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Session 48 PD, Extreme Events for Insurers: Correlation, Models and Mitigations

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Extreme Events for Insurers: Correlation, Models, & Mitigation

Tom Edwalds, FSA
DePaul University
May 17, 2016

SOCIETY OF ACTUARIES

Extreme Event Risk – Why Bother?

- Risk management is costly
  - Risk avoidance usually not possible
  - Risk mitigation actions use resources
    - Fire drills, safety equipment, harassment policies
  - Risk transfer costs premium
  - Risk retention uses capital
- Extreme event probably won't happen
  - Risk ignorance costless for non-event
  - Unprepared competitors gain advantage

Extreme Event Risk – Why Bother?

- HOWEVER, if extreme event happens:
  - Prepared firms survive
  - Unprepared competitors fail or become impaired
    - Ultimate cost of risk ignorance strategy
- Need low-cost approach
  - Ready response if event occurs
  - Enough to beat competitors

Two Types of Extreme Risk

- Extreme value of key variable
  - Economic index
    - Stock market return, Interest rate, Commodities price
  - Risk index
    - Storm damage, Mortality trend, Health cost trend
- Unprecedented event
  - 2011 Japan earthquake/tsunami/nuclear meltdown
  - 9/11/2001 Terrorist attack
  - AIDS epidemic
- Report addresses both

Extreme Value of Key Variable

- Central Limit Theorem
  - Important role of Normal Distribution
  - Refers to distribution of sample mean
  - Does not address any other percentiles
- Extreme Value Theory
  - Addresses behavior of tails
  - Identifies small set of distributions in limit

Unprecedented Event Risk

- No historical data
- Study historical events to stimulate ideas
  - Connection between risks is key
  - “Under stress, all correlations go to 1”
- Reconsider your axioms

2011 Tohoku Earthquake & Tsunami

- Estimated economic loss $235 Billion
  - Largest natural disaster economic loss in history
- Unprecedented?
  - 9.0 magnitude largest ever for Japan
    - But 4th largest in worldwide history
    - 13 Japan quakes 8.0+ in 200 yrs, up to 8.5
    - 15th earthquake of 6.6 magnitude or more since 2000
  - Combined with tsunami
    - Happens about once per decade in Japan
  - Caused nuclear meltdown
    - Magnitude combined with proximity of epicenter

Tail Risk Models & Tohoku Quake

- Include scenarios more extreme than record worst
  - Unless strong reason not to
- Consider consequential risks
  - What other loss might occur in extreme scenario?
  - Correlated risk in extreme scenario drives maximum loss potential

AIDS: Black Swan Event?

- HIV identified ~ 1983
- Epidemic identified ~ 1981
- “Case 0” enters US ~ 1969
- Virus mutates into HIV ~ 1959

AIDS: Life Insurance Impact

- Increased mortality cost
- Expanded use of blood testing
- Preferred underwriting
- Secondary market
- STOLI

Lessons from AIDS Epidemic

- Similar story for 1980's interest rate spike
- Events developed slowly
  - Years or decades
  - Difficult to pinpoint "moment"
- Businesses were not prepared
- Consequences developed even more slowly
- Ultimately reshaped life insurance industry

Risks to Consider

- Transformative Technology
- Global warming
- Geopolitical Risks
  - Impact of mass migration
  - Terrorism
- Cyber attacks
  - Losses if your systems & data are compromised
    - Productivity, sales, reputation, strategy, liability, remediation
  - Losses if supplier or regulator is attacked

Thank You!

SOCIETY OF ACTUARIES

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Extreme Events for Insurers: A Primer for Practitioners

