MERCER OLIVER WYMAN

Casualty Actuarial Society
Enterprise Risk Management Symposium in Chicago
Integrated Treatment of Enterprise-wide Risks (CS 7D)

April 27, 2004

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Main Objective of This Presentation Is To Illustrate Integrated Treatment of Enterprise-wide Risks Using Practical Examples

- Banking, P&C Insurance, Life Insurance and Energy Company examples
- Uses of the output of probabilistic risk aggregation
  - Calculation of diversification benefits
  - Economic Capital attribution
  - Risk-adjusted performance measurement
  - Identification of accumulations and concentrations
  - Risk control, limit setting
  - Risk-based pricing
  - Understanding earnings volatility
  - Reinsurance optimization
- Description of conceptual architectures for calculations
- Analytical, practical and numerical challenges

At the Most Strategic Level, Risk Aggregation Provides Insights for Better Risk, Capital and Value Management

Where is capital attributed?

What is the return on shareholders' capital?

What do shareholders require for risk?

What is the business worth?

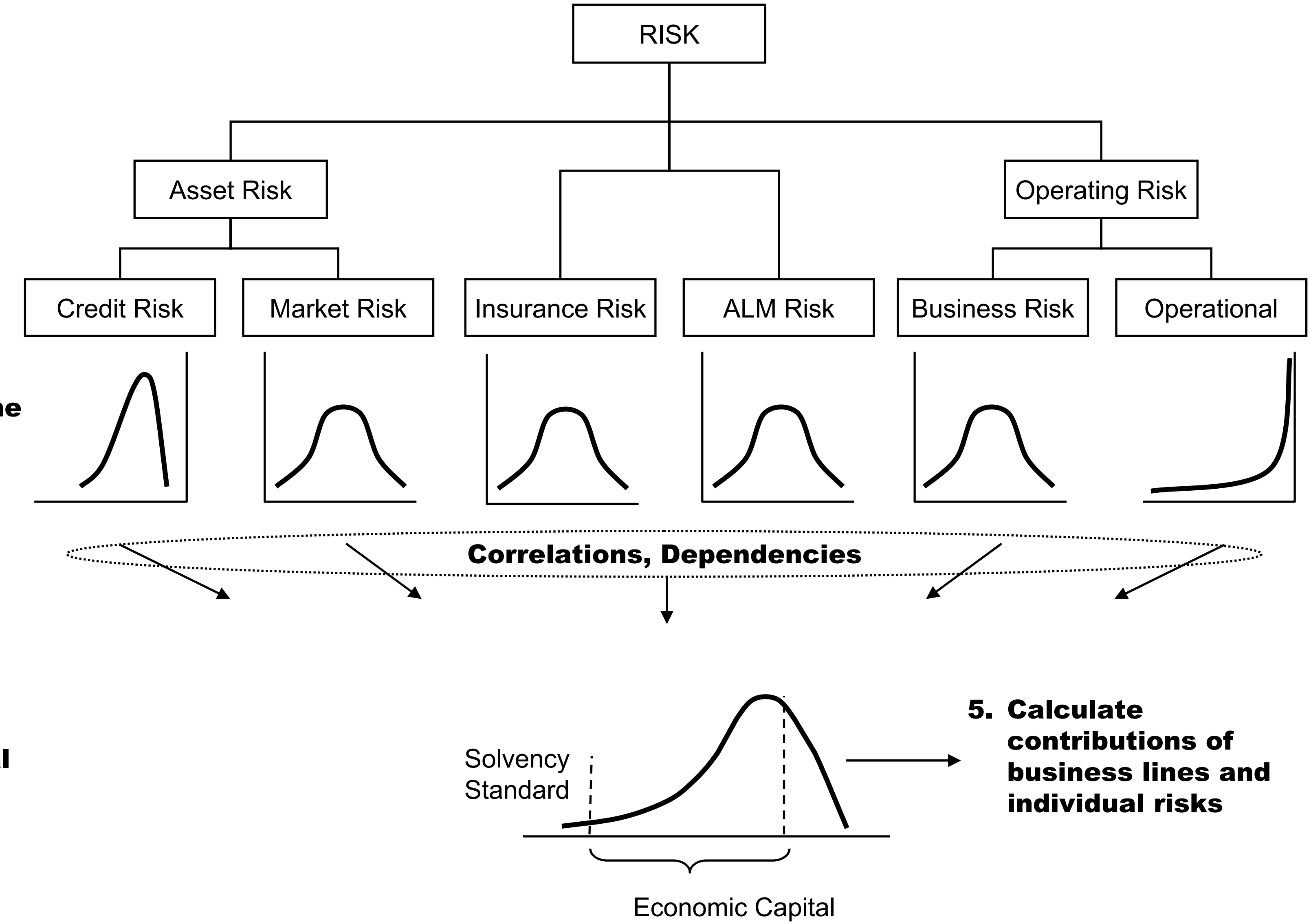
BUSINESS UNIT	ECONOMIC CAPITAL	RAROC	HURDLE	GROWTH	INTRINSIC VALUE
Business Unit A	$1.3 BN	35%	15%	5%	$3.9 BN
Business Unit B	$1.8 BN	10%	15%	7%	$0.7 BN
Business Unit C	$0.9 BN	15%	15%	8%	$0.9 BN
Business Unit D	$0.5 BN	40%	15%	6%	$1.9 BN
Total Economic Capital	$4.5 BN	21%			$7.4 BN
Excess Capital	$0.5 BN	7%	15%	0%	$0.2 BN
Total Available Capital	$5.0 BN	20%			$7.6 BN

