Stress Testing

International Risk Conference

Alla Gil

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NOVANTAS

New York Chicago Toronto Madrid

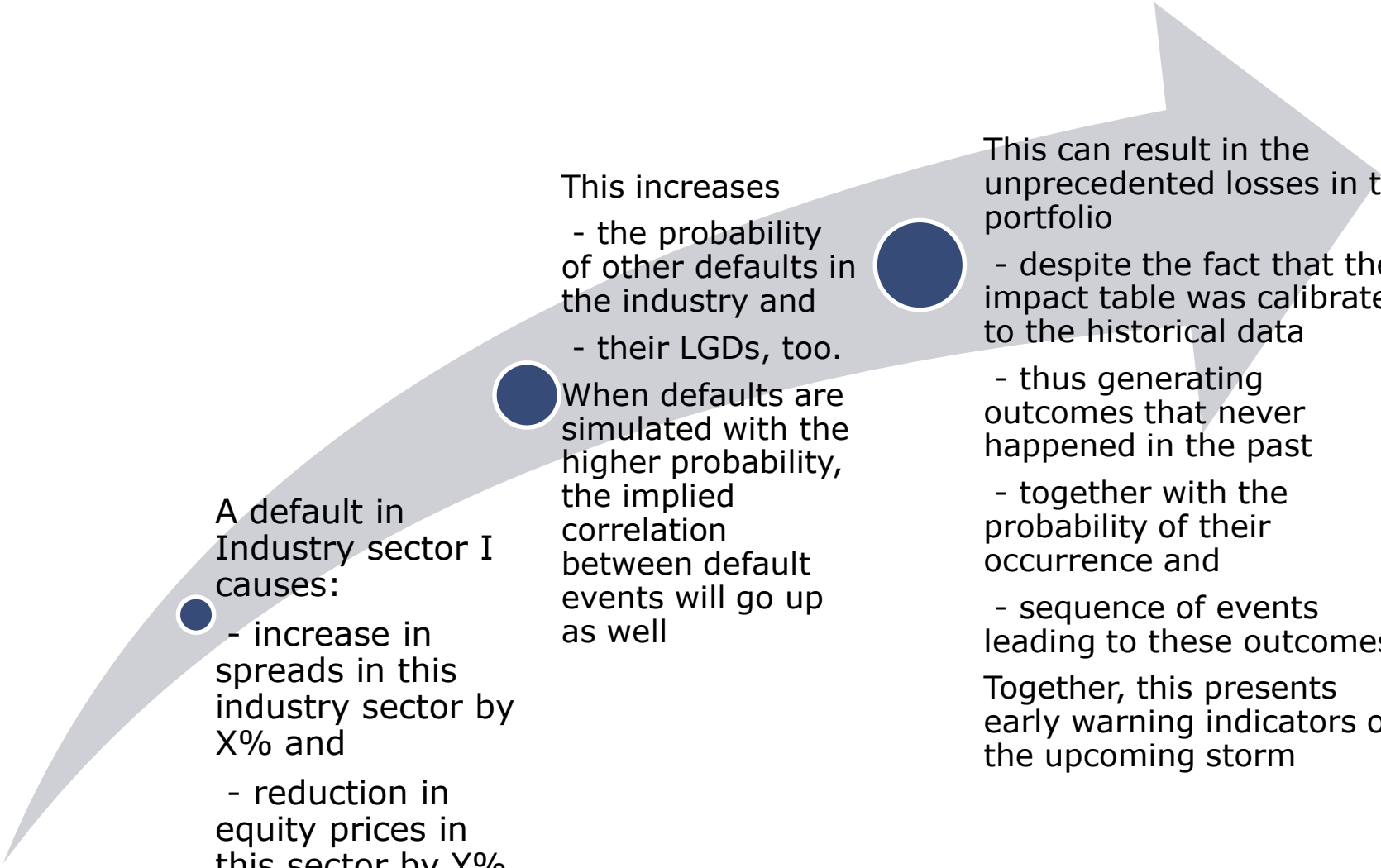
Will Basel II save you from the next crisis?

- Even if fully implemented prior to 2007, Basel II would not provide full protection for the following reason
  - Pro-cyclicality
  - Ineffective stress testing
    - Shocking one parameter at a time
    - Using only scenarios based on historical experience or hypothetical catastrophes
    - Selecting only scenarios with mild shocks, shorter durations and static long term correlations between the risk factors
  - Lack of proactive capital strategies
- Basel III is unavoidable - a number of recent adjustments and recommendations represents the intermediate steps

The Difference between Sensitivity Analysis, Scenario Analysis and Stress Testing

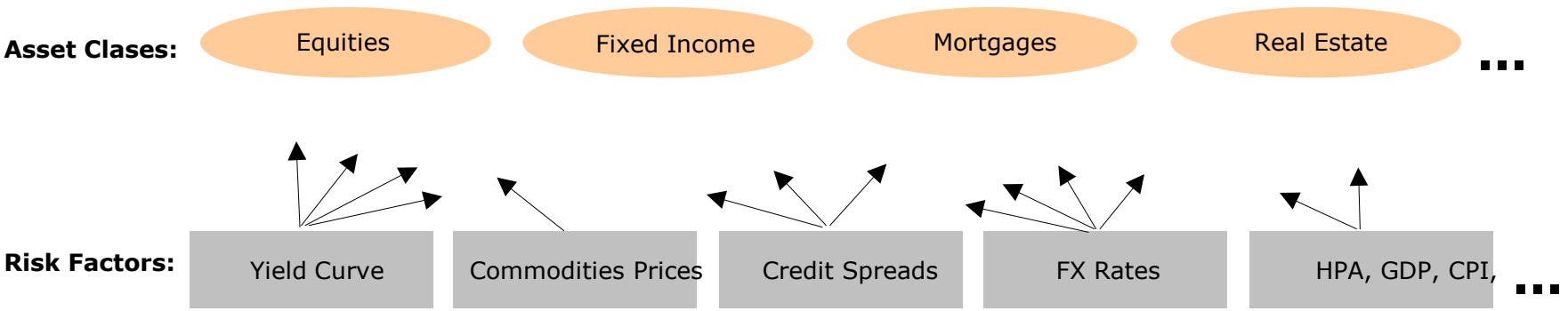
- Sensitivity Analysis – to establish sensitivity of model outputs to the initial assumptions and parameters
  - Different periods and / or methodologies (historical vs. implied) for parameter calibration
  - Applying to one parameter at a time
- Scenario Analysis – to verify and validate model performance
  - Verifying that model performs as expected given a specific scenario / expert opinion
  - Testing model outcomes on historical or hypothetical scenarios
- Stress Testing – to identify institution specific scenarios leading to the tail events
  - Must show paths never experienced before
  - Combination of events specific to the portfolio with their probabilities
  - Demonstrate on which paths the institution might fail

Domino effect: how to create scenarios and which ones to use for stress testing



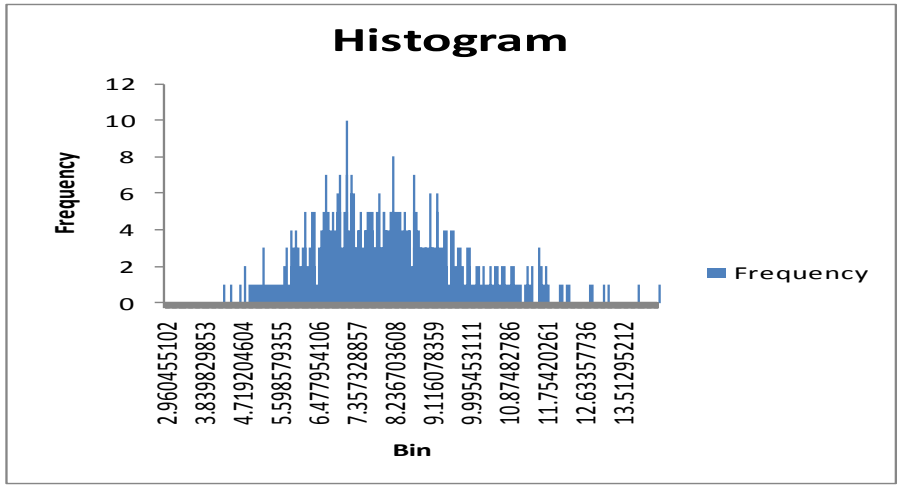
Big Bangs: how to incorporate macro factors into stress testing