Marc Vincelli, M.Sc., ASA

May 17, 2016

Agenda

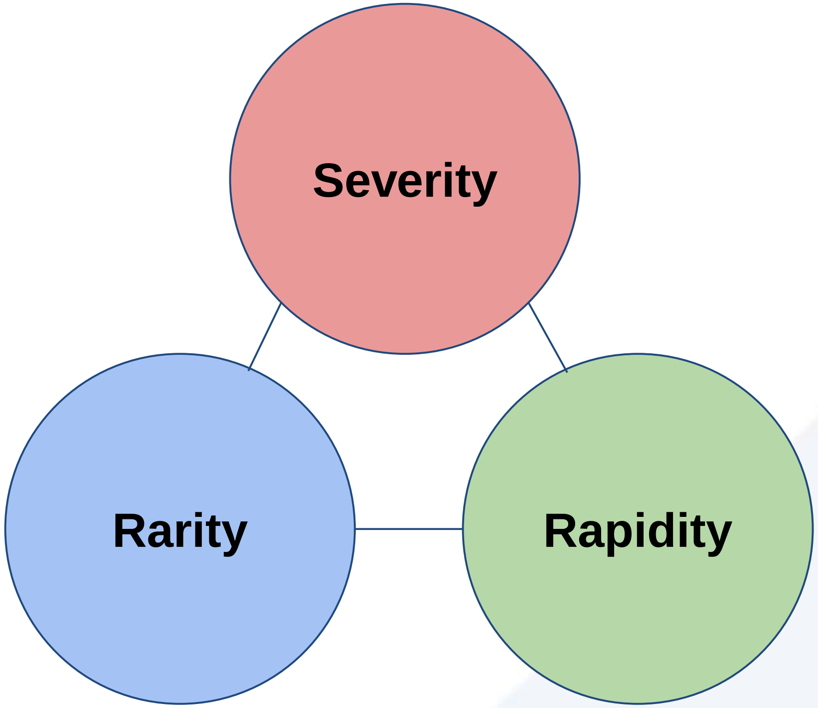
- Characterizing Extreme Events
- Extreme Event Modeling Challenges
- Possible Solutions
- Sample Application of Extreme Value Theory

- Based on research report coauthored with Kailan Shang
  - Title: *Extreme Events for Insurers: Correlation, Models and Mitigation*[1]
  - Sponsors: SOA's Committee on Life Insurance Reinsurance and the SOA's Financial Reporting Section
  - Published: April 2015

[1] **https://www.soa.org/Research/Research-Projects/Life-Insurance/2015-extreme-events-for-insurers.aspx**

What Constitutes an Extreme Event?

- Useful tridimensional framework presented by Stephenson in *Climate Extremes and Society* (2008)



- Consider mitigation strategies in place (e.g., hedging)
- Consider systemic and ideosyncratic risk events

Extreme Event Modeling Challenges

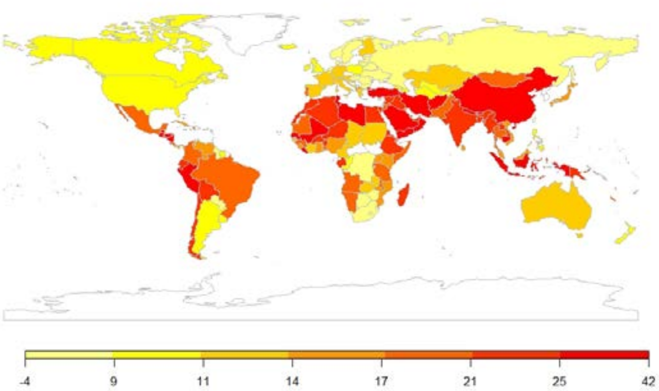
Challenge	Implication(s)	Possible Solution(s)
Traditional Statistical Techniques Based on Normality and Linearity are Insufficient	• Traditional Statistical Techniques Often Underestimate Key Attributes of Extreme Events (e.g., Frequency, Severity, and Rapidity)	• Extreme Value Theory (EVT)
Experience Data Limitations	• Unstable Estimates • Have Not Seen Extremes	• Proxies • Delphi Method • EVT
Risk Evolution	• Future May Not Resemble the Past	• Proxies • Delphi Method • EVT
Multivariate Dependencies and Temporal Clustering	• Underestimated Risk Driver Correlations Across Space and Time • Overestimated Diversification Benefits	• Correlation Matrices • Copulas • GARCH / HMM

Proxies - Simple Yet Powerful

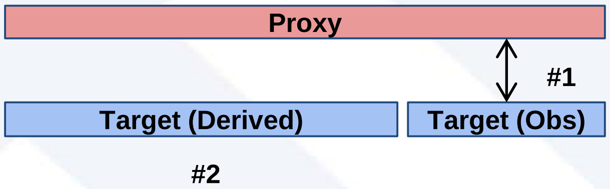
- Proxy Variable: A variable that serves in place of an unobservable or immeasurable (target) variable