How much capital is needed?

How does excess capital affect value?

Economic Capital is Calculated By Considering the Distributions of All Sources of Risk and The Dependencies Between Them

1. **Identify all sources of risk**
2. **Characterize the distributions**
3. **Aggregate distributions**
4. **Measure required capital**



5. **Calculate contributions of business lines and individual risks**

Several Banks Disclose Economic Capital and the Diversification Benefit Calculated from Risk Aggregation

- Citigroup CFO presented the following Economic Capital results on March 29, 2004

Credit	$28.7 BN
Market	$16.8 BN
Operational	$6.1 BN
Insurance	$0.3 BN
Standalone Sum	$51.9 BN
Diversification Benefit	($5.2 BN)
Total Economic Capital	$46.7 BN

- There is also significant risk aggregation and diversification calculations within Credit Risk
  - Multiple transactions with a customer, outstanding loans, leases, credit line commitments, derivative positions, leading to the need for aggregation of
    - Transactions to customer ID level
    - Additional exposure to subsidiaries and guarantee structures
    - Lending, leasing, treasury
    - Different geographies
  - Various models to incorporate correlation into credit risk portfolio models
    - Merton-based
    - Econometric
    - Actuarial

There Are Several Challenges In Risk Aggregation and Economic Capital Attribution Centered Around Achieving Consistency In Standalone Risk Measurement and Estimating Correlations

- Consistency of risk measurement by risk type before aggregation
  - Units measured . . . Change in value versus economic loss
  - Exposure measured . . . Exposure at default versus outstanding/MTM versus unutilized lines
  - Time horizon . . . One day versus one year versus multi-year
  - Common risk metric . . . Confidence interval, standard deviation, conditional tail estimate
- Embedding and estimation of correlations and dependencies
  - Dependence measure . . . Correlation matrix, factor-based modeling, joint pdf, copulas
  - Difficulties in parameter estimation . . . Empirical observations from historical data, industry benchmarks, analogs, expert judgment, Delphi method; parameter error, non-stationary dependencies
  - Sensitivity testing . . . To understand impact of assumptions and parameter error
- Aggregation technique for correlated non-normal random variables/processes
  - Risk component versus risk driver approaches
  - Analytical approximations to simulation-based approaches to numerical integration
- Disaggregation/Attribution of Economic Capital to different risks/business lines
  - Haircut factor, Continuous marginal, Discrete marginal and Shapley value

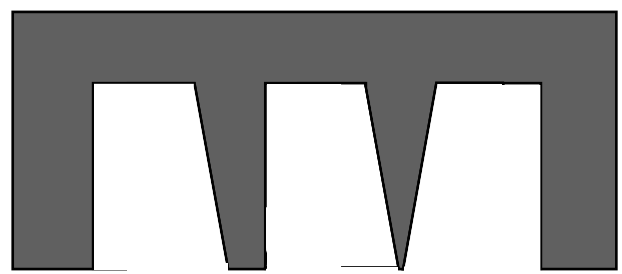
Two Potential Designs For Risk Aggregation: Risk Component Approach And Risk Driver Approach