- Identify the set of macroeconomic events that can shock the balance sheet, like GDP, unemployment, HPA, CPI
- Incorporate feedback effects that impact risk factors system-wide: interest rates; credit spreads; probabilities of default; equity markets; recovery rates
- Generate new tail correlation patterns as these events unfold on the paths thus overcoming the limitations of traditional risk management models

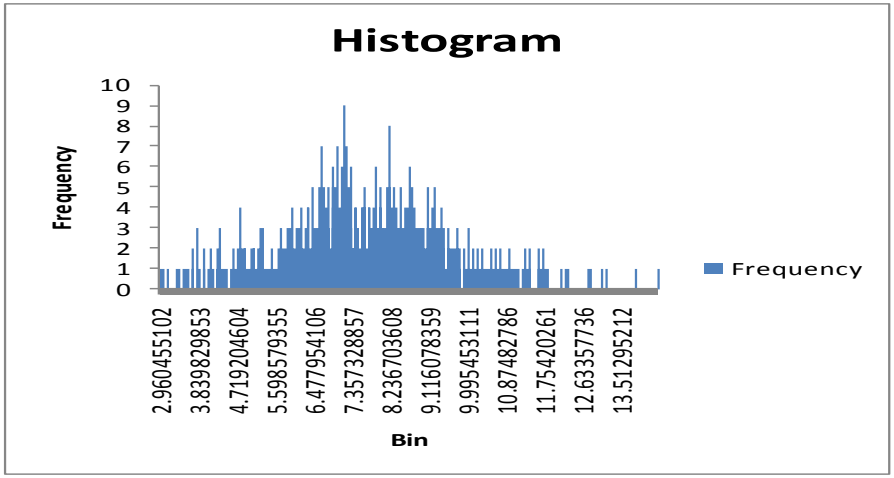


Devil is in the details: the microeconomic aspect of stress testing

Without Jumps



With Jumps

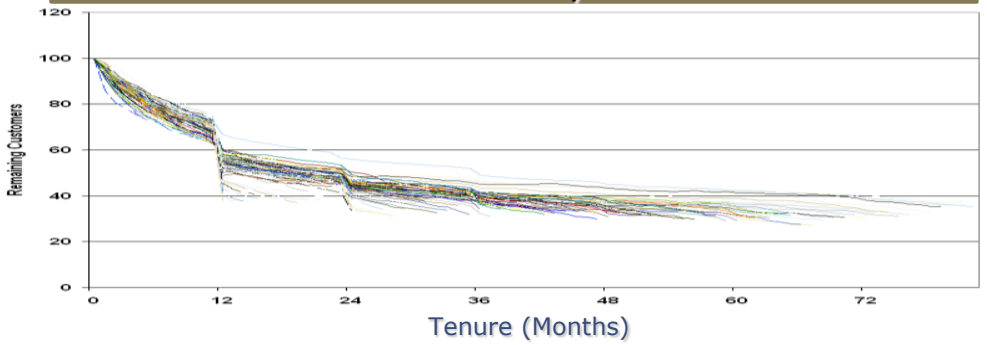


8.03%	Expected Value	7.70%
5.11%	1% Worst Case Outcome	3.67%

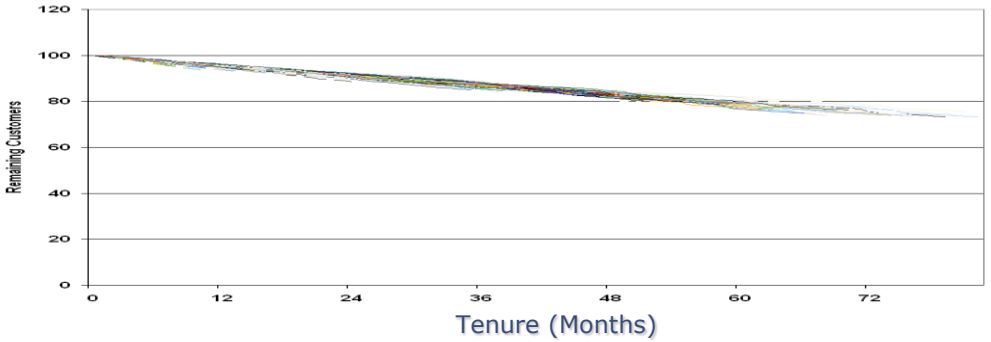
Impacts	Jump 1	Jump 2	…(example: China event)	Jump N
Variable 1	X% down			
Variable 2	Y% up			
…(example: Manufacturing sector)			40% down	
Variable N				

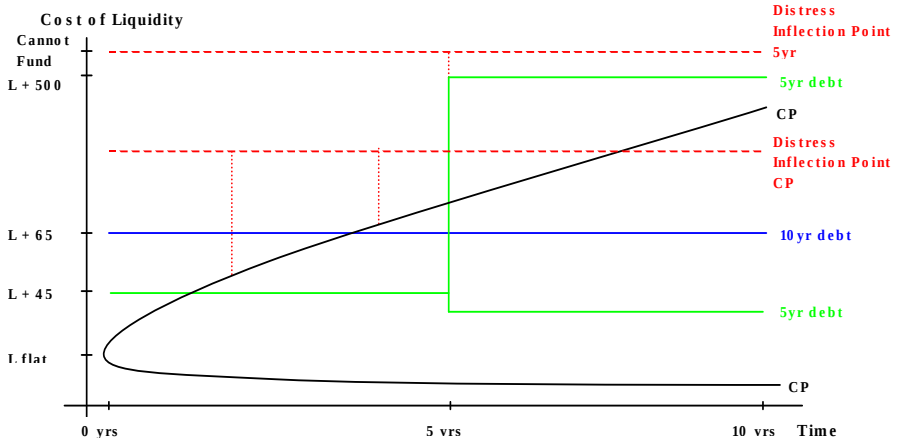
Various Liquidity Aspects

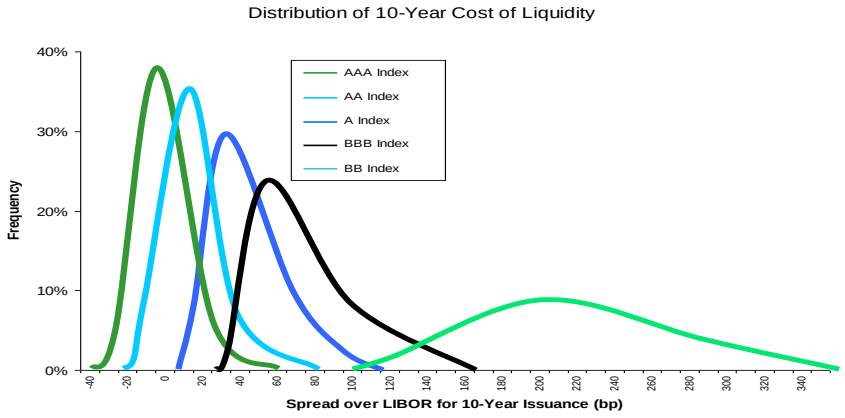
Customer Attrition Curves by Cohort – Product A



