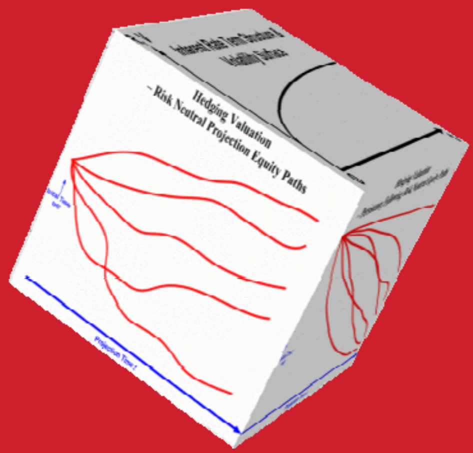
Financial Engineering and Actuarial Science

In the Life Insurance Industry

Presentation at USC
October 31, 2013



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Actuaries
Risk is Opportunity.

Table of Contents

Who We Are

- We are the insurance quants and business people
- We operate in the space between capital market and insurance
- We utilize blended skills of financial engineering and actuarial science
- We solve both technical and business problems

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Traditional Insurance Risk Management

- Life insurance products include mostly life insurance and annuities
- Traditional operating model is to investment money from policyholders to prepare for future insurance claims
- Insurance business is long term business
- Actuaries are engineers of the insurance companies
- The insurance products have traditionally worked reliably based on the old and true principle of “law of large numbers”
- Actuaries have used statistics and probability to calculate and measure the risks

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Capital Market Risk Management

- Capital markets represented by Wall Street and portfolio investments
- Traditional investments in fixed income (bonds), equity (stocks), and modern derivatives (options)
  - Fixed income portfolio management focuses on interest rate risk and credit risk
  - Equity investment focuses on systematic risk (measured by beta)
  - Derivatives are priced using financial engineering techniques
- Financial engineering is based on “law of one number” or no arbitrage
- Wall Street has used financial engineering to price and manage the risks for derivatives

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Variable Annuity (VA)

- Life insurance products are increasingly derivatives oriented and many of the same derivatives valuation techniques apply
- The hybrid products also create unique challenges and opportunities to financial engineers and derivatives markets
- Variable annuity is a retirement investment account sold by life insurers
  - Underlying investments are generally “mutual funds” of various asset classes
  - Contract holders pay insurer and mutual fund manager fees over time
  - The account value can go higher or lower due to investment results
  - Guarantee payoffs = f(guaranteed amount - total basket value of mutual funds)
  - Death benefit is paid when a) the account value is lower than principal and b) Policyholder died
  - Living benefits can be paid without having to die, based on different designs such as accumulation guarantees (wait for10 years), withdrawal benefits (guaranteed withdrawal amounts, regardless of investment performance)
  - Policyholders keep upside potential of the account performance – and insurance company provides the downside guarantees (put options!)
  - Many VA contracts have much more exotic benefits
  - Policyholder may or may not exercise optimally

Variable Annuity: Sample GMDB Designs

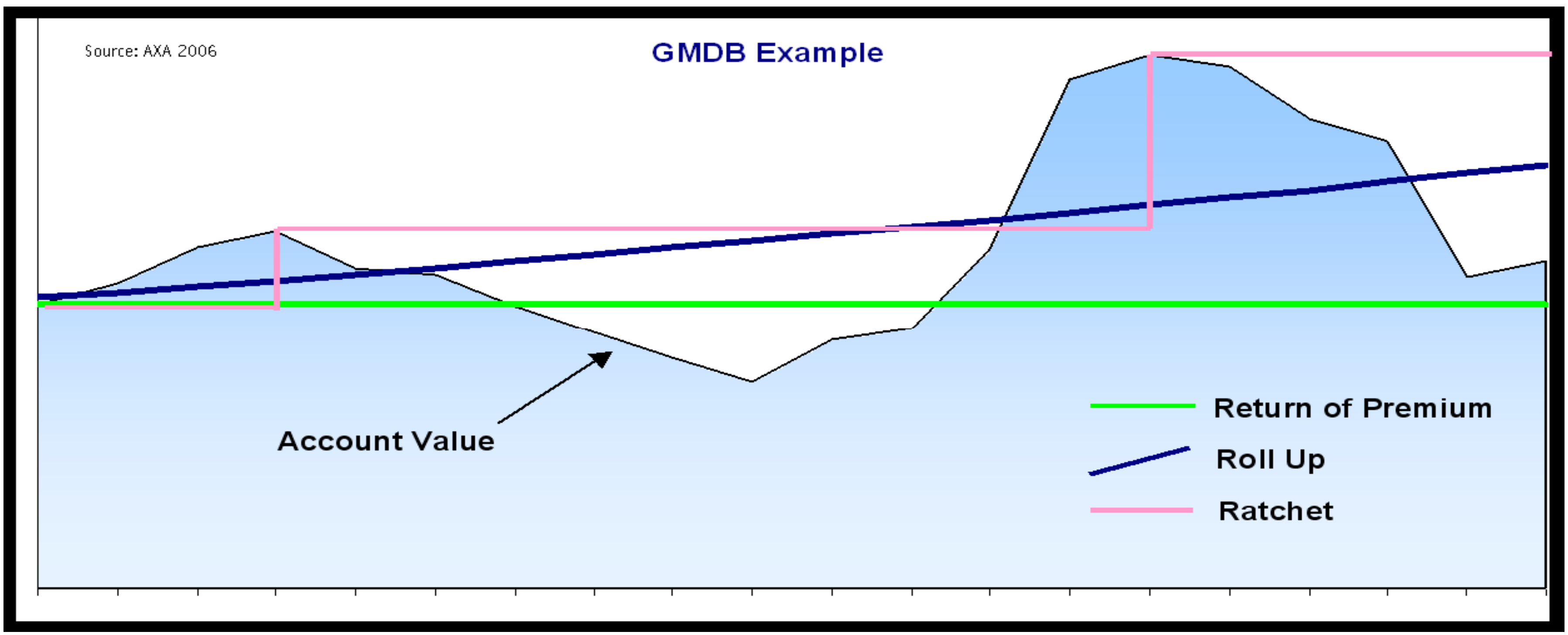
- **Different strikes for different designs**

  Return of premium: strike = initial AV = initial premium deposits

  Ratchet: discrete look back strike = max (sample AVs during the contract life)

