MOODY'S ANALYTICS

Economic Scenario Generators

CASE Spring Meeting – Nashville, TN

LOIC GRANDCHAMP

March 27, 2013

What is an ESG? What can you use it for?

1. Introduction

1. Overview
2. Simple example
3. Correlations
4. Calibrations

2. Applications

1. Market risk
2. Reserving / Underwriting
3. Capital modeling
4. Asset allocation

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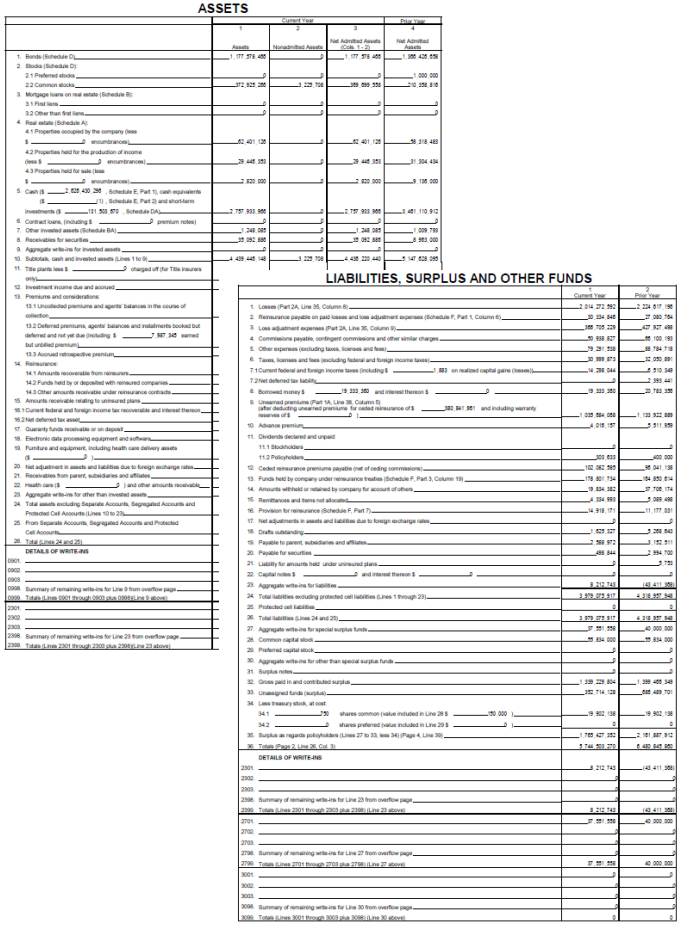
Introduction to ESG

Economic scenario generators – Why?

What are the sources of market and economic risks for P&C insurers?

- Interest rates
  - Government bonds (incl. inflation-linked bonds)
  - Municipal bonds
  - Mortgage-backed securities
- Credit
  - Corporate bonds
  - Reinsurance counterparties
- Currency
- Price inflators
  - CPI / Wage inflation
  - Specific claims exposures: medical, construction, auto
- Equity & property markets
- Correlations / dependencies



ASSETS

	Current Year 1 Assets	2 Nonadmitted Assets	3 Net Admitted Assets (Cols. 1 - 2)	Prior Year 4 Net Admitted Assets
1. Bonds (Schedule D)	1,177,579,485	0	1,177,579,485	1,066,426,658
2. Stocks (Schedule D):				
2.1 Preferred stocks	0	0	0	1,000,000
2.2 Common stocks	972,925,286	3,229,706	969,695,580	910,358,918
3. Mortgage loans on real estate (Schedule B):				
3.1 First liens	0	0	0	0
3.2 Other than first liens	0	0	0	0
4. Real estate (Schedule A):				
4.1 Properties occupied by the company (less $ 0 encumbrances)	62,401,126	0	62,401,126	58,918,483
4.2 Properties held for the production of income (less $ 0 encumbrances)	39,445,353	0	39,445,353	31,304,434
4.3 Properties held for sale (less $ 0 encumbrances)	2,820,000	0	2,820,000	8,195,000
5. Cash ($ 2,626,430,295, Schedule E, Part 1), cash equivalents ($ 0, Schedule E, Part 2) and short-term investments ($ 191,503,870, Schedule DA)	2,797,934,165	0	2,797,934,165	3,461,119,912
6. Contract loans, (including $ 0 premium notes)	0	0	0	0
7. Other invested assets (Schedule BA)	1,248,085	0	1,248,085	1,009,780
8. Receivables for securities	35,092,680	0	35,092,680	8,983,000
9. Aggregate write-ins for invested assets	0	0	0	0
10. Subtotals, cash and invested assets (Lines 1 to 9)	4,489,445,148	3,229,706	4,486,220,440	5,147,626,085
11. Title plants less $ 0 charged off (for Title insurers only)				
12. Investment income due and accrued				
13. Premiums and considerations:				
13.1 Uncollected premiums and agents' balances in the course of collection				
13.2 Deferred premiums, agents' balances and installments booked but deferred and not yet due (including $ 7,987,345 earned but unbilled premium)				
13.3 Accrued retrospective premium				
14. Reinsurance:				
14.1 Amounts recoverable from reinsurers				
14.2 Funds held by or deposited with reinsured companies				
14.3 Other amounts receivable under reinsurance contracts				
15. Amounts receivable relating to uninsured plans				
16.1 Current federal and foreign income tax recoverable and interest thereon				
16.2 Net deferred tax asset				
17. Guaranty funds receivable or on deposit				
18. Electronic data processing equipment and software				
19. Furniture and equipment, including health care delivery assets ($ 0)				
20. Net adjustment in assets and liabilities due to foreign exchange rates				
21. Receivables from parent, subsidiaries and affiliates				
22. Health care ($ 0) and other amounts receivable				
23. Aggregate write-ins for other than invested assets				
24. Total assets excluding Separate Accounts, Segregated Accounts and Protected Cell Accounts (Lines 10 to 23)				
25. From Separate Accounts, Segregated Accounts and Protected Cell Accounts				
26. Total (Lines 24 and 25)				
DETAILS OF WRITE-INS				
0901				
0902				
0903				
0998. Summary of remaining write-ins for Line 9 from overflow page				
0999. Totals (Lines 0901 through 0903 plus 0998)(Line 9 above)				
2301				
2302				
2303				
2398. Summary of remaining write-ins for Line 23 from overflow page				
2399. Totals (Lines 2301 through 2303 plus 2398)(Line 23 above)				

LIABILITIES, SURPLUS AND OTHER FUNDS

	1 Current Year	2 Prior Year
1. Losses (Part 2A, Line 35, Column 8)	2,014,272,762	2,224,517,196
2. Reinsurance payable on paid losses and loss adjustment expenses (Schedule F, Part 1, Column 6)	30,334,946	27,080,764
3. Loss adjustment expenses (Part 2A, Line 35, Column 9)	388,705,229	427,927,486
4. Commissions payable, contingent commissions and other similar charges	70,938,827	66,100,193
5. Other expenses (excluding taxes, licenses and fees)	79,291,538	68,794,718
6. Taxes, licenses and fees (excluding federal and foreign income taxes)	30,999,873	32,050,891
7.1 Current federal and foreign income taxes (including $ 7,883 on realized capital gains (losses))	14,286,044	8,510,348
7.2 Net deferred tax liability	0	2,993,441
8. Borrowed money $ 19,333,350 and interest thereon $ 0	19,333,350	32,793,356
9. Unearned premiums (Part 1A, Line 36, Column 5) (after deducting unearned premiums for ceded reinsurance of $ 380,841,961 and including warranty reserves of $ 0)	1,035,584,056	1,133,922,889
10. Advance premium	4,016,157	5,511,959
11. Dividends declared and unpaid:		
11.1 Stockholders	0	0
11.2 Policyholders	300,000	400,000
12. Ceded reinsurance premiums payable (net of ceding commissions)	102,562,595	96,041,138
13. Funds held by company under reinsurance treaties (Schedule F, Part 3, Column 19)	178,801,734	164,850,614
14. Amounts withheld or retained by company for account of others	19,894,362	27,708,174
15. Remittances and items not allocated	4,394,999	5,089,496
16. Provision for reinsurance (Schedule F, Part 7)	14,918,171	11,177,031
17. Net adjustments in assets and liabilities due to foreign exchange rates	0	0
18. Drafts outstanding	1,625,227	5,268,540
19. Payable to parent, subsidiaries and affiliates	3,566,972	3,152,511
20. Payable for securities	488,844	2,994,700
21. Liability for amounts held under uninsured plans	0	5,793
22. Capital notes $ 0 and interest thereon $ 0	0	0
23. Aggregate write-ins for liabilities	8,212,743	(43,411,358)
24. Total liabilities excluding protected cell liabilities (Lines 1 through 23)	3,979,073,917	4,318,957,848
25. Protected cell liabilities	0	0
26. Total liabilities (Lines 24 and 25)	3,979,073,917	4,318,957,848
27. Aggregate write-ins for special surplus funds	37,551,556	40,000,000
28. Common capital stock	59,934,000	59,934,000
29. Preferred capital stock	0	0
30. Aggregate write-ins for other than special surplus funds	0	0
31. Surplus notes	0	0
32. Gross paid in and contributed surplus	1,339,229,804	1,399,466,549
33. Unassigned funds (surplus)	352,714,128	(646,489,701)
34. Less treasury stock, at cost: 34.1 750 shares common (value included in Line 28 $ 750,000)	19,902,138	19,902,138
34.2 0 shares preferred (value included in Line 29 $ 0)	0	0
35. Surplus as regards policyholders (Lines 27 to 33, less 34) (Page 4, Line 39)	1,769,427,352	2,161,987,912
36. Totals (Page 2, Line 26, Col. 3)	5,748,501,270	6,480,945,760
DETAILS OF WRITE-INS		
2301	8,212,743	(43,411,358)
2302	0	0
2303	0	0
2398. Summary of remaining write-ins for Line 23 from overflow page	0	0
2399. Totals (Lines 2301 through 2303 plus 2398)(Line 23 above)	8,212,743	(43,411,358)
2701	37,551,556	40,000,000
2702	0	0
2703	0	0
2798. Summary of remaining write-ins for Line 27 from overflow page	0	0
2799. Totals (Lines 2701 through 2703 plus 2798)(Line 27 above)	37,551,556	40,000,000
3001	0	0
3002	0	0
3003	0	0
3098. Summary of remaining write-ins for Line 30 from overflow page	0	0
3099. Totals (Lines 3001 through 3003 plus 3098)(Line 30 above)	0	0