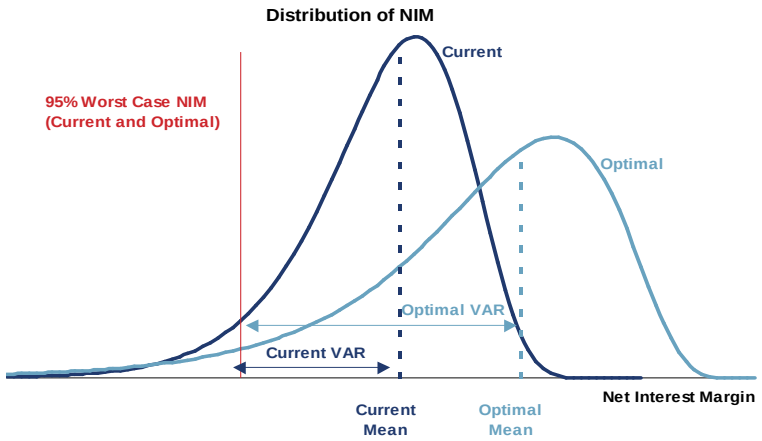
Customer Attrition Curves by Cohort – Product B

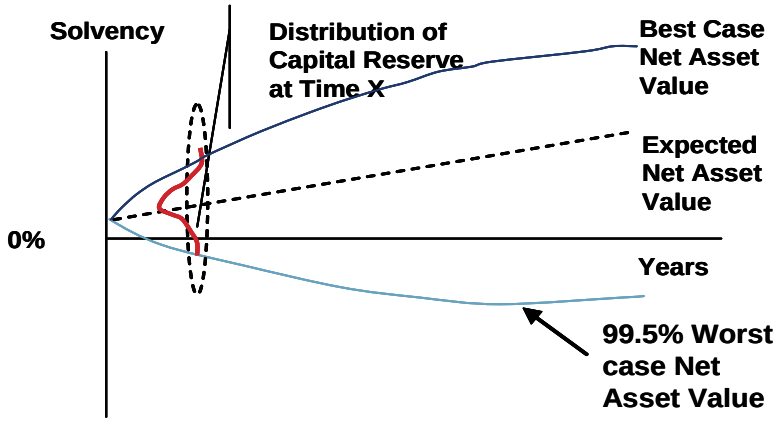




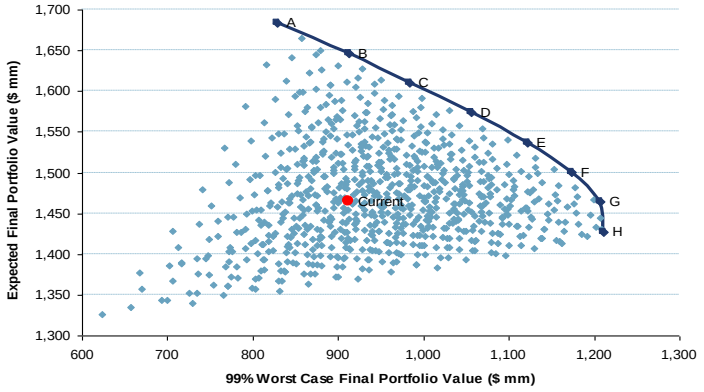


Stress Testing and Economic Capital



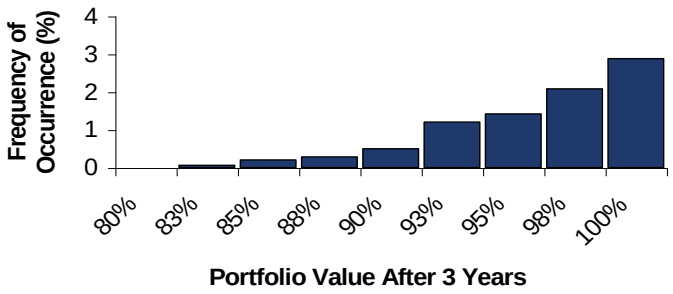


- Economic Capital by definition includes tails of risk
- Worst case outcome with a given confidence interval is a better measure of risk than (a number of) standard deviations
- RAROC should be replaced with Tail Risk Adjusted Return on Economic Capital and used for optimal capital allocation



Stress scenarios leading to the worst case (with a given confidence intervals) outcomes provide intuition for strategic hedges

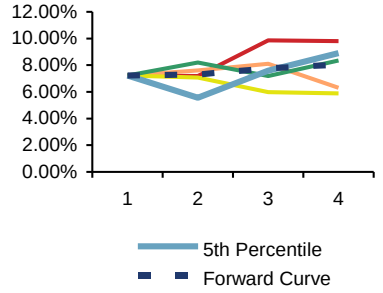
Value Loss Over Horizon



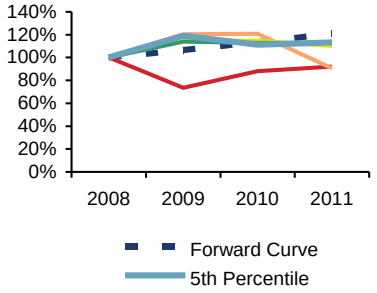
Loss Contributors on Worst 1% Paths

Contributor	Average 3-Yr Effect
Corporate Default Events	**(3.14)%**
US Investment Grade Defaults	(0.18)
Int'l Investment Grade Defaults	(0.15)
US High Yield Defaults	(2.37)
Int'l High Yield Defaults	(0.44)
Regional Default Events	**(0.20)%**
Latin American Region Default	(0.14)
Asian Region Default	(0.06)
E. Europe / Mid. East Region Default	0.00
Major Shock Scenarios	(3.11)%
Index Volatility	(4.95)%
Average Portfolio Return	(11.41)%

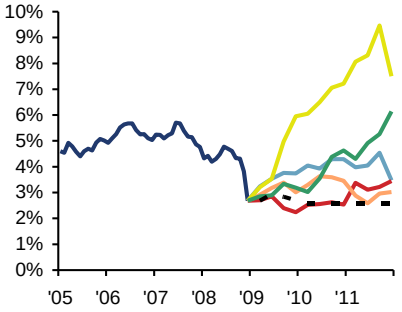
Corporate Rates



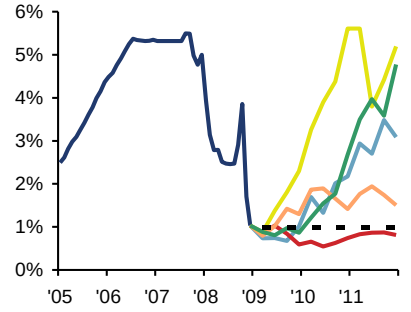
Equities



10y Swap Rates



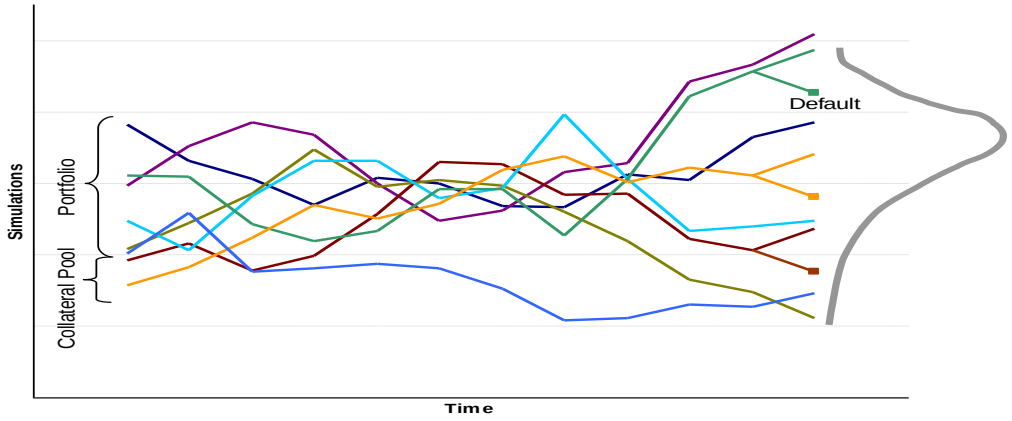
1m Libor



Specific Risks and Products

- Problems:
  - The following risks were not sufficiently covered by stress tests:
    - Impact of liquidity crunch on the behavior of complex structured products;
    - Basis risk in hedging strategies;
    - Funding liquidity risk.