- Two types of proxies useful for developing extreme outcomes
  - Direct: Variables describing similar phenomena but differing in time or space
  - Indirect: Variables describing different phenomena that can be mathematically related and extrapolated

Change in Life Expectancy (1960 to 2012)



Data source: World Bank



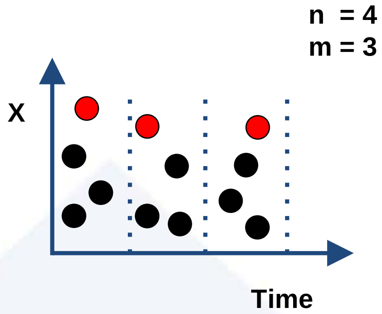
Delphi Method - Not Just for the Military!

- Developed by the RAND Corporation in the 1950s to forecast the impact of technology on warfare
- A way to generate a fan of outcomes from expert opinion where no experience exists
- Key Steps:
  1. Define Problem and Compile Questionnaire
  2. Select Expert Panel
  3. Have Panel Members Answer Questionnaire Anonymously
  4. Tabulate Responses
  5. Request that Panel Members with Extreme Opinions Justify their Position
  6. Share Tabulated Responses and Justifications with Panel Members
  7. Repeat Steps 3-6 Until "Consensus" is Reached

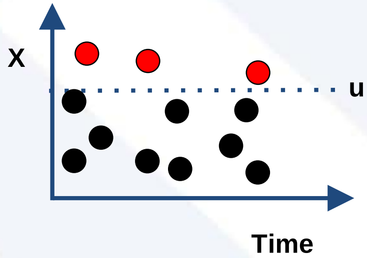
Extreme Value Theory (EVT)

- Provides the limiting distributions of the extremes of a random variable, and therefore a richer description of the extremes than one would otherwise obtain

- Approach 1: Model Block Maxima/Minima
  - $M_n = \max\{X_1, X_2, \ldots, X_n\}$ ~ Generalized EV (GEV) Distribution
  - Convergence requires sufficient number of observations per block (n) and sufficient number of blocks (m)
  - GEV Distribution combines Gumbel, Frechet, and Weibull Distributions and assumes X_i are iid



- Approach 2: Model Exceedances (Peak-Over-Threshold Method)
  - $\Pr(X - u < y | X > u)$ ~ Generalized Pareto Distribution
  - Convergence requires sufficiently large threshold (u)



EVT Application: US Tornado Deaths

- **Goal:** Model the distribution of deaths arising from the most extreme historical tornado events in the United States
- **Time Period:** 1991 to 2013 inclusive
- **Data Source:** NOAA's National Weather Service Storm Prediction Centre (http://www.spc.noaa.gov/climo/torn/fatalmap.php?yr=1991.)
- **Dataset Construction:** Using the interactive features on the NOAA site, we determined the number of fatalities associated with the most deadly U.S. tornado annually
- **Modeling Tool:** R (code provided in paper)
- **Note:** Our focus here is on the modeling of singular extreme events (the "big one"), rather than on the modeling of cumulative impacts

