Multi-Period Credit Risk Analysis: A Macro-Scenario Approach

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Multi-Period Credit Risk Analysis
A Macro-Scenario Approach

• The problem we are solving
Overcome the challenge of analyzing credit risk dynamically (multi-period) and integrate stress testing (credit risk, PPNR, provisions, mark-to-market) into a unified management framework.

• Motivation

“The Basel Market Risk Amendment – finalized in 1995 – contained a provision encouraging the use of stress tests to augment the Value at Risk (VaR) measures of computing risk-weighted assets, the denominators in various measures of risk-based capital. VaR models consider the probability distribution of the value of a portfolio of assets. In principle VaR models can be thought of as the result of thousands of individual scenarios, weighted by their probability. In practice however the distributions are not tied to real-world variables other than the observed empirical distributions of the values of various assets.”
Multi-Period Credit Risk Analysis

A Macro-Scenario Approach (cont.)

Why is this relevant?

(i) embed stress testing process into the banks’ credit management practices (forecasting, provisioning, profitability, risk-based pricing, risk concentration, capital adequacy), (ii) dynamic risk and profitability assessment, (iii) optimal capital management, (iv) risk appetite.

Specifics of what we do

Compute analytical solutions to multi-period credit risk management.

(1) Dynamic simulations of macro scenarios and probabilities for each path.
(2) Multi-period risk parameter simulations (leveraging stress testing models) for conditional credit and mark-to-market parameter realizations.
(3) Analytical calculation of (intra-period and cumulative) expected and unexpected losses, and the corresponding asset contributions.
(4) Scenario-specific analysis: embedding ST into the framework.
(5) Further applications: risk-based pricing, concentration and tail-risk analysis, analytical reverse stress testing, dynamic optimization, integrated mark-to-market and default risk assessment, enhanced Monte Carlo methods.
Dynamic Simulations of Macro Scenarios and Probabilities for Each Path
Forward-Looking Scenario Generation & Severity Ranking

GDP Growth, % Q/Q: Forecasts per Quarter

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

Density Function

Max Drop in Cumulative GDP Growth, %
Severity of Alternative Macroeconomic Scenarios

GDP growth, q/q % -- alternative severity points

![Graph showing severity points for alternative macroeconomic scenarios](image-url)
Dynamic Simulations of Credit Risk Parameters (Retail Credit As Leading Example)
U.S. First Mortgage Portfolio – Quarterly Vintages

US First Mortgages - Vintage PD Simulations
Simulated values from +Q1 to +Q9 - Old/Seasoned Vintage

US First Mortgages - Vintage PD Simulations
Simulated values from +Q1 to +Q9 - Mid-age Vintage

US First Mortgages - Vintage PD Simulations
Simulated values from +Q1 to +Q9 - Young Vintage

US First Mortgages - Vintage PD Simulations
Simulated values from +Q1 to +Q9 - Future Vintage
U.S. First Mortgage Portfolio – Quarterly Vintages (cont.)

US First Mortgages - PD Simulations over Scenario Blocks
Simulated values for +Q5 - Old/Seasoned Vintage

US First Mortgages - PD Simulations over Scenario Blocks
Simulated values for +Q5 - Young Vintage

US First Mortgages - PD Simulations over Scenario Blocks
Simulated values for +Q5 - Mid-age Vintage

US First Mortgages - PD Simulations over Scenario Blocks
Simulated values for +Q5 - Future Vintage
Analytical Calculation of (Intra-period and Cumulative) Expected and Unexpected Losses, Asset Contributions.
## U.S. First Mortgage Portfolio – Loss Metrics

<table>
<thead>
<tr>
<th>Intra-Period</th>
<th>Intra-Period Exp Loss</th>
<th>Intra-Period Sigma</th>
<th>Intra-Period VaR(99.9%)</th>
<th>Cumulative Exp Loss</th>
<th>Cumulative Sigma</th>
<th>Cumulative VaR(99.9%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>+Q1</td>
<td>$7,784.9558</td>
<td>$648.5309</td>
<td>$10,078.3132</td>
<td>$7,784.9558</td>
<td>$648.5309</td>
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<tr>
<td>+Q5</td>
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<td>$12,933.1039</td>
<td>$37,443.8230</td>
<td>$4,124.4656</td>
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<td>+Q6</td>
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<td>$44,650.6077</td>
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<td>+Q7</td>
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<td>$65,794.3186</td>
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</tr>
</tbody>
</table>