Economic scenario generators – Why?

Decision making under uncertainty / Risk management

- Projections
  - Financial markets are unpredictable
  - However, variability exhibits structure and shape
- ESG have useful inputs for:
  - Projecting how the assets and liabilities of an insurer will evolve over time
    - Asset values – Driven by interest rates, inflation, equity returns
    - Liability values – Impacted by claims inflation, interest rates, other macroeconomic variables (GDP, unemployment, …)
- Questions ESG can help answer
  - How severe could my losses be?
  - What is the range of possible outcomes?
  - Risk-based assessments
- ESG are also used for pricing contingent liabilities (in Life insurance)

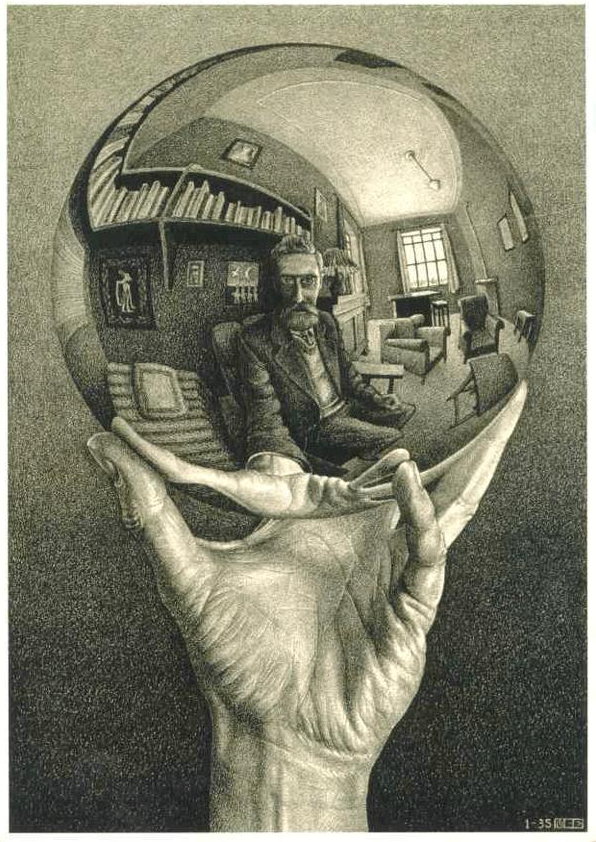
Economic scenario generators – What?

ESG outputs

» An ESG produces forward-looking scenarios for multiple risk drivers

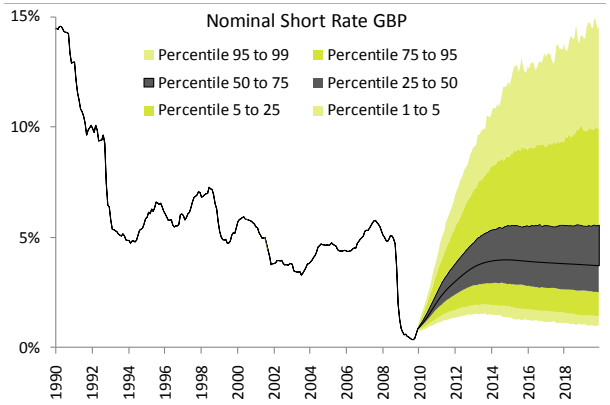
- ESG provides a distribution of possible values for economic risk factors at future timesteps
- Output is a time series of variables for each scenario (trial)
- Economically coherent joint distributions of financial and economic factors attempting to capture the dynamics of financial markets – dependency, tail risk

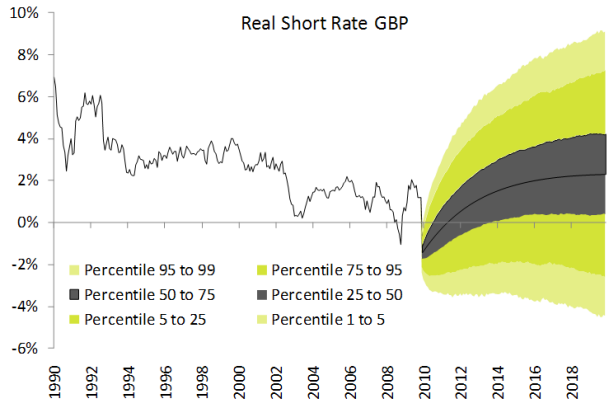
Trial	Time Step	Interest Rate	FX	…
1	0	0.20%	1.25	…
1	1	0.21%	1.19	…
1	2	0.25%	1.22	…
1	3	0.23%	1.30	…
2	0	0.20%	1.25	…
2	1	0.23%	1.33	…
2	2	0.21%	1.34	…
2	3	0.30%	1.27	…
3	0	0.20%	1.25	…
…	…	…	…	…

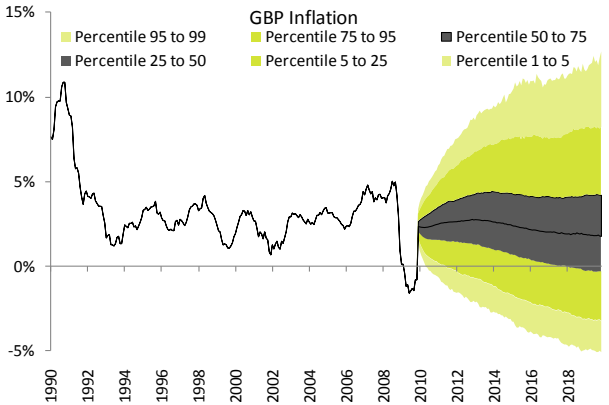


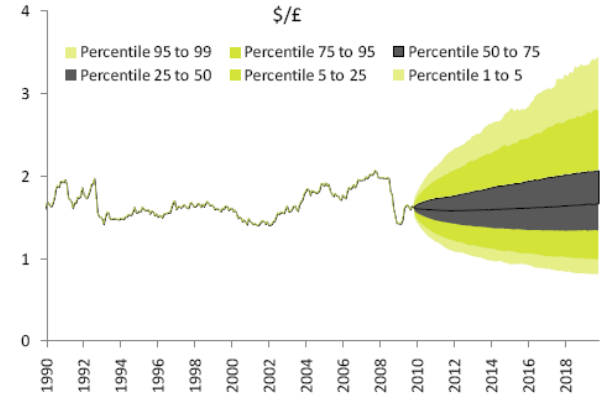
Economic scenario generators – What?

