Consumer & Retail Credit Forecasting: DFAST bank case study with Global Regulatory Requirements

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Moody’s Analytics
Agenda

• Introductions

• Practical Case Study: Meeting business and global regulatory objectives
  ➢ Forecasting & Stress Testing
  ➢ Challenges around Regulatory Submissions
  ➢ Gaining Value from the Exercise

• Consumer Credit Methodologies & Challenges
  ➢ Panel-data structures: vintage analysis as a leading example
  ➢ Multi-period simulation techniques
  ➢ Optimal allocations
  ➢ Reverse stress testing
Practical Case Study
United States vs. Europe – The Core Requirements of Stress Testing Regulations are Aligned Across Regions

<table>
<thead>
<tr>
<th>Regulatory Body</th>
<th>Europe</th>
<th>United Kingdom</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EBA / ECB / NCA 1</td>
<td>BoE / PRA 1</td>
<td>Federal Reserve</td>
</tr>
<tr>
<td>Coverage</td>
<td>Largest Eurozone/Significant Banks (approx. 128 banks)</td>
<td>Largest UK Banks &amp; Building Societies</td>
<td>BHC&amp;FBO 6; assets &gt; than $10bn (DFAST), $50bn (CCAR)</td>
</tr>
<tr>
<td>Data Requirements / Reporting</td>
<td>Historical/AQR Data – Core (ADC, TR, CSV) &amp; Additional (CSV) Templates 2,3</td>
<td>FDSF 4 – Historical, Year-End Data &amp; P/L Projections</td>
<td>FRY Reports – A/Q/M Data; P/L Projections</td>
</tr>
<tr>
<td>Modeling Approach</td>
<td>Bottom-Up &amp; Challenger/Top-Down; Firms’ Own Models</td>
<td>Bottom-Up /Granular; Firms’ Own Models</td>
<td>Bottom-Up; Firms’ Own Models; Dynamic Projections</td>
</tr>
<tr>
<td>Scenarios</td>
<td>Regulatory Baseline, Stress Scenario</td>
<td>Common Stress, Bespoke Firm Stress, Common Baseline</td>
<td>Baseline, Adverse, Severely Adverse; Firms’ Scenarios</td>
</tr>
<tr>
<td>Disclosure</td>
<td>Public Disclosure of Results (Bottom-Up)</td>
<td>Public Disclosure of Results</td>
<td>Public Disclosure of Results</td>
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<tr>
<td>Frequency</td>
<td>Annual (2009-2011 EBA); 2014 (ECB)</td>
<td>Annual</td>
<td>Annual (regulator-led); semiannual (bank-led)</td>
</tr>
<tr>
<td>Corrective Measures / Use of Outputs</td>
<td>Recapitalization Plan</td>
<td>Input Capital Adequacy CRDIV &amp; firms’ PRA buffer; FPC Tool 5</td>
<td>Input Capital Plan, Approval by Fed; Dividend Planning, etc.</td>
</tr>
</tbody>
</table>

Source – Moody’s Analytics

1. European Banking Authority (EBA), European Central Bank (ECB), National Competent Authorities (NCA), Bank of England (BoE), Prudential Regulation Authority (PRA)
2. Asset Quality Review (AQR)
3. Advanced data collection (ADC), Transparency (TR) and Calculation, Validation & Support (CSV) Templates
4. Firm Data Submission Framework (FDSF)
5. Financial Policy Committee (FPC); Capital Requirements Directive IV (CRD IV)
6. Bank Holding Companies (BHC), Foreign Banking Organizations (FBO)
Engaging the Business

- Treat as a full business planning exercise, albeit one with highly pessimistic macroeconomic assumptions (akin to business continuity management)
  - Business Units “BAU” activities
  - Staffing Decisions / Collection Efforts
- Finance should take the lead role, though Risk may provide technical expertise and tools given additional modelling challenges
- Knowledgeable project manager should coordinate work streams
- Significant time should be invested in management actions, ensuring:
  - Actions are realistic given resource and operational constraints
  - Reaction time reflects reality and doesn’t assume “benefit of foresight”
  - Customer impact is considered (avoid the sledgehammer)
- Existing mitigation impacts should be separated from new mitigants

Stress testing is a “whole business” exercise.
The Right Tools for the Job

• Sophistication of modelling approach for a given portfolio should be driven by:
  − Portfolio materiality / activity
  − Data availability
  − Sensitivity

• Ideally a single consolidated model would capture all interrelated elements

• Acknowledge the limitations of any one modelling approach, triangulate
  − Top-down vs bottom-up
  − Analytical vs intuitive
  − Predictive vs experiential

• Model output must easily fit into current practices in the Institution
  − Business units manage portfolio with a roll-rate structure in mind
  − Business Units need accounts and Dollars forecasts
  − Business Units need segmentation: retail partnerships / risk levels

