Operational Risk

Presentation for QRM Students

Michael Amrein, Dr. sc. ETH Zurich, Actuary SAA
Executive Director, Model Risk Management & Control
Head Monitoring, Surveillance & Operational Risk Models Validation

May 23rd, 2019
Disclaimer

The views and opinions expressed in this presentation are those of the author, may not reflect the views and opinions of UBS and should not be cited as being those of UBS.

This document/presentation and the information contained herein are provided solely for information purposes, and are not to be construed as a solicitation of an offer to buy or sell any securities or other financial instruments in Switzerland, the United States or any other jurisdiction. No investment decision relating to securities of or relating to UBS AG or its affiliates should be made on the basis of this document. Refer to UBS’s first quarter 2019 report and its Annual Report on Form 20-F for the year ended 31 December 2018 for additional information. These reports are available at www.ubs.com/investors. No representation or warranty is made or implied concerning, and UBS assumes no responsibility for, the accuracy, completeness, reliability or comparability of the information contained herein relating to third parties, which is based solely on publicly available information.

© UBS 2019. The key symbol and UBS are among the registered and unregistered trademarks of UBS. All rights reserved.
Topics of Today's Lecture

- What is Operational Risk (Op Risk)?
- Applications of Operational Risk models in the banking industry
  - Op Risk Measurement – Pillar 1 (Minimum capital requirements)
  - Op Risk Measurement – Pillar 2 (Supervisory review of capital adequacy)
  - Monitoring & Surveillance of Op Risks
Section 1

What is Operational Risk?
Definition of Operational Risk (Op Risk)?

- Definition (Basel Committee): The risk of loss resulting from inadequate or failed internal processes, people and systems or from external events. This definition includes
  - Legal Risk – financial loss that can result from lack of awareness or misunderstanding of, ambiguity in, or reckless indifference to, the way law and regulation apply to your business, its relationships, processes, products and services
  but excludes
  - Strategic Risk – loss arising from a poor strategic business decision
  - Reputational Risk - damage to an organization through loss of its reputation or standing

- The seven Basel Op Risk categories
  - **Internal Fraud** – misappropriation of assets, tax evasion, intentional mismarking of positions, bribery
  - **External Fraud** – theft of information, hacking damage, third-party theft and forgery
  - **Employment Practices and Workplace Safety** – discrimination, workers compensation, …
  - **Clients, Products, and Business Practice** – market manipulation, product defects, fiduciary breaches, …
  - **Damage to Physical Assets** – natural disasters, terrorism, vandalism
  - **Business Disruption and Systems Failures** – utility disruptions, software failures, hardware failures
  - **Execution, Delivery, and Process Management** – data entry errors, accounting errors, …
Examples of Op Risk Losses

Forex Scandal

In the course of 2014 and 2015, Barclays, Citi, JP Morgan, Royal Bank of Scotland and UBS were forced to pay more than $5.6 bn* to UK and US authorities.

Libor Scandal

Several banks and brokers pay settlements of close to $9 bn to regulators in relation to the rigging of benchmark interest rates.

BNP Paribas Sanctions Violations

BNP Paribas was forced to pay $9 bn to US authorities in June 2014 after admitting that it flouted sanctions against Cuba, Iran and Sudan.

* In English, 1bn = 1 billion = 10^9
Deutsche Bank agreed to pay a civil monetary penalty of $3.1 bn and to provide $4.1 bn in consumer relief in the US in connection with the bank’s issuance and underwriting of Residential mortgage-backed securities (RMBS) between 2005 and 2007.

Prosecutors estimated the size of the fraud to be $64.8 bn, based on the amounts in the accounts of Madoff’s 4800 clients as of November 30, 2008.

$2 bn* were lost as a result of unauthorized trading performed by Kweku Adoboli, a director of the bank’s Global Synthetic Equities Trading team in London.

* In English, 1bn = 1 billion = 10^9
A number of banks has experienced material yearly OR losses in recent years