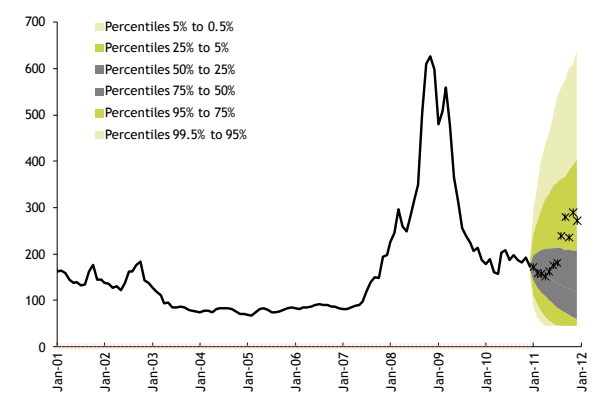
Sample ESG outputs

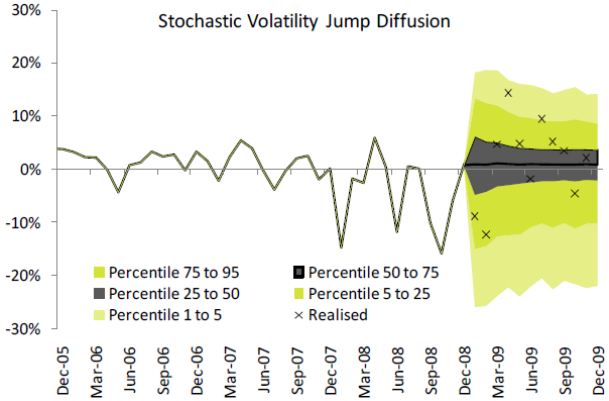












Economic scenario generators – How?

ESG modeling process

- Goal: Realistic and justifiable projections of financial and economic variables
- Roadmap in principle
  - Develop and document stylized facts and beliefs
    - E.g. interest rates are mean reverting
    - Credit spreads and equity returns are negatively correlated
  - Structure, calibrate and validate models
  - Validate and review the stylized facts and model regularly

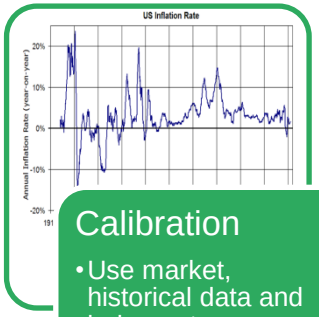
$$dr(t) = \alpha(\mu' - r(t))dt + \sigma dZ(t)$$

$$d\ln r(t) = \alpha(\mu' - \ln r(t))dt + \sigma dZ(t)$$

$$dr(t) = \alpha(\mu' - r(t))dt + \sigma\sqrt{r(t)}dZ(t)$$

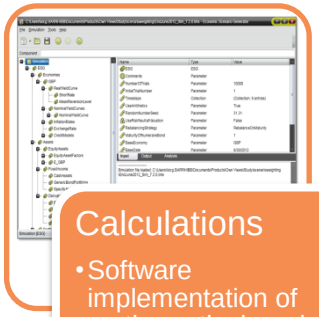
Models

- Mathematical models developed to reproduce the dynamics of financial markets



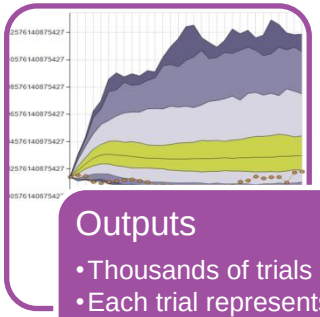
Calibration

- Use market, historical data and judgment
- Generate model parameters specific to application and market conditions



Calculations

- Software implementation of mathematical models
- Use parameters determined through calibration



Outputs

- Thousands of trials
- Each trial represents an history of what could happen in the future

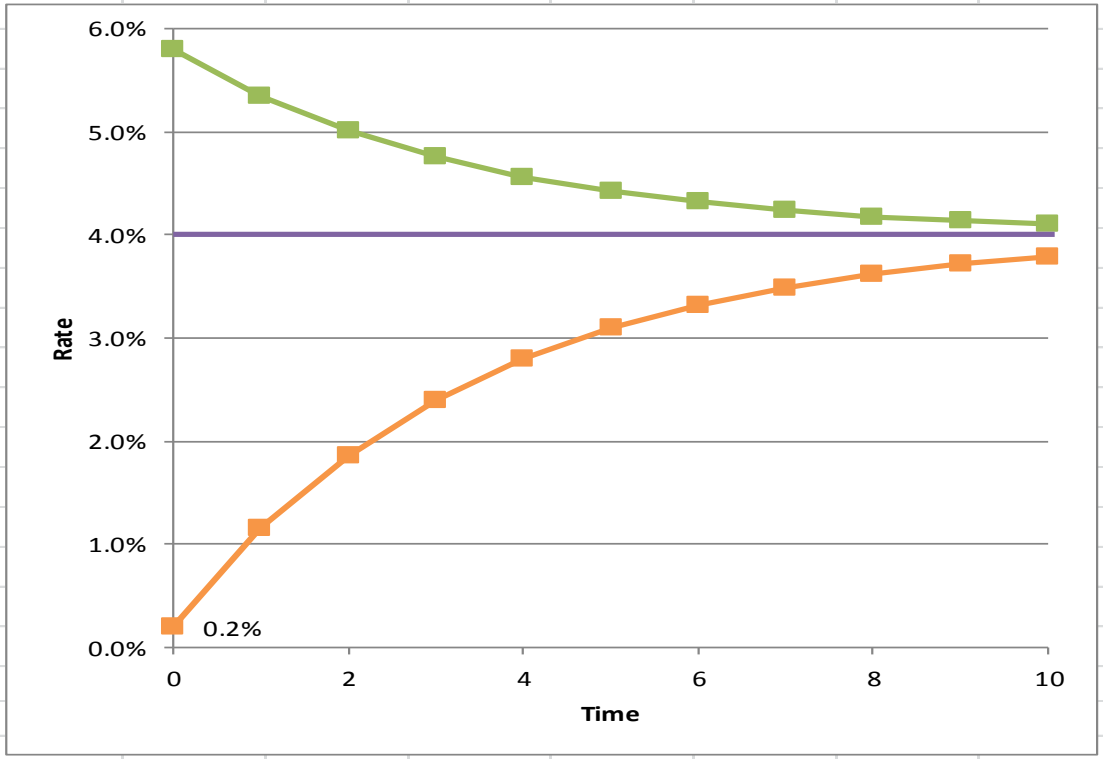
A simple deterministic interest rate model

A deterministic mean reverting process

$$dr(t) = \alpha(\mu' - r(t))dt$$

r(0)	0.2%	5.8%
mu	4.0%	4.0%
alpha	0.25	0.25

t	Rate	Rate
0	0.2%	5.8%
1	1.2%	5.4%
2	1.9%	5.0%
3	2.4%	4.8%
4	2.8%	4.6%
5	3.1%	4.4%
6	3.3%	4.3%
7	3.5%	4.2%
8	3.6%	4.2%
9	3.7%	4.1%
10	3.8%	4.1%



