Operational Risk Management

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Significant differences between Operational Risks and Financial Risks have implications on quantifying OpRisks

- OpRisks are endogeneous - vary significantly based on a company's internal operations
  - need company-specific data
  - data must be representative of current ops environment
- OpRisks are managed by changes in process, technology, people, organization and culture - not through capital markets
  - need to model risks as a function of operational decisions
  - need to understand causal factors
- OpRisks have skewed distributions - not "random walk"
  - need to use 'coherent risk measures' for determining and allocating capital

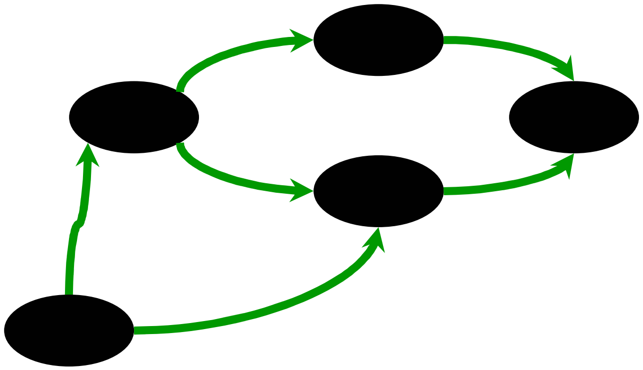
OpRisk modeling must tap knowledge of experienced managers to supplement the data.

We will cover the following three modeling methods that combine historical data and expert input

- System Dynamics Simulation
  - Developed by Jay Forrester, MIT
  - Used primarily in engineering sciences but becoming prominent in business simulation
- Bayesian Belief Networks (BBNs)
  - Based on Bayes’ Rule developed by Rev. Thomas Bayes (1763)
  - Used primarily in decision sciences
- Fuzzy Logic
  - Based on fuzzy set theory developed by Lotfi Zadeh
  - Used primarily in engineering control systems, cognitive reasoning and artificial intelligence