- Solutions:
  - Focus on the cash flow effects thus assuming no liquidity in structured products markets (mark-to-market doesn't matter if a product can't be sold at any price);
  - Represent structured products, hedging strategies and funding costs by their basic underlying instruments so that the impact of stressful paths is clearly observable and can be combined at the product / strategy / balance sheet level.



Appendix

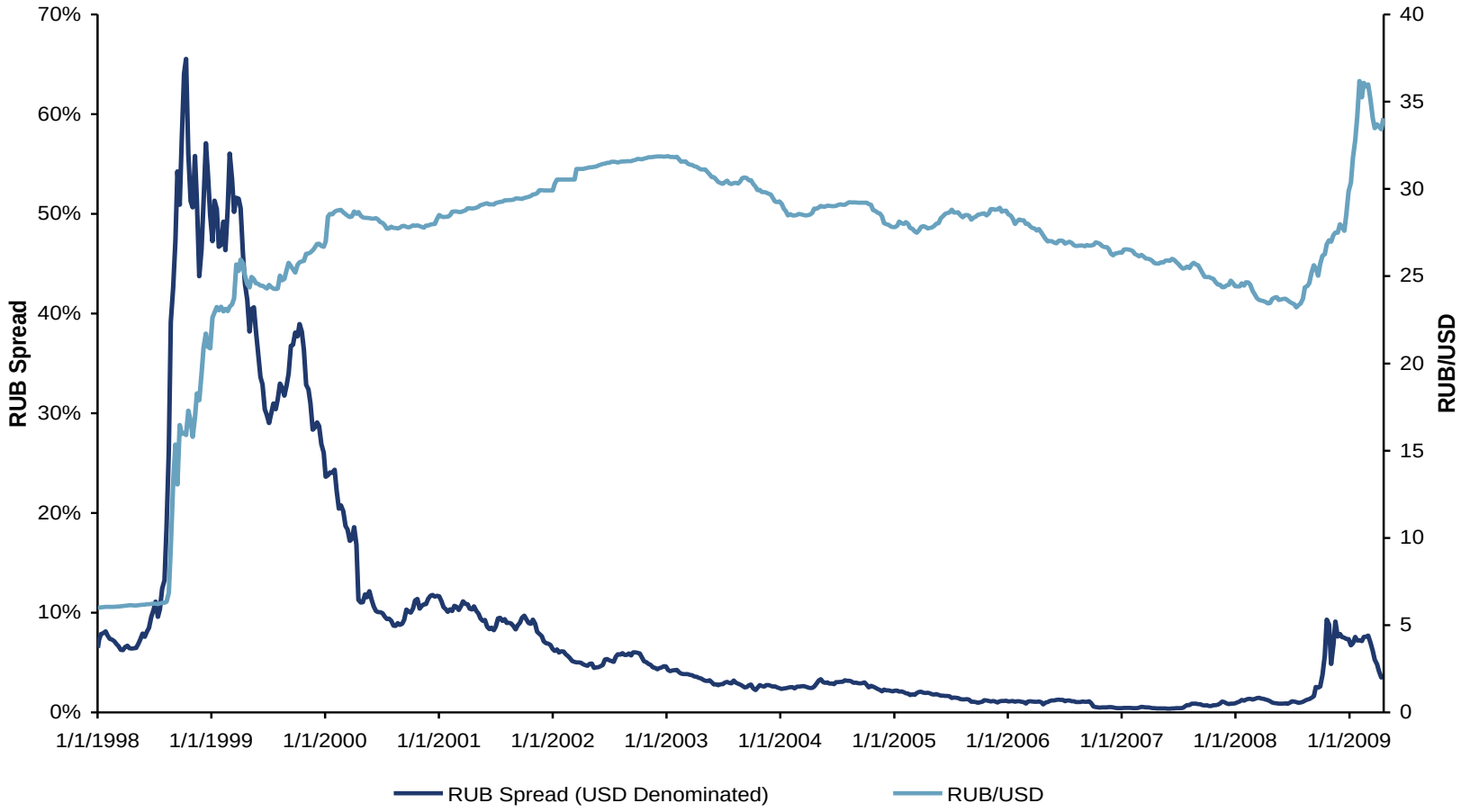
Description of Methodology

Examples of Solutions

Suggested methodology utilizes the best features of existing approaches while overcoming their flaws

- Leading edge risk models that incorporate established credit portfolio methodologies take two primary forms:
  - Structural approach based on the information extracted from the equity markets and the fundamental analysis of the balance sheet of a firm
  - Reduced form approach uses information from market credit spread based instruments
- Our methodology combines information from both equity and credit markets:
  - Utilizes structural approach for LGDs, EADs, and correlations between PDs and LGDs
  - Relies on reduced form approach for calibrating PDs, rating transition probabilities, and increased correlation between default events in stressful markets
  - Incorporates:
    - Certain "jump" events, such as credit defaults and major market shock scenarios
    - "Feedback" onto other assets
  - Allows to extract actionable, institution specific, reverse stress scenarios for proactive risk and capital management

Example of changing correlations

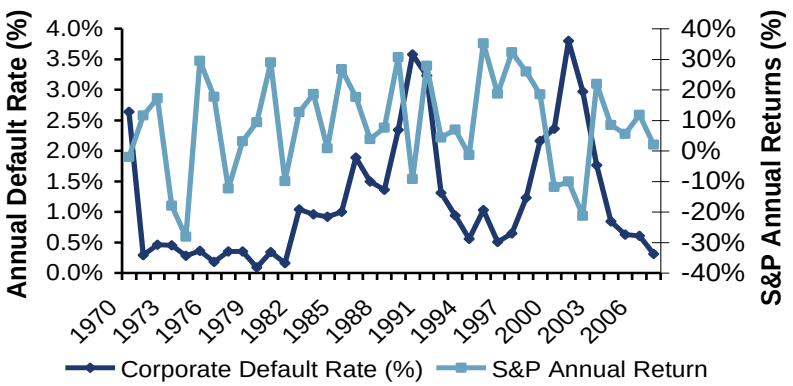


Credit and equity markets

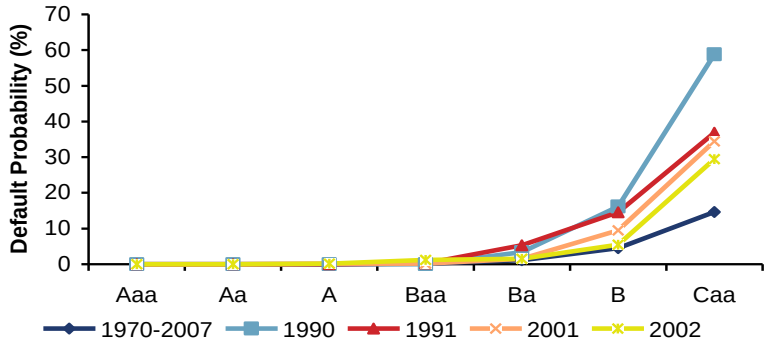
Commentary

- Credit defaults have often come in groups, referred to as credit crunches or credit crises, which lead to fat tails at the negative end of the risk distribution
- This effect is compounded by the fact that spikes in credit defaults are generally accompanied by falls in the equity markets