A simple stochastic interest rate model

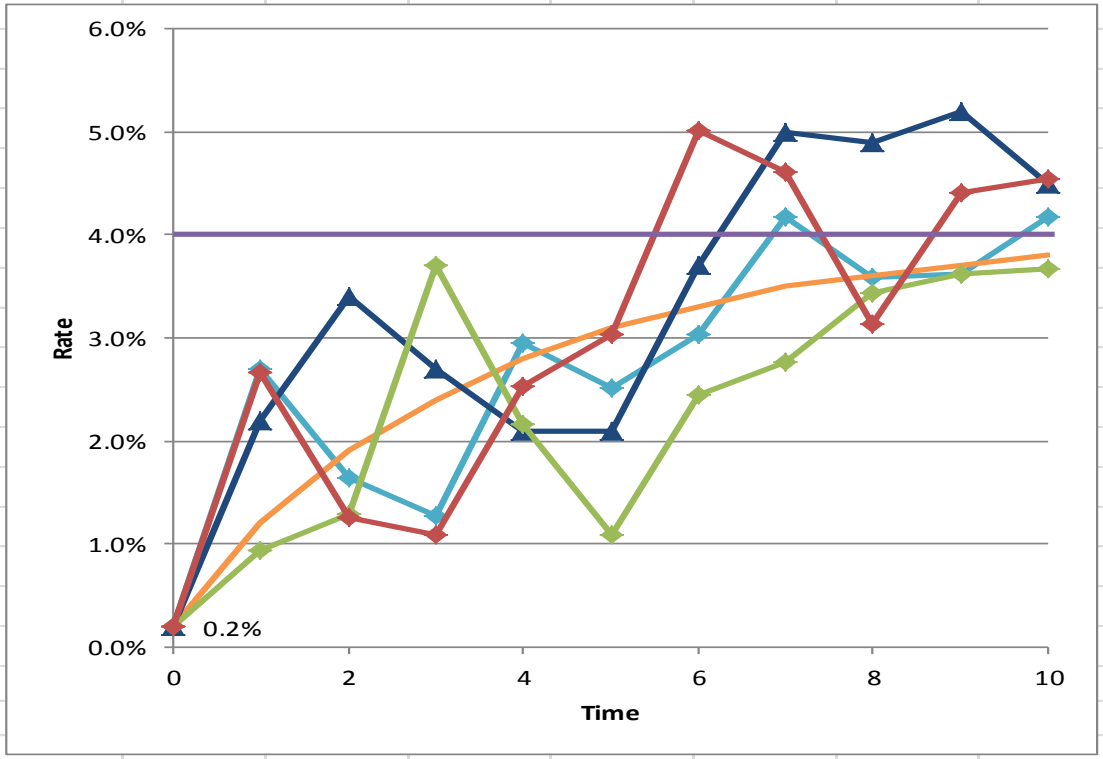
1-Factor Vasicek

$$dr(t) = \alpha\left(\mu' - r(t)\right)dt + \sigma dZ(t)$$

random shocks

r(0)	0.2%
mu	4.0%
alpha	0.25
sigma	1.0%

t	Rate	dZ
0	0.2%	1.555
1	2.7%	(1.394)
2	1.6%	(0.954)
3	1.3%	0.998
4	3.0%	(0.696)
5	2.5%	0.142
6	3.0%	0.907
7	4.2%	(0.550)
8	3.6%	(0.060)
9	3.6%	0.455
10	4.2%	



Variations

Other simple interest rate models

» 1-Factor mean-reverting short rate models

Model	Mean Reversion	Distribution of Rates	Positive Rates	Analytically Tractable
Vasicek $dr(t) = \alpha(\mu - r(t))dt + \sigma dZ(t)$	Y	Normal	N	Y
Cox-Ingersoll-Ross $dr(t) = \alpha(\mu - r(t))dt + \sigma\sqrt{r(t)}dZ(t)$	Y	Non-central chi-squared	Y	Y
Black-Karasinski $d\ln r(t) = \alpha(\mu - \ln r(t)) + \sigma dZ(t)$	Y	Lognormal	Y	N

» Limitations of these mean reverting 1-factor short rate models

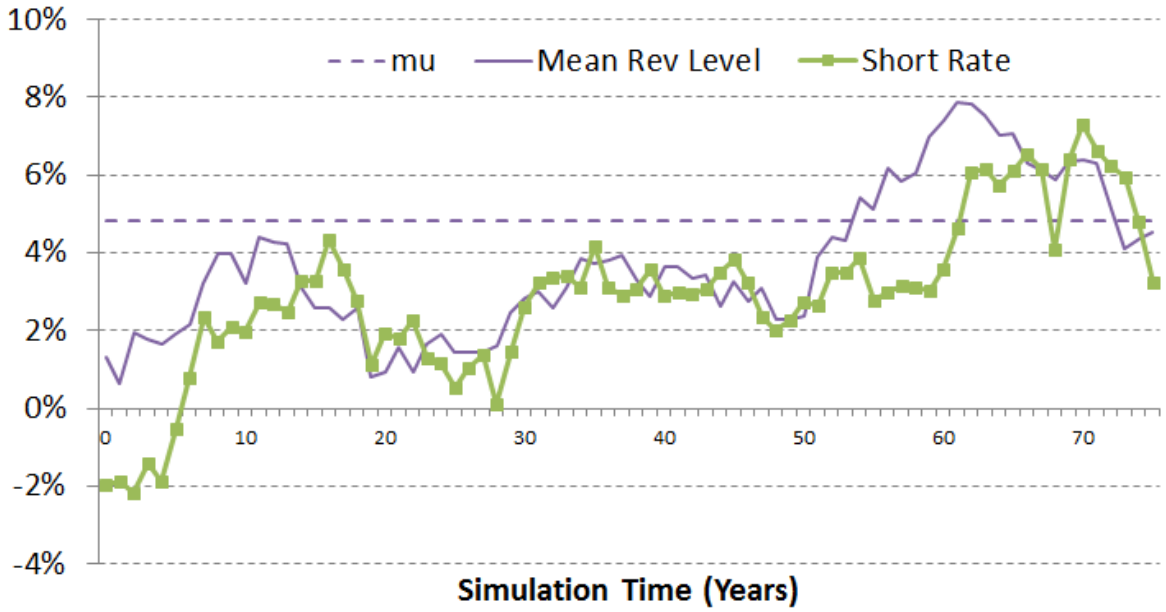
- All points on the yield curve are perfectly correlated
- They do not fit the initial term structure

More variations

A richer yield curve

- Multi-factor models
  - Adding stochastic variables allows imperfect correlation between different points on the yield curve
  - E.g. 2F-Vasicek
    - Z_1, Z_2 are standard normal variables
    - The mean follows a mean-reverting stochastic process
    - Imperfect correlation between different points on the yield curve

$$dr = \alpha_1(m(t) - r(t))dt + \sigma_1 dZ_1(t)$$
$$dm = \alpha_2(\mu - m(t))dt + \sigma_2 dZ_2(t)$$



The mean reversion level now follows a stochastic mean reverting process to the long term average mu

More variations

Matching the initial term structure

- Time-varying parameters
  - Models can be extended to fit the initial term structure of rates using time-varying parameters
  - E.g. 1 factor Black-Karasinski

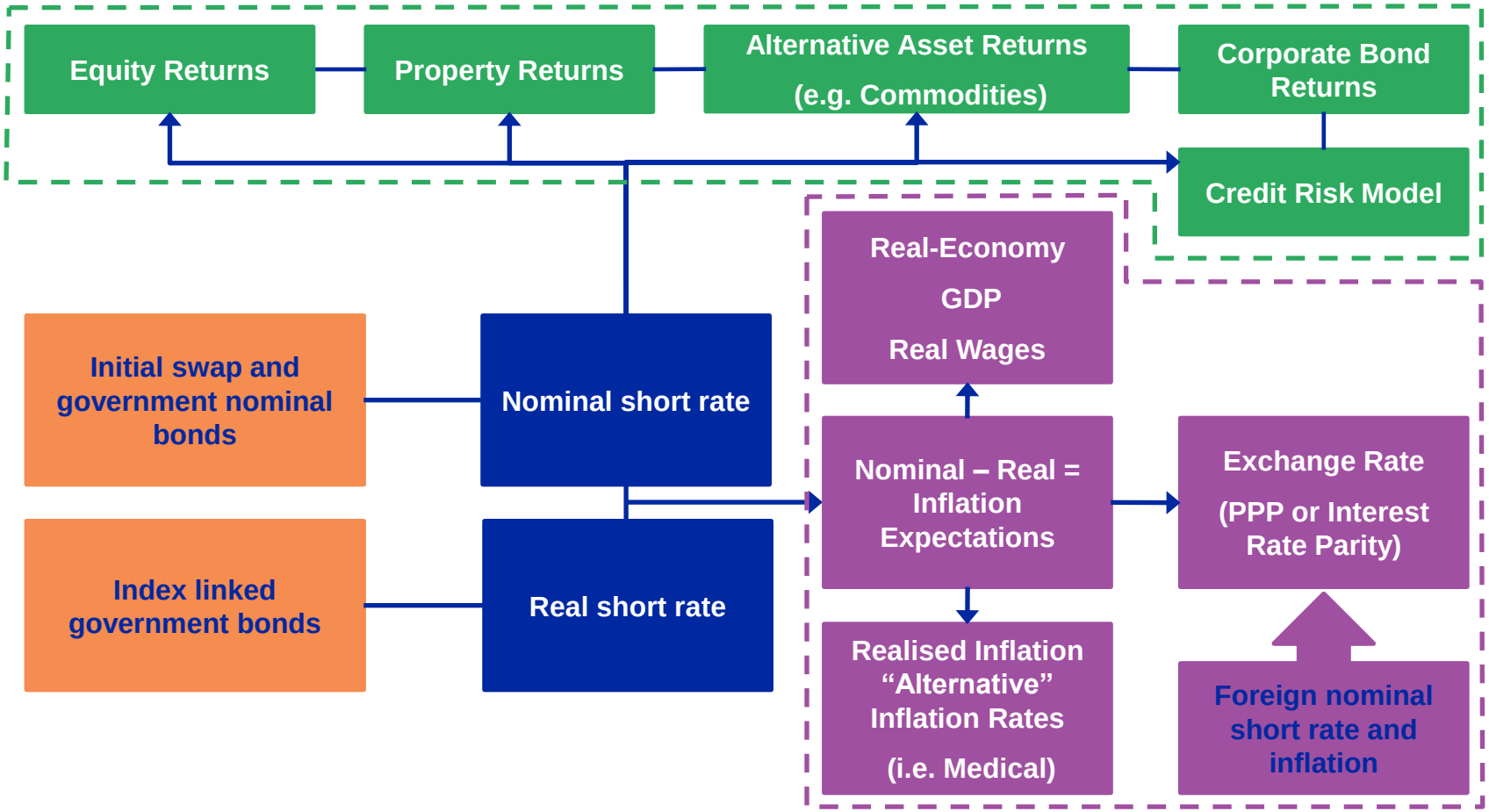
$$d \ln r(t) = \alpha\left(\mu(t) - \ln r(t)\right)dt + \sigma dZ(t)$$