There is no one “best” approach.
Gaining Value from the Exercise

• Building stress testing models will improve baseline models
• Discussing management actions under highly stressed scenarios improves response time to less severe situations and identifies operational deficiencies preventing effective responses
• Developing strong controls and processes for stress testing improves regular business planning activities
• Meeting rigorous external documentation requirements provides a sound framework for internal documentation
• Offers an opportunity to consolidate organizational knowledge
• Fully documented models
• Modelers support to key personal to ensure proper ownership of the model

Stress testing is a theoretical exercise with practical value.
Model Structure Diagram: A Vintage Approach

Active Balance

Active Balance/01-29 Dlq. Roll Rate

30-59 Dlq./60-89 Dlq. Roll Rate

90-119 Dlq./120-149 Dlq. Roll Rate

150 plus/Charge-off Roll Rate

1-29 Dlq. Balance

60-89 Dlq. Balance

90-119 Dlq. Balance

120-149 Dlq. Balance

150 plus Dlq. Balance

Charge-off Balance

Good Balance

30-59 Dlq. Balance

01-29 Dlq./30-59 Dlq. Roll Rate

60-89 Dlq./90-119 Dlq. Roll Rate

120-149 Dlq./150 plus Dlq. Roll Rate
Model Output
Portfolio Level Roll-Rates: Multiple Delinquency States

Roll-Rates: Multiple Delinquency Buckets (2005m1-2013m12)

- Portfolio: Balance Flow Rate to 1-29 Days (Spliced), Baseline
- Portfolio: Balance Flow Rate to 30-59 Days (Spliced), Baseline
- Portfolio: Balance Flow Rate to 60-89 Days (Spliced), Baseline
- Portfolio: Balance Flow Rate to 90-119 Days (Spliced), Baseline
- Portfolio: Balance Flow Rate to 120-149 Days (Spliced), Baseline
Great Variation in Vintages Sizes (as of 2013m12)

Period
- 1999 (30.38%)
- 2000 to 2003 (26.94%)
- 2004 to 2010 (15.3%)
- 2011 to 2013 (27.38%)
Charge-off Amount Across Segments
Case Study Summary

• Large Credit Card Business with footprint in different countries
  ➢ Engaging the business
  ➢ Using the right tools
  ➢ Gaining value from the exercise

• Unified methodology to forecast future performance and implement scenario analysis and stress testing exercises
  ➢ Transparency
  ➢ Unified methodology facilitates flow of information within the Institution

• On the other hand:
  ➢ Different Regulatory Environments, particularly around Stress Testing exercises
  ➢ Specific Business Needs
Vintage Methodology and Stress Testing Challenges
Methodology: Dynamic Panel-Data Structure

Time series performance for a given vintage and segment = \( f \)

(1) Lifecycle component
- Dynamic evolution of vintages as they mature
- Nonlinear model against “age”

(2) Vintage-quality component
- Vintage attributes (LTV, asset class/collateral type, geography, etc.) define heterogeneity across cohorts
- Early arrears serve as proxies for underlying vintage quality
- Economic conditions at origination matter
- Econometric technique accounts for time-constant, unobserved effect

(3) Business cycle exposure component
- Sensitivity of performance to the evolution of macroeconomic and credit series
US Auto PD Model – Fixed-Effects Panel Data Estimation

<table>
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<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>Number of obs = 465</th>
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<td>9.90869691</td>
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<td>5.67184058</td>
<td>416</td>
<td>0.01363423</td>
<td>46</td>
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<tr>
<td>Total</td>
<td>481.289292</td>
<td>464</td>
<td>1.03726141</td>
<td>46</td>
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</table>

log_pd

| log pd | Coef.   | Std. Err. | t     | P>|t| | [95% Conf. Interval] |
|--------|---------|-----------|-------|------|----------------------|
| dummy_age_1 | 1.631347 | 0.0473693 | 34.44 | 0.000 | 1.538234, 1.724466 |
| dummy_age_2 | 2.217711 | 0.0805546 | 27.53 | 0.000 | 2.059367, 2.376056 |
| dummy_age_3 | 2.041324 | 0.1159124 | 34.44 | 0.000 | 1.813477, 2.269171 |
| dummy_age_4 | 1.643777 | 0.1465386 | 11.31 | 0.000 | 1.368728, 1.918825 |
| dummy_age_5 | 1.279536 | 0.1661623 | 7.70  | 0.000 | 0.952913, 1.606158 |
| dummy_age_6 | 0.940323 | 0.1867412 | 5.04  | 0.000 | -0.083749, 0.014595 |
| dummy_age_7 | 0.650373 | 0.2102897 | 3.07  | 0.002 | 0.228924, 0.471732 |
| dummy_age_8 | 0.341205 | 0.253284 | 2.00  | 0.046 | 0.001659, 0.582834 |
| dummy_age_9 | 0.106486 | 0.0533284 | 2.00  | 0.046 | 0.001659, 0.582834 |
| dummy_age_10 | 0.461767 | 0.0382239 | 12.08 | 0.000 | 0.386580, 0.536852 |

