Scenario Analysis For Measuring and Managing Operational Risk

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Agenda

- Scenario Data and current challenges in operational risk measurement
- Adopting an approach in an AMA framework
- Use and Evaluation of Scenario Data in the Measurement and Management of Operational Risk
- Future of stress testing

The Discussion is based on following papers:

- Dutta Kabir and D. Babbel, “Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach” Working paper, Financial Institution Center, The *Wharton School, University of Pennsylvania 2010 Also forthcoming in the Journal of Risk and Insurance*

- Dutta Kabir and J. Perry, “A Tale of Tails: An Empirical Analysis of Loss Distribution Models for Estimating Operational Risk Capital” Federal Reserve Bank of Boston Working paper, 2007

- Dutta Kabir and K. Chernak, “Generating and Validating Scenario Data in the Context of Operational Risk” (under review; expected soon)

- Babbel David, *“A Note on Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach”* Working paper, Financial Institution Center, The Wharton School, *University of Pennsylvania, 2011*

Let’s Not Reinvent the Wheel

Scenario Analysis is not a new concept and in each of the following application it is used for measurement

- Defense
- Medicine
- Manufacturing
- Marketing
- Management Strategy
- Market Risk Management

WHY?

Risk Management

Exposure Analysis

Regulatory Expectation

Possibility Analysis and Not a Forecast

- Understanding "*TAIL*" events:
  - Institutions have made considerable progress in developing internal loss data collection systems
  - Many institutions have acquired external databases, but use of external data varies considerably
  - Scenario analysis is a tool for **generating synthetic data** not yet observed

WHAT?: Data

Current State

Scenarios: Another Look

Human Cognitive Psychology

Scenario Classification

Frame Construction

Common Pitfalls

Current State: Cart Before the Horse

- Largely a data generation process:
  - Rehash of (often poor) external data
  - Sometimes Overly specialized
  - Not purpose-driven
  - Used only to satisfy regulatory expectations
  - ***"Hopeless AND Useless"*** from the measurement perspective
- "A waste of time and resources!!!":
  - Cost of completing workshops (man hours) alone can exceed several millions for a large financial institution

The Scenarios: Another Look

- Scenarios are hypothetical
- Scenarios describe processes
- Scenarios should be thought of with respect to their importance, desirability, and probability
- Scenarios are influenced by human cognitive psychology

It is a Possibility Analysis Process and Not a Confession Process

- Experts are not “really” Experts
- Some modelers imagine that any kind of data of their wish can be generated
  - Models are created without taking any consideration of how such data can be generated
  - Example: What will be the 95 percentile loss of the severity?
- Garbage in will be garbage out

Example

- At an institution, an event caused their trading system to break down on July 15, 2001. An immediate consequence was felt in trading, FX, and P&S services. Roughly 10,000 customers were affected. The institution incurred a $25 MM loss.
    - If similar events happen at Super Bank (SB), what can be our possible loss and how often?
    - What can go wrong with respect to SB's system functions for us to incur a $25 MM loss and how often?
    - Given our current infrastructure, could such event happen? If so, what will be the severity of the loss amount and how often?

The Scenario Data

- Scenarios are inherently biased
  - Beliefs are by definition biased
- In our experience we have found that the data in the following format are very common and best suited for workshop participants to answer:
  - *N* numbers of loss (with dollar amount) happening in *M-years*
  - Dollar *X* can be range or point estimates
- Some institutions generate scenarios in a bucket approach where severity ranges are predetermined for the workshop participants to fill in the frequencies

Process vs. Factors

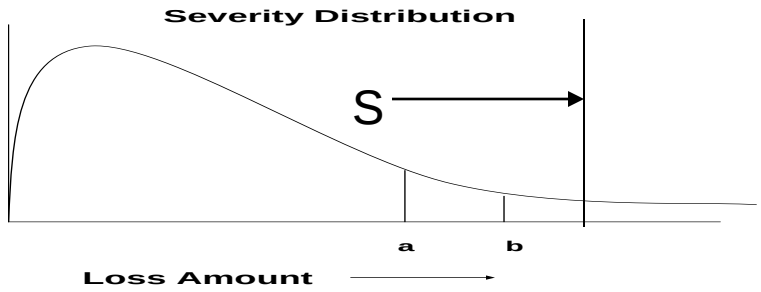
- A process is determined by the underlying factors
  - We model the process by using the factors
- A Damage to Physical Assets (DPA) process may be driven by the following factors:
  - Earthquake
  - Flood
  - Fire
- Typically scenarios are generated by factors in the workshop