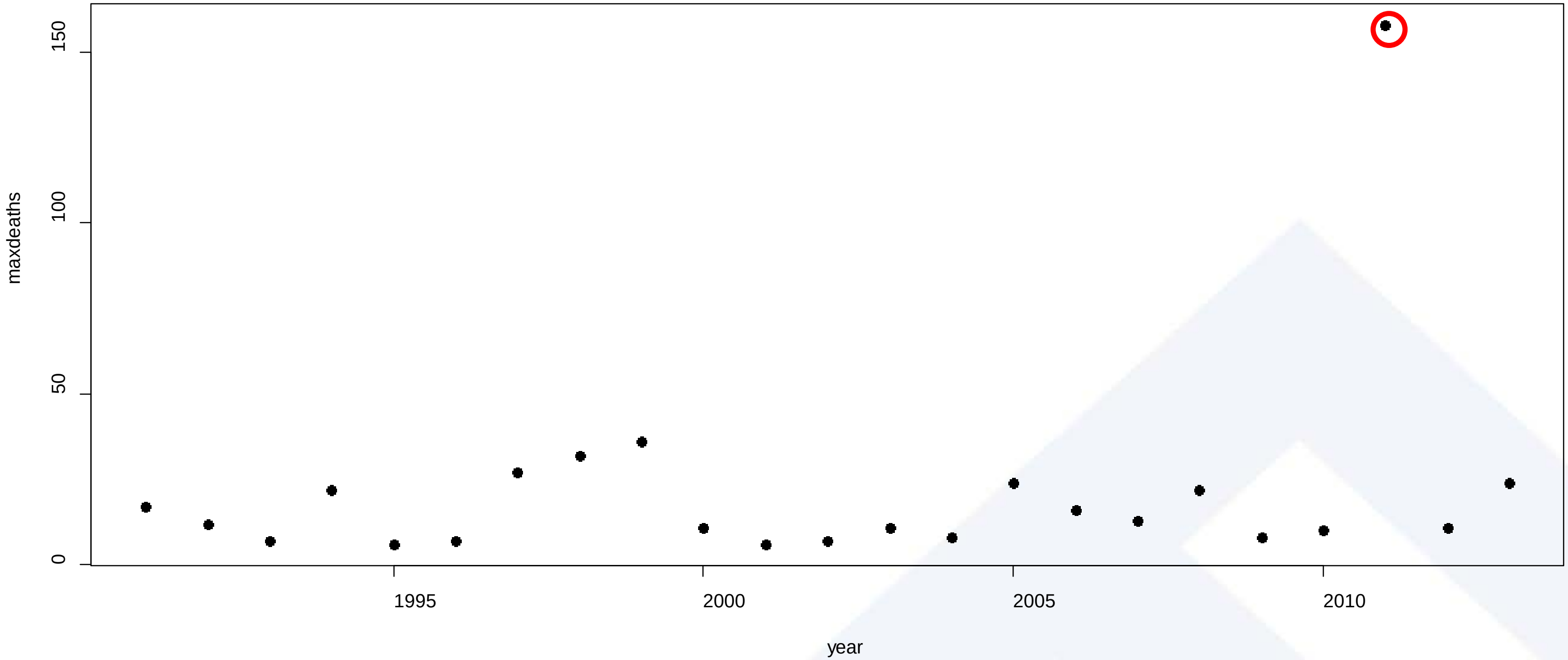
US Tornado Deaths (continued)

Year	No. of Deadly Tornados	Total No. of Deaths	No. of Deaths for Most Severe Event (Max)	Year	No. of Deadly Tornados	Total No. of Deaths	No. of Deaths for Most Severe Event (Max)
1991	15	39	17	2003	16	54	11
1992	16	39	12	2004	19	35	8
1993	16	33	7	2005	12	38	24
1994	22	69	22	2006	25	67	16
1995	15	30	6	2007	26	81	13
1996	13	26	7	2008	37	126	22
1997	23	68	27	2009	10	22	8
1998	32	130	32	2010	21	45	10
1999	30	94	36	2011	59	553	158
2000	13	41	11	2012	22	69	11
2001	23	40	6	2013	14	55	24
2002	25	55	7				

Event of Interest: Deadly Tornados in the United States
Variable of Interest: Number of Deaths per Deadly Tornado
Block: Calendar Year
$m = 23$; $n \in \{10, \ldots, 59\}$

US Tornado Deaths (continued)