### Intra-Period Expected Losses, $\sigma$ and VaR(99.9%) (Millions of USD)

![Graph showing Intra-Period Expected Losses, $\sigma$ and VaR(99.9%)](image)

- **Intra-Period Exp Loss**
- **Intra-Period $\sigma$**
- **Intra-Period VaR(99.9%)**
U.S. First Mortgage Portfolio – Loss Metrics (cont.)

Q1 cumulative loss

Q5 cumulative loss

Q9 cumulative loss

Q1 cumulative loss

Q5 cumulative loss

Q9 cumulative loss

Moody’s Analytics
U.S. First Mortgage Portfolio – Loss Metrics (cont.)

RCs to cumulative EL

RCs to Cumulative Loss Volatility
U.S. First Mortgages – Tail-Risk Contributions

Tail Risk Contributions for Cumulative Losses up to Q9

Moody’s Analytics
Scenario-Specific Analysis: Embedding ST Into Dynamic Portfolio Analysis
U.S. First Mortgages – Intra-Period Scenario Losses

Scenario-Specific Intra-Period Losses (Millions of USD)
U.S. First Mortgages – Cumulative Scenario

Q1 cumulative loss

Q5 cumulative loss

Q9 cumulative loss

Loss ($bn)

CCAR bl
CCAR Adv
CCAR Sev Adv

Loss ($bn)

CCAR bl
CCAR Adv
CCAR Sev Adv

Loss ($bn)

CCAR bl
CCAR Adv
CCAR Sev Adv

CCAR bl
CCAR Adv
CCAR Sev Adv
U.S. First Mortgages – Cumulative Scenario Losses (cont.)

Prob(Cumulative L<=Scenario Specific Cumulative Losses) +Q9 (End of Stress Testing Period)
U.S. First Mortgages – Cumulative Scenario Losses (cont.)

RCs to cumulative CCAR Severely Adverse

Vintage

Moody's Analytics
Practical Applications: RAROC, Optimization, Optimal Importance Sampling, and Reverse Stress Testing
Risk Adjusted Pricing (RAROC)

Analytical calculation of the portfolio volatility up to the new deal’s maturity allows us to instantaneously price.

The Sharpe ratio of the new portfolio with the new deal (or deals) should be larger than without:

\[
\frac{\mu^* - r}{\sigma(L^*)} > \frac{\mu - r}{\sigma(L)} \quad \text{BUY}
\]
Portfolio Optimisation

What is the portfolio composition $n_i$ that minimises the portfolio loss volatility given a level of expected loss (and hence return) $EL = L$?

Using the Lagrange multipliers:

$$\Lambda(n_i, \lambda) = \sigma(L; n_i) + \lambda(EL(n_i) - L)$$

Thus:

$$n_i C_i + \lambda EL_i^* = 0$$

$$\sum_{i=1}^{N} n_i EL_i^* - L = 0$$

- Extend the current framework to study DYNAMIC OPTIMISATION (infinite horizon)

*Recursive Dynamic Programming* (Bellman Equations) and the study of the optimal solutions to the underlying stochastic difference equations
Optimal Importance Sampling

Instead of drawing random numbers with unconditional probability from conditional distribution $w_z$ draw from conditional $w_z(\alpha)$. After the simulation reweigh the loss distribution using $\text{weight} = \frac{w_z}{w_z(\alpha)}$. 

Total Loss in period 4

![Diagram](image-url)
Analytical Reverse Stress Testing
Mark-to-Market Risk Examples
Interest Rates (Gov Bond Yields) and Corporate Credit Spreads
Interest Rate Modeling
Impact on government bond yields

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

Impact on 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
Credit Spread Modeling

Impact on credit spreads for financials - over maturities and rating classes

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

Aaa

A

Bbb

B