Mean reversion level becomes a function of time

  - μ(t) can be calibrated to be consistent with the initial term structure
    - Referred to as “no-arbitrage” model
    - Models without this feature referred to as “equilibrium” models

ESG structure

One economy



Correlations and dependencies

A good model should capture appropriate relations between different market risk variables

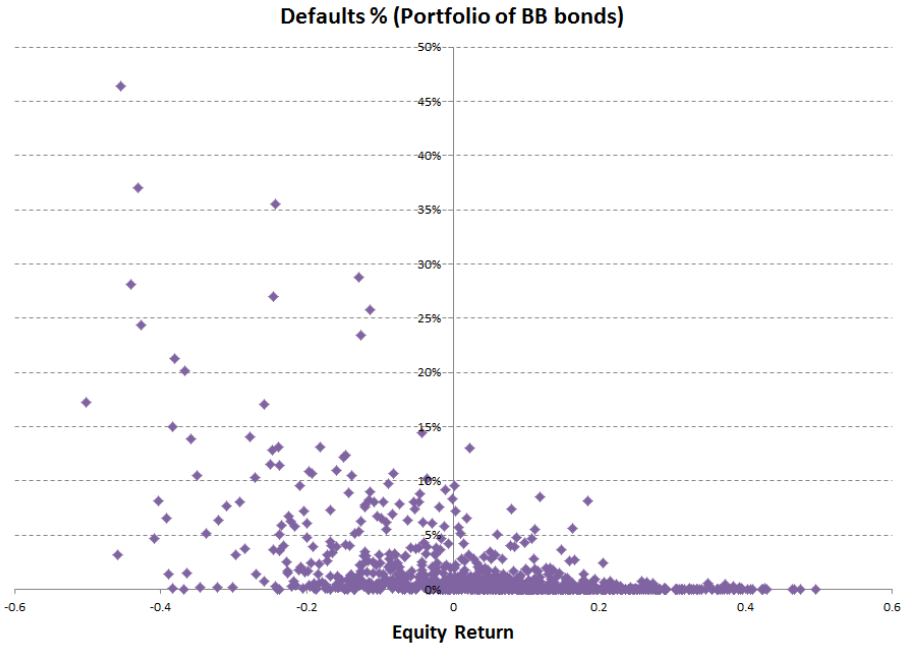
- Structural relationships
  - E.g. nominal – real = inflation
- Statistical relationships
  - E.g. periods of high equity volatility tend to be associated with low returns
  - In times of stress correlations across markets increase

Modeling dependency is difficult

- From a modeling and calibration perspective
- Especially difficult to discern co-movements of data from history
- Correlations are not stable in time

Example ESG correlations

- Ways of implementing / controlling correlations
  - Via ESG structure
  - Via ESG correlation matrix
  - Via factor models
- Correlation matrix
  - Fundamental stochastic variables in ESG are "shocks"
    - Normally distributed random variables Φ(0,1)
    - Generally shocks are not independent
- Factor model
  - Equity-Equity correlations
    - Describe target correlation matrix in basis of N factors
- In practice
  - Can only target a few correlations between pairs of economic variables
  - Verify that other correlations are reasonable

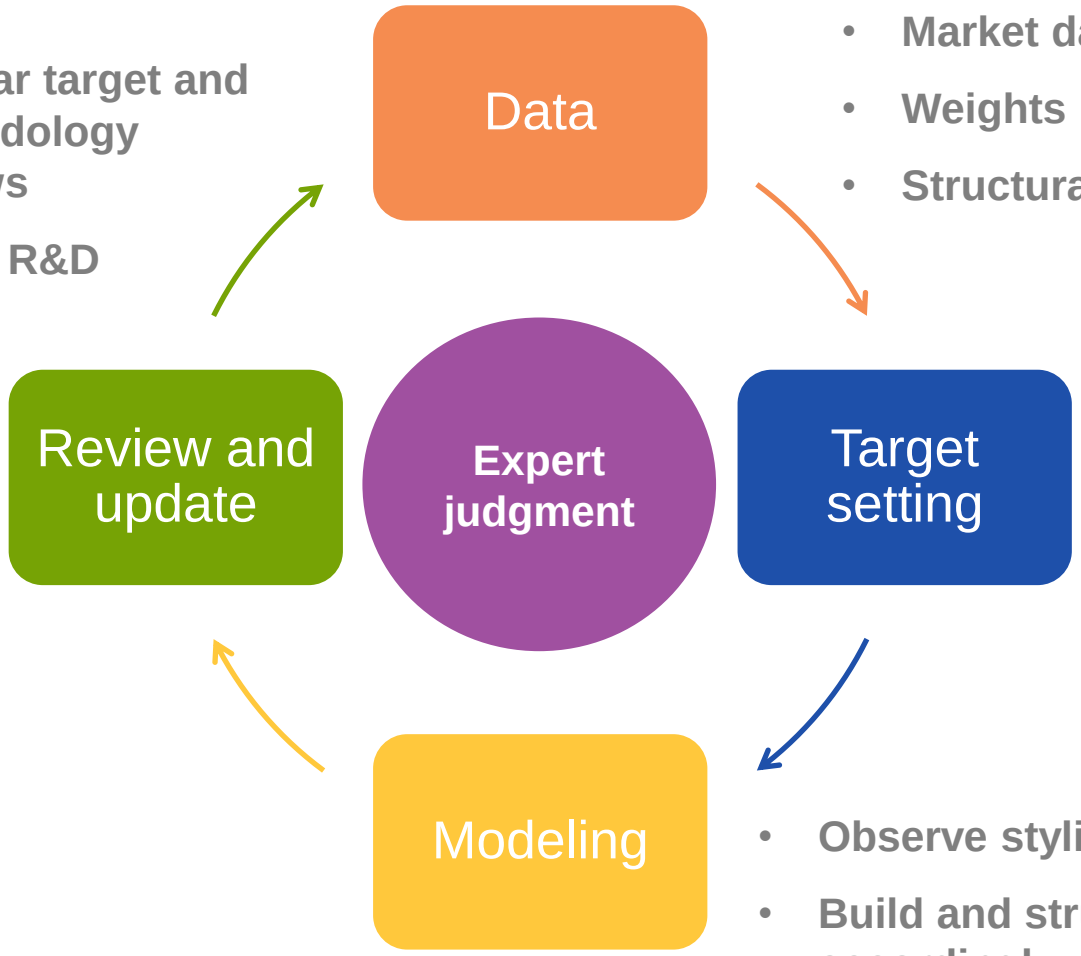


ESG calibration

Overview

- Optimization of model parameters in order to match pre-defined criteria, for example:
  - Market prices
  - Expected returns and volatility
  - Higher moments of distribution such as skew and kurtosis
- For Real World modeling the challenge is setting the pre-defined criteria (targets)
  - What should the volatility of interest rates be?
  - What use can we make of historical data?
  - Should the calibration reflect average long-term market risk or risks conditional on the current market?
- It's a core component of the ESG
- Why (re)calibrate? Ownership issue
  - The ESG asset returns are different from the business plan
  - The ESG asset VaR is higher than our fund manager's estimate
  - For AM Best SRQ, let's use a lower inflation assumption

Calibration approach



- Market data, historical data
- Weights
- Structural breaks

- Long term (unconditional) targets
- Short term targets

- Observe stylized facts
- Build and structure models accordingly

- Regular target and methodology reviews
- Model R&D

Calibration matters

Real-world vs market-consistent

A clarification of terminology…

	Real-world	Market-consistent
Question to answer	What is the probability distribution of future asset prices?	What is the current market-consistent value of future cashflows?
Usage	Financial projections for ALM, cashflow testing, probability of ruin analysis	Fair valuation of liabilities (and Greeks)
Calibration	Calibrated to best-estimate targets	Calibrated to market option-implied volatilities
Risk premium	Y	N