Process vs. factors (continued)

- Let us consider the set of scenarios
  - A loss amount of $10 million due to earthquake happens once in 10 years
  - A loss amount of $5 million due to fire happens once in 20 years
- It will not be advisable to ignore the loss due to fire unless we know for sure that earthquake and fire can't happen at the same time
  - Earthquake loss may happen again in 20 years
  - If no other scenarios exist then at the end of 20 years a $15 million loss may happen due to both earthquake and fire

Scenario selection

- How such selection should be made?
  - By workshop
  - By scenario evaluation criteria
  - By other benchmarking process
- Example (Do we need the following scenario S?)



Scenario Data Generation and Selection for Measurement

- Scenarios are important for risk management and measurement
  - Using for management without measuring its impact is a job half done
  - Who will decide which one for management and which one for measurement? On the basis of what criteria?
- Modeler should not decide which scenario to choose
  - There is no credible mathematical or statistical approach known that can automate scenario selection process
    - We have observed in practice several misuse and misinterpretation in the scenario selection by modeler
  - Scenario selection, if needed, should be done with careful risk management consideration

Scenario Data Generation and Selection for Measurement (Continued)

- Scenario generation should be purpose driven
  - Model should be compatible to the data and not other way
- Some institutions arbitrarily generated scenarios without any regard to its purpose
- Scenario generation process is not about sampling out of severity distributions and, that's too, arbitrarily chosen
- Like internal loss data collection process scenario generation should be under close scrutiny and governance

HOW?

Modeling Challenges: Current State

Our Experience

Modeling Challenges: Current State

- Scenario data generates unrealistic capital
- Scenario data and internal data are inconsistent with respect to their meanings:
  - At an institution, an event caused their trading system to break down on July 15, 2001. An immediate consequence was felt in trading, FX, and P&S services. Roughly 10,000 customers were affected. The institution incurred a $25 MM loss
    - Scenario: 20 M (one in 10 yrs)
    - Internal data : 5 yrs old
- 1 in 10 years is not 10% -- Absolutely ABSURD!!
  - 1 in 10 years is equivalent to 10% years but probability is dimensionless
  - Dutta-Babbel made the frequency count dimensionless

Current State…..

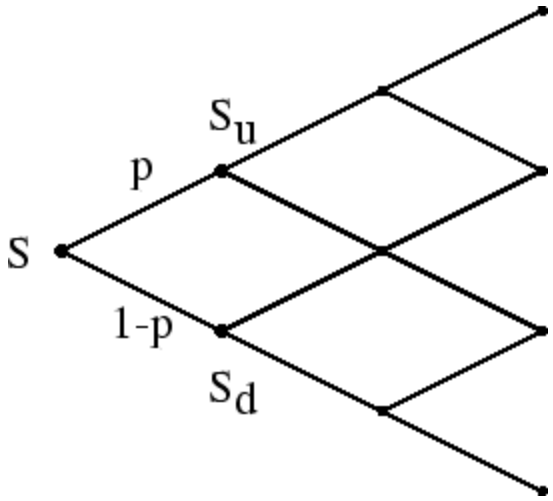
- Several approaches observed
  - Bucket Approach
  - Percentile mapping approach
  - Arbitrary distribution approach
  - Empirical approach
  - Weighting approach

Option Pricing Theory: A Scenario in the Context of Asset Prices

- CSCO is trading at $17
- At the option market you have CSCO call at strike 25, 20, 15, 10
- Each option is trading at a price which is nothing but a probability assigned for the CSCO trading at the corresponding strike price on or before the option expiration
  - It is a scenario
  - The effect of the scenario is priced for the future state given the current state (CSCO trading at $17)
  - Future state of $25 will never happen before $20 happening and $ 20 will never happen before $ 18 happening
  - Price for $25 option will be less than the price of $20 option and price of $20 option will be less than the price of $ 18
  - What about price of $15 option when the stock is trading at $ 17
- Change of measure theory
  - Is a method that Measures the future state given the current state
  - It relates future probability of a state as multiple of the probability of the current state