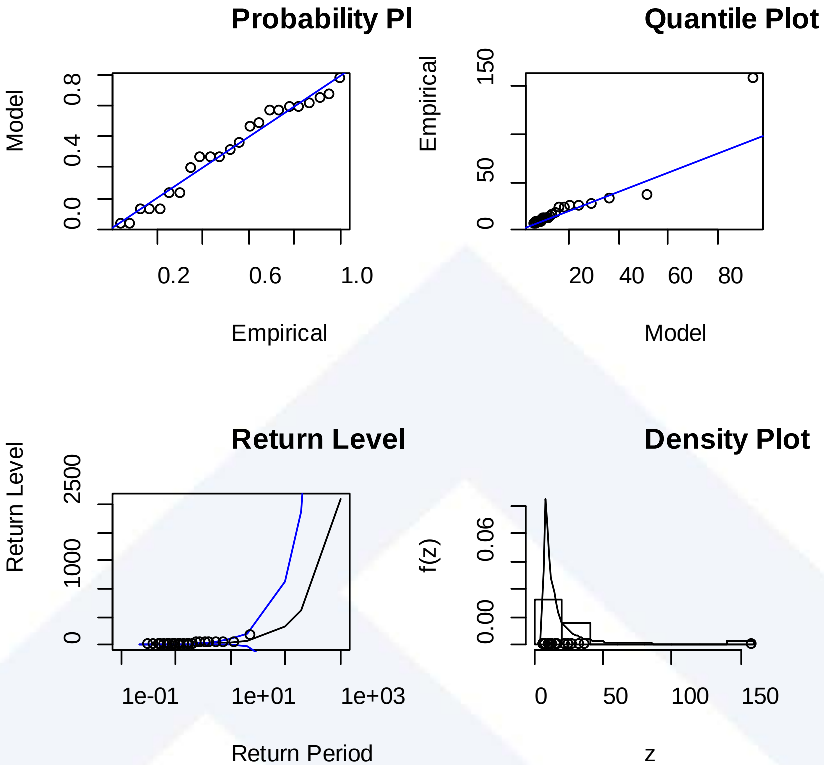
- Confirm absence of trend in maxima



US Tornado Deaths (continued)

- Estimate GEV parameters and assess fit

	Location μ	Scale σ	Shape ξ
MLE	9.61	4.82	0.89
Standard Error	1.26	1.50	0.34



Return Level (R^k)

- R^k is the (1 − 1/k) quantile of the fitted distribution
- k is called the Return Period (one period equals one block)
- What does $R^{10} = 20$ mean?

US Tornado Deaths (continued)

- Determine quantiles of interest
  - Leverage qgev function in R package *fExtremes*
    - $R^{10} = 44.5$
    - $R^{20} = 80.9$
    - $R^{43} = 158.2$

- Note that since our tornado dataset contained only 23 annual blocks, we are extrapolating once we look beyond the 95th percentile (1 – 1/23 = 0.957)

Extreme Events for Insurers: Correlations, Models and Mitigation

2016 SOA Life & Annuity Symposium

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May 2016

Agenda

1. Correlation
2. Tail Risk Management

Correlation

Correlation

Time Period	Equity Return and TB Yield*	Equity Return and Credit Spread*	TB Yield and Credit Spread
Jan. 1990 to Sept. 2014	0.7%	−9.3%	−61.7%
Jul. 2008 to Mar. 2009	83.8%	−62.9%	−73.1%

* With three-month time lag to reflect market reaction time

1. It takes time for policymakers to collect and absorb market information before reacting, such as reducing interest rates.
2. The correlation between equity return and TB yield drops from 83.8 to 27.7 percent without the time lag.
3. The correlation between equity return and credit spread increases from −62.9 to −29.4 percent without the time lag.

Risk Driver Dependencies

Historical Correlation

Correlated extreme events including the order and timing information.

Correlation Matrix

Correlation matrix at a chosen confidence level.

Copula

Deriving the joint distribution based on marginal distributions and a copula function.
$\mathrm{P}(X \leq x, Y \leq y) =$
$C\big(\mathrm{P}(X \leq x), \mathrm{P}(Y \leq$