Risk Component Approach

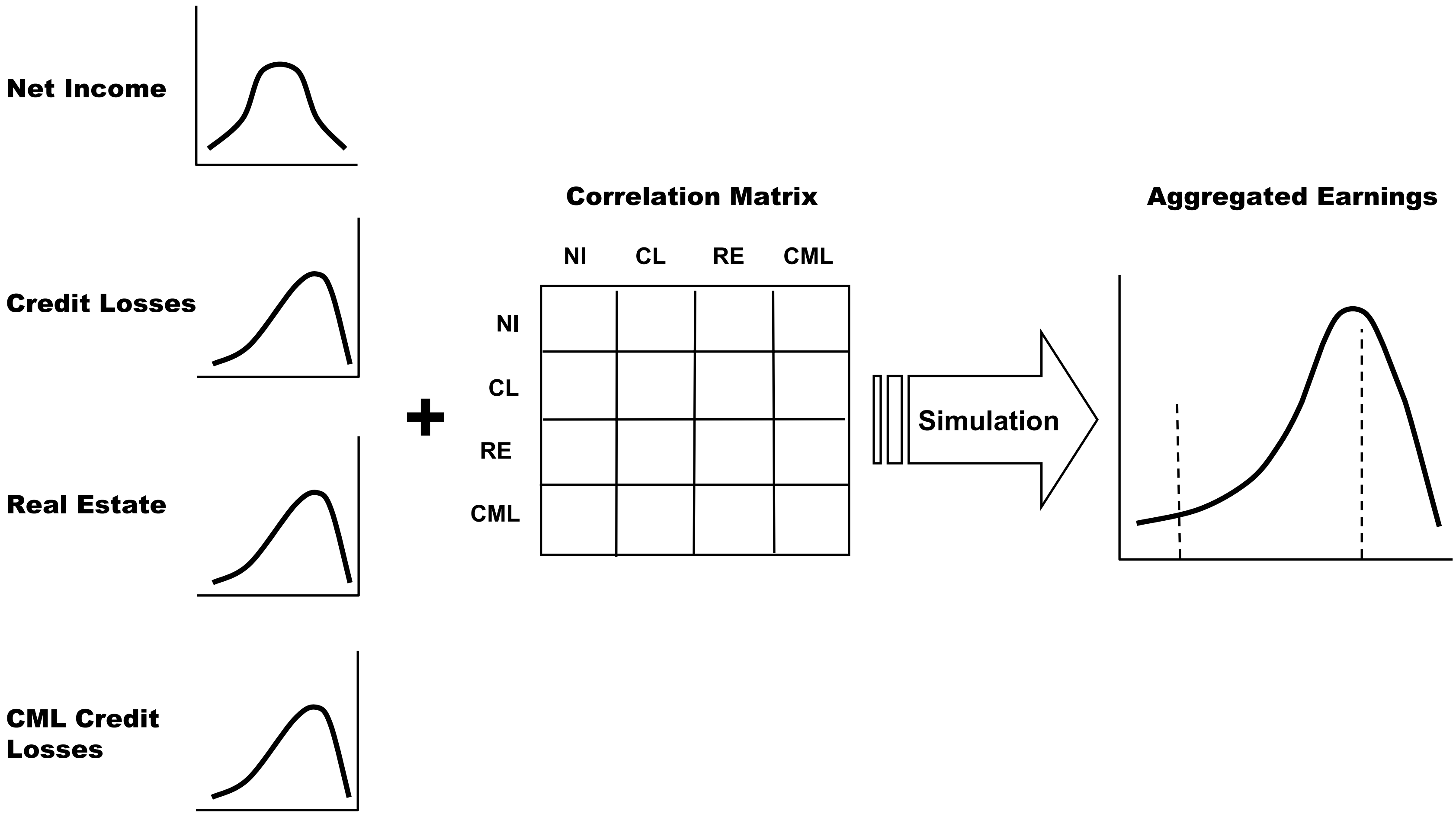
- Each risk type is modeled using “best of breed” methodologies available
- A dependence structure (correlations) among component risks is then introduced
- An algorithm (usually simulation) is applied to determine the aggregate risk distribution and diversification benefits

Risk Driver Approach

- A set of risk drivers such as interest rates, equity index returns (by industry and geography), GDP, unemployment rate that explain component risks (and therefore aggregate risk) are identified
- Regression studies are performed to link component risks to these risk drivers
- A common set of scenarios (states-of-the-world) for the risk drivers is simulated
- These scenarios are applied to each component risk and losses are calculated for each scenario
- The histogram of aggregate losses provides us the loss distribution and diversification benefits



Risk Component Approach – Example Annuity Business



Correlation/Dependence Parameter Estimation Is a Combination of Art and Science in The Risk Component Approach

	Risk A	B	C	D	E	F
Risk A	100%					
B		100%				
C			100%			
D				100%		
E					100%	
F						100%

Symmetric

Historical data of indices (Stress Correlations) and some high level macro sensitivity analysis