<table>
<thead>
<tr>
<th>Parent Name</th>
<th>Tot CHF m</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank of America Corporation</td>
<td>37,305</td>
<td>406</td>
<td>38</td>
<td>177</td>
<td>951</td>
<td>111</td>
<td>67</td>
<td>28</td>
<td>1,355</td>
<td>1,025</td>
<td>610</td>
<td>12,291</td>
<td>3,916</td>
<td>11,736</td>
</tr>
<tr>
<td>Citigroup Incorporated</td>
<td>17,234</td>
<td>37</td>
<td>565</td>
<td>2,708</td>
<td>2,484</td>
<td>145</td>
<td>96</td>
<td>1,796</td>
<td>1,054</td>
<td>534</td>
<td>166</td>
<td>3,288</td>
<td>3,329</td>
<td>872</td>
</tr>
<tr>
<td>Wells Fargo &amp; Company</td>
<td>11,777</td>
<td>10</td>
<td>11</td>
<td>44</td>
<td>16</td>
<td>9</td>
<td>12</td>
<td>24</td>
<td>323</td>
<td>347</td>
<td>6,226</td>
<td>4,403</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Deutsche Bank</td>
<td>8,729</td>
<td>4</td>
<td>114</td>
<td>101</td>
<td>377</td>
<td>227</td>
<td>28</td>
<td>67</td>
<td>91</td>
<td>613</td>
<td>179</td>
<td>586</td>
<td>3,111</td>
<td>1,205</td>
</tr>
<tr>
<td>Societe Generale Group</td>
<td>7,871</td>
<td>11</td>
<td>5</td>
<td>124</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td>7,375</td>
<td>8</td>
<td>53</td>
<td>93</td>
<td>12</td>
<td>175</td>
<td></td>
</tr>
<tr>
<td>HSBC Holdings PLC</td>
<td>6,329</td>
<td>482</td>
<td>94</td>
<td>21</td>
<td>4</td>
<td>55</td>
<td>260</td>
<td>174</td>
<td>245</td>
<td>1,070</td>
<td>106</td>
<td>2,210</td>
<td>1,015</td>
<td>2</td>
</tr>
<tr>
<td>Credit Suisse Group</td>
<td>5,291</td>
<td>195</td>
<td>194</td>
<td>203</td>
<td>38</td>
<td>220</td>
<td>145</td>
<td>13</td>
<td>1,221</td>
<td>35</td>
<td>593</td>
<td>27</td>
<td>449</td>
<td>1,220</td>
</tr>
<tr>
<td>Barclays PLC</td>
<td>5,068</td>
<td>112</td>
<td>4</td>
<td>141</td>
<td>419</td>
<td>101</td>
<td>16</td>
<td>322</td>
<td>129</td>
<td>481</td>
<td>27</td>
<td>449</td>
<td>1,220</td>
<td></td>
</tr>
<tr>
<td>Royal Bank of Scotland Group PLC</td>
<td>4,837</td>
<td>7</td>
<td>1</td>
<td>11</td>
<td>40</td>
<td>36</td>
<td>196</td>
<td>568</td>
<td>12</td>
<td>82</td>
<td>80</td>
<td>258</td>
<td>3,178</td>
<td>309</td>
</tr>
<tr>
<td>Morgan Stanley</td>
<td>3,620</td>
<td>1</td>
<td>166</td>
<td>80</td>
<td>229</td>
<td>141</td>
<td>133</td>
<td>133</td>
<td>714</td>
<td>118</td>
<td>111</td>
<td>70</td>
<td>334</td>
<td>1,387</td>
</tr>
<tr>
<td>American International Group Incorporated</td>
<td>2,823</td>
<td>9</td>
<td>135</td>
<td>17</td>
<td>21</td>
<td>239</td>
<td>198</td>
<td>32</td>
<td>918</td>
<td>609</td>
<td>507</td>
<td>19</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>SunTrust Banks Incorporated</td>
<td>2,705</td>
<td>12</td>
<td>1</td>
<td>1</td>
<td>26</td>
<td>1</td>
<td>17</td>
<td>842</td>
<td>36</td>
<td>1,754</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goldman Sachs Group</td>
<td>2,319</td>
<td>2</td>
<td>112</td>
<td>72</td>
<td>55</td>
<td>44</td>
<td>2</td>
<td>105</td>
<td>175</td>
<td>639</td>
<td>12</td>
<td>201</td>
<td>394</td>
<td></td>
</tr>
<tr>
<td>Bank of China</td>
<td>2,285</td>
<td>619</td>
<td>56</td>
<td>86</td>
<td>6</td>
<td>161</td>
<td>19</td>
<td>98</td>
<td>500</td>
<td>2</td>
<td>490</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- A number of banks has experienced material yearly OR losses in recent years
Section 2