Annual Credit Default Rate vs. S&P 500 Returns



Default Probabilities in Credit Downturn



Downgrade Probabilities in Credit Downturn

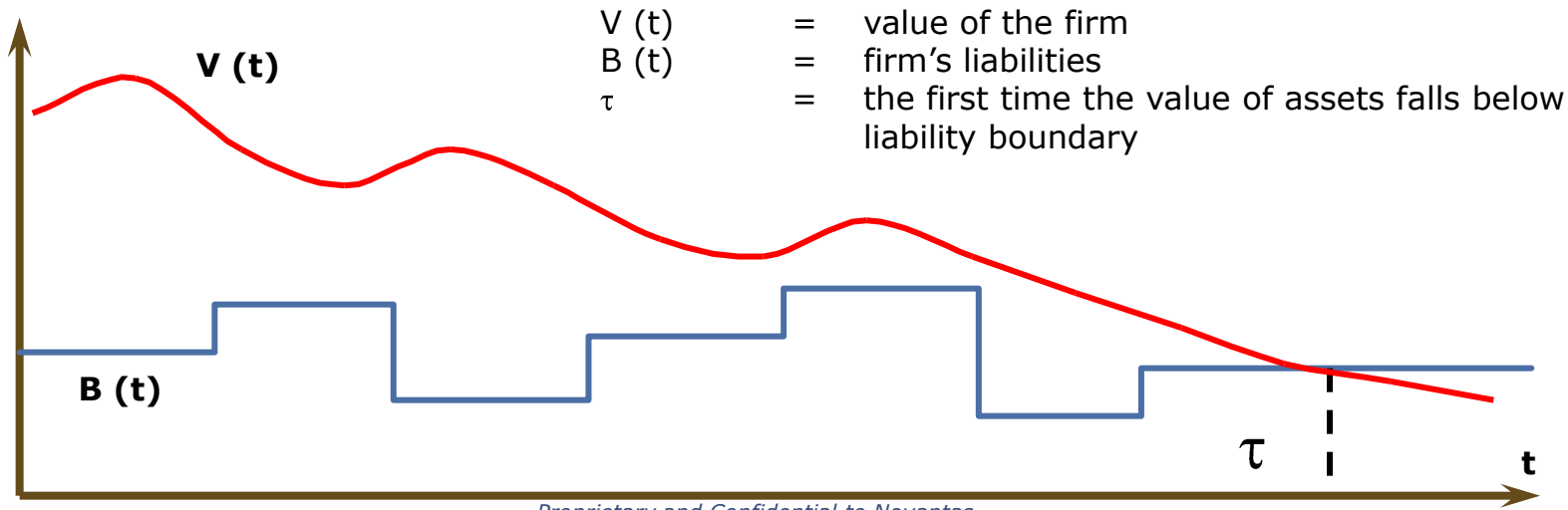
Commentary

Different Aspects of Risk

- There are two major approaches to assessing credit risk and therefore pricing:
  - structural approach is based on the information extracted from the traded equity and the fundamental analysis of the balance sheet of a firm;
  - reduced-form approach uses information from the market credit spreads
- Credit spreads to Treasury yields of the "risky" instruments traded on the market are observable. They consist of:
  - Liquidity component
  - Expected Recovery rate
  - Spread dynamics due to the changes in credit quality
  - Default risk

Value of the Firm: Equity-Based Approach

- Assumptions:
  - Non-Stochastic interest rates (can be relaxed)
  - Value of the firm follows a lognormal diffusion process
  - Default occurs if the value of the firm's assets falls below liability level
- Strength:
  - Easy to implement
- Weaknesses:
  - The firm's liabilities are not as strongly prioritized in bankruptcy proceedings as model assumes
  - Value of the firm is unobservable and its volatilities are hard to estimate



Credit Rating Transition Matrix

- Assumptions:
  - Bankruptcy process is a finite state Markov process in firm's credit ratings
  - Credit spreads are calibrated to risk-neutral rating transition probabilities

- Strengths:
  - Easy to implement because of availability of historical credit ratings transition matrices
  - Allows pricing of options on changes in credit ratings
  - It can be used for calibrating the parameters of stochastic process for the credit spreads

- Weaknesses:
  - Credit ratings lag behind actual changes in credit spreads
  - Credit spreads are diffusive in nature contrary to model's implication
  - It becomes more difficult to use if correlations between the risky issuers need to be taken into account

1 year(Average)	Rating To							
Rating From	AAA	AA	A	BBB	BB	B	CCC-C	Default
AAA	92.18%	6.51%	1.04%	0.25%	0.02%	0.00%	0.00%	0.00%
AA	1.29%	91.62%	6.11%	0.70%	0.18%	0.03%	0.00%	0.07%
A	0.08%	2.50%	91.36%	5.11%	0.69%	0.11%	0.02%	0.14%
BBB	0.04%	0.27%	4.22%	89.16%	5.25%	0.68%	0.07%	0.31%
BB	0.02%	0.09%	0.44%	5.11%	87.08%	5.57%	0.46%	1.25%
B	0.00%	0.04%	0.14%	0.69%	6.52%	85.20%	3.54%	3.87%
CCC-C	0.00%	0.02%	0.04%	0.37%	1.45%	6.00%	78.30%	13.81%

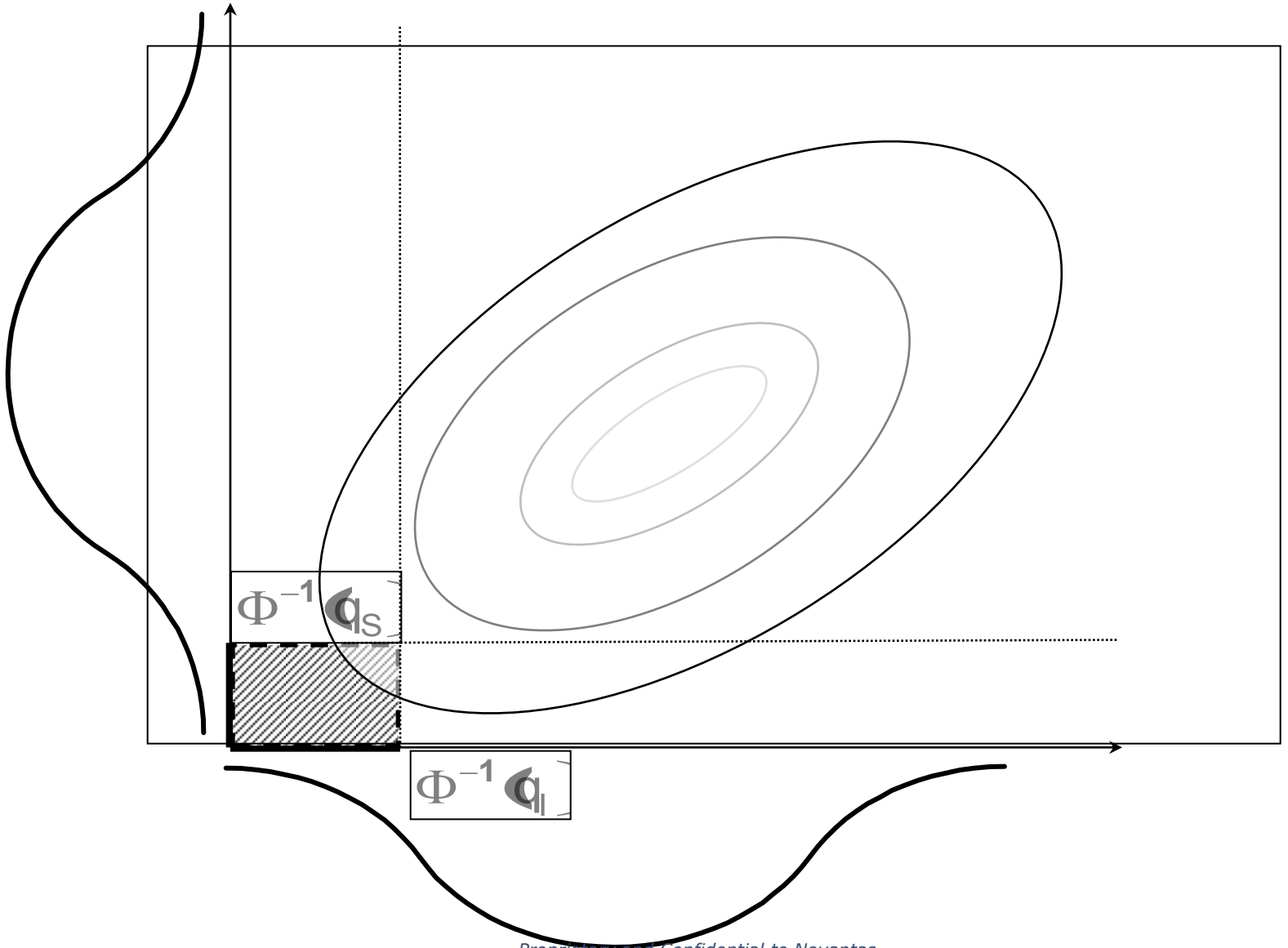
Modeling of Credit Spreads: Duffie and Singleton

- Assumptions:
  - Payoff upon default is a state dependent fraction of the market value before default;
  - Corporate bond spreads are the functions of risk-neutral default intensity, liquidity and recovery rate processes.