Industry Data

Intuition

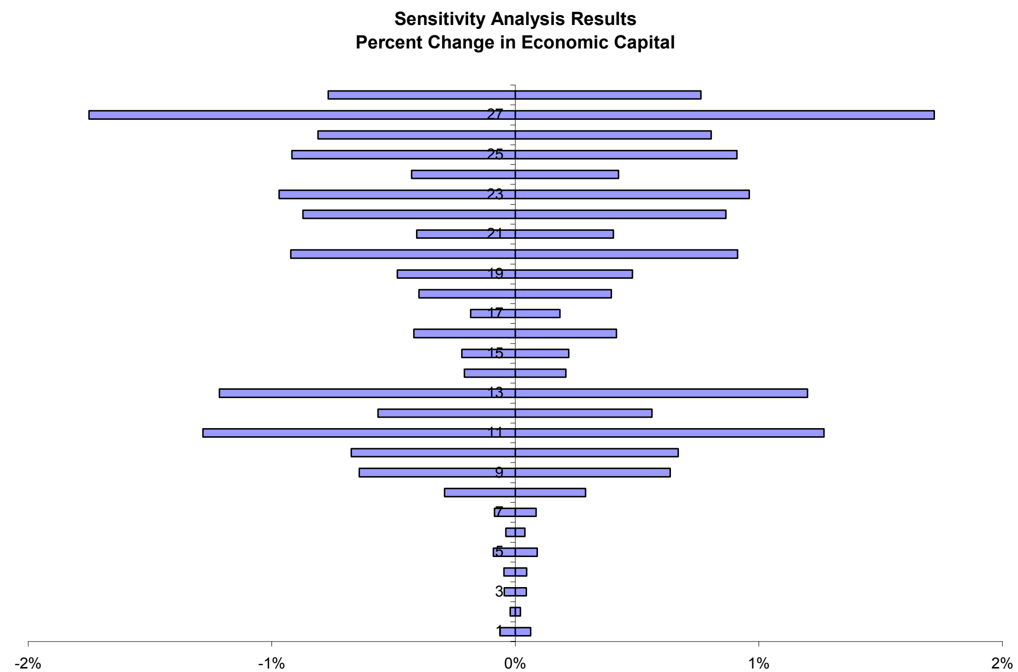
Internal Data

Expert Opinion
Delphi Method

Sensitivity Studies Help us Identify The Important Correlations

Example - US P&C Insurer
Sensitivity of Economic Capital w.r.t. changes in linear correlations (+-10%)

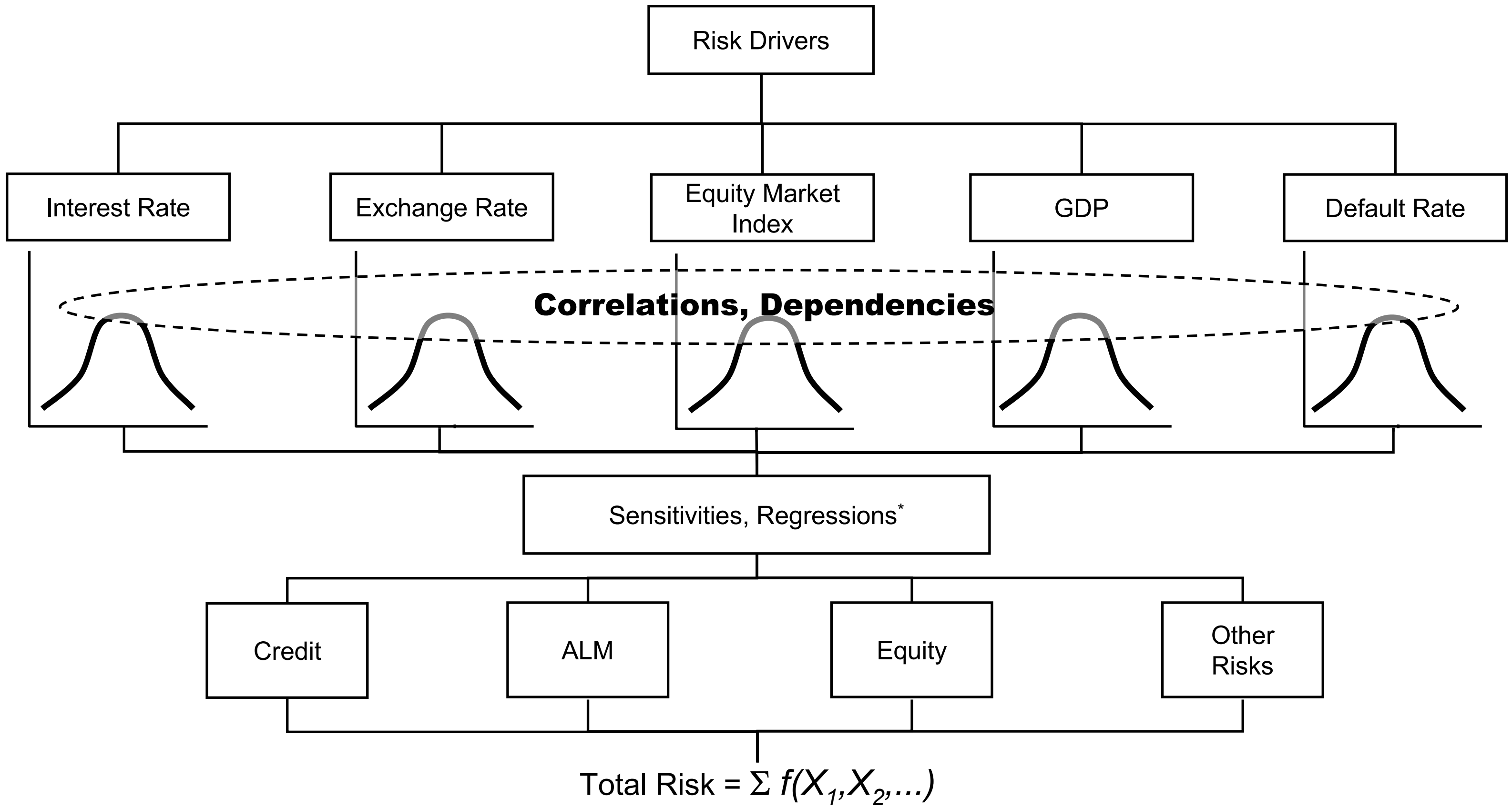
	Correlation
1	Credit, Market Correlation
2	Credit, ALM Correlation
3	Credit, Operating Correlation
4	Credit, Unknown MT Correlation
5	Credit, Known MT Correlation
6	Credit, Non Cat Correlation
7	Credit, Cat Correlation
8	Market, ALM Correlation
9	Market, Operating Correlation
10	Market, Unknown MT Correlation
11	Market, Known MT Correlation
12	Market, Non Cat Correlation
13	Market, Cat Correlation
14	ALM, Operating Correlation
15	ALM, Unknown MT Correlation
16	ALM, Known MT Correlation
17	ALM, Non Cat Correlation
18	ALM, Cat Correlation
19	Operating, Unknown MT Correlation
20	Operating, Known MT Correlation
21	Operating, Non Cat Correlation
22	Operating, Cat Correlation
23	Unknown MT, Known MT Correlation
24	Unknown MT, Non Cat Correlation
25	Unknown MT, Cat Correlation
26	Known MT, Non Cat Correlation
27	Known MT, Cat Correlation
28	Non Cat, Cat Correlation