Op Risk Measurement – Pillar 1
Minimum Capital Requirements

- Banks must hold a regulatory minimum capital for Op Risk. Currently, there are three approaches.
  - **Basic Indicator Approach (BIA)**
    - for regional, non-complex firms
    - not risk-sensitive
  - **The Standardized Approach (TSA)**
    - expected for most financial services firms
    - not risk-sensitive
  - **Advanced Measurement Approach (AMA)**
    - is currently in place at many of the global systemically important banks and requires prior regulatory approval
    - involves complex statistical modelling, allows for flexibility
Basic Indicator Approach (BIA)

- The Regulatory Capital (RC) under the BIA equals 15% of the average annual gross income over the previous three years where it was positive, i.e.,

\[
RC^{BIA}_t = 15\% \cdot \left( \frac{\sum_{k=1}^{3} \max\{GI_{t-k}, 0\}}{\sum_{k=1}^{3} \mathbb{I}_{GI_{t-k} > 0}} \right)
\]

where \(GI_{t-k}\) is the annual gross income in year \(t - k\)
The Standardized Approach (TSA)

- The TSA is similar to the BIA, but the calculation is performed separately for each business line with different weights, i.e., the Regulatory Capital (RC) is given by

\[
RC_{TSA}^t = \frac{1}{3} \cdot \sum_{k=1}^{3} \max\left\{ \sum_{b=1}^{8} \beta_b G_{t-k}^b, 0 \right\}
\]

where \( G_{t-k}^b \) is the annual gross income in year \( t - k \) of business line \( b \) and \( \beta_b \) is its weight.

- The 8 business lines and their weights are (note the sum of weights is equal 1.2 = 8x15%):
  - Corporate finance (18%)
  - Trading & sales (18%)
  - Retail banking (12%)
  - Commercial banking (15%)
  - Payment & Settlement (18%)
  - Agency Services (15%)
  - Asset management (12%)
  - Retail brokerage (12%)
Advanced Measurement Approach (AMA)

- Allows banks to use their internally generated risk estimates

- Supervisory Guidance:
  - Operational Risk – Supervisory Guidelines for the Advanced Measurement Approaches, Basel Committee on Banking Supervision
  - Supervisory Guidance for Data, Modeling, and Model Risk Management Under the Operational Risk Advanced Measurement Approaches, FED
  - … (and more)

- The Regulatory Capital is equal to the **Op Risk loss that is exceeded only once in 1000 years**, i.e., $\text{VaR}_{0.999}(L)$, where the random variable $L$ is the total annual Op Risk loss.

- Common approach to model $L$, taken in large banks, is the Loss Distribution Approach (LDA)
Typical LDA Setup within the AMA Framework

- Define Units of Measure (UoM)
  - A UoM combines business lines / loss event types, e.g. Investment Bank / Fraud

- For each UoM \( u \), \( u \in \{1, 2, ..., U\} \), we model the annual loss \( L_u \) as compound sum of
  - the annual loss frequency: \( N_u \) is number of losses in UoM \( u \) per year
  - the loss severity: \( X_{k,u} \) is the amount of the \( k \)-th loss in UoM \( u \),

  that is, \( L_u = \sum_{k=1}^{N_u} X_{k,u} \),

  where we assume that \( \{X_{k,u}: k = 1, 2, ..., N_u\} \) are i.i.d and independent from \( N_u \).

- The total annual Op Risk loss \( L \) is then \( L = \sum_{u=1}^{U} L_u \).

  Very challenging problem! We need to estimate / justify
  - Segmentation into UoM
  - Frequency distribution, i.e., distribution of \( N_u \)
  - Severity distribution, i.e., distribution of \( X_{1,u} \)
  - Dependence between UoM via copula
The Four Data Elements For LDA Estimation

More objective but backward-looking:

- **Internal Operational Loss Event Data (ILD)**
- **External Operational Loss Event Data (ELD)**
  - data consortia, e.g. Operational Riskdata eXchange Association (homogeneous classification standards, data relevance)
  - publicly available data, e.g. media or annual reports (reporting bias)

Forward-looking but more subjective:

- **Scenario Analysis (SA)**
  - systematic process of obtaining expert opinions to derive reasoned assessments of the likelihood and loss impact of plausible, high-severity operational losses, typically developed through workshops
  - Expert biases (overconfidence, anchoring, …) and subjectivity
- **Business Environment and Internal Control Factors (BEICF)**
  - indicators designed to provide a forward-looking assessment of a banking organization's business risk factors and internal control environment (impact of discontinuing a line of business, a change in the internal control environment, …)
  - might be used to adjust operational risk exposure
Modelling Options within LDA

• Frequency: Poisson, Negative Binomial, \( N \sim NB(r, p) \) \( \iff \) \( P[N = n] = \binom{n+r-1}{n} p^n (1-p)^r, n \in \mathbb{N}_0 \)