Example

Many different paths (scenarios) to arrive at a node in the tree

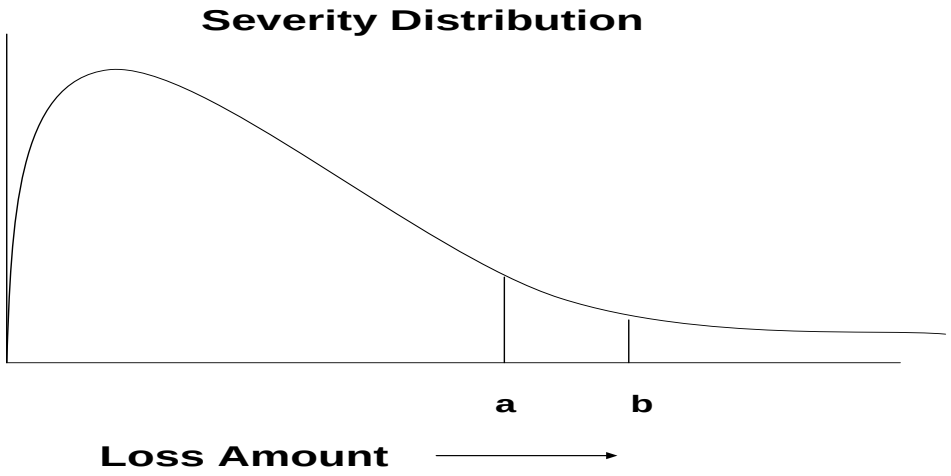


Change of Measure Theory in Operational Risk Measurement in the context of Scenario Analysis

- Internal Loss data and severity and frequency distributions derived out of internal loss data is the current state
- Scenario data are future states
- Should any, some, or all of the future states happen how does the severity and frequency distributions should change
  - Change of measure helps to find that
  - No nonsensical overflow of capital
  - Proper accounting of the effect of each of the scenarios
  - It helps one to do
    - what-if analysis
    - Stress testing
    - Complete integration of scenario with the internal data
    - More Important Scenarios at the loss level are used to model

Method of loss distribution

Using Sample: $\{X_1, X_2, \ldots., X_n\}$ we Create the following loss estimation tool the severity distribution $f(\alpha,\beta)$:



This includes any loss amount not observed in the sample, including 1 trillion dollar

Questions

Given a set of scenarios $\{S_1, S_2, \ldots, S_n\}$ independently occurring will *f(α,β) be able to "match" the "belief"?*

Given a set of scenarios $\{S_1, S_2, \ldots, S_n\}$ independently occurring what should be the value of *α and β such that the f(α,β), the severity distribution optimally matches the probabilities given in the scenarios?*

Change of Measure method introduced by Dutta and Babbel is a method for finding such *α and β and when appropriate finding f*

Measure of an Event is the Probability Measure

- By Event we mean **[a b]**
- By Measure we mean $\boldsymbol{\mu} = \int_a^b f(x)\, dx$
- Internal data based measure will not be the same as implied by the scenario
  - We systematically adjust the probability of each event as Implied by the scenarios
    - Introduce the term Implied probability by each scenario
  - Proper accounting of the effect of each of the scenarios
    - In the process of systematic adjustment we make sure the cumulative effect of implied probabilities are aggregated properly
    - Please refer to the Appendix of the paper for an example
  - Complete integration (NOT MIXING) of scenario with the internal data

Observations

- The method is based on $\int_X^Y f(x) = \frac{1}{\lambda M}, where\ \lambda$ is average frequency
- If scenario is generated in the [*$X, $Y*] with frequency 1-in-M-years format (or its variation discussed earlier) then the above formula is the only correct formulation (which can be mathematically verified)
- The above can also be easily verified by simulation
- As shown in the paper, the construction of the cumulative matrix determines the cumulative effect of a set of scenarios for both severities and frequencies

Change of Measure Multiples in the Scenario Selection

Using the Change of Measure approach one can:

- Measure the future state given the current state
- Relate future probability of a state as a multiple of the probability of the current state
- In the context of operational risk, relate the probability of future state given in the scenario as a multiple of the probability of the current state
- $$\text{COM} = \frac{\text{Future (Implied) Probability}}{\text{Current Probability}}$$