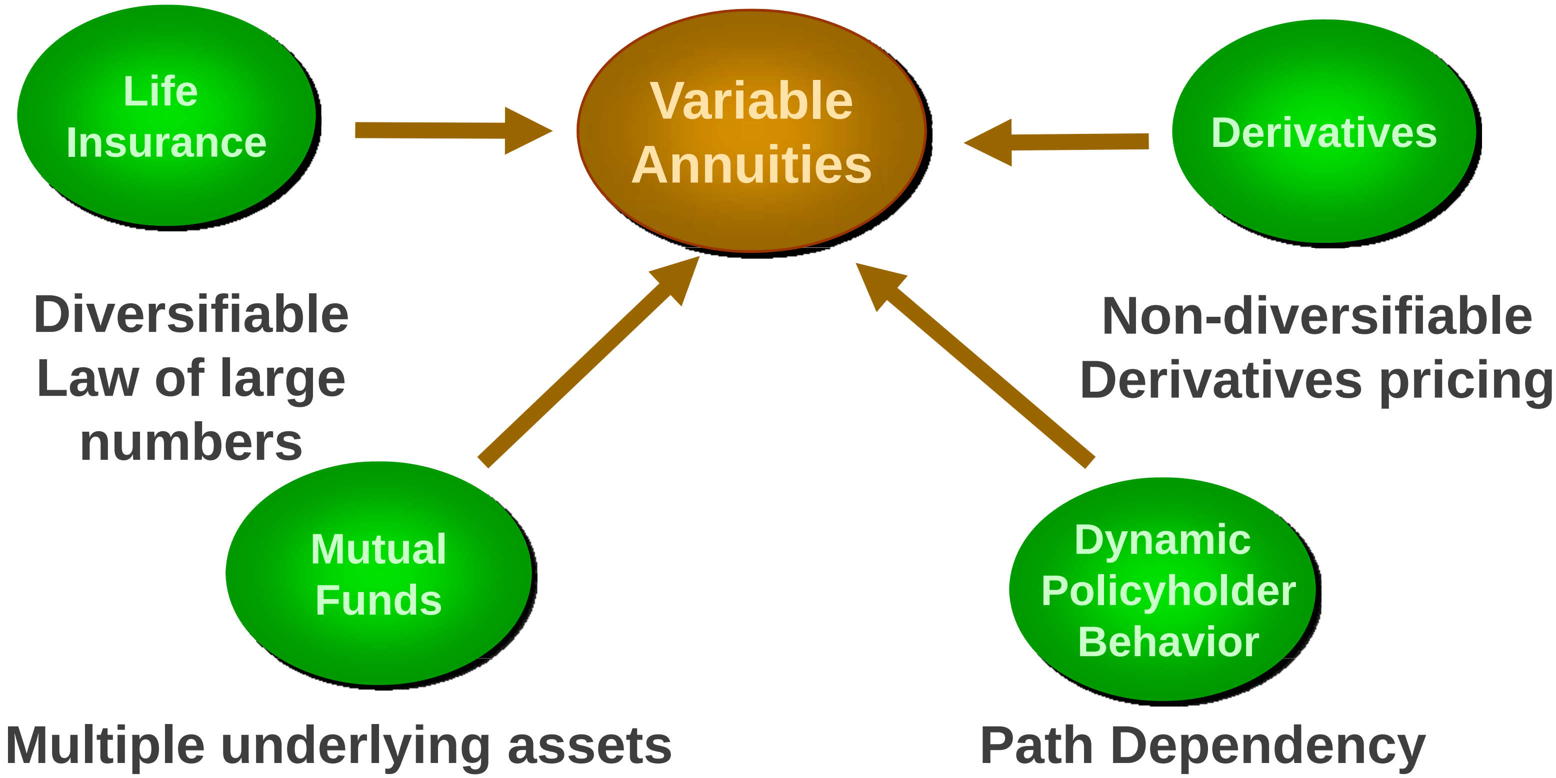
  Rollup: increasing strikes at an annual rate x: strike $_t$ = $(1+x)^t$

  Combinations: strike = max of ratchet and rollup



Life Insurance or Derivatives?

Variable annuity (VA) guarantees blur the boundary between derivatives products and traditional life insurance products: Living or dying!

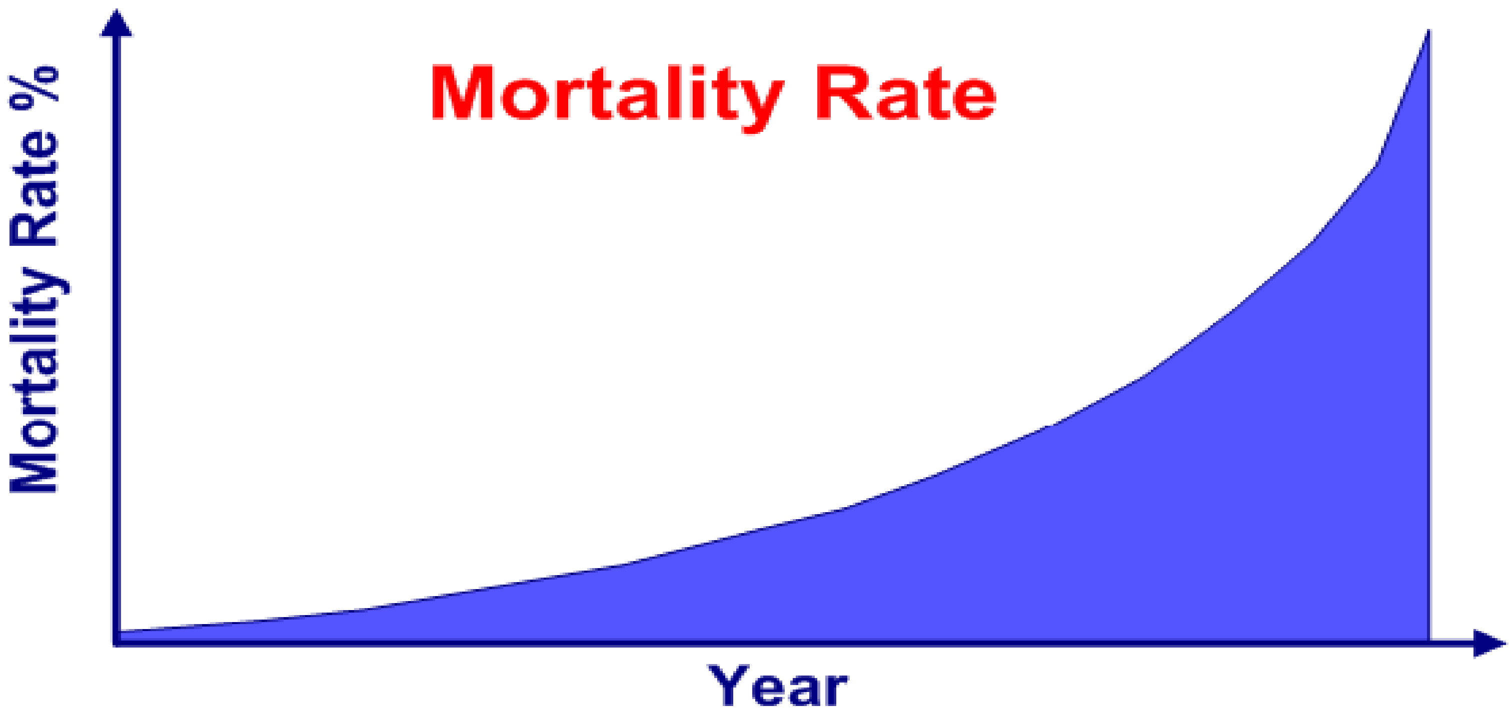


All VA contracts invest in mutual funds, paying fees to insurer, and getting guarantee benefits
GMDB (Guaranteed Minimum Death Benefit) => Payable at death
VAGLB (Variable Annuity Guaranteed Living Benefit) => Payable Under Predefined Condition:

GMAB (Guaranteed Minimum Accumulation Benefit) for account value guarantee
GMIB (Guaranteed Minimum Income Benefit) for annuitized payouts guarantee
GMWB (Guaranteed Minimum Withdrawal Benefit) for withdrawals guarantee

GMDB Pricing
Benefit Paid Upon Death

Death benefit paid upon death
Rate of mortality based on law of large numbers
Mortality rates increase quickly at older ages

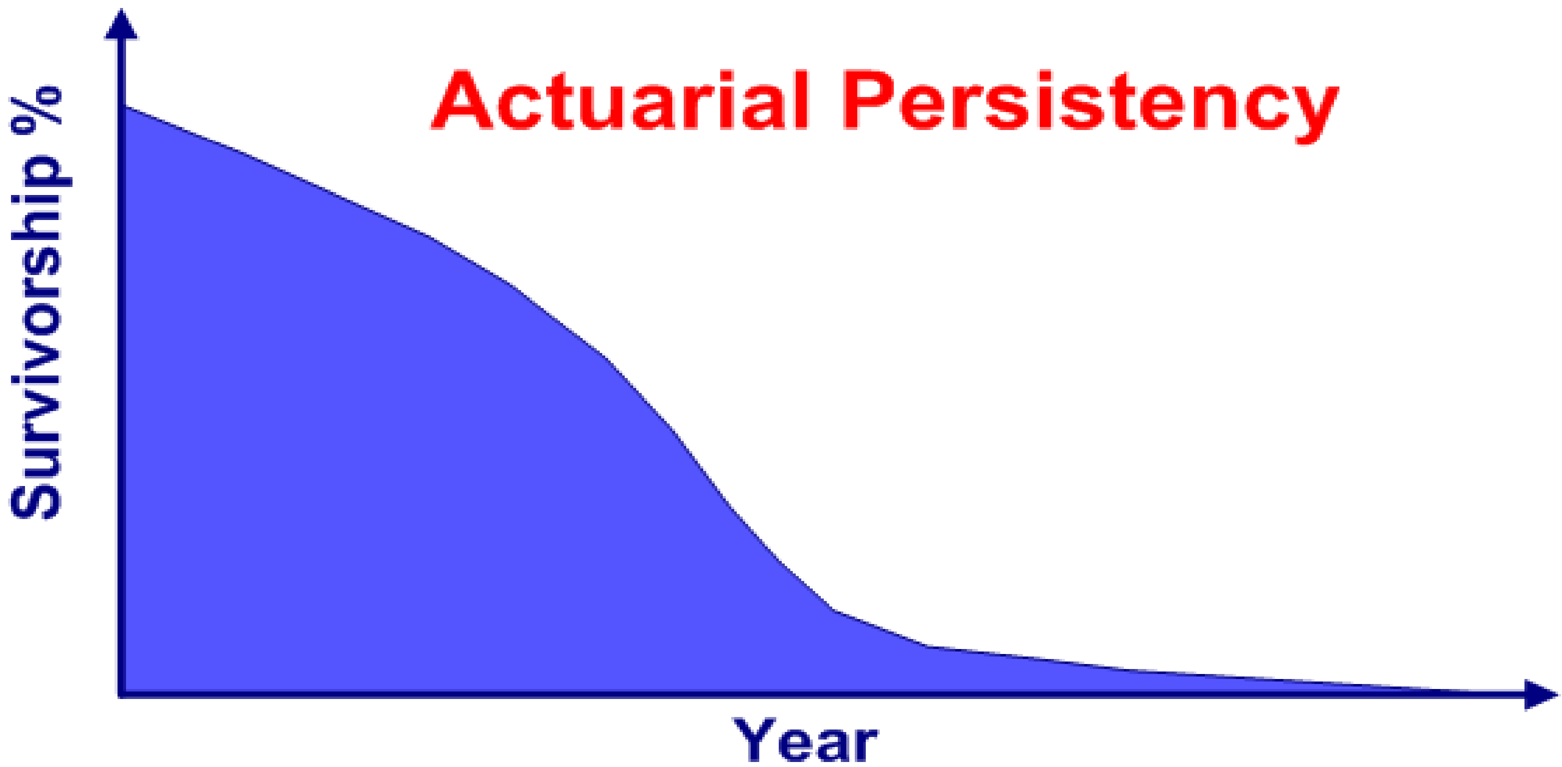


GMDB Pricing