• Severity: Log-Normal, Log-Gamma, Generalized Pareto, …

• Dependence
  – Dependence between annual losses \( L_u, u \in \{1, 2, \ldots, U\} \) vs dependence on frequency / severity level
  – Copulas: \( t \), Clayton, Gumbel, Frank, …

• Use the four data elements (ILD, ELD, SA, BEICF)
  – Filtering ELD to remove non-relevant events
  – Scaling ELD to account for differences in size or business activities
  – Mixing data vs mixing distributions, e.g. fit distribution to ILD plus weighted ELD vs fit distributions to both ILD and ELD and mix the densities
  – Benchmarking, e.g., compare ILD based main model with ELD challenger based model
  – Build and own SA distribution vs SA based adjustments
  – Bayesian approach: use SA distributions as prior and calculate posterior given ILD and ELD
  – Parameter adjustments based on BEICF
  – … (use your imagination)

➤ The flexibility is tremendous within LDA!
AMA Model from UBS in a Nutshell

<table>
<thead>
<tr>
<th>Model component</th>
<th>Modelling choice</th>
<th>Data elements used for calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Units of Measure</td>
<td>• Expert driven definition&lt;br&gt;• Typically an internal risk category, e.g. External Fraud, Market Conduct, Suitability, Cross Border Business Conduct</td>
<td>• None</td>
</tr>
<tr>
<td>Event Frequency</td>
<td>• Negative Binomial distribution</td>
<td>• ILD</td>
</tr>
<tr>
<td>(per UoM)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Event Severity</td>
<td>• Body: Continuous version of the empirical distribution&lt;br&gt;• Tail: Truncated lognormal distribution&lt;br&gt;• Truncation point is unknown</td>
<td>• ILD&lt;br&gt;• Filtered and weighted ELD</td>
</tr>
<tr>
<td>(per UoM)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dependence</td>
<td>• Mirrored Clayton copula to link annual UoM loss distributions</td>
<td>• ILD</td>
</tr>
<tr>
<td>Expert Adjustments</td>
<td>• Frequency: adjustment of the expected number of events per year&lt;br&gt;• Severity: uniform scaling of the severity distribution with a constant</td>
<td>• SA&lt;br&gt;• BEICF</td>
</tr>
</tbody>
</table>

**Capital Calculation**

- Calculation of cumulative loss distribution (CLD) per UoM via discretization of severity distribution combined with Fast Fourier Transform
- Aggregation of UoM CLD's via copula using Monte Carlo simulation. To control the Monte Carlo simulation error, capital calculation is averaged over 100 repetitions with sample size 1'000'000
Some Insights into Frequency Calibration

- Several models were investigated for the event frequency
  - Poisson, Neg Bin (variance is a quadratic function of the mean), Neg Bin Linear (variance is a linear function of the mean)
  - no trend in mean over time, linear trend in mean (using a generalized linear model) and piecewise cubic trend in mean (using a generalized additive model)

- Akaike Information Criterion (AIC), Kolmogorov-Smirnoff (K-S) and Anderson-Darling (A-D) tests were used to evaluate goodness of fit

<table>
<thead>
<tr>
<th>Model</th>
<th>AIC</th>
<th>K-S</th>
<th>A-D</th>
<th>$\lambda$ (Year)</th>
<th>$\sigma$</th>
<th>$r^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poisson</td>
<td>7677</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>1624.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NegBin</strong></td>
<td><strong>1813</strong></td>
<td><strong>0.8</strong></td>
<td><strong>0.7</strong></td>
<td><strong>1624.25</strong></td>
<td><strong>39.55</strong></td>
<td><strong>41.07</strong></td>
</tr>
<tr>
<td>Poisson GLM</td>
<td>6928</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>1212.77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NBL GLM</td>
<td>1791</td>
<td>0.16</td>
<td>0.06</td>
<td>1212.77</td>
<td>41.23</td>
<td>29.42</td>
</tr>
<tr>
<td>NegBin GLM</td>
<td>1785</td>
<td>0.1</td>
<td>0.07</td>
<td>1055.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poisson GAM</td>
<td>2468</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>657.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NBL GAM</strong></td>
<td><strong>1586</strong></td>
<td><strong>0.55</strong></td>
<td><strong>0.17</strong></td>
<td><strong>664.41</strong></td>
<td><strong>8.85</strong></td>
<td><strong>75.06</strong></td>
</tr>
<tr>
<td>NegBin GAM</td>
<td>1576</td>
<td>0.36</td>
<td>0.21</td>
<td>664.41</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Some Insights into Dependence Calibration

- Direct estimation of the copula is difficult: we had only 14 data points for a 15 dimensional copula.

