward contracts, options)

- Objective function

- Trading budget constraint

Authors: Oleksandr Romanko, Helmut Mausser
Hyperparameter tuning improves the quality of RPs

In-sample

Out-of-sample

R² = 0.9004

R² = 0.8523

Budget = 7 B

Budget = 626 M

Interest Rate Sensitive Instruments

Authors: Oleksandr Romanko, Helmut Mausser
Machine Learning allows to choose the optimal and stable RP

The out-of-sample error has a point of minimum corresponding to cardinality 230.

Search the "ideal" trading budget by averaging out-of-sample frontiers across cross-validation folds and selecting the point of minimum.

The workflow should facilitate the automation of cross-validation to select the "ideal" trading budget that minimizes the out-of-sample error.

Authors: Oleksandr Romanko, Helmut Mausser
The minimum of the Out-of-Sample Efficient Frontier is the optimal Replicating Portfolio
Thanks

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