- Strengths:
  - Provides a general expression for pricing risky bond.

- Weaknesses:
  - Complicated implementation and calibration;
  - Difficult to hedge using treasury security because the risk-free rate is not modeled explicitly - calibration of all the components is done simultaneously.

Gaussian copula



The methodology starts with this hybrid approach and adds behavioral analytics to model credit, liquidity, and other risks

Foundation Elements

Reduced Form
Credit Market Based
- Credit Spreads
- Transition Matrix
- Probability of Default
- Historical/Implied Recoveries

Structural Approach
Equity Market Based
- Market Equities Prices
- Value of Firm
- Liquidation Value
- Distance to Default

Novantas Behavioral Analytics
- Customer behaviour calibrated to historical information
- Stressed deposit behaviour for liquidity

Produces

Default intensity based on simulated spread level and credit rating implied by the spread and transition matrix

Recoveries based on asset values

Lookup tables of behavioural patterns

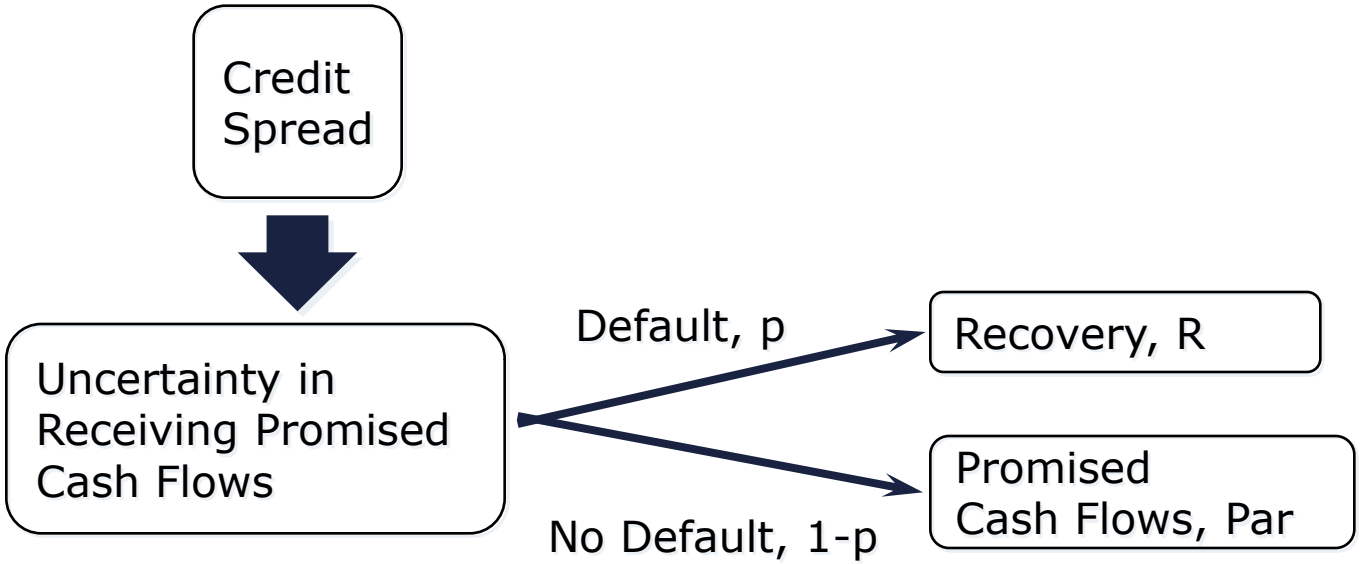
Combined into New Insights and Results

Hybrid Model

Calculations
- Combines credit and equity markets data
- Monte Carlo-based jump diffusion models
- Implicit adjustments to correlations using impacts of jump events
- Loan portfolio PDs, LGDs, EADs

Results
- Portfolio specific worst-case scenarios with their probabilities
- Outcome specific paths that can be analyzed and hedged
- Actionable regulator-ready stress testing engine
- Early warning signaling for proactive capital management

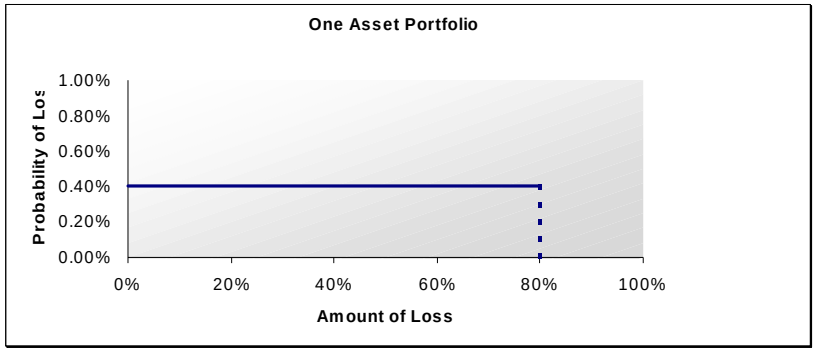
One Period Spread Model

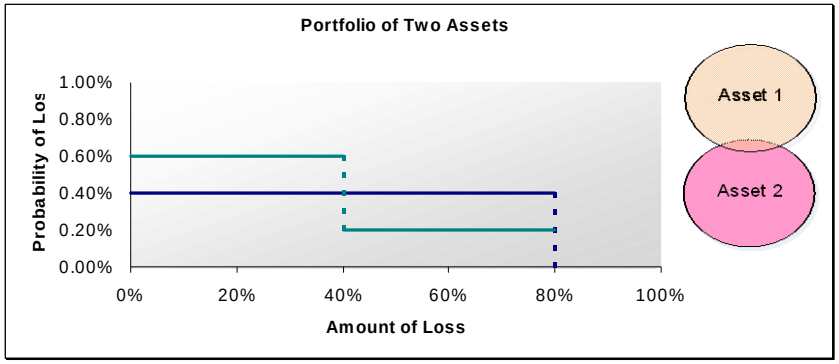


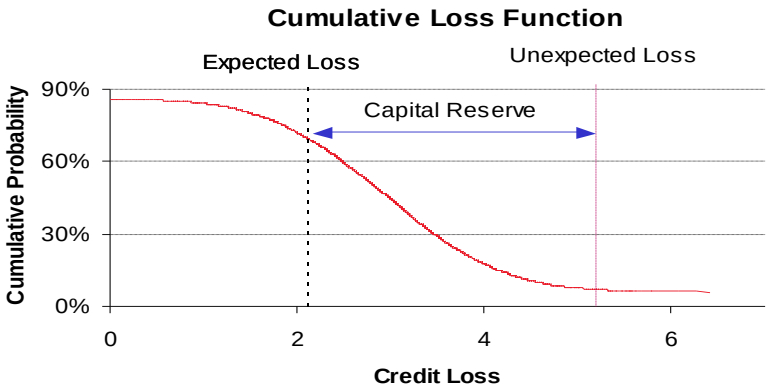
$$1 - s \approx 1/(1 + \text{spread}) = p*R + (1 - p)$$