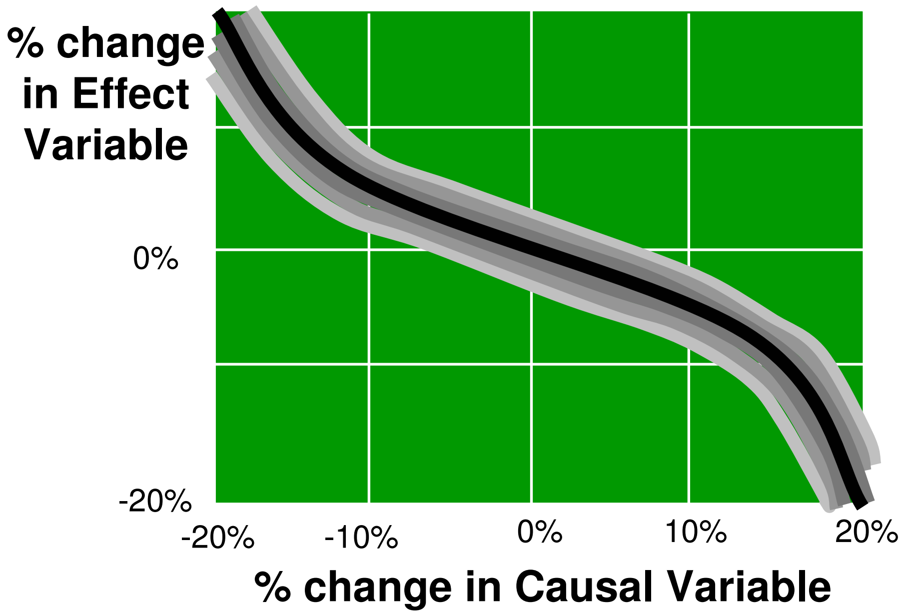
System Dynamics Simulation

- Use expert input to develop a system map of cause-effect relationships



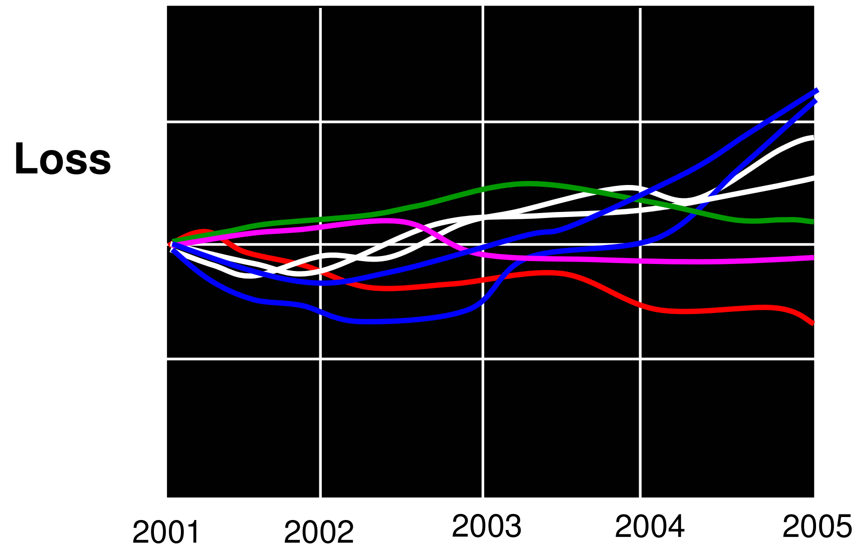
System Dynamics Simulation

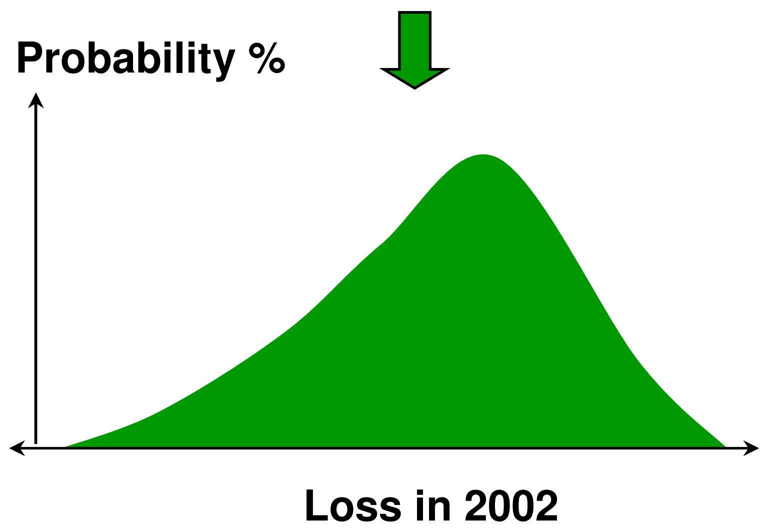
- Use expert input to develop a system map of cause-effect relationships
- Quantify each cause-effect relationship using a combination of data and expert input
- Explicitly reflect the uncertainty of expert input as ranges around point estimates