Point-in-time vs through-the-cycle

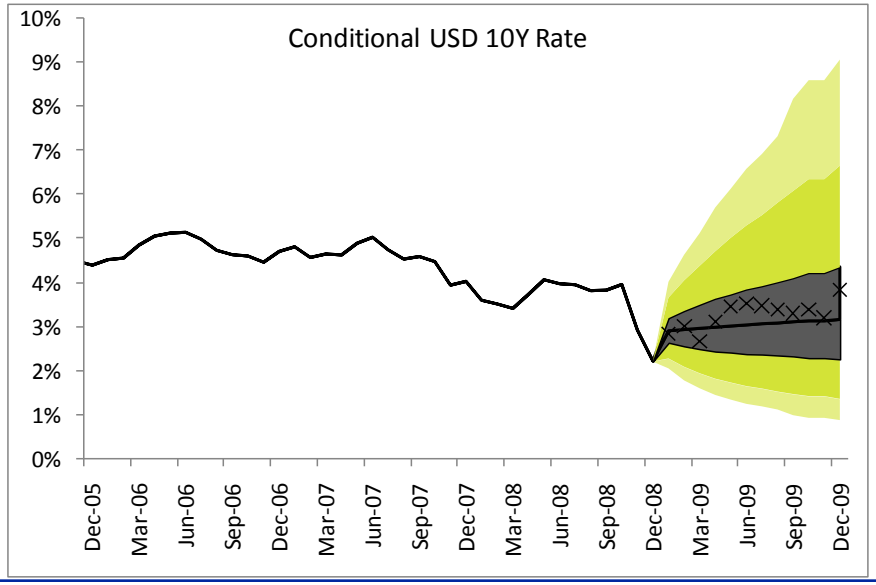
Is the aim to generate a forward looking projection for the coming year or for a typical year?

» Example: Equity markets – use current or historical volatility

» This decision will have significant impact on the EC requirement

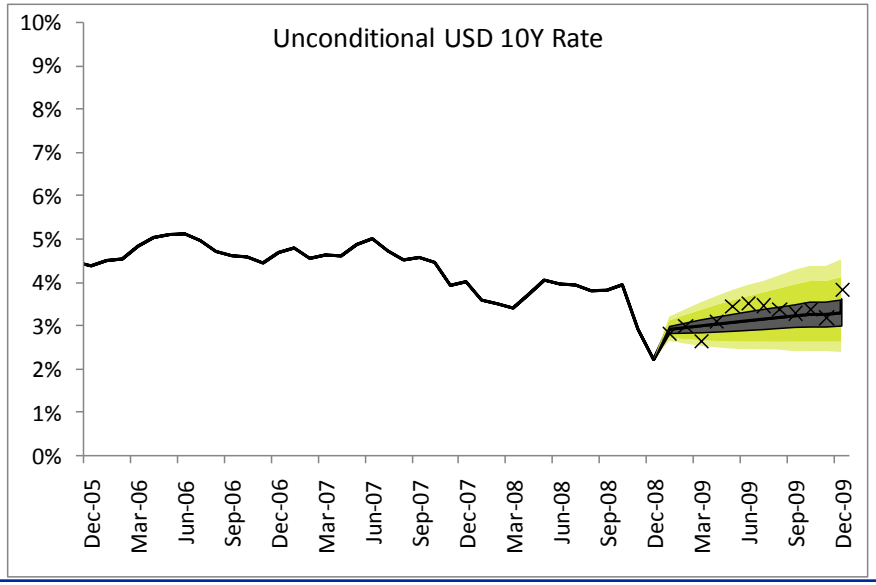
Point-in-Time (PIT)

» Capital held to be in business next year with a 99.5% probability



Through-the-Cycle (TTC)

» Capital held to be solvent in 199 out of 200 years on average



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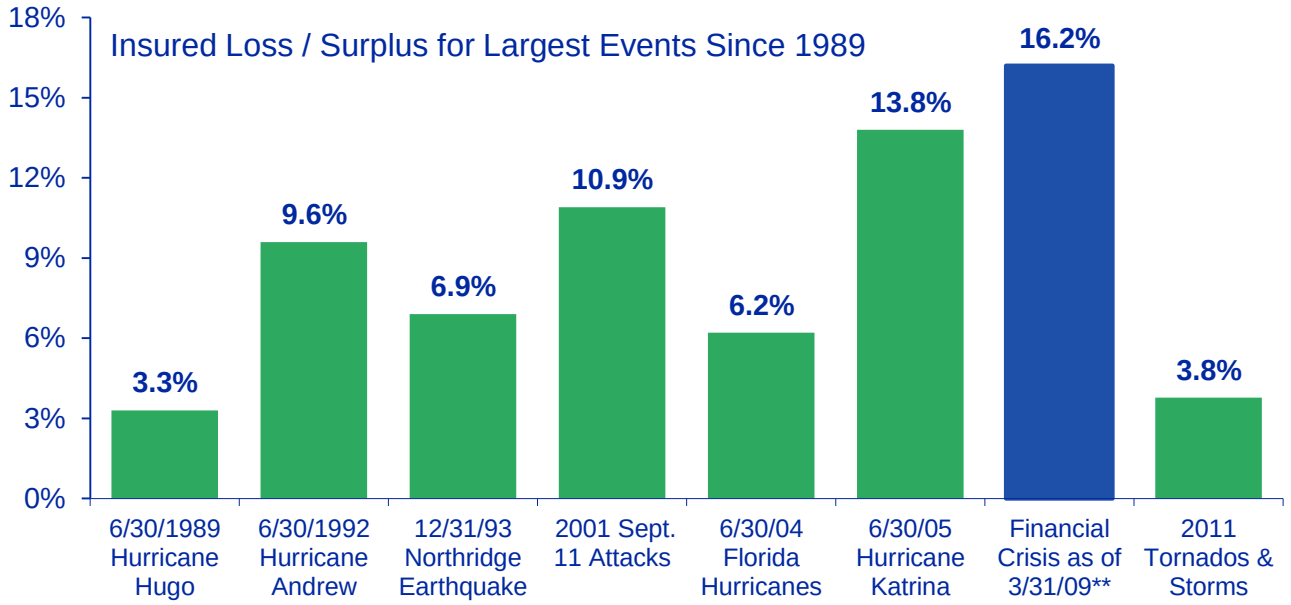
Applications for P&C Insurers

Market risk management

Market risk is important

- Tends to be underestimated especially since asset management is typically outsourced
- Investment income is a very significant share of insurers' earnings
- Low yields / volatile environment



** Date of maximum capital erosion

Source: PCS; Insurance Information Institute (Dr. Robert Hartwig presentation at CARE, June 5, 2012)

A schematic market risk model

ESG Distributions for:		Asset allocation:
Cash return		Cash %
Govt bonds return		Govt bonds %
Corporate bonds returns	⊗	Corporate bonds %
MBS returns		MBS %
Equities returns		Equities %
Alt. asset returns		Alt. asset %
…		…

Reserving

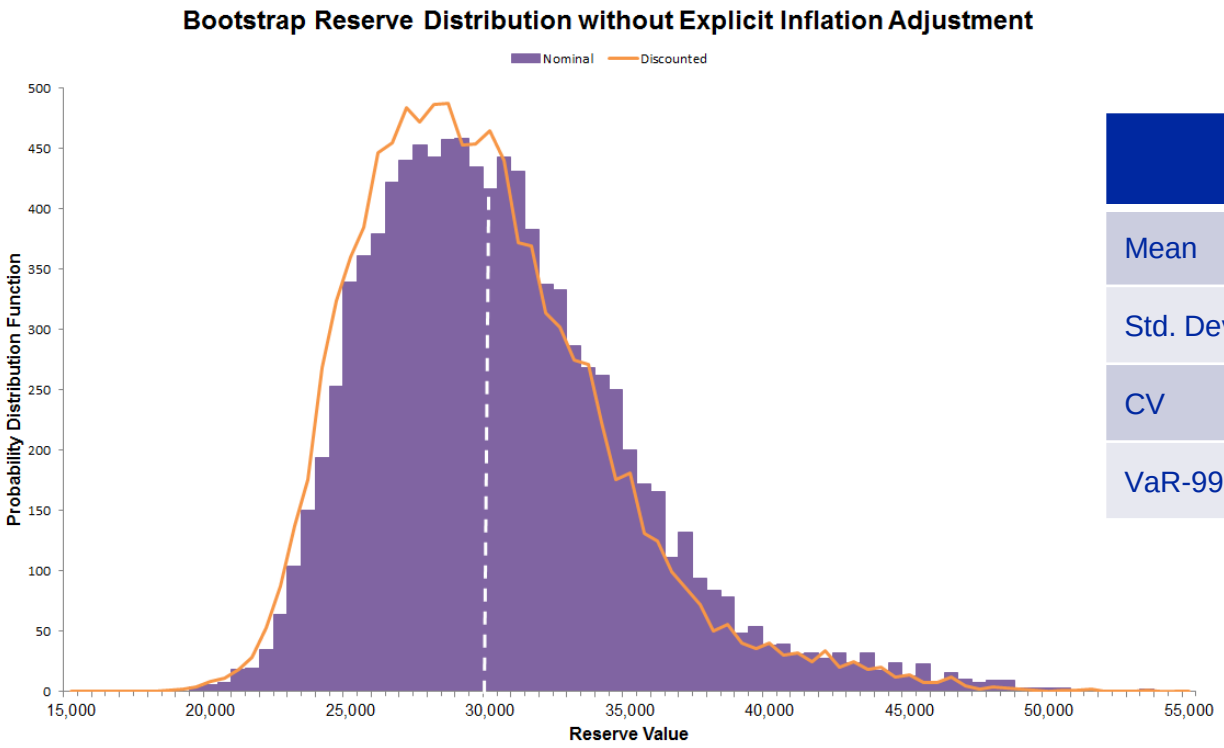
Inflation risk on reserves

- Inflation risk can be very significant especially on long-tailed lines of business
  - Many types of (claims) inflation
  - Topical subject due to recent monetary policy
    - Subject to more scrutiny recently (AM Best SRQ)
- LDFs reserving methods
  - No explicit inflation adjustment
  - Past inflation is implicitly reflected in the selected LDF
  - And is projected forward (if no trends adjustments)
  - Without consideration for inflation variability
  - When discounted, discount rate and inflation are assumed to be independent
- Relevant ESG outputs
  - Interest rates
  - Inflation indices