- A permutation test (that reflects the copula in question) with test statistic maximum yearly loss over all UoM was chosen to analyse four one parameter copula families (mirrored-Clayton, Gumbel, t with v degrees of freedom and no correlation, equicorrelated Gaussian).

- The p-values quickly decrease monotonically as the parameters move away from independence.

<table>
<thead>
<tr>
<th>mirrored-Clayton</th>
<th>Gumbel</th>
<th>Student-t</th>
<th>Gaussian</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta$</td>
<td>p-value</td>
<td>$\theta$</td>
<td>p-value</td>
</tr>
<tr>
<td>0.00</td>
<td>0.2792</td>
<td>1.00</td>
<td>0.2723</td>
</tr>
<tr>
<td>0.02</td>
<td>0.2306</td>
<td>1.02</td>
<td>0.2354</td>
</tr>
<tr>
<td>0.04</td>
<td>0.2060</td>
<td>1.04</td>
<td>0.2066</td>
</tr>
<tr>
<td>0.06</td>
<td>0.1734</td>
<td>1.06</td>
<td>0.1736</td>
</tr>
<tr>
<td>0.08</td>
<td>0.1479</td>
<td>1.08</td>
<td>0.1540</td>
</tr>
<tr>
<td>0.10</td>
<td>0.1335</td>
<td>1.10</td>
<td>0.1308</td>
</tr>
<tr>
<td>0.12</td>
<td>0.1149</td>
<td>1.12</td>
<td>0.1193</td>
</tr>
<tr>
<td>0.14</td>
<td>0.1003</td>
<td>1.14</td>
<td>0.1033</td>
</tr>
<tr>
<td>0.16</td>
<td>0.0864</td>
<td>1.16</td>
<td>0.0893</td>
</tr>
<tr>
<td>0.18</td>
<td>0.0749</td>
<td>1.18</td>
<td>0.0777</td>
</tr>
<tr>
<td>0.20</td>
<td>0.0654</td>
<td>1.20</td>
<td>0.0707</td>
</tr>
<tr>
<td>0.22</td>
<td>0.0600</td>
<td>1.22</td>
<td>0.0650</td>
</tr>
<tr>
<td>0.24</td>
<td>0.0565</td>
<td>1.24</td>
<td>0.0514</td>
</tr>
<tr>
<td>0.26</td>
<td>0.0486</td>
<td>1.26</td>
<td>0.0506</td>
</tr>
<tr>
<td>0.28</td>
<td>0.0389</td>
<td>1.28</td>
<td>0.0407</td>
</tr>
<tr>
<td>0.30</td>
<td>0.0364</td>
<td>1.30</td>
<td>0.0413</td>
</tr>
</tbody>
</table>
Main Criticisms

• Comparability of AMA minimum capital figures is questionable due to the full methodological freedom within the LDA

• How reliable are the quantitative estimates? 1-in-1000 year loss vs 15 years of ILD!
  – Limited availability of data / high confidence levels ➔ uncertainty / instability in estimates
  – Over-fitting and extrapolation issues

Standardized Measurement Approach (SMA)

• A more simple and comparable approach will be implemented in 2022, see Standardized Measurement Approach for Operational Risk, Basel Committee on Banking Supervision

• The SMA combines the Business Indicator, a simple financial statement proxy of operational risk exposure, with bank-specific operational loss data to provide some incentive for banks to improve their operational risk management

• Nevertheless, comparability of capital charges remains a concern because
  – the collection of operational loss data is still determined by individual bank rules (no common standard),
  – national regulators may grant exclusion of (parts of) the loss history from the calculation (due to backward-looking nature of the SMA).
Section 3

Op Risk Measurement – Pillar 2
In the Internal Capital Adequacy Assessment Process a bank needs to assess (among other things) whether it considers its capital adequate to cover the level and nature of the risks to which it is exposed.

This includes the risk types from Pillar 1, but extends to every possible risk type and their aggregation / diversification.