An Illustration

Individual Effect

Individual Effects for 16 Scenarios Taken One at a Time

No	Lower Bound	Upper Bound	Normalized Frequency	Change of Measure				
				GPD	Loglogistic	Lognormal	Burr	GB2
1	1	5	7	1.00	1.00	1.00	0.98	1.02
2	2	18	10	1.00	0.97	0.99	1.06	1.02
3	13	26	14	0.98	0.95	1.00	1.05	0.98
4	18	33	7	0.99	0.99	1.00	0.97	0.98
5	60	110	10	1.02	1.02	0.99	0.98	0.90
6	75	200	13	1.01	0.99	1.04	0.99	1.05
7	75	225	14	0.98	1.02	1.02	0.97	1.02
8	75	250	20	1.07	1.04	1.13	1.11	1.26
9	76	336	7	1.01	0.99	1.00	1.02	1.10
10	103	206	14	1.14	1.01	1.14	1.16	1.22
11	106	152	5	1.00	0.97	1.02	1.06	0.96
12	119	186	3	0.98	1.04	1.03	0.98	0.97
13	400	600	3	1.06	1.03	1.16	1.04	1.26
14	1160	1935	20	2.97	1.49	4.63	2.67	5.76
15	1697	1979	2	1.16	1.06	1.23	1.11	1.49
16	3500	7500	7	2.03	1.16	2.82	1.71	4.11

Group Effect

Group Effects for 16 Scenarios Taken All at a Time

No	Lower Bound	Upper Bound	Cumulative Frequency	GPD	Change of Measure: Loglogistic	Lognormal	Burr	GB2
1	1	5	7	0.88	0.96	0.92	0.88	0.95
2	2	18	14	1.01	1.13	1.13	1.05	0.97
3	13	26	18	1.41	1.39	1.56	1.53	1.37
4	18	33	16	1.55	1.44	1.72	1.68	1.55
5	60	110	10	2.34	1.69	2.81	2.50	2.79
6	75	200	20	2.66	1.76	3.29	2.80	3.35
7	75	225	34	2.70	1.77	3.35	2.83	3.43
8	75	250	54	2.73	1.78	3.39	2.87	3.49
9	76	336	60	2.82	1.80	3.51	2.95	3.66
10	103	206	60	2.86	1.81	3.66	2.99	3.73
11	106	152	63	2.75	1.79	3.49	2.89	3.53
12	119	186	58	2.90	1.82	3.76	3.03	3.82
13	400	600	3	4.42	2.08	7.19	4.37	7.11
14	1160	1935	20	6.54	2.35	14.49	6.11	12.77
15	1697	1979	8	7.07	2.40	17.08	6.53	14.34
16	3500	7500	7	10.02	2.67	33.97	8.76	24.17

An Evaluation Criteria for the Scenario Data

- Change of Measure can be used as an evaluation tool
- An extremely high change of measure can be due to any of three situations:
  - Either the historical measure is inaccurate and inconsistent with the risk profile of an institution, or
  - The scenario is a nearly impossible given the current state of an institution, or
  - Risk of an institution is uninsurable (self retention or through risk transfer)
- Scenarios should be evaluated for group effect as well as for the individual effect (Please refer the paper)
- It will also help in the communication with business line management where the risk has originated

Impact of scenarios in the capital number

- Under Dutta-Babbel method “capital” number goes up in a residual way
- Change of Measure method ensures the convergence within a family of distribution
- The method works with the assumption of independent occurrence (or possibility of occurrence) of risk
  - If scenarios are generated in a correlated way this method can be very easily extended

Few Important Facts

- Dutta-Babbel method can work with any of the following data formats
  - Any type of ranges for the severity data
  - Data collected in a bucket approach
  - Any type of ranges given in the frequency
  - Multiple ranges of severity and frequencies

Few Important facts (Continued)

- Dutta-Babbel method does not increase “capital” in an arbitrary way (a very unfortunate mischaracterization that it does)
  - It adjusts the severity distribution in a residual way
  - Like any credible model for risk management it reacts to the “data” in an appropriate way
- A model that does not react to the data is a “dead” and “dangerous” model
  - We all know what normal copula did in credit risk management!!!!!
- This method works at the very granular loss level as well as at the aggregate level (another mischaracterization that it does not)

Future of Stress Testing

- Factor based stress testing
  - Macro factor used in US regulators
  - Internal covariates
  - Macro environment factors
    - Legal system
    - Environmental system
  - Control factors

Future of Stress Testing (Continued)

- It is not clear which macro factors, if any other than control, have any correlation with operational losses
  - Spurious correlation
  - Tail severities are found to have no correlation with any of the factors discussed
- Scenario is the best way to stress test tail events

Conclusion

- Scenario Data should be purposefully generated
- Scenario data generation and scenario modeling should be two independent process
- Through COM evaluation the justification of scenario can be evaluated

Thank you