Chain-ladder reserving

Paid chain-ladder – Bootstrap results

- Discounted reserves have lower variability than nominal reserves
  - Much of reserve variability stems from uncertainty in tail factors
  - This is mitigated by larger discount factors (understated in this example)

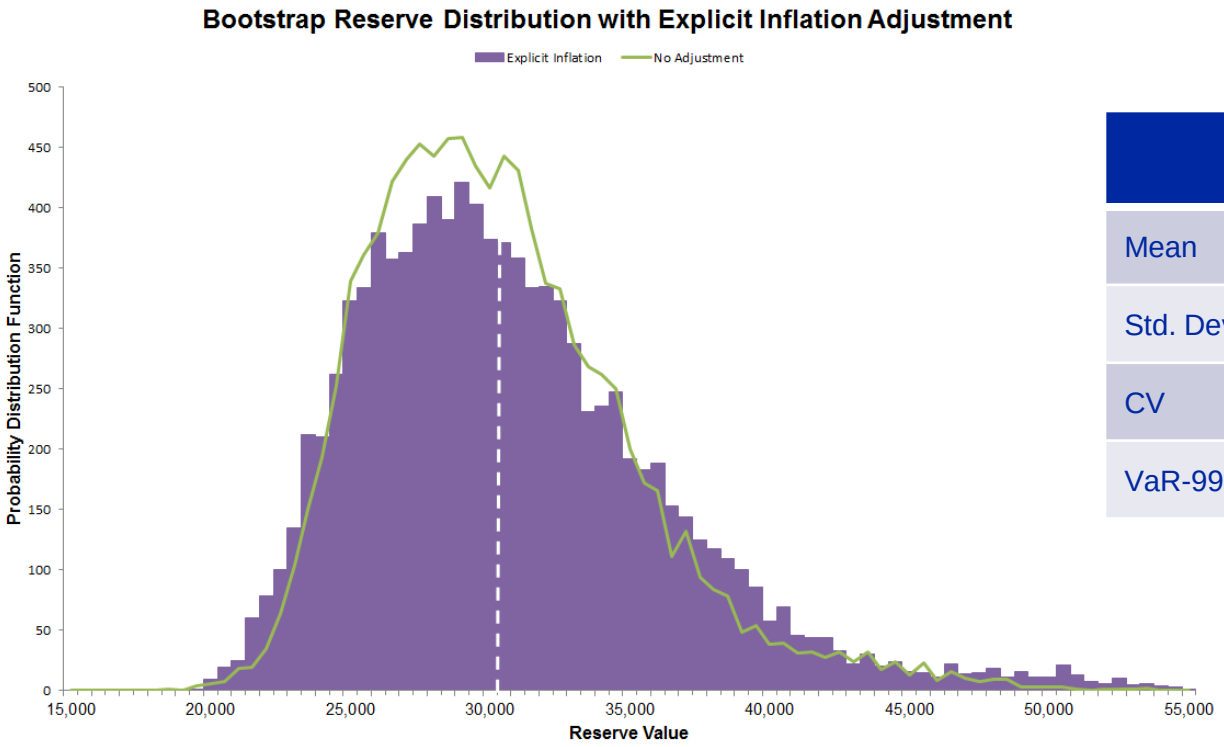


	Nominal Reserves	Discounted Reserves
Mean	30,077	29,417
Std. Dev	4,717	4,449
CV	15.7%	15.1%
VaR-99	45,011	43,380

Reserving using ESG inflation and rates

Explicit inflation adjustments

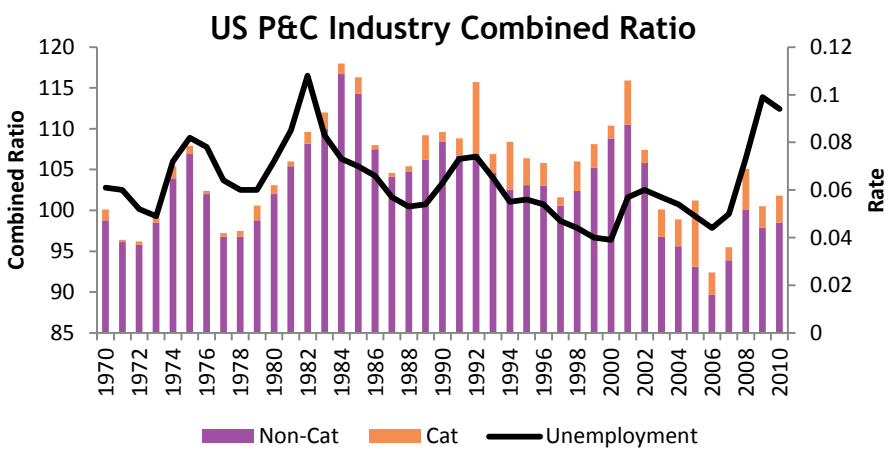
- Restate triangle removing historical inflation
- Calculate LDFs from “inflation-free” triangle
- Apply ESG inflation index and discount rates

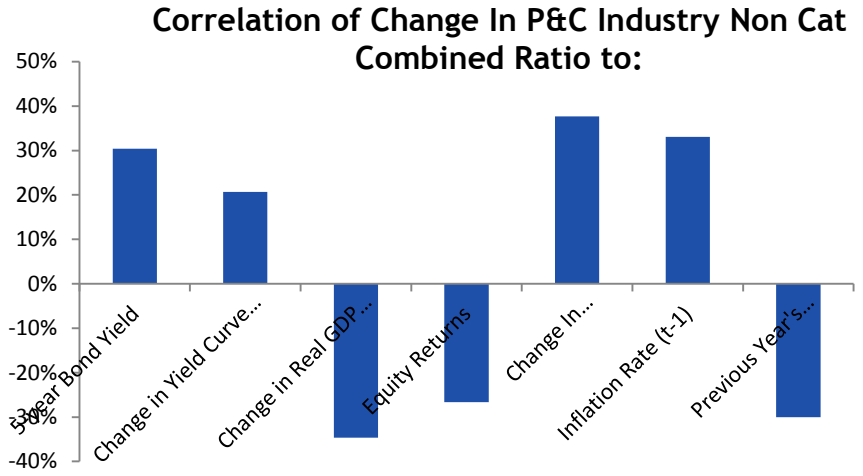


	Inflation Adjustment	No Adjustment
Mean	30,509	30,077
Std. Dev	5,557	4,717
CV	18.2%	15.7%
VaR-99	49,039	45,011

Economic drivers of P&C underwriting

P&C insurance risks depend on economic variables





- High interest rates are associated with lower underwriting profitability
  - Higher investment return offsets lower premium rates
- Negative shocks to GDP growth lead to increases in combined ratio
  - Downwards effect on exposure, premium rates, upwards effect on claims
- (Claims) inflation increases claims costs differently across LOBs
- Other drivers for specific classes e.g. unemployment, GDP, commodities...
- Economic variables also impact asset returns