Benefit Paid Only If GMDB Contract Stays In Force At Death

Not all contracts initially issued still in force in later years

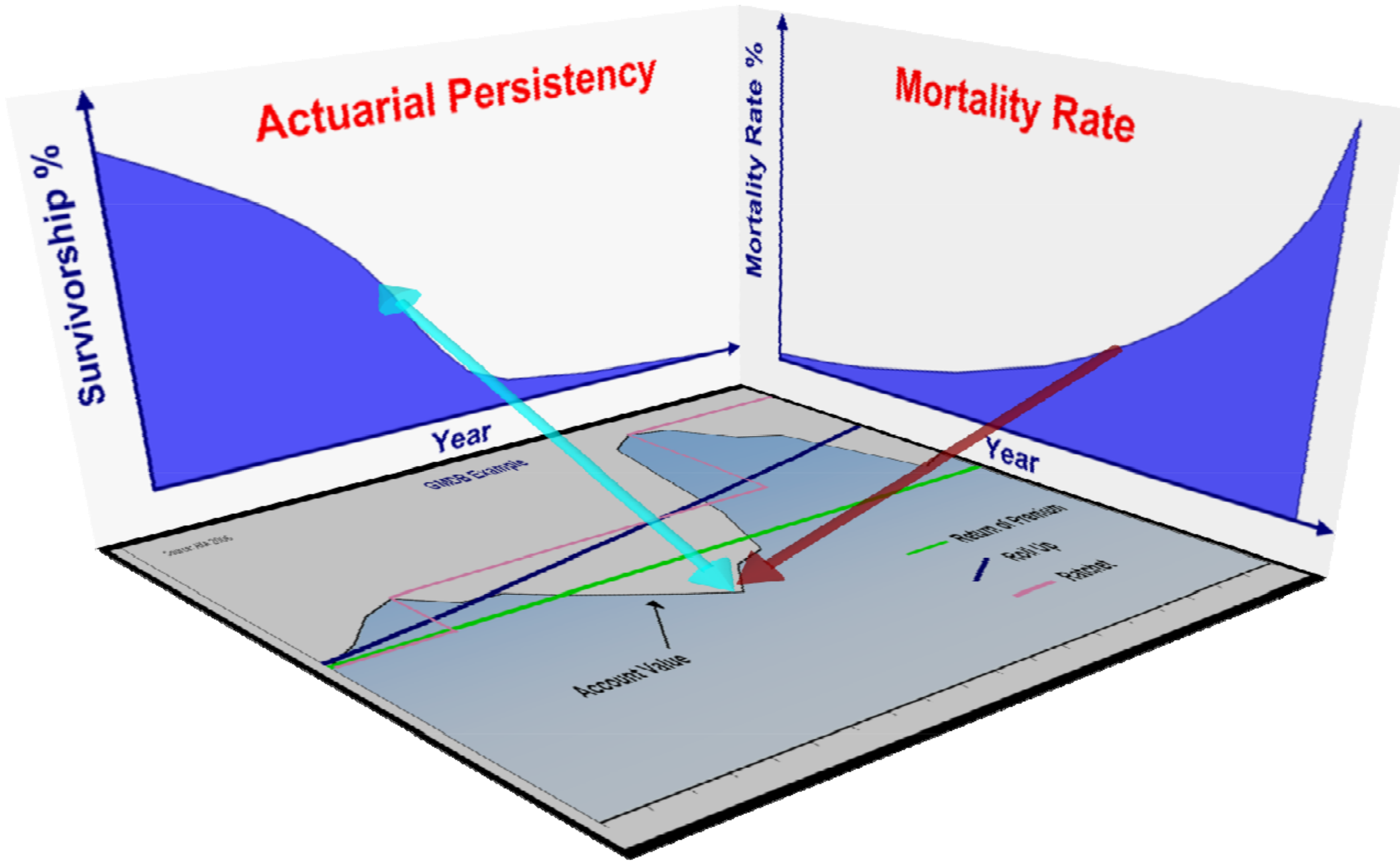
People could lapse the contract or annuitize (decrements)



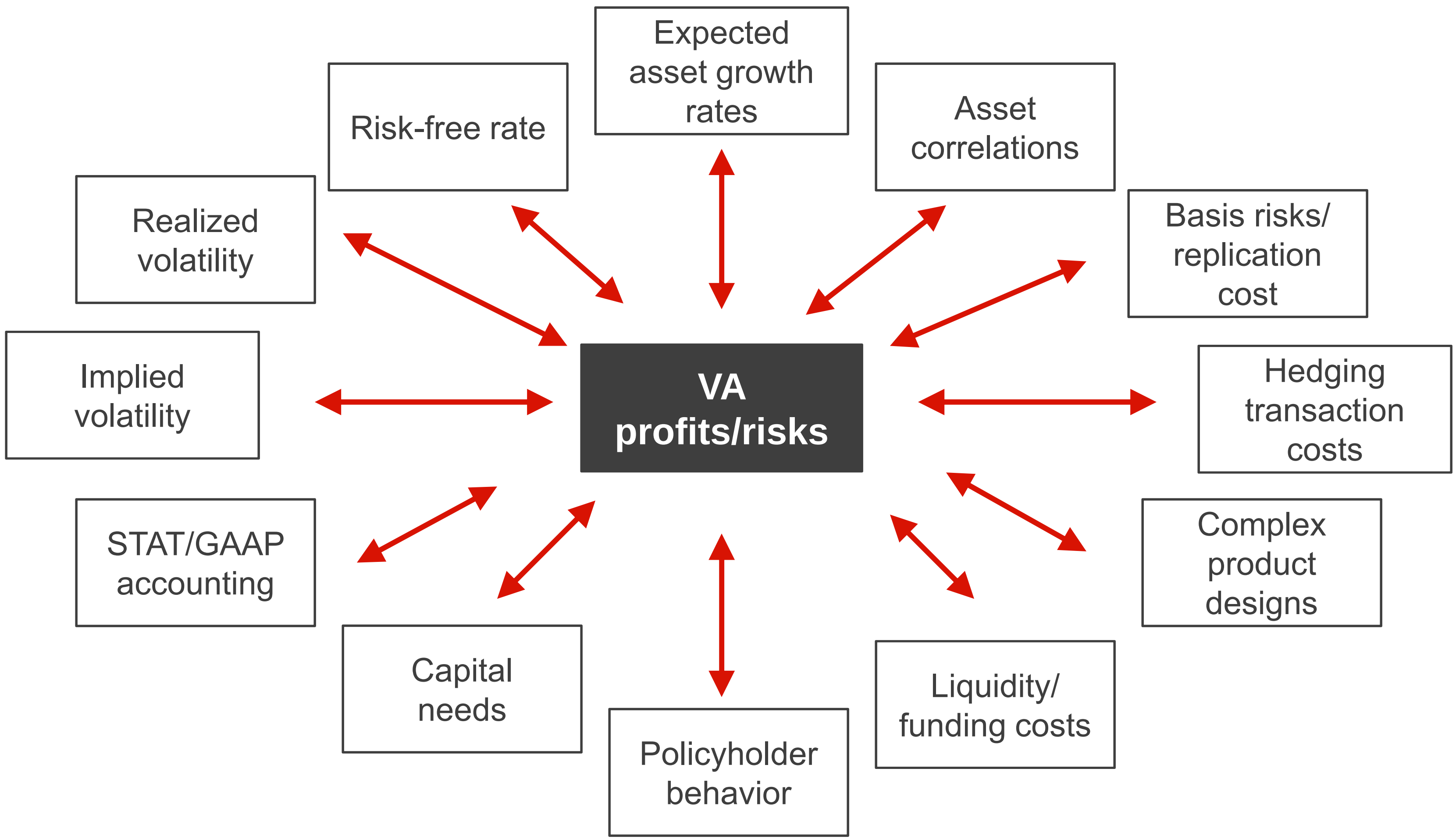
Variable annuity derivatives pricing

Risk Neutral Valuation

- ❑GMDB is paid only If GMDB is in the money and still In force **at death**
- ❑Price = sum of all future possible death payoffs on persist contracts