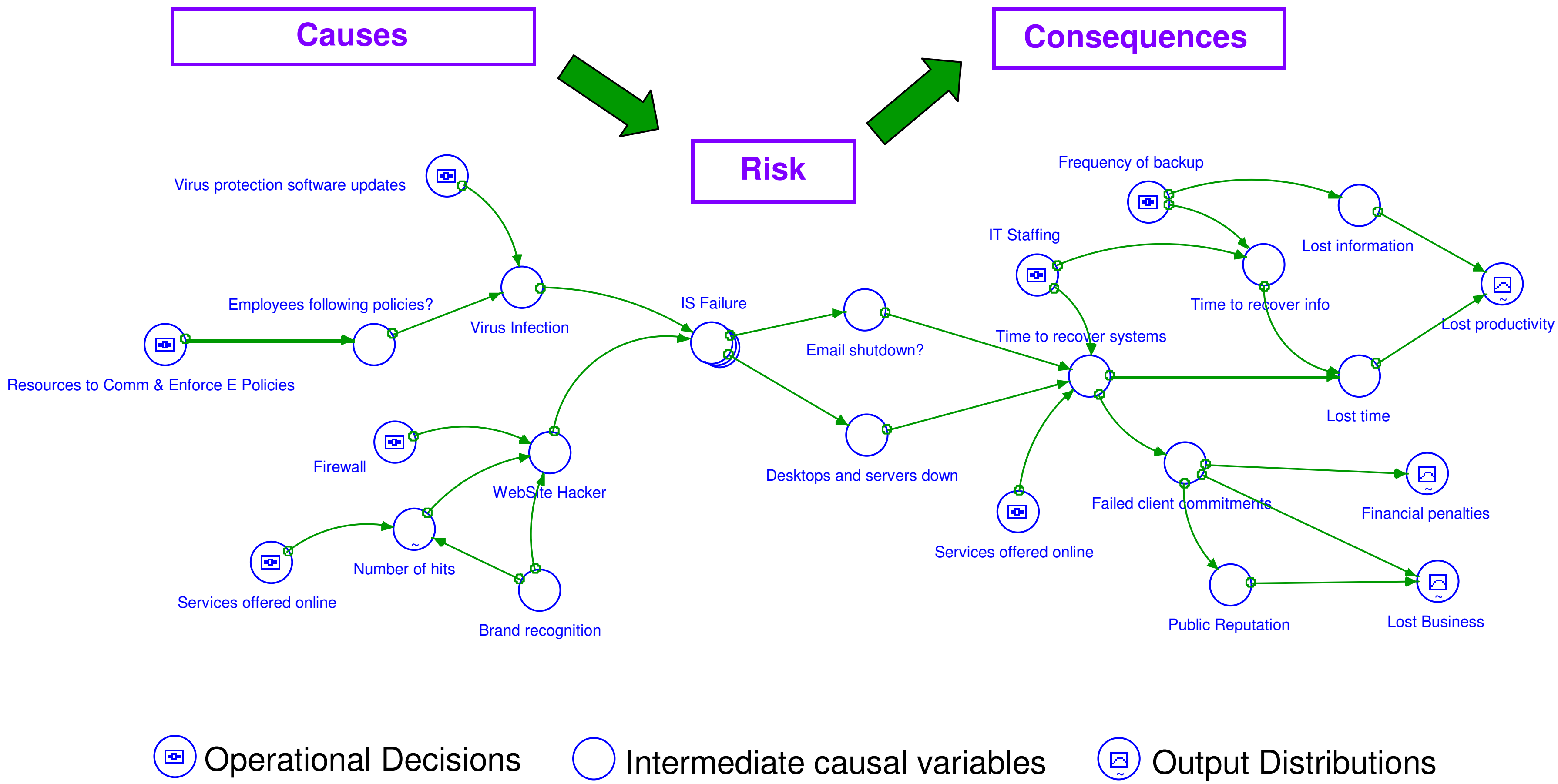
System Dynamics Simulation

- Use expert input to develop a system map of cause-effect relationships
- Quantify each cause-effect relationship using a combination of data and expert input
- Explicitly reflect the uncertainty of expert input as ranges around point estimates
- Computer simulate the range of outcomes
- Summarize outcomes as probability distribution





For example, here is an illustrative System Dynamics map for Information Systems Failure



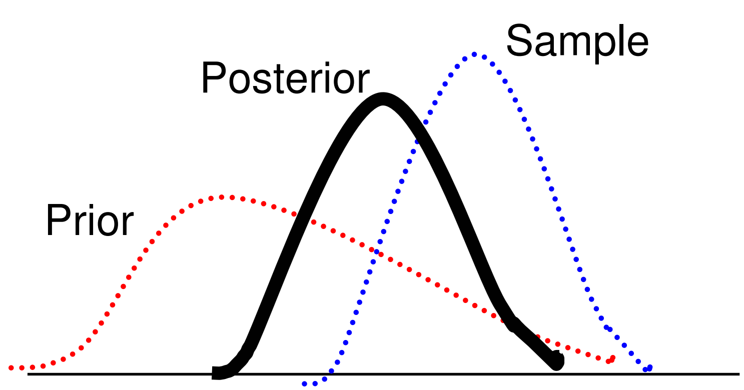
Demonstration of
System Dynamics Simulation Model

Bayesian Belief Networks (BBNs)

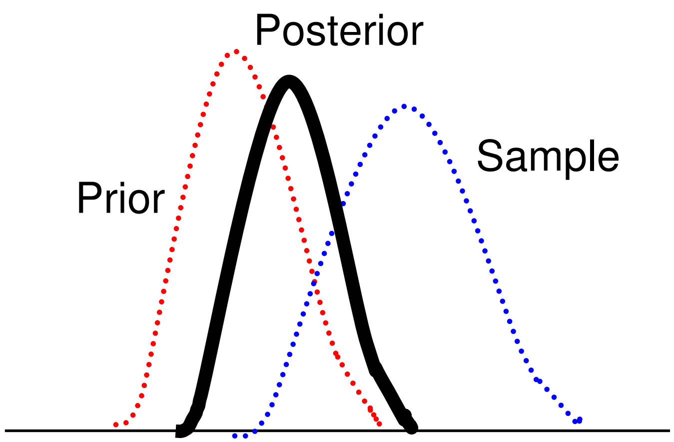
- Based on Bayes' Rule:

prob(X|Y) = [prob(Y|X) / prob(Y)] * prob(X)