Applications

ESG and insurance risk models

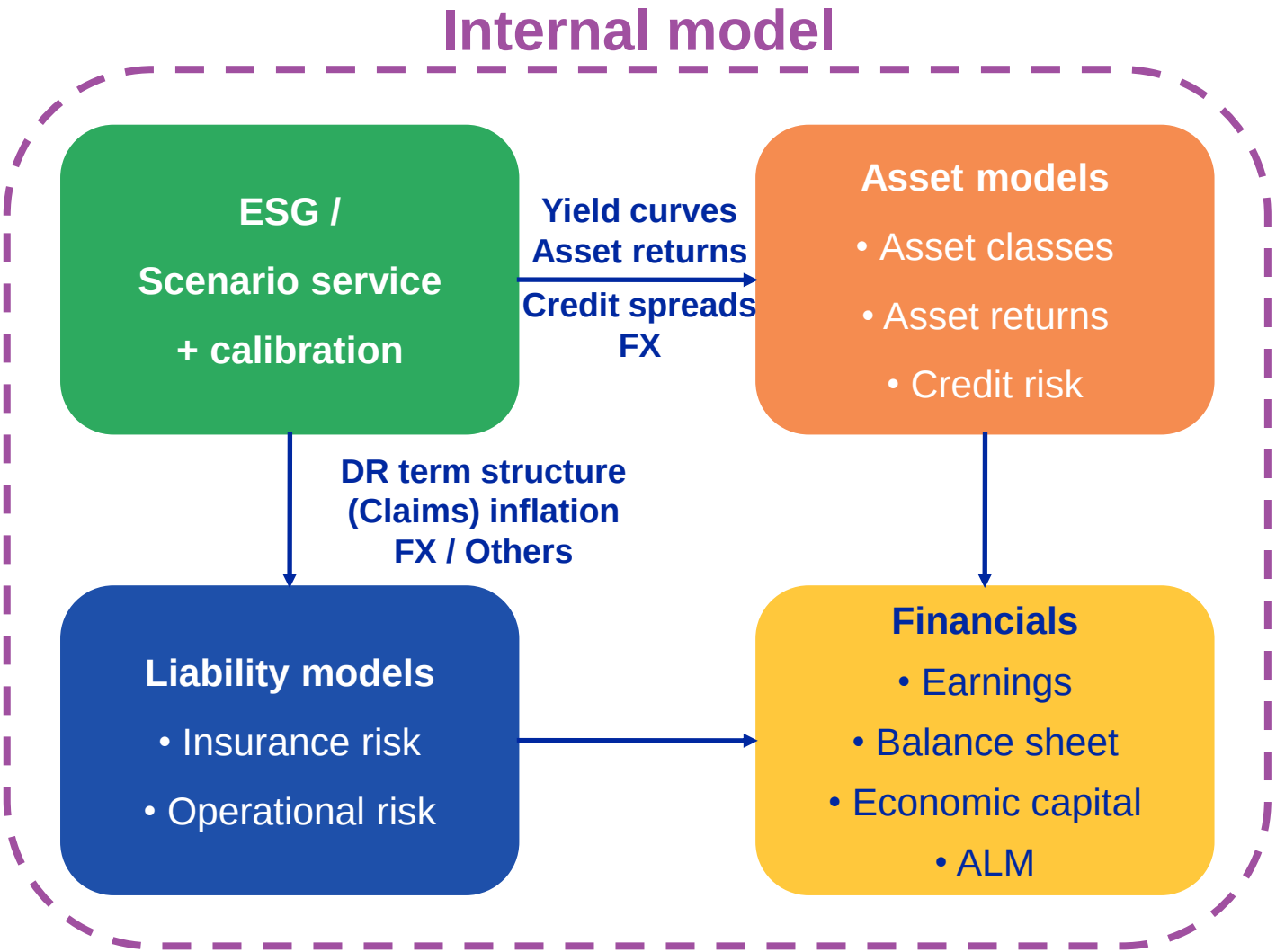
ESG outputs (especially non-market risk factors) can have a wide range of applications to refine insurance risk models

- Impact of future economic environment, at the line of business level, on:
  - Volume levels
  - Rates
  - Profitability
  - Reserve development
- Enforce consistency between different economic drivers for different lines of business
  - Better capture of concentration / diversification between lines of business
  - Capture correlations between underwriting and reserving risks
- Especially useful
  - Multi-year models
  - Incorporating longer term effects linked to economic factors
- Improve modeling of interactions between market risk and insurance risk

Economic capital models

Drivers

- Regulators
- Rating agencies
- ERM best practice



Own risk and solvency assessment

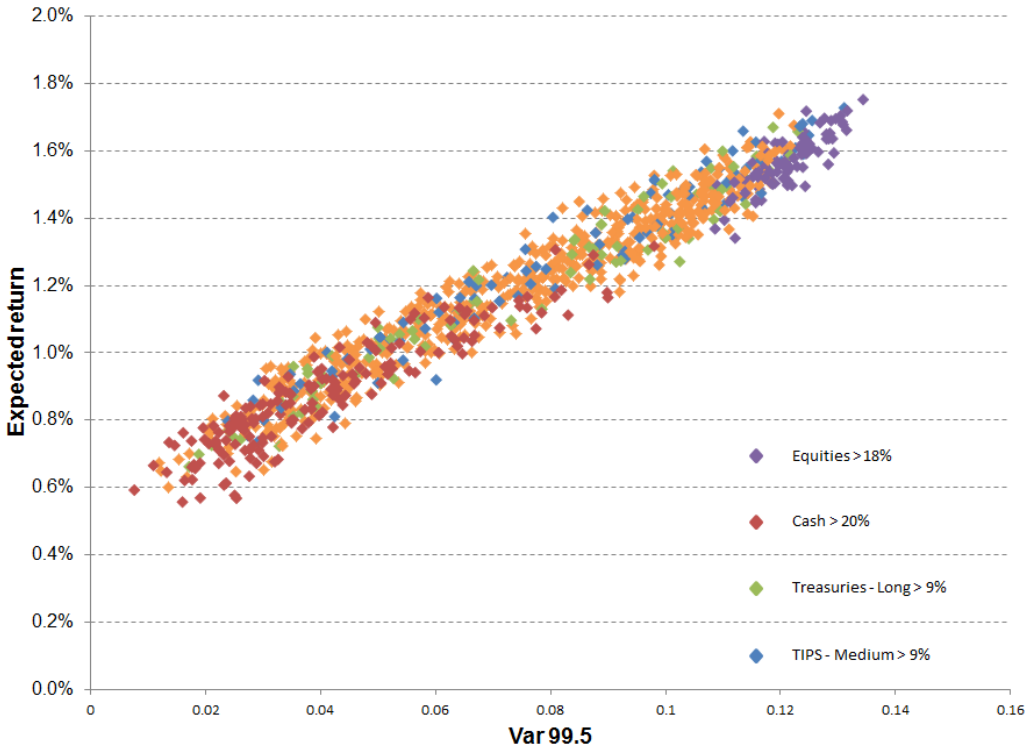
ESG and ORSA

- ORSA to become a worldwide requirement
  - ICP 16
- NAIC ORSA
  - Guidance manual (November 2011)
  - RMORSA Model Act (September 2012)
- Increased ESG usage for preparing the ORSA Summary report
  - Section 2- Insurer's Assessment of Risk Exposure
  - Section 3- Group Risk Capital and Prospective Solvency Assessment
- ESG called for:
  - Assessment of economic risks on the company risk profile
  - Assessment of market risk
  - Capital adequacy assessment
  - Multi-year modelling for the prospective solvency assessment
  - Assessment of risks in both normal and stressed environments
  - Model validation, stress testing and sensitivity analyses

Strategic asset allocation

Asset allocation analysis which considers the overall risk profile of the company (insurance risks + asset risks + interactions)

- Common economic factors influence both u/w and investment risks
  - Economic risks needs to be aggregated across assets and liabilities
- Opportunities to reduce risk as well as increase expected return
  - Risk measures: More than expected return vs. volatility
- Consider company-level impact of asset allocation on risk profile
  - Dynamic triggers provide guidance on how to rebalance the portfolio given risk appetite



In practice

Integrating investment and u/w risk management is difficult

- Existing tools and structures do not make it easy for investment managers to use internal capital models
- Detailed P&C underwriting model not always transparent to the investment team
- Restricted access to IM outside the capital modeling team
- Internal models can be slow and cumbersome to run
- Actuaries and asset managers have different focus
  - Tail versus median
  - Granularity

Benefits

- Direct application of ECM to solve a very visible business issue
- Outperform peers who set asset allocations on a standalone basis
- Capital management
- Use test

Summary

- Emerging regulation and accepted best practice are driving P&C insurers to adopt more sophisticated tools for understanding the potential future behaviour of the asset side of the balance sheet and economic drivers of liabilities
- Market and economic risks can make a material contribution to solvency capital and earnings uncertainty
- Usage of ESGs within the P&C industry is increasing
  - More scrutiny of the ESG outputs
    - Challenged by companies views
  - ESGs being used outside the asset module of an internal model
    - Input in insurance risk models
  - Common economic factors impact both sides of the balance sheet
    - Strategic asset allocation
- Building successful ESG solutions requires users to access and build experience with these tools

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