Modelling Interest Rates and Market Factors
Leading Examples

(1) Swaps and Sovereign Curves (term structure models for interest rates)
Principle component approach

(2) Stock Market Returns, Historical and Implied Volatilities
Time series model with conditional heteroskedasticity and Global Equity Factor (GEF) related to global economic conditions

(3) Mortgage-backed Securities: Agency and Non-agency
Term structure models with GEF and prepayment factor

(4) Corporate CDS and Corporate Bond Spreads by Sector and Rating Category
Time series model with Global Credit Factors, combined with principal component analysis

(5) Sovereign CDS by Country and Maturity
Time series model with long memory, combined with principal component analysis

(6) Credit Migration
Transition matrices for credit portfolios, two-stage approach: (i) discrete-choice model combined with (ii) quantile and time-series analysis
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Overall Modelling Approach
Map alternative scenarios assumptions to market risk variables in multivariate, parametric and semi-structural framework.

Satellite models allow for explicit and transparent connection to core drivers; no feedback between satellite variables \( z \) and core drivers \( (x,y) \).

Model selection is based on a combination of economic theory, regulatory assumptions, and the statistical properties of estimated model.

Models have reasonable in-sample fit; produce consistent, sensible forecasts and stressed scenarios out of sample.

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**Market Risk Stress Testing Models**

- Satellite Model 1
  \[ z^1 = g^1(x,y) \]
  \[ (x,y) \rightarrow z^1 \]

- Satellite Model S
  \[ z^S = g^S(x,y) \]
  \[ (x,y) \rightarrow z^S \]

- Satellite Model 3
  \[ z^3 = g^3(x,y) \]
  \[ (x,y) \rightarrow z^3 \]

- Satellite Model 2
  \[ z^2 = g^2(x,y) \]
  \[ (x,y) \rightarrow z^2 \]

- **CORE MODEL**
  \[ F(x,\varepsilon,y) = 0 \]
  \[ (x,\varepsilon) \rightarrow y \]
Model Selection Procedure

- Potential core drivers identified based on macroeconomic intuition and consistency with regulatory assumptions.
- The potential drivers undergo the **exhaustive search process** to obtain the most robust and predictive model available from the tested variables.
- Typical exhaustive search criteria include:
  - All possible combinations of potential drivers (including lags)
  - A max number of macro drivers selected
  - No strong correlation between drivers
  - Coefficient estimates must be statistically significant
  - Expected signs and magnitude of the estimates
  - Maximization of a target index (e.g. Adjusted R² /RMSE, Log-likelihood, AIC, MAE, etc.)
Typical Model Validation

- **Post-estimation analysis**
  Diagnostic methods to verify regression model assumptions and detect. Residual & outlier analysis, in-sample goodness of fit.

- **Beta elasticities**
  Quantifies the response of the dependent variable to a 1 standard-deviation shock on each driver.

- **Impulse-response analysis**
  Time-series analysis of the effect of a permanent and/or temporary shock (e.g. 1 standard-deviation) applied to any given driver. The output is the response function (over time) of our endogenous variable to an impulse on any of the drivers.

- **Backtesting**
  Remove parts of the sample data from the model estimation and use the model to generate forecasts for the resulting holdout sample to assess model accuracy.
Model Drivers
Global Growth Factor (GGF)

Global Growth Factor
Alternative Scenarios

Global GDP Growth
PRA Baseline

Global GDP Growth
PRA Stress

Moody's Analytics
Model Drivers (cont.)
Global Equity Factor (GEF)

Global Equity Factor
Alternative Scenarios

Global Equity Growth
PRA Baseline

Global Equity Growth
PRA Stress

PRA BL  PRA ST
Model Drivers (cont.)
Global Equity Volatility Factor (GEVF)

Global Equity Volatility Factor
Alternative Scenarios

2000q1 2005q1 2010q1 2015q1 2020q1

PRA BL  PRA ST

Global Equity Volatility
PRA Baseline

Global Equity Volatility
PRA Stress

2000q1 2005q1 2010q1 2015q1 2020q1

GEVF  VIX INDEX  VSTOXX  VNKY  VFTSE  US Volatility, PRA ST
Macroeconomic Scenario Simulations

GDP Growth, % Q/Q: Forecasts per Quarter

Example of a Marginal Loading into Overall Scenario Rank-Ordering Algorithm

Max Cumulative Drop in GDP growth
Scatter over Marginal Rank Order

Density Function

Max cumulative drop in GDP Growth
Macroeconomic Scenario Simulations (cont.)

GDP Growth, % Q/Q: Over Scenario Blocks

Unemployment Rate, %: Over Scenario Blocks
Examples of Market Risk Models:
Swap Rates, Bond Yields & Libor Rates
Equity Returns & Volatilities
Corporate Credit Spreads
Swap Rates
Euro curve level and slope factors with core drivers

Level Factor vs Money Market Rate

Level Factor vs DEU 10y Yield

Slope Factor vs Term Premium

Slope Factor vs GDP Growth

Money Market Rate

DEU 10y yield

Level

Term premium

GDP growth, L2

Moody’s Analytics
Swap Rates (cont.)
Euro term structure history and forecasts, ECCA scenarios

Baseline

S3

S4

S8
Swap Rates (cont.)
Euro term structure history and forecasts, CCAR scenarios

Baseline

Adverse

Severely Adverse
Government Bond Yields

Government Bond Yield Curves
Box-Plots Across Maturities at +Q9
Government Bond Yields (cont.)

Government Bond Yields - Leading Maturities
Simulations over Scenario Blocks (1 for Good, 5 for Stressed) at +Q9

3 Months

1 Year

5 Years

10 Years
Government Bond Yields (cont.)

Yield Curve Slope (10y vs. 3m Spread, %)
Analysis Over Quarters and Simulations

Distribution for +Q9

Box-Plot for +Q9

+Q9 Values over Simulations

Box-Plots, all +Qs
Equity Returns and Volatilities
Stock indexes history and forecasts, ECCA scenarios
Equity Returns and Volatilities (cont.)
Implied 30-day volatility history and forecasts, ECCA scenarios
Equity Returns and Volatilities (cont.)

Example of daily forecasts – Dow Jones Industrial Average

Forecast daily returns over time – consistent with Baseline & Severe Scenarios
Corporate Credit Spreads
Financials - over maturities and rating classes

Corporate Spread Curves - Financials
5 Quarters out of Sample (+Q5) - Across Rating Classes

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Corporate Credit Spreads (cont.)
5Y Credit Spreads for Financials - over quarters and ratings

Corporate Spread Curves - Financials
5 Quarters out of Sample (+Q5) - Across Rating Classes

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Concluding Remarks

- Model set-up
- Scenario-driven and simulated projections
- Leverage credit risk stress testing models to achieve consistent outcomes
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