0.005 0.01 0.015 0.02

pd

Histogram of Residuals

Multi-period Simulation Analysis
Dynamic Macroeconomic Scenarios
Bayesian Estimation – Prior & Posterior Distributions – Simulations

\[ f(\theta | x) = \frac{f(x | \theta) f(\theta)}{f(x)} \]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Density</th>
<th>(1)</th>
<th>(2)</th>
<th>Parameter</th>
<th>Density</th>
<th>(1)</th>
<th>(2)</th>
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<td>InvGamma</td>
<td>0.10</td>
<td>2.00</td>
<td>( \rho_w )</td>
<td>Beta</td>
<td>0.50</td>
<td>0.20</td>
</tr>
<tr>
<td>( \sigma_b )</td>
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<td>2.00</td>
<td>( \mu_p )</td>
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<td>0.20</td>
</tr>
<tr>
<td>( \sigma_c )</td>
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<td>2.00</td>
<td>( \mu_w )</td>
<td>Beta</td>
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<td>0.20</td>
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<tr>
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<td>( \rho_a )</td>
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<td>0.50</td>
<td>0.20</td>
<td>( r_{sy} )</td>
<td>Normal</td>
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<td>0.05</td>
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<td>( \rho_b )</td>
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<td>0.50</td>
<td>0.20</td>
<td>( \bar{T} )</td>
<td>Normal</td>
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<td>2.00</td>
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<td>( \rho_c )</td>
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<td>( \rho_{pe} )</td>
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<td>0.20</td>
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<td>0.20</td>
<td>( 100(\beta^{-1} - 1) )</td>
<td>Gamma</td>
<td>0.25</td>
<td>0.10</td>
</tr>
</tbody>
</table>

US Auto PD Model – Projections – 2012Q3 Vintage

2012Q3 Vintage at +Q5
Default Rate (#) over Simulations (ordered by macro ranking)

2012Q3 Vintage at +Q5: Histogram of Default Rates (#)
US Auto PD Model – Projections – 2014Q3 Vintage
Dynamic Forecast – Example of PD Projections for a “Future” Vintage
### US Auto Lending – Multi-period Analytical Metrics

**Expected and Unexpected (Volatility) Losses**

<table>
<thead>
<tr>
<th>Period</th>
<th>EL ($m)</th>
<th>Analytical Volatility ($m)</th>
<th>Monte Carlo Volatility ($m)</th>
<th>Cumulative EL ($m)</th>
<th>Cumulative Analytical Volatility ($m)</th>
<th>Cumulative Monte Carlo Volatility ($m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>1321</td>
<td>80.3</td>
<td>80.3</td>
<td>1321</td>
<td>80.3</td>
<td>80.3</td>
</tr>
<tr>
<td>Q2</td>
<td>1322</td>
<td>96.2</td>
<td>96.4</td>
<td>2644</td>
<td>152.4</td>
<td>152.5</td>
</tr>
<tr>
<td>Q3</td>
<td>1309</td>
<td>110.0</td>
<td>109.9</td>
<td>3953</td>
<td>235.2</td>
<td>235.5</td>
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<tr>
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<td>123.2</td>
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<td>329.6</td>
<td>329.7</td>
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<td>Q6</td>
<td>1243</td>
<td>145.5</td>
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<td>552.1</td>
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<tr>
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<td>1225</td>
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<td>155.2</td>
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<td>10182</td>
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<td>Q9</td>
<td>1197</td>
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<td>172.1</td>
<td>11379</td>
<td>950.3</td>
<td>950.4</td>
</tr>
</tbody>
</table>
Portfolio Optimization

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 methodology:

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

The efficient frontier can be calculated by solving the following system of equations:

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

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

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

**Recursive Dynamic Programming** (Bellman Equations) and the study of the optimal solutions to the underlying stochastic difference equations.
Reverse Stress Testing
Reverse Stress Testing – Mathematical Challenges

The math behind reverse engineering of risk modeling

Macro & Capital Market Scenarios

Risk Parameters & Correlation: Credit, Market, Liquidity, Organizational Risks

Outputs: Loss Distribution, Capital Requirements, Liquidity, etc.

But $z_1 \rightarrow \{y_1, y_2, ..., y_s\} \rightarrow \{x_1, x_2, ..., x_{n+m}\}$ opens the door to multiplicity

$\text{LGD} = f(\text{PD})$
Reverse Stress Testing – US Auto Lending Example

Output: Updated Distribution of Scenarios
Case 1: L < EL

Output: Updated Distribution of Scenarios
Case 2: L > EL

Starting Distribution
Scenarios are ranked-ordered by severity
L = EL (unconstrained)
To learn more about this topic:

» Make an appointment to meet 1-1 with our experts in the Solutions Café:
  – Cris deRitis, Senior Director
  – Erlind Dine, Senior Product Strategist
  – Jeffrey Hollander, Solutions Specialist
  – Juan Licari, Senior Director
  – Tony Hughes, Managing Director

» Attend related sessions taking place after this session:
  – Economic Scenario Generation for Stress Testing
  – Consumer and Retail Credit Forecasting
  – Cyclical Loss Volatility in Auto Lending

» Read related materials available in the RPC Mobile App:
  – Designing Macroeconomic Scenarios for Stress Testing
  – Is U.S. Auto Lending About to Bubble Over?