Scenario Analysis in Operational Risk

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Overview

1. Problem Statement
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3. Outlook

Main Problem

- Understand the effect of scenario based analysis on a base-line loss distribution approach operational risk model.
- Formulate a methodology that takes input from business experts to determine an adjusted operational risk capital.

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- Problem framed by investigating impact of several catastrophic events that classify as operational risk events that affect a bank. Obtain frequency estimates of events occurring.
- Assign few levels of probability to the severity of events.
- How can we collect useful information about the disaster happening frequency, the probability of each severity level, and the impact on specific cell of bank business lines?
- The historical data is of shortage, that is the main reason of scenario analysis being proposed. The idea is to organize workshop to solicit useful information from experts.
  - frequency and severity possibility information from disaster planning experts/insurance P&C experts
  - banking experts provide useful information about possible financial impact on the bank.

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Toy example: assumptions and notations

- Toy example assumption:
  - 2 catastrophic events
    - Event 1: Vancouver earthquake, denoted by E
    - Event 2: Montreal ice storm, denoted by S
  - 3 Severity level
    - Level 1: low, indicated by 1
    - Level 2: medium, indicated by 2
    - Level 3: high, indicated by 3
  - 2×3 specific scenarios, i.e. a catastrophic event at a specific severity level, which is denoted by

$$\{E(j), \quad S(j)\} \quad j = 1, 2, 3$$

    for instance, the scenario of Montreal ice storm at medium severity level is denoted by $S(2)$.
  - 10 bank business line cells, denoted by

$$B_k, \quad k = 1, 2, \cdots, 10.$$

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Capturing useful information from disaster planning experts

- Frequency information:
  - Vancouver earthquake is a 1 in 100 years event, to obtain the probability $\mathbb{P}(E)$.
  - Montreal ice storm is a 1 in 20 years event, to obatin the probability $\mathbb{P}(S)$.
- Severity possibility information:
  - For each catastrophic event, there are three severity levels with different probabilities.
    - For $j = 1, 2, 3$, we obtain

$$\mathbb{P}(E(j)|E) = p_{1j}$$
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Capturing information from banking experts

- Possible loss of each cell in each scenario
  - denote by L_{ijk} the possible loss once the jth event with kth severity level happens, we characterize each possible loss L_{ijk} by a lognormal random variable with a pair of parameters $(\mu_{ijk}, \sigma_{ijk})$
  - we ask two questions to calibrate $(\mu_{ijk}, \sigma_{ijk})$
    - median of possible loss m_{ijk}
    - 3/4 quantile of possible loss l_{ijk}
  - solve the following equations:

$$\begin{cases} \mu_{ijk} & = \ln(m_{ijk}) \\ \sigma_{ijk} & = \frac{\ln(\frac{l_{ijk}}{m_{ijk}})}{\Phi^{-1}(3/4)} \end{cases}$$

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Mathematical formulation of our goal

- Our goal is to determine the capital requirement due to operational loss, which is modeled by the VaR (99.9%) of annual loss. Mathematically, we need to find the 99.9% quantile of the annual loss distribution, that is to find the value x such that

$$\mathbb{P}(L > x) = 1 - 0.999$$

- Approximation

$$\begin{aligned}\mathbb{P}(L > x) = \mathbb{P}(L > x|ES)\mathbb{P}(ES) + \mathbb{P}(L > x|ES^c)\mathbb{P}(ES^c) \\ + \mathbb{P}(L > x|E^cS)\mathbb{P}(E^cS) + \mathbb{P}(L > x|E^cS^c)\mathbb{P}(E^cS^c) \\ \approx \mathbb{P}(L > x|ES^c)\mathbb{P}(ES^c) + \mathbb{P}(L > x|E^cS)\mathbb{P}(E^cS) \\ \approx \mathbb{P}(L > x|E)\mathbb{P}(E) + \mathbb{P}(L > x|S)\mathbb{P}(S)\end{aligned}$$

Pseudocode to implement the Monte Carlo approach

▷ define a $N \times 1$- vector Loss [1:N] to hold the realizations of annual losses

- start iteration for $n = 1 : N$
  ▷ Define a 2×1- vector Disater_loss [1:2] to hold the realizations of each Disaster loss
  - start iteration for $j = 1 : 2$
    - if the j event happens (generate a uniform $[0, 1]$ r.v. or a poisson r.v.)
      ▷ generate the severity level indicator $k = 1, 2, 3$
      ▷ to simulate the possible loss of each cell loss under certain scenario generate 10 loss l_{ijk} from a lognormal distribution $lognorm(\mu_{ijk}, \sigma_{ijk})$, for $i = 1, 2, \cdots, 10$
      ▷ compute the sum $\sum_{i=1}^{10} l_{ijk}$, and assign the sum to Disaster_loss [j]
    - if the j event does not happen
      ▷ then just assign 0 to Desaster_loss [j]
  - end iteration for $j = 1 : D$

  ▷ compute the sum of the vector Disaster_loss [1:2] and assign it to Loss [n]
- end iteration for $i = 1 : N$

MATLAB and C++ implementation

- We implemented the Monte Carlo approach with both MATLAB and C++.
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Outlook

- Proposed methodology provides a method to guide the scenario formulation process, quantify select parameters, and determine an adjusted operational risk capital number.
- Consider more scenarios even with reasonable correlation between each scenario.
- We only used lognormal distribution to characterize the possible loss, it would not be difficult to try other various heavy-tailed distributions (Weibull, Generalized Pareto Distribution, etc).
- Optimize our algorithm of simulations.

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THANK YOU!