Structured Models

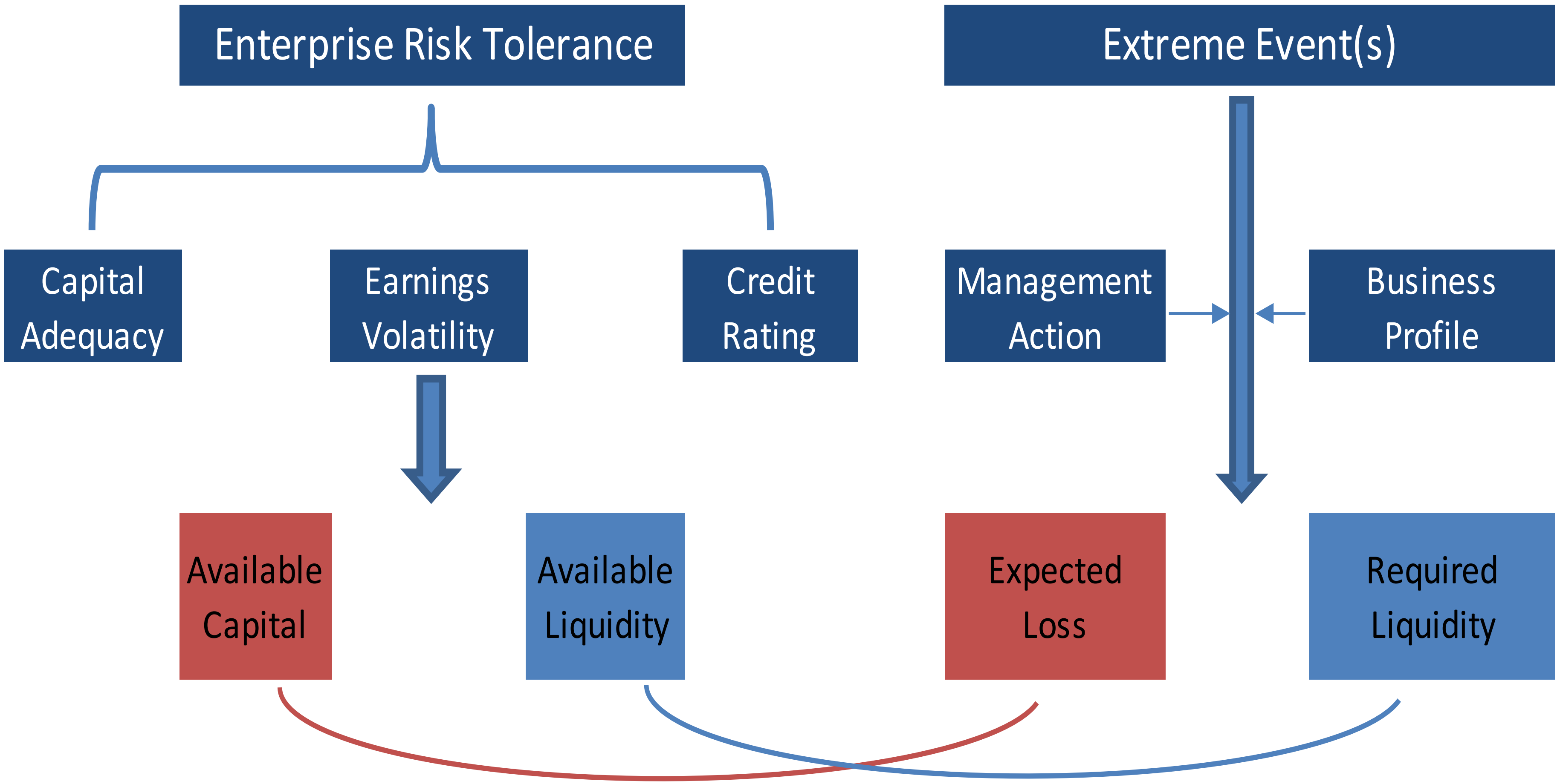
Correlated simulation models are used to reflect nonlinear correlation and timing of extreme events.

Cause-and-Effect Relationships

1. New business sales, policyholder premium payments, lapses, and option exercises are affected by the economic environment. Household financial planning is key to understanding dynamic policyholder behavior.
2. *Irrational decision* such as giving up a deep-in-the-money guarantee for the cash surrender value
3. *Sentiment.* People's risk averse changes from time to time.
4. Contagion
    a. systematically important financial institutions
    b. Sovereign risk
    c. Pandemic flu

Tail Risk Management

Risk Tolerance for Extreme Events



Risk Tolerance for Extreme Events

Available Capital (40% Available Statutory Capital)