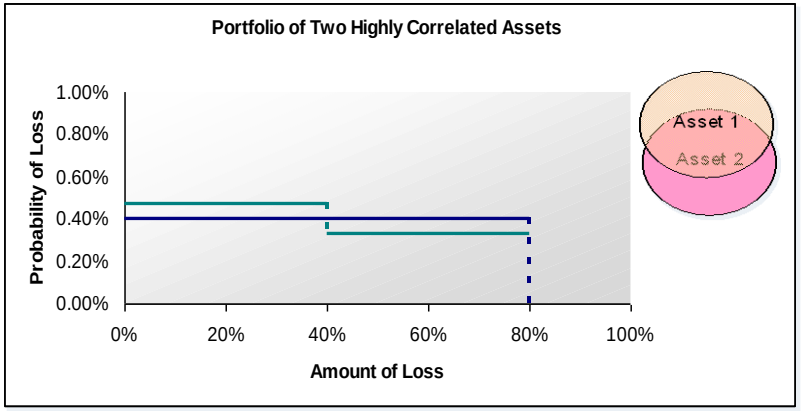
$$s = p*(1 - R)$$

Distribution of Losses

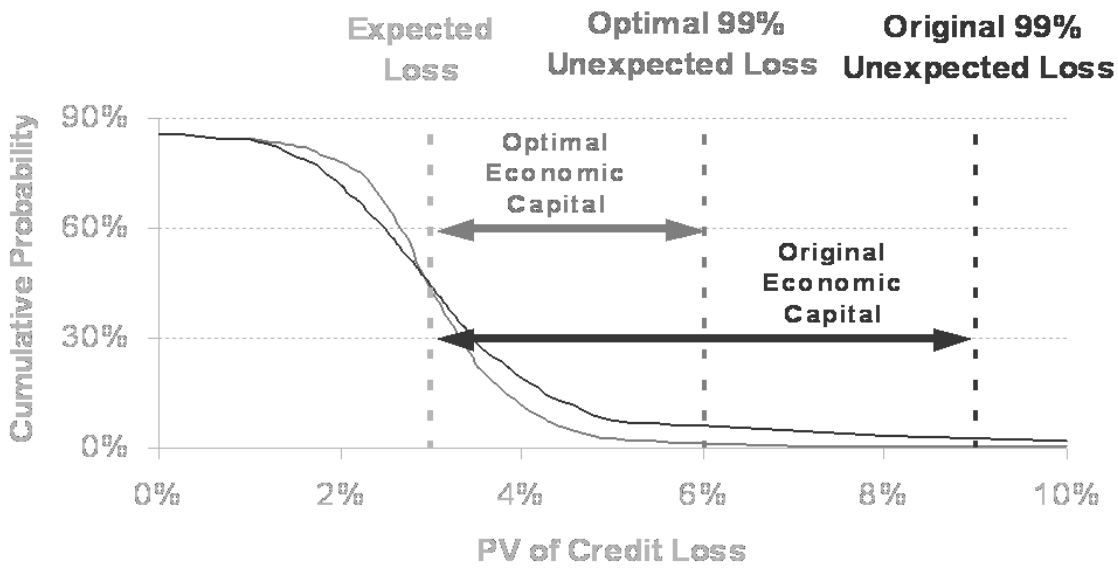


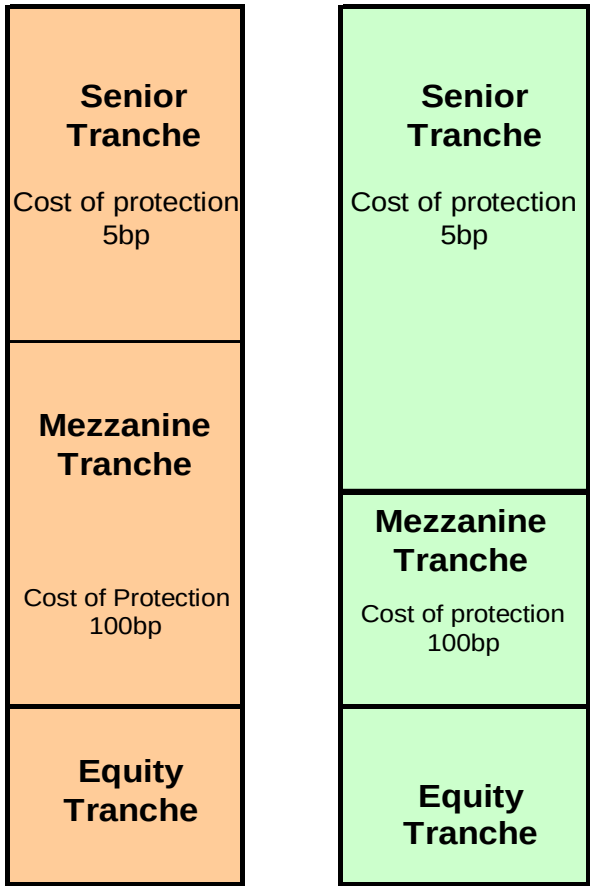




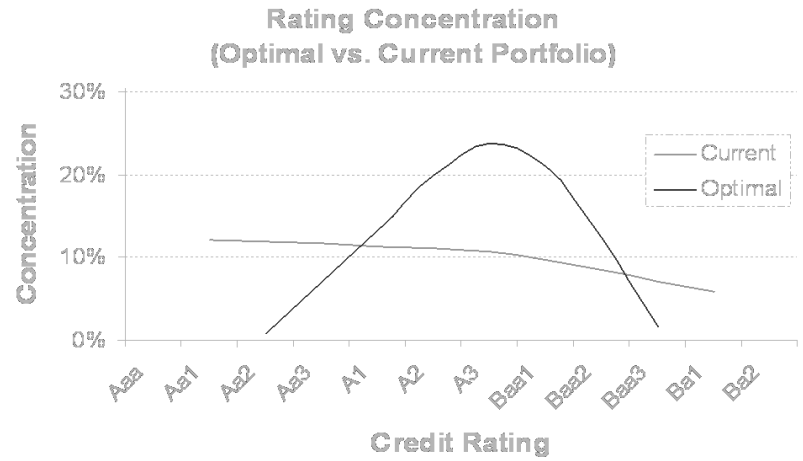


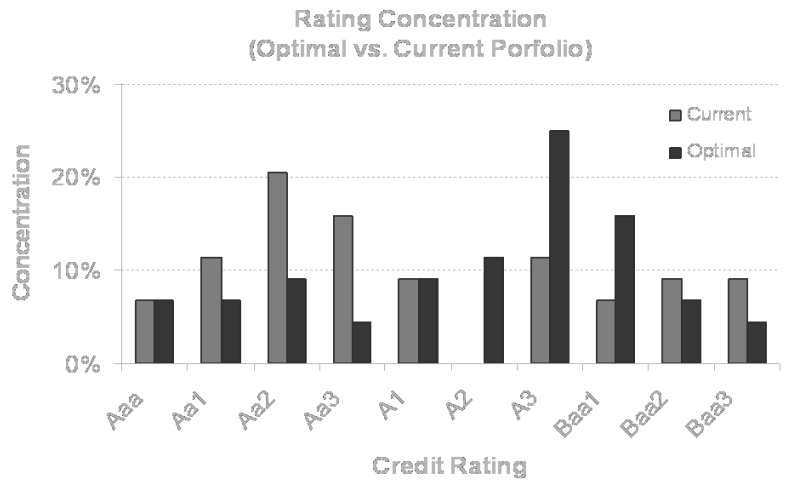
Securitization and Economic Capital





Optimal Credit Rating Concentration



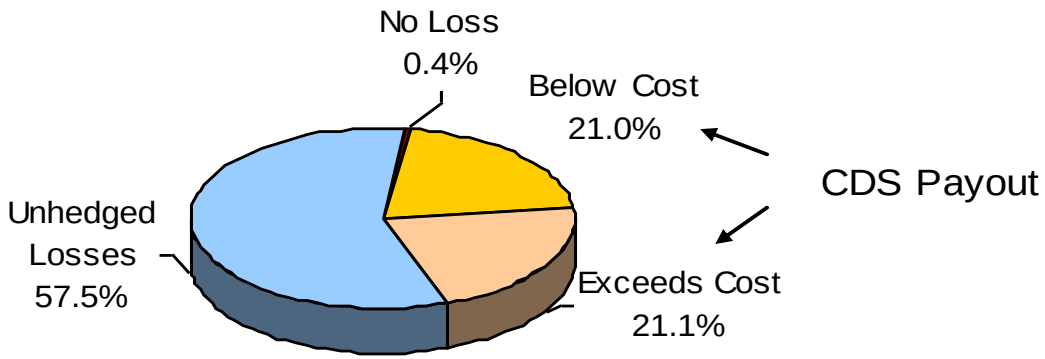


Road Map

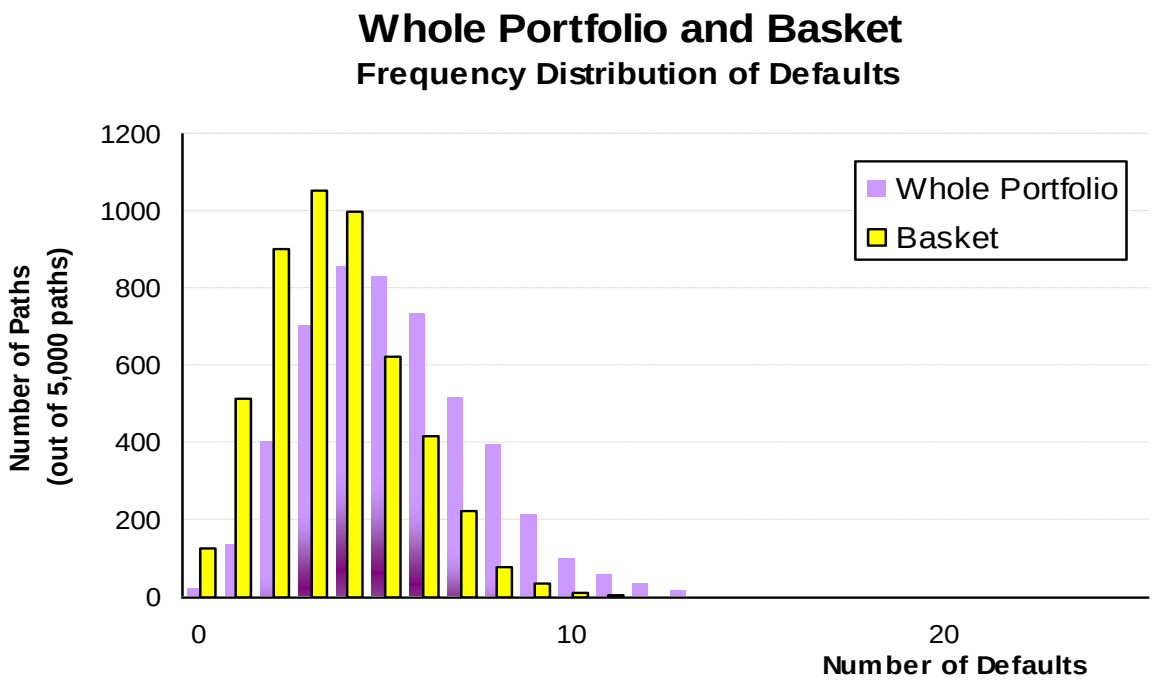
	Aaa	Aa1	Aa2	Aa3	A1	A2	A3	Baa1	Baa2	Baa3
Automobile	-	-	-	-	-	-	-	25	-	-
Chemicals	-	-	-	-	-	-	25	-	-	-
Electronics	-	-	-	-	-	-	75	-	-	-
Entertainment	-	-	-	-	-	50	-	-	-	-
Finance	-	-	-	(150)	-	-	(100)	-	-	(50)
Food	-	-	-	-	-	25	-	50	-	-
Grocery	-	-	-	-	-	50	75	-	-	-
Healthcare	-	-	-	-	-	-	25	-	-	-
Insurance	-	-	-	-	-	50	-	-	-	-
Machinery	-	-	-	-	-	-	25	-	-	-
Manufacturing	-	-	-	-	-	75	-	-	-	-
Metals	-	-	-	-	-	-	25	75	-	-
Municipal	-	(100)	-	(100)	-	-	-	-	-	-
Oil and Gas	-	-	-	-	-	-	25	-	-	-
Packaging	-	-	-	-	-	-	-	-	(50)	-
Real Estate	-	-	-	-	-	-	-	-	-	(50)
Retail	-	-	-	-	-	-	50	50	-	-