Many Factors Affecting VA Guarantee Profits/Risks

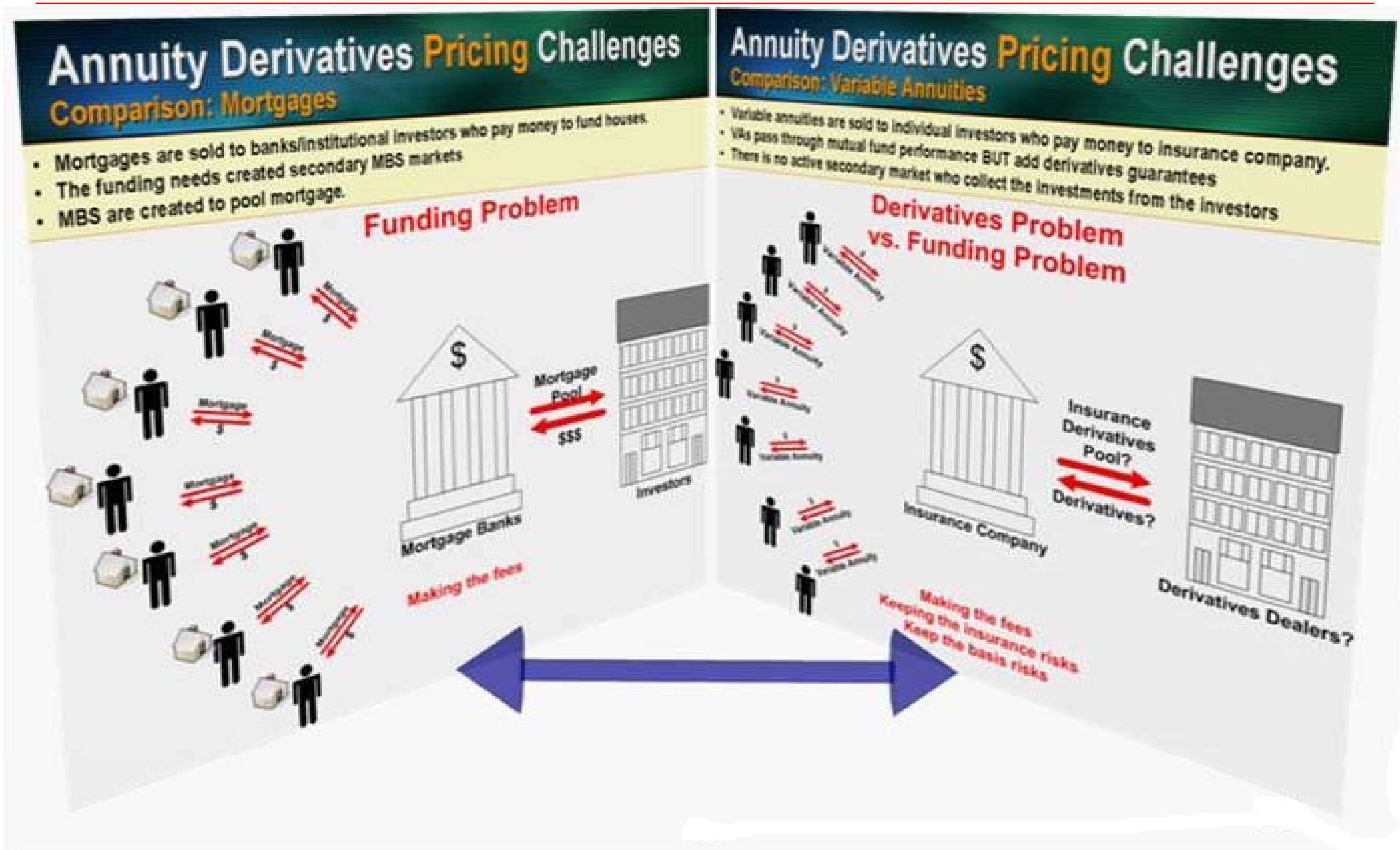


These are some of the most exotic, super-long dated, and hybrid derivatives ever created!

Annuity Derivatives Pricing Challenges
Stochastic Simulations

- Simulations often the only choice
  - No closed form solutions
  - Path dependency
  - Amortizing options
  - Multiple underlying assets
  - Very complex rules
  - Individual modeling
  - Option premiums (fees) collected over time
  - Policies are not uniform, i.e. everything is customized by individual investments
- A lot of exciting challenges and opportunities ahead
  - Most existing theoretic researches can't deal with path dependency
  - Passport optionality
  - American optionality
  - Lattice approach rarely used
  - Large scale grid computing (i.e. thousands of CPUs) typical
  - Model efficiency critical

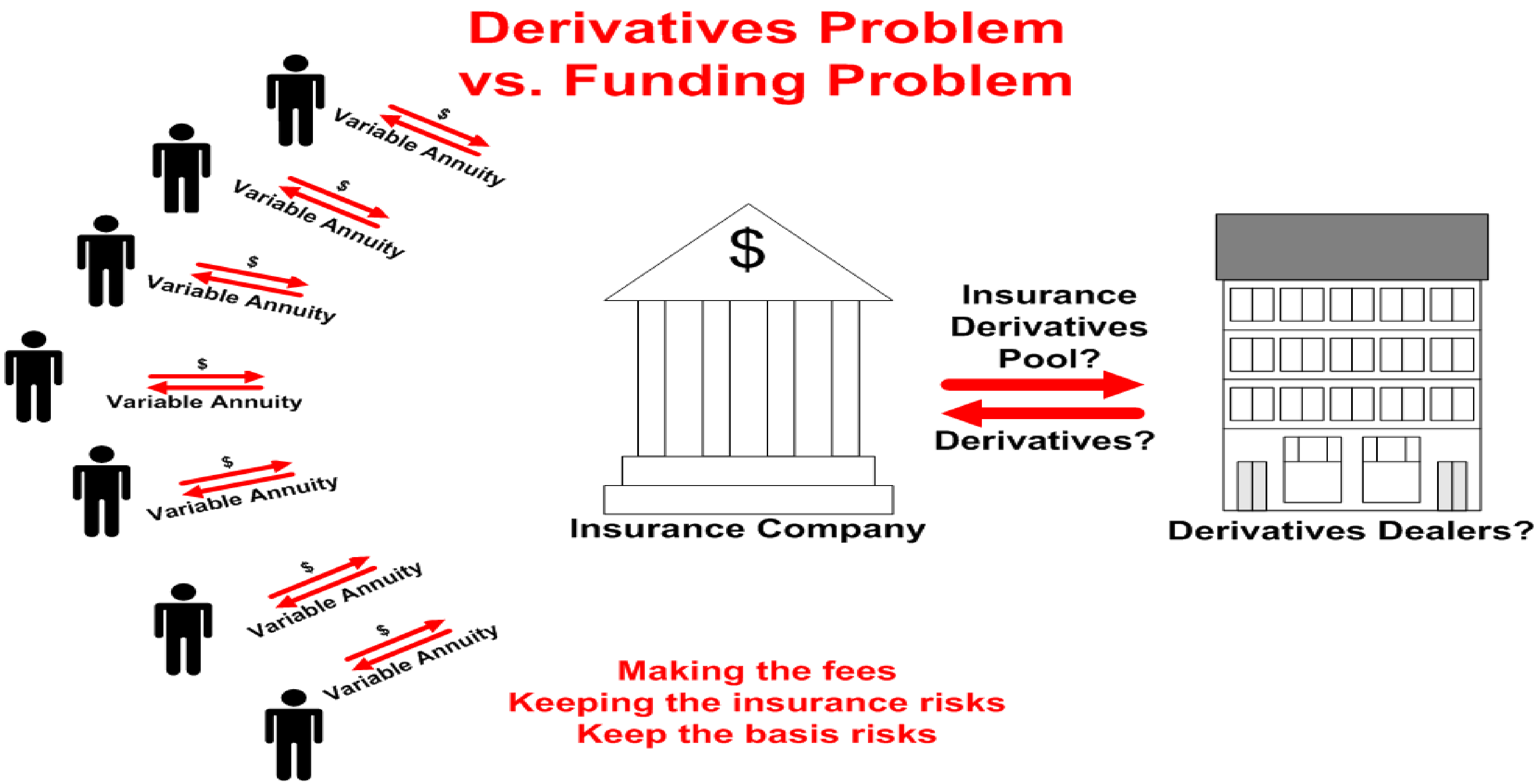
Annuity Derivatives vs. Mortgage Backed Securities