$4 Billion

Predicted Loss

$3.8 Billion

\+ Liquidity Loss

$1 Billion

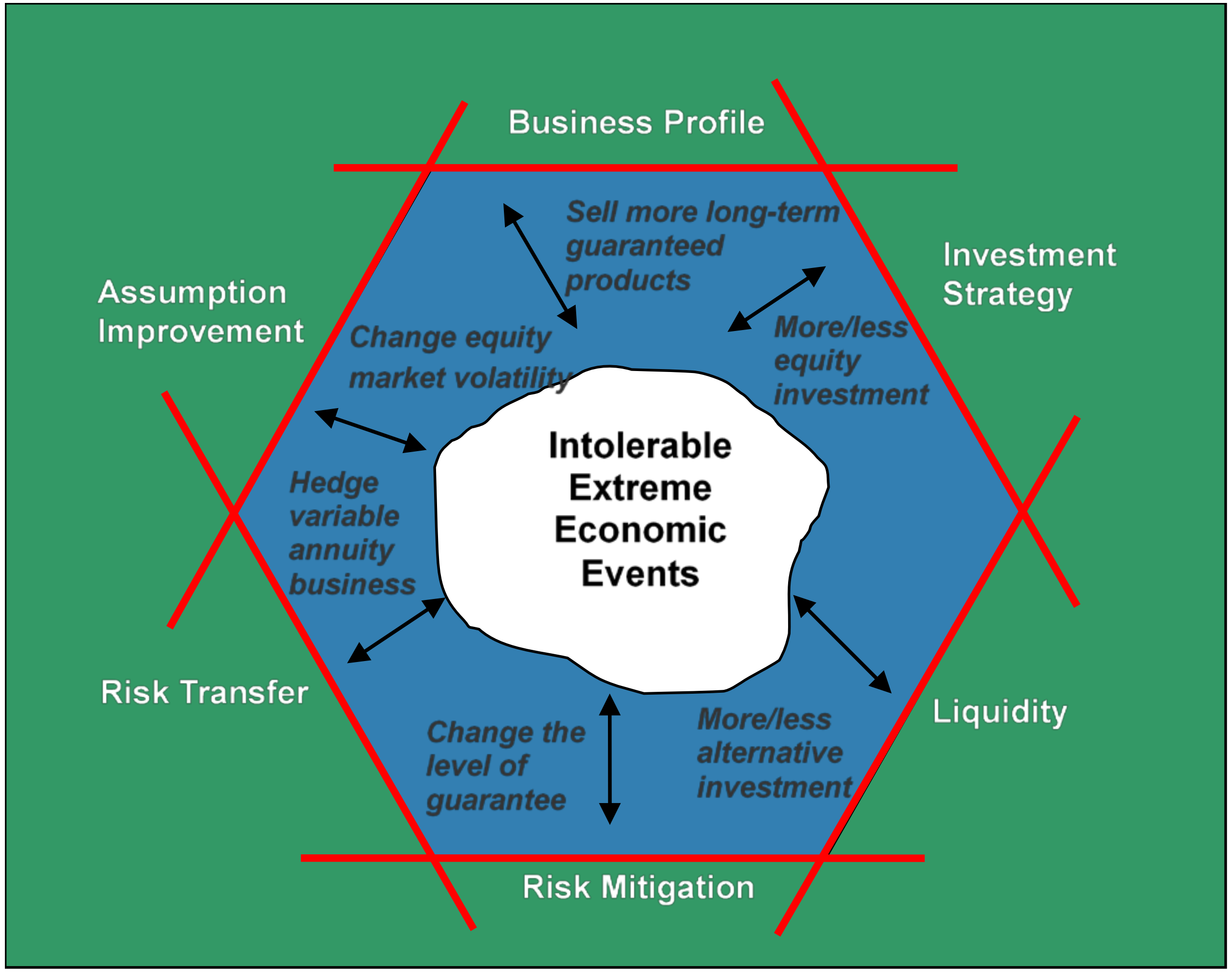
\- Management Action

$0.7 Billion

= Adjusted Loss

$4.1 Billion

Tail Risk Monitoring



	Current	Warning	Intolerable
Equity market volatility	25%	35%	40%
Equity allocation	15%	20%	25%
Real estate allocation	8%	12%	15%
Guaranteed credit interest rate	2.5%	2%	3%
Growth rate of long-term guarantee products	2%	4%	5%
Effective hedging ratio	55%	40%	30%

Tail Risk Mitigation

Risk Diversification	Hedging
Reinsurance	Risk Sharing with Clients
Risk Avoidance	Contingent Planning

Tail Risk Mitigation – CAT Risk

Catastrophe Reinsurance

Risk Avoidance

Hedging:
CAT Bond
CAT Equity Put

Risk Diversification:
Geographic Diversification

Hedging Strategy

Equity Put Option	Volatility Swap/ Variance Swap	VIX Options/Futures	Credit Derivatives	Sovereign Risk Hedging
Asset Allocation Based on Tail Risk	Tail Risk Index	CAT Bond	Extreme Mortality Securitization	Longevity Swap
Longevity Bond	Industry Loss Warranty	CAT Equity Put	Contingent Capital	Contingent Liquidity Swap

Thank you!

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Swin Solutions is a strategy consulting firm located in Ontario, Canada focusing on business intelligence and risk management.

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