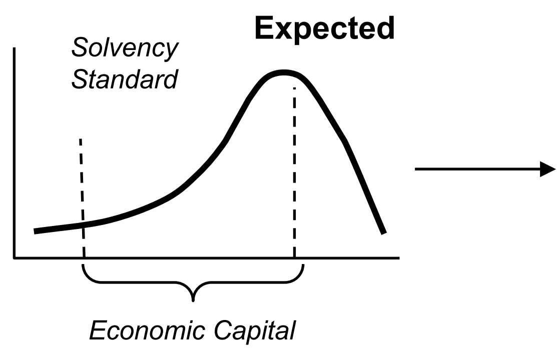
Number

Risk Driver Approach Models Component and Aggregate Risks as Function of a List of Risk Drivers

1. **Identify all risk drivers**
2. **Characterize distributions and dependencies of risk drivers ($X_1, X_2, \ldots$)**
3. **Model individual risks as function of risk drivers**

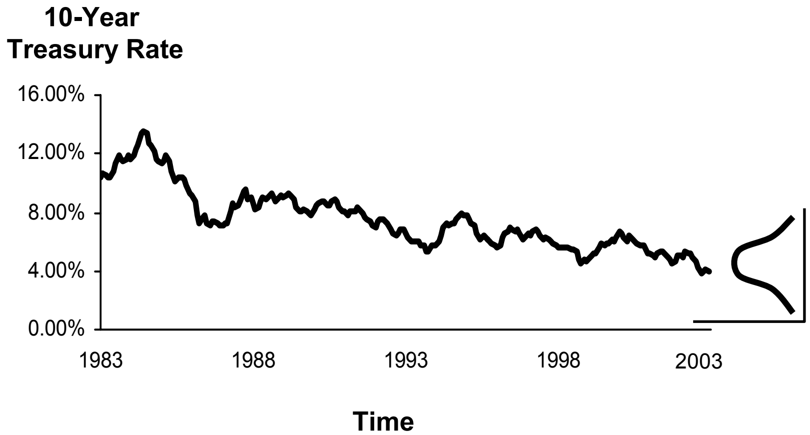


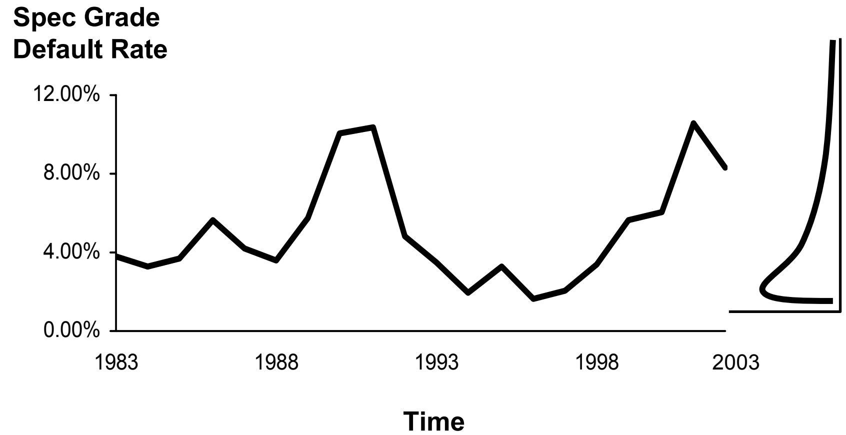
4. **Calculate total risk as function of risk drivers**

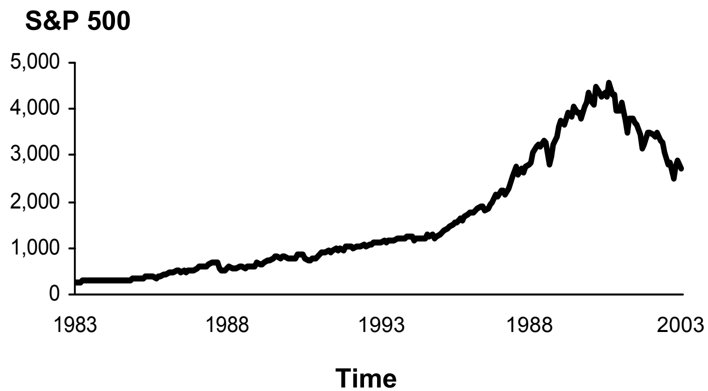


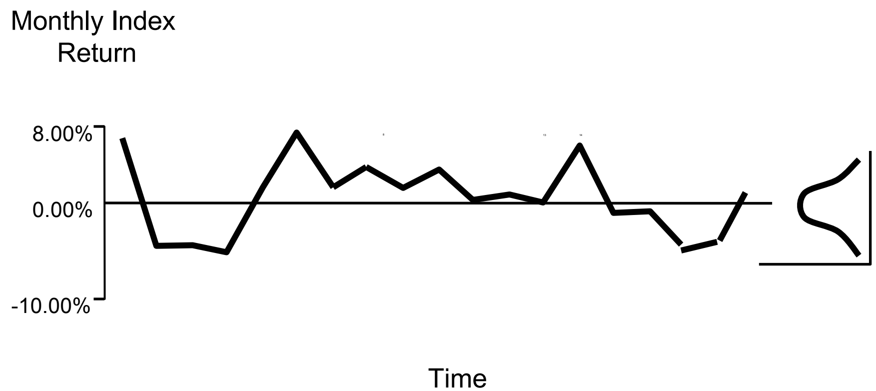
5. **Calculate contributions of business lines and individual risks**