Annuity Derivatives Pricing Challenges

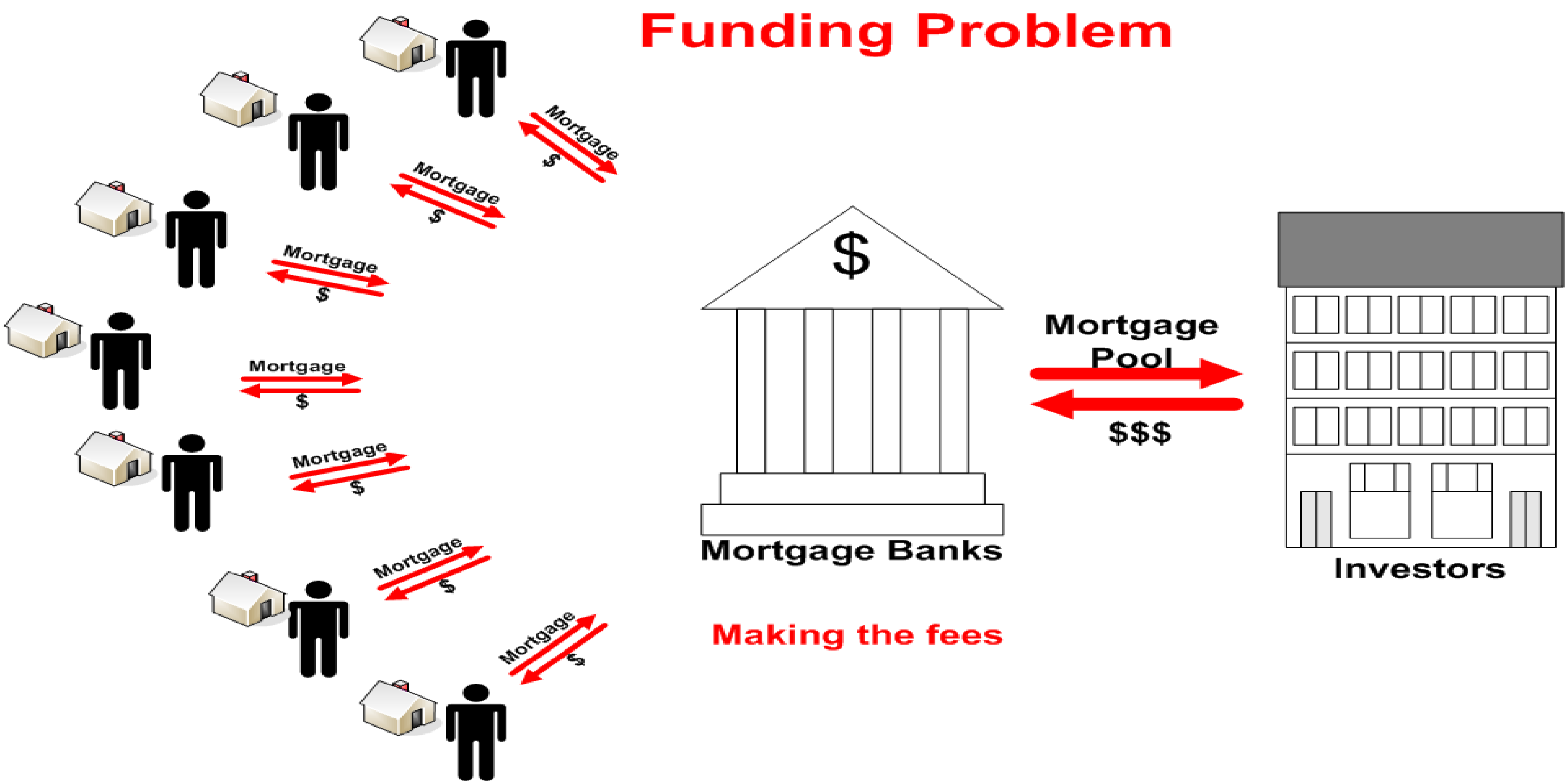
Comparison: Variable Annuities

- Variable annuities are sold to individual investors who pay money to insurance company.
- VAs pass through mutual fund performance BUT add derivatives guarantees
- There is no active secondary market who collect the investments from the investor



Annuity Derivatives Pricing Challenges
Comparison: Mortgage Backed Securities

- Mortgages are sold to banks/institutional investors who pay money to fund houses.
- The funding needs created secondary MBS markets
- MBS are created to pool mortgages.



Annuity Derivatives Pricing Challenges

Dynamic Policyholder Behavior Modeling – Critical But Difficult

- Dynamic policyholder behavior modeling is critical & difficult
  - Key driver for pricing but options not always exercised optimally
  - Mortality risk managed by pool of large numbers but living benefits much more challenging
  - Behavior very difficult to predict and with little or no experience
  - Policyholder dynamics causing significant gamma exposure
  - Capital market risks not diversifiable as insurance risks

- MBS prepayment vs. annuities dynamic policyholder behavior modeling
  - MBS prepayments based on real world experience or expectations but validated by active capital market MBS prices, unlike annuities
  - Risk neutral pricing standard in financial engineering, but transition from actuarial expectations to risk neutral pricing caused confusions about probability distributions and stochastic simulations
  - MBS markets not usually concerned with nested stochastic projections that mix risk neutral world and risk neutral valuations, unlike annuities