Telecom	-	-	-	-	-	-	50	-	-	-
Utilities	-	-	(250)	-	-	-	25	-	-	-

Effectiveness of Current CDS Protection

- Evaluating effectiveness of a hedging strategy of protecting the portfolio through a set of individual credit default swaps
  - Over the next 5 years, the protection brings a net positive benefit in only 21% out of 5,000 simulated paths
  - The protection had no benefit in 58% of the outcomes on the simulated paths (no defaults occurred among the 22 protected names)

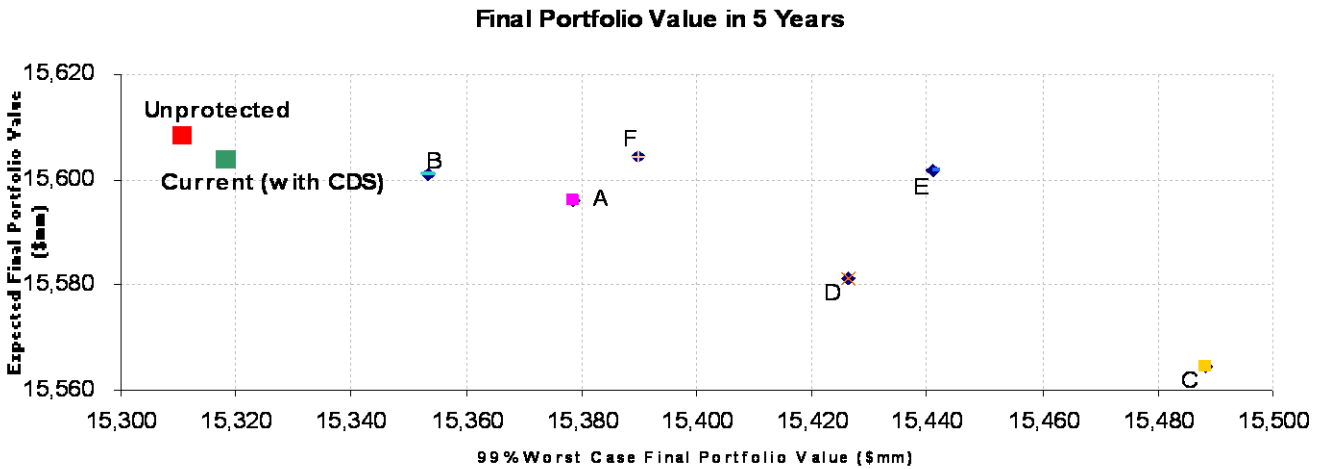


Distribution of Defaults over 5 years



Number of Defaults	# Paths in Portfolio	# Paths in Basket
0	19	127
1	132	515
2	403	903
3	704	1054
4	857	999
5	830	627
6	731	418
7	517	224
8	392	77
9	215	35
10	95	11
11	54	8
12	29	1
13	14	1
14	3	0
15	2	0
16	3	0
17	0	0
18	0	0
19	0	0
20	0	0
21	0	0
22	0	0
23	0	0
24	0	0

Impact of Basket Protection



Various Basket Hedging Scenarios

Attachment Point	Detachment Point	Face Amount ($mm)	% of Notional Protected	
			80%	50%
0.00%	1.00%	113.0	A	B
0.00%	2.50%	282.4	C	D
1.00%	2.50%	169.4	E	F