<table>
<thead>
<tr>
<th>Position risks</th>
<th>Credit</th>
<th>Loans</th>
<th>Derivatives</th>
<th>IB Loan Underwriting</th>
<th>Issuer</th>
<th>Settlement</th>
<th>Country (transfer) risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market</td>
<td></td>
<td>Trading books</td>
<td>Banking book</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investment</td>
<td></td>
<td>Equity investments</td>
<td>Debt financial investments</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consequential risks</td>
<td>Operational risk</td>
<td>Funding risk</td>
<td>Structural FX</td>
<td>Property &amp; equipment risk</td>
<td>Uncertain tax risk</td>
<td>Pension risk</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Business risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Liquidation cost</td>
<td></td>
</tr>
</tbody>
</table>
Economic Capital: amount of capital required to ensure solvency over a year with a pre-specified probability (e.g. 95% or 99.9%)

Risk types are modelled via their annual marginal loss distribution and then aggregated using copulas.

- For Op Risk, LDA can be used again (if one already has an AMA LDA model)
**Stress Testing**

- Senior UBS representatives from Risk, Research, and the business discuss major economic concerns.
- Economists define 70 to 90 macroeconomic and financial market factors (e.g. real GDP, unemployment rate, equity prices, interest rates, real estate prices, ...) of the scenario for the next 8 quarters.

**Scenario**

- **Credit Drivers**
  - PD
  - LGD
  - EAD
  - Spread
  - IR
  - FX
  - EQ
- **Market Drivers**
  - Spread
  - IR
  - FX
  - EQ
- **Business Drivers**
  - Fee income
  - Trading Income
  - FXInterest Income

**Portfolio Risk Drivers**

**Stress Losses**

- **Credit Risk**
- **Market Risk**
- **Issuer Risk**
- **Investment Risk**
- **Country Risk**
- **Operational Risk**
- **Funding Risk**
- **Structural FX**
- **Pension Risk**
- **Business Risk**

**Results**

- **PnL**
- **OCI impacts**
- **Reg Cap impacts**
- **RWA impacts**
- **LRD impacts**

**Summation**

**CET1 Capital Ratio**

Critical threshold

Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8

**Stress Testing**: analysis to determine whether there is enough capital to withstand the impact of an unfavorable economic scenario, including the causality chain by which losses would arise if the scenario were to unfold.
Stress Testing Op Risk Model Overview*

Per risk category (e.g. External Fraud, Market Conduct, Suitability, Cross Border Business Conduct):

- The linkage of event frequencies and loss severities to macroeconomic variables is investigated via generalized linear models
  - Frequency: log-link with Poisson distribution
  - Severity: log-link with Gamma distribution (constant shape)

- If a link can be established, expected number of events (frequency) and/or expected loss size (severity) are predicted with the model for each quarter and normalized with the historical quarterly average to calculate quarterly stress factors $SF_{Freq,t}$ and $SF_{Sev,t}$ for $t = 1,2,...,n$ – otherwise, the stress factor is set to 1.

- The quarterly stress loss in quarter $t$ is calculated via
  \[
  \text{StressLoss}_t = \frac{\text{Expected Loss under AMA}}{4} \cdot SF_{Freq,t} \cdot SF_{Sev,t}
  \]
  (assuming independence between frequency and severity)

* Model used in 2018
Section 4

Monitoring & Surveillance of Op Risks
We use **alert generating** models to monitor many of our key operational risks in the bank.

**Goals:**
- Detect improper client and employee practices at the earliest opportunity
- Deal with ever more complex rules and increasing severity of noncompliance
- Effective and efficient use of human resources
Typical Characteristics of a M&S Model

- M&S-Models are embedded in a subject matter expert review process

- Essentially a binary classification problem: predict "fraud" (alert) or "non-fraud" (no alert)

<table>
<thead>
<tr>
<th>Prediction / Actual</th>
<th>&quot;Fraud&quot;</th>
<th>&quot;Non-Fraud&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alert</td>
<td>True Positives</td>
<td>False Positives – Type I Error</td>
</tr>
<tr>
<td>Non Alert</td>
<td>False Negatives – Type II Error</td>
<td>True Negatives</td>
</tr>
</tbody>
</table>

- Often large amounts of data are being processed:
  Conversations (emails, chat streams, audio data) / trade data / client transaction data
Modelling Techniques for M&S

- Often rule / lexical search based
- Use of Machine Learning is taking up speed in this area
  - Classification / supervised learning
    - Logistic Regression
    - Linear and quadratic discriminant analysis
    - Trees / Random Forests
    - Support Vector Machines
    - Artificial Neural Networks
    - …
  - Clustering / unsupervised learning (for feature engineering and dimension reduction)
    - K-means / K-medoids
    - Nonparametric density estimation
    - Hierarchical clustering
    - Principal Component Analysis
    - …
Q&A