Once Risk Drivers Are Identified, These Are Modeled Statistically

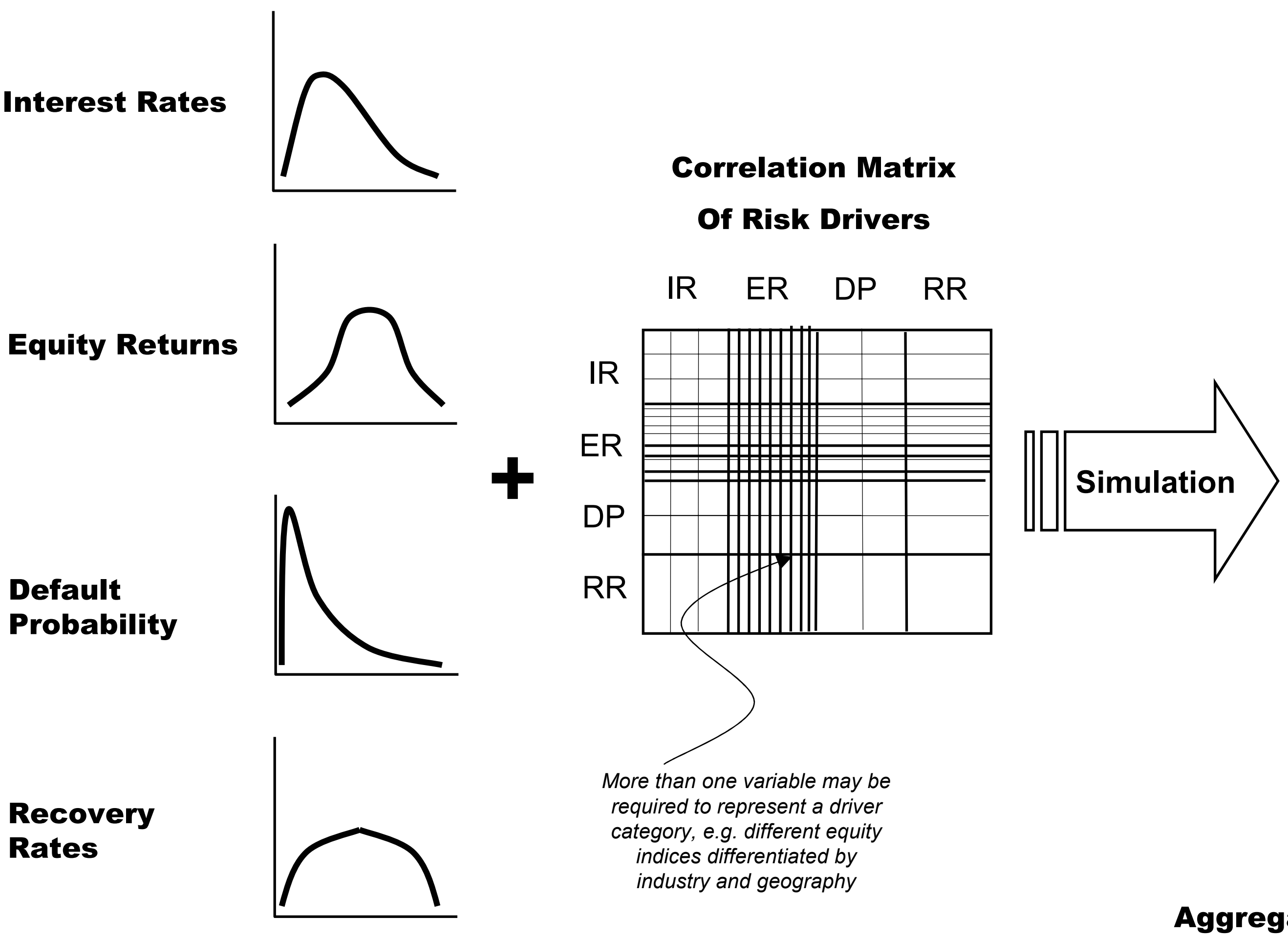






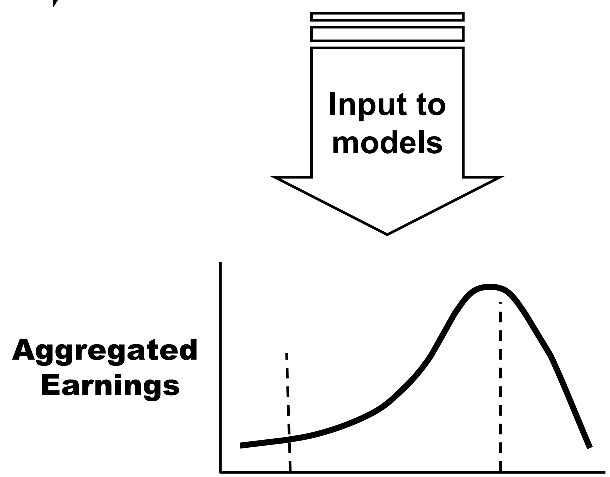


The Risk Driver Approach Can Be Applied by Simulating the Risk Drivers and Running the Models Under the Generated Scenarios



A Set of Consistent Scenarios

Run	Change in Spread Between 2- & 10-Year Interest Rates	Change in 10-Year Interest Rate	Change in S&P 500 Total Return	Investment Grade PD	Speculative Grade PD	Recovery Rate
1	0.014712	-0.001353	0.045995	0.000002	0.103976	0.346779
2	0.001253	0.000247	0.049912	0.000513	0.047590	0.335682
3	-0.004856	0.015264	0.026855	0.000001	0.043307	0.487343
4	-0.001840	0.008736	0.112229	0.000003	0.031767	0.472619
5	0.005317	0.002680	0.031489	0.003012	0.065992	0.321608
6	-0.015701	-0.010767	0.400308	0.000000	0.016890	0.414426
7	0.003158	0.009256	-0.064265	0.000393	0.018778	0.504109
8	0.006747	-0.007487	0.047993	0.003073	0.048818	0.256633
9	0.003042	-0.013135	0.296717	0.000013	0.064238	0.408333
10	-0.005554	-0.017385	0.454249	0.000006	0.044962	0.385277
11	-0.004915	0.000483	0.298752	0.000001	0.040279	0.374541
12	0.015932	-0.026831	-0.075248	0.004840	0.054020	0.284303
13	0.006909	-0.002403	0.334106	0.000000	0.025317	0.478960
14	0.003735	-0.001741	0.389211	0.000000	0.034282	0.531850