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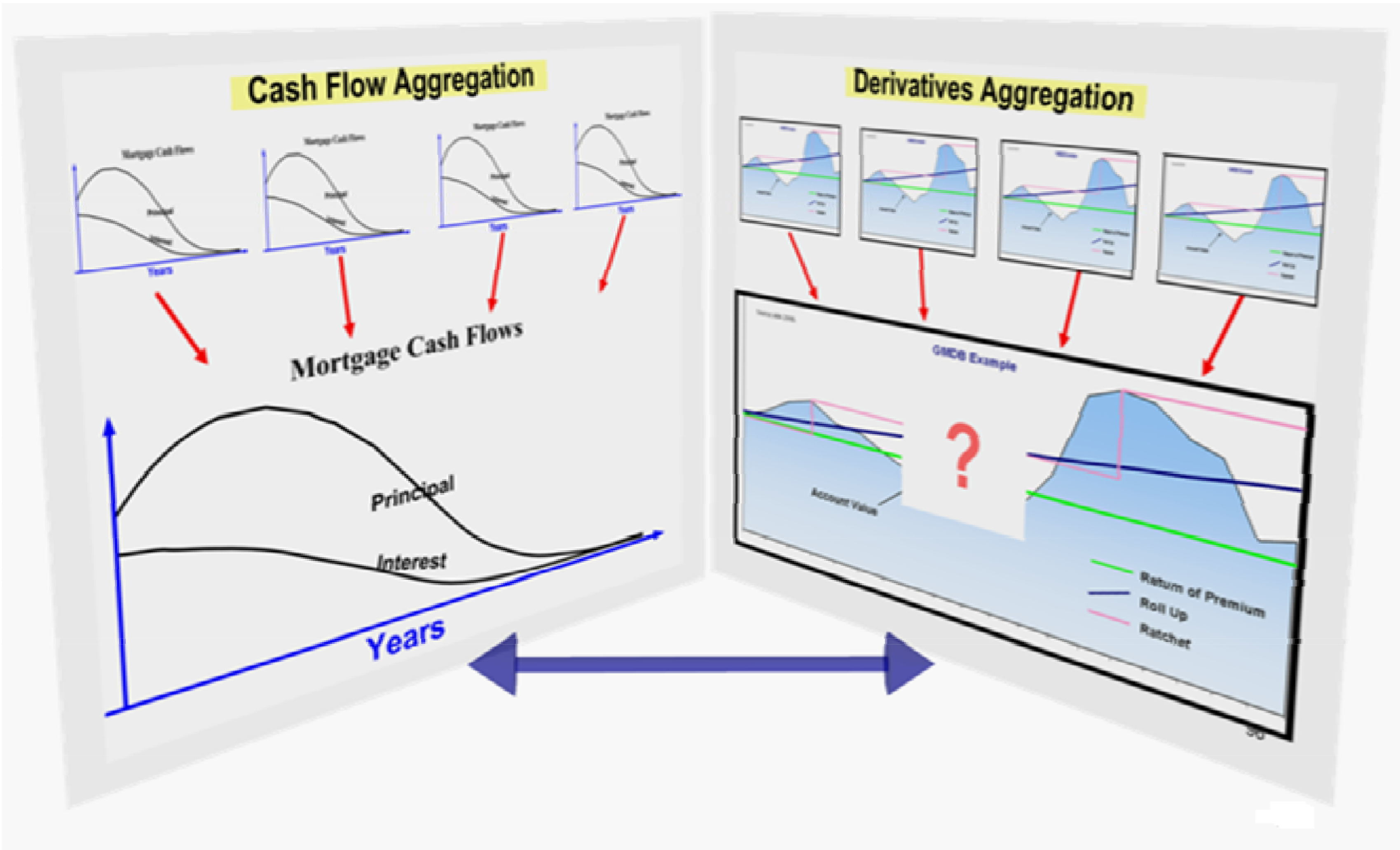
Insurance or Mortgage Cash Flows vs. Derivatives Averaging

Be careful when using cells to average the derivatives



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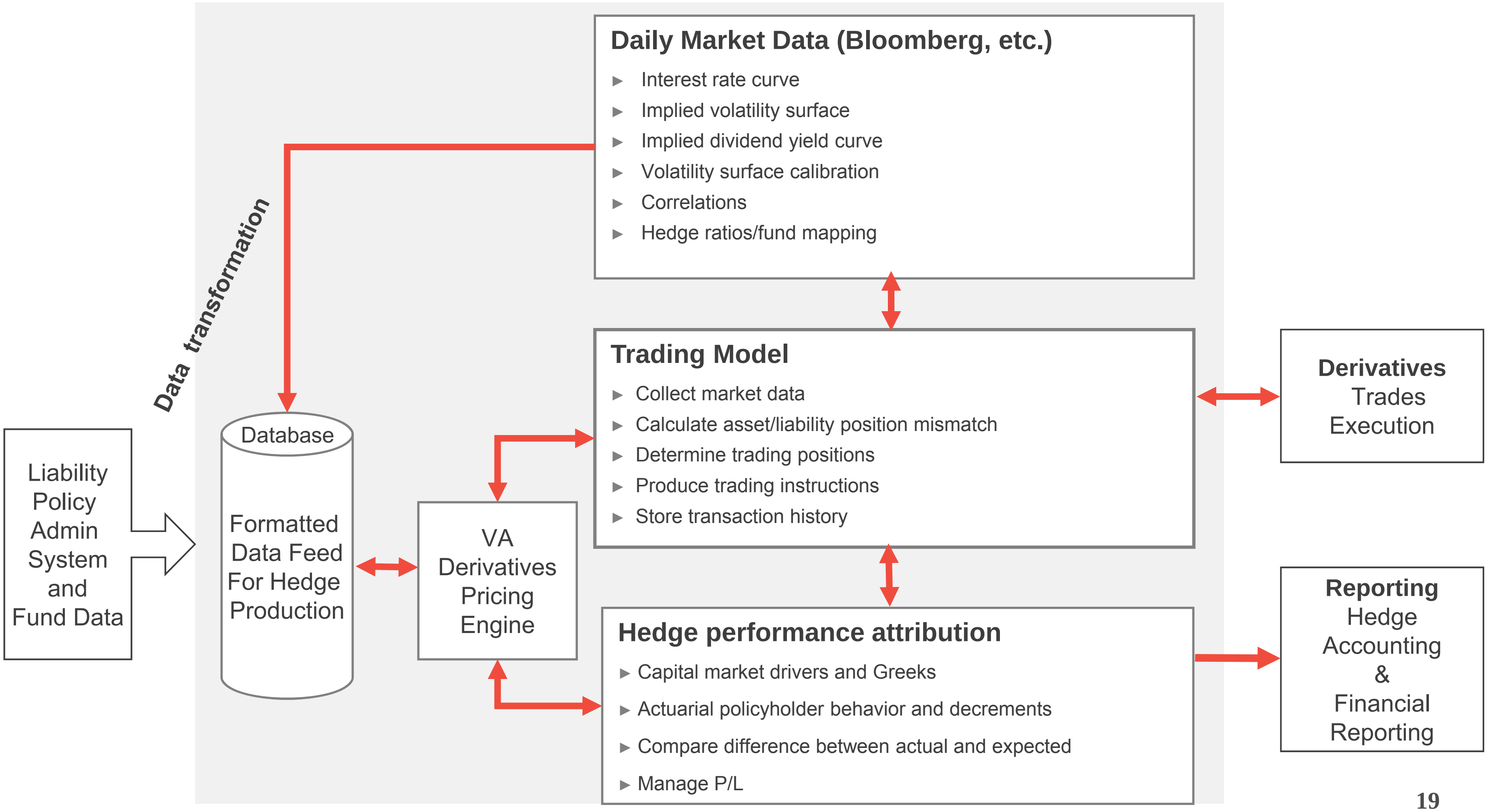
A Dynamic Hedging Program (A "Trading Book")