Posterior Density ∝ Sample Likelihood * Prior Density



Uncertain Expert Input
for Prior Distribution



Confident Expert Input
for Prior Distribution

Bayesian Belief Networks (BBNs)

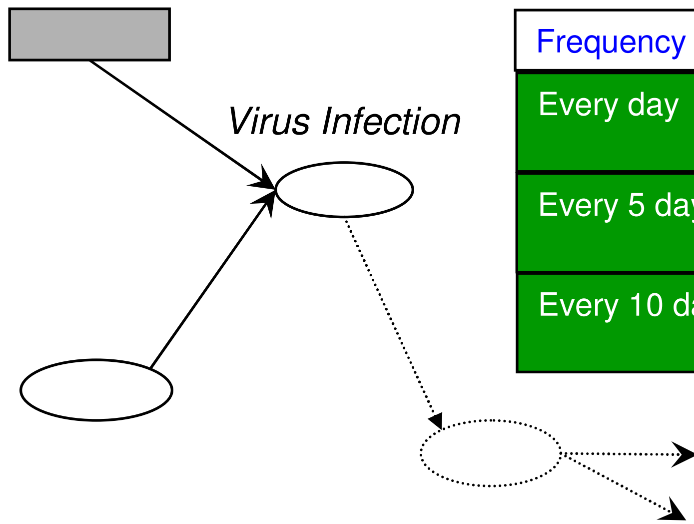
- Nodes - represent decision variables, causal variables and outputs
- Arcs - connect Nodes indicating the logical causal relationship
- Node probabilities - probabilities for various values of the Node variable, conditioned on values of its causal variables

Frequency Of Virus Protection Updates

Every day	0.0
Every 5 days	1.0
Every 10 days	0.0

Employees following E-Policies?

Yes	.25
No	.75



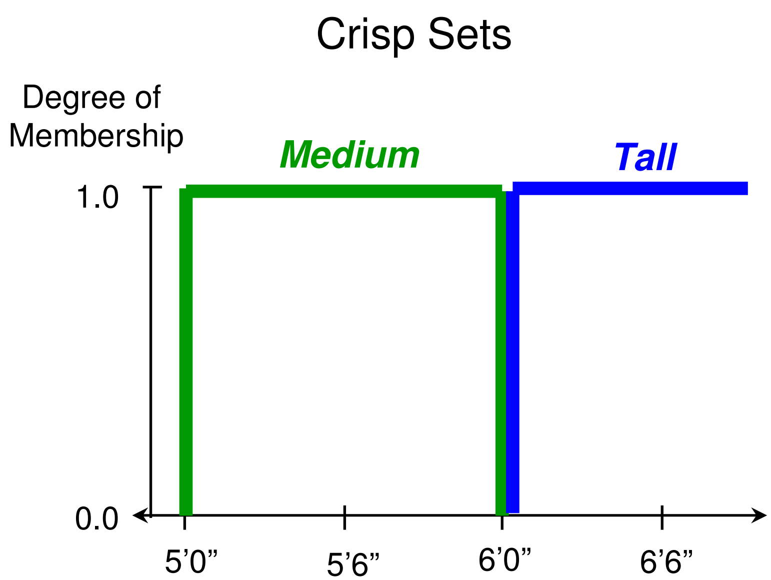
		Infection?	
Frequency	Emp	Yes	No
Every day	Yes	.01	.99
	No	.02	.98
Every 5 days	Yes	.02	.98
	No	.05	.95
Every 10 days	Yes	.05	.95
	No	.10	.90