Basle II Provides a Closed-Form Formula For Risk Aggregation for Credit Exposures

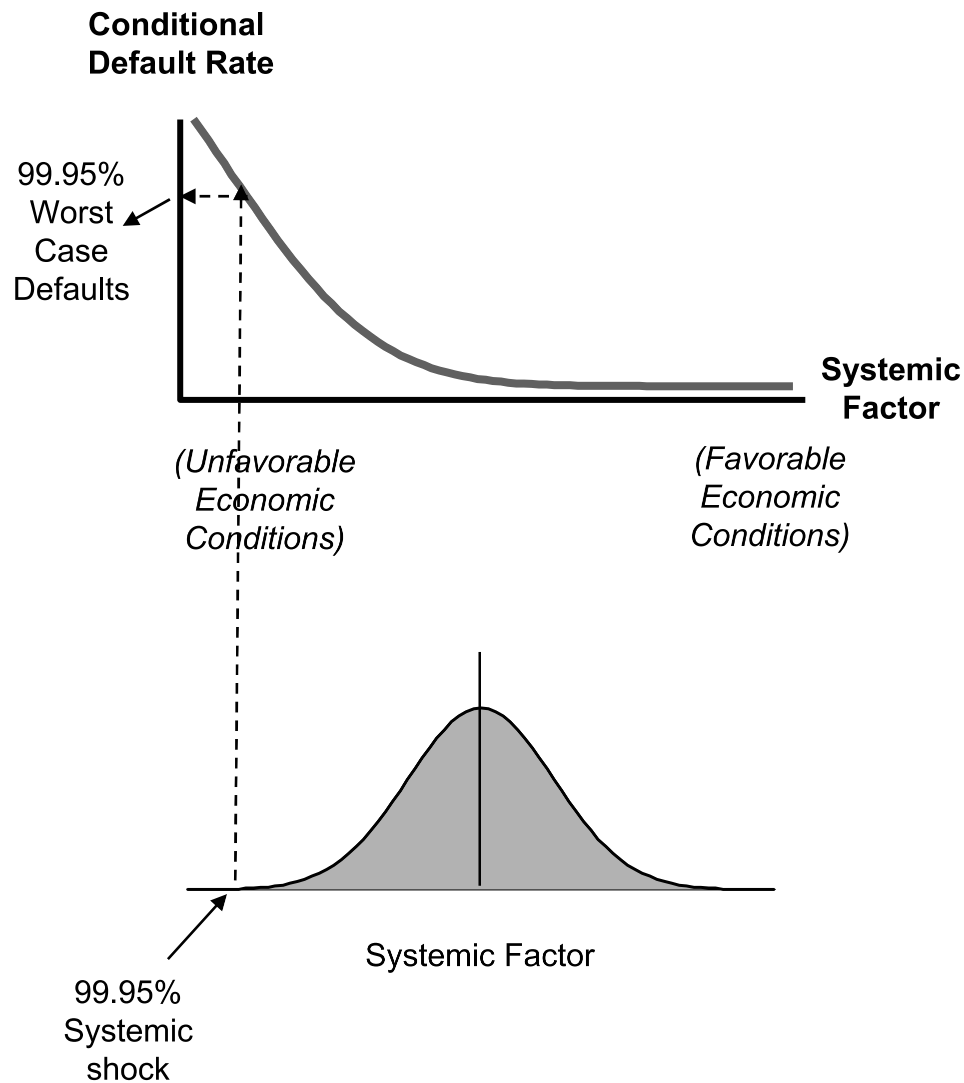
SINGLE FACTOR MERTON MODEL OF DEFAULT

- A firm defaults when value of assets is less than value of liabilities

- For a firm with a given rating, the default occurs when asset returns are very poor, and the critical level of poor returns is linked to rating of the firm

- Asset correlation between firms then incorporates joint default likelihood

- Basel Formula
    - There is a single factor that drives systemic risk. Intuitively, this factor is a combination of equity index returns, GDP growth, interest rate changes, unemployment rate etc.
    - For a diversified portfolio, worst-case cumulative loss occurs when the single factor is very unfavorable (e.g. 99.95%), default rates are at worst-case in that scenario
    - Single factor formulation doesn't require an asset correlation matrix. It only requires asset correlation of obligors to the factor, usually a function of PD and size (as in Basle II)



Energy Company – Insurance Optimization

Raw Data Processor

Insurance Filter
Policy Filter

Aggregation Within Risk Type

Simulation Engine (aggregation across lines)