- There may be hundreds of thousands or millions of derivatives contracts in a book
- No closed form solutions but stochastic simulations for path dependent, long-dated, and basket options in VA book.
- Need very large computing grid for overnight simulation runs
- Maybe active derivatives trading to hedge the Greeks



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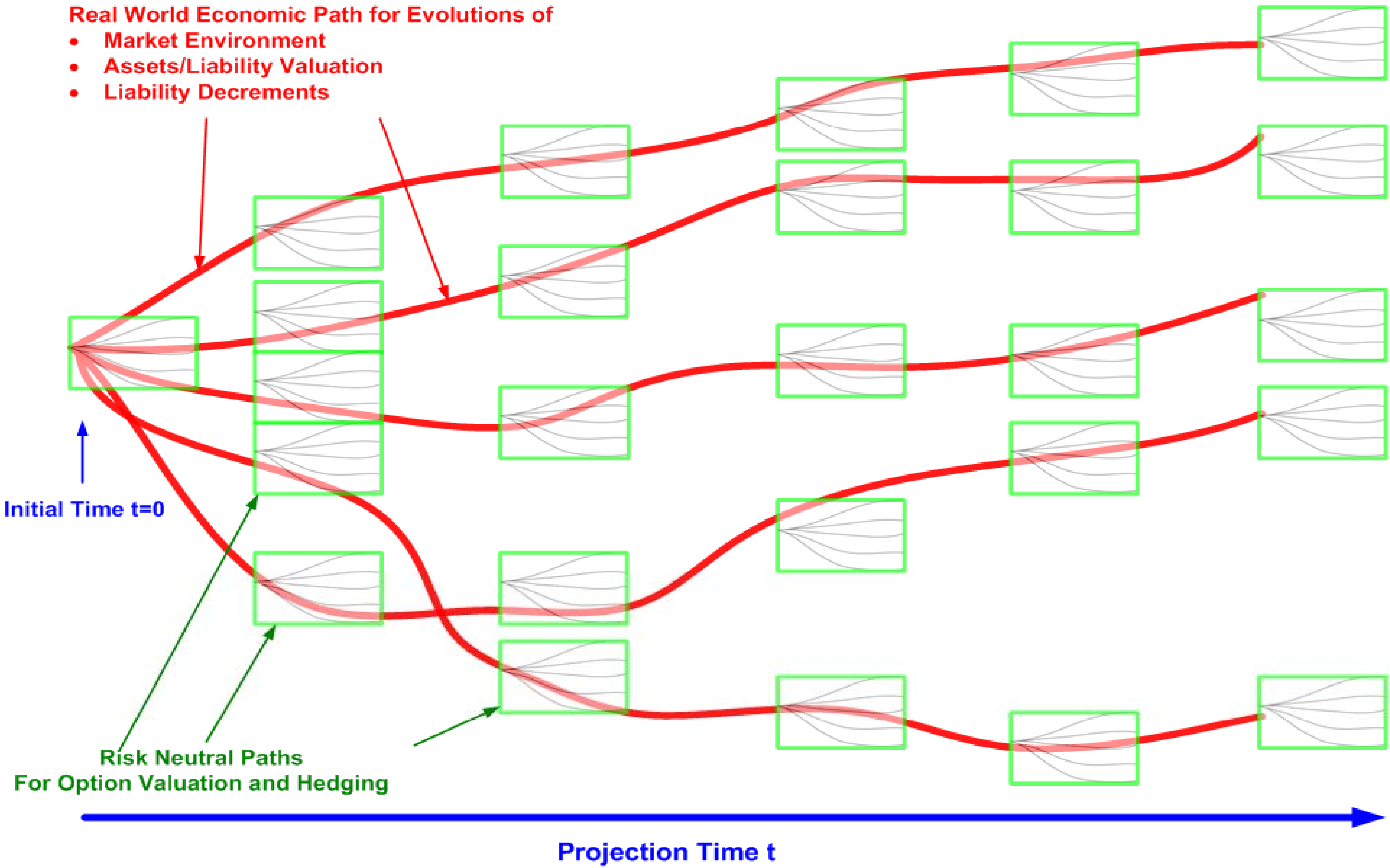
Hedging Program Financial Projections – A Stochastic On Stochastic System



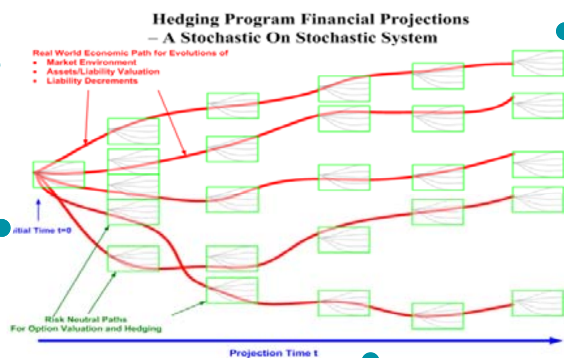
Long Term Financial and Hedging Projections
There is something better than back testing (alone)

For projecting VaR and economic capital into the future and testing different techniques for efficient financial and capital managements under different accounting rules and capital rules

Stochastic-on-stochastic real world and risk neutral projections

Long term financial projections are core of actuarial technology

Required for regulatory capital and reserve CTE calculations



"Realistic" projections of the future more dynamic and comprehensive than simple back testing or stress testing

To test optimized hedge strategies and derivatives positions under different market scenarios

Calculate option values and Greeks along the paths of real world financial projections

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Insurance Quants Are in High Demand

- One of the best places who graduates with Master or PhD degree in
  - Financial Engineering
  - Financial Mathematics
  - Computational Finance
  - Finance
  - Actuarial Science
  - Computer Science
  - Mathematics
  - Physics
  - Probability and Statistics
- Blend skills of financial engineering, actuarial science, and computer science
- Blend expertise of capital market, insurance, and IT background
- We are only interested in highly motivated candidates

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