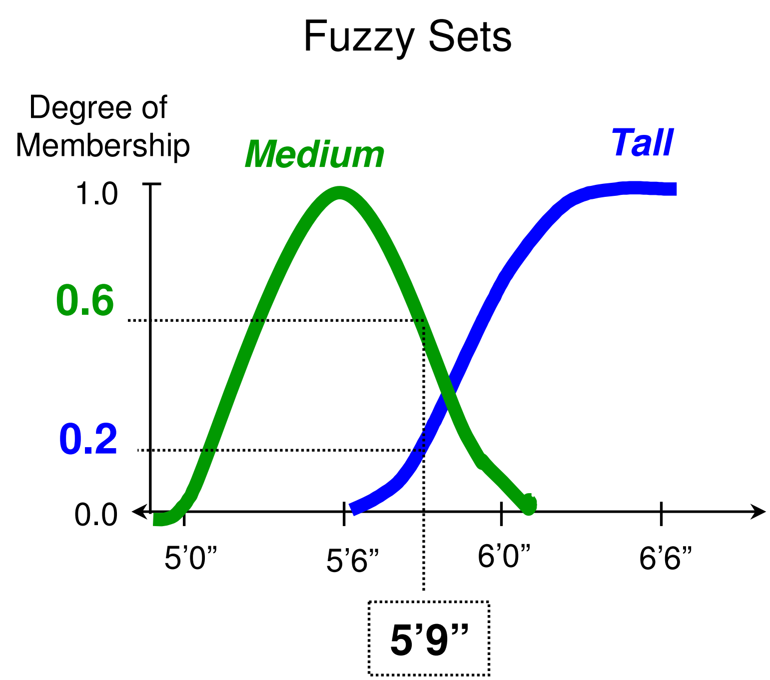
Analytical "cousin" to System Dynamics Simulation - however, simulation offers much greater modeling flexibility

Fuzzy Logic

- Based on fuzzy set theory
  - for non-fuzzy sets (crisp sets), an element is either a "member of the set" or is not a "member of the set"
  - for fuzzy sets, an element is a "member of the set to some degree" from 0% to 100%" --- degree of truth

Examples of Membership functions to characterize Height





Fuzzy Logic

- Fuzzy sets make way for the use of “linguistic variables” instead of numerical variables
  - *Tall, Medium, Low, High, ...*

- Adjectives and adverbs are used to modify the membership curves mathematically:

Adjectives/Adverbs	Membership Curve Change
almost, definitely, positively	Intensify contrast
generally, usually	Diffuse contrast
neighboring, close to	Approximate narrowly
vicinity of	Approximate broadly
above, more than, below, less than	Restrict a fuzzy region
quite, rather, somewhat	Dilute a fuzzy region
very, extremely	Intensify a fuzzy region
about, around, near, roughly	Approximate a scalar
not	Negation or complement

Fuzzy Logic

- Fuzzy set mathematics are used to combine fuzzy sets:

Fuzzy Set Operators		Meaning
Intersection:	Set A ∩ Set B	Min. of $M_A(x)$ and $M_B(x)$
Union:	Set A ∪ Set B	Max. of $M_A(x)$ and $M_B(x)$
Complement:	~Set A	$1 - M_A(x)$

- Fuzzy rules, specified by experts, define cause-effect relationships:
  - Rule 1: If ***age* is *YOUNG*** then ***risk*** is ***HIGH***
  - Rule 2: If ***distance.to.work*** is ***FAR*** then ***risk*** is ***MODERATE***
  - Rule 3: If ***accidents*** are ***above ACCEPTABLE*** then ***risk*** is ***EXCESSIVE***
  - Rule 4: If ***dwi.convictions*** are ***above near ZERO*** the ***risk*** is ***UNACCEPTABLE***

Demonstration of Fuzzy Logic Model

There is a continuum of methods for quantifying risks based on the relative availability of historical data vs. expert input

- Empirically from historical data
- Fit parameters for theoretical p.d.f.
- Extreme Value Theory
- Stochastic Differential Equations (SDEs)
- Regression over variables that affect risk
- System Dynamics simulation
- Neural Networks
- Influence diagrams
- Bayesian Belief Networks
- Fuzzy logic
- Direct assessment of relative likelihood or fractiles
- Preference among bets or lotteries
- Delphi method

Each method has advantages/disadvantages over the other methods — method should be selected to suit facts and circumstances.

There are several advantages of using modeling methods that explicitly incorporate expert input

- Explicitly depicts cause-effect relationships
  - lends itself naturally to development of risk mitigation strategies
  - can determine how OpRisk changes based on operational decisions
- Explicitly models interaction of risks across an enterprise
  - by aggregating knowledge that is fragmented in specialized functions
- Provides organizational learning
  - ongoing use calibrates subjective beliefs with objective data
  - managers develop an intuitive understanding of the underlying dynamics of their business
- Focuses the data-gathering effort
  - sensitivity analysis identifies areas of expert input that should be supported by further data

Operational Risk Management is not just a modeling exercise
- senior and middle management must get involved!

Coherent Risk Measures

Operational risk measures for determining and allocating capital

- Operational risks will often have skewed probability distributions - unlike “random walk” for asset risks
- Traditional risk measures used for financial risks may not be appropriate for OpRisks, for example:
  - Value-at-Risk (VaR) used in banking
  - Probability of Ruin used in insurance

Here's an example ...

- Under a 1% probability of default, or 99% VaR, risk constraint, Companies A & B need to hold the same amount of assets, i.e., $10,000

		Probability	***Loss***	***Required Assets***	***Shortfall***	***ECOR Ratio****
Company A	**Scenario 1**	**97%**	**8,784**	**10,000**	**0**	
	Scenario 2	**2%**	**10,000**	**10,000**	**0**	
	Scenario 3	**1%**	**28,000**	**10,000**	**18,000**	
	Expected	**100%**	**9,000**		**180**	**2.0%**
Company B	**Scenario 1**	**97%**	**8,505**	**10,000**	**0**	
	Scenario 2	**2%**	**10,000**	**10,000**	**0**	
	Scenario 3	**1%**	**55,000**	**10,000**	**45,000**	
	Expected	**100%**	**9,000**		**450**	**5.0%**

ECOR is the Economic Cost of Ruin and is equal to the expected Shortfall.
ECOR Ratio is the Expected Shortfall divided by Expected Loss

- But Company B is much more risky. Its loss distribution has a "fatter tail" than the one for Company A.

Continuing the example ...

- If we combine Company A and Company B, the new Company C appears to need **more**, not less, capital

	Scenarios	Joint Probability	Loss	Required Assets	Shortfall	ECOR Ratio
Company C	A1 x B1	94.09%	17,289	22,000	-	
	A2 x B1	1.94%	18,505	22,000	-	
	A1 x B2	1.94%	18,784	22,000	-	
	A2 x B2	0.04%	20,000	22,000	-	
	A3 x B1	0.97%	36,505	22,000	-	
	A3 x B2	0.02%	38,000	22,000	-	
	A1 x B3	0.97%	63,784	22,000	25,784	
	A1 x B3	0.02%	65,000	22,000	27,000	
	A1 x B3	0.01%	83,000	22,000	45,000	
	Expected	100.00%	18,000		260	1.4%

- How can this be?

Lessons learned from the example ...

- Probability of ruin, VaR and other quantile measures do not properly reflect the tail of the loss distribution
- When the loss distributions of are not uniform across the range of outcomes, quantile measures distort the determination of required capital for business combinations and capital allocations
- Expect this to be the case frequently for operational risks - as well as other insurance risks - which have:
  - Non-symmetrical distributions
  - “Fat-tail” distributions

Coherent Risk Measures for Operational Risks

- A Coherent Risk Measure* is one which meets the following four criteria:
  - If a portfolio X does better than portfolio Y under all scenarios, then the capital for X should be less than for Y
  - Combining uncorrelated risks should never increase the capital requirement
  - Combining perfectly correlated risks should never change the capital requirement
  - If a non-risky investment of $X is added to a risky portfolio, then the capital requirement should decrease by $X
- Probability of Ruin and VaR are not Coherent Risk Measures because they fail the second criteria

* Defined by Artzner, Delbaen, Eber, and Heath (1997)

ECOR Ratio is a Coherent Risk Measure

- Using the ECOR ratio leads to intuitively correct results
  - Company B needs more capital than Company A
  - Company C needs ***less*** capital than Company A + Company B

	At 1.0% Prob. Of Ruin or 99% VaR Required Assets	At 1.4% ECOR Ratio Required Assets
Company A	10,000	15,039
Company B	10,000	42,039
Company C	38,000	38,000
Sum of A and B	20,000	57,078
Diversification Benefit (Penalty)	(18,000)	19,078

Conclusion

- Intuitively simple and well understood measures of risk can be seriously misleading.
- For capital allocation and business combinations, use of a coherent risk measure such as the ECOR ratio, is preferable.

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