



**SOA**

**2020 VIRTUAL  
ANNUAL MEETING  
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# Session 3E: Analyzing Pension Surplus Risk for Liability Driven Investing and Practical Applications

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# Models and measurement of risk

# Financial Risk Models

- Physics vs. financial markets
  - Most financial risk models came from techniques used in physics
  - Financial markets are driven by human behavior and changing set of rules
  - Many conditions often required (such as ergodicity, stationarity, etc.) often do not hold
  - To understand model usefulness and applicability it is critically important to thoroughly understand its assumptions.
- Ex ante vs. Ex post risk metrics
  - Relevance: “Past returns are not indicative of future performance”
  - Regime shifts and model misspecification
  - Noise from changes in portfolio composition

# Financial Risk Models - Continued

- Capital Market Models
  - Multi-period Monte Carlo simulations
  - Rely on existence of equilibria conditions
  - Rely on persistence of certain premia (e.g. equity risk premium)
  - Useful framework for assessing return profiles, less so for surplus risk
- Market Risk Frameworks
  - Assumption of zero expected returns allows for more flexibility in risk estimation
  - Typically short horizon / single period
  - Often relies on volatility clustering assumption (via use of GARCH or EWMA)
  - Flexibility to calibrate to specific asset and liability composition
  - Ultimately rely on historical data

# Market Risk Measures

## *Importance of multiple perspectives*

- Distributional metrics
  - Volatility, VaR, CVaR/ES, etc.
  - Can be parametric/Monte Carlo or non-parametric (historical simulation)
- Scenario analysis
  - Historical: replay of past events
  - Predictive: propagation of scenario to other risk factors
- Risk factor sensitivity
  - Simple: duration, equity delta, FX delta
  - Predictive: propagation of shock to other risk factors
- Reverse stress testing
  - What are the conditions that result in funded status of x%?



# Market Risk Decomposition

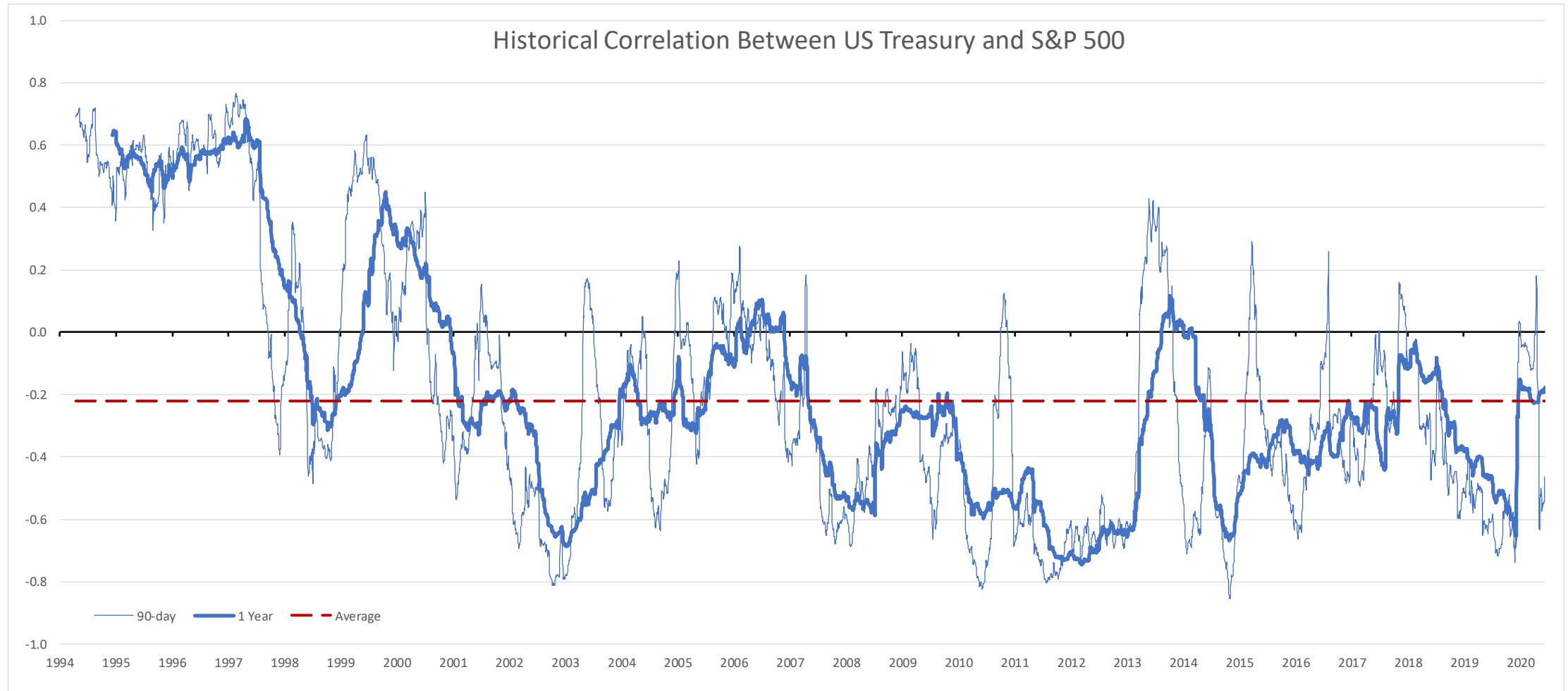
- Market risk can be decomposed into three components<sup>1</sup>:

$$\sigma_p = \sum_m \underbrace{x_m}_{\text{Risk Exposure}} \cdot \underbrace{\sigma_m}_{\text{Volatility}} \cdot \underbrace{\rho(r_m, R)}_{\text{Correlation}}$$

Marginal contribution to risk

1. Menchero, J., and B. Davis., 2011. Risk contribution is exposure time's volatility time's correlation: decomposing risk using the x-Sigma-rho formula. The Journal of Portfolio Management, 37(02): 97-106. <http://dx.doi.org/10.3905/jpm.2011.37.2.097>

# Correlations Spotlight



\* Constructed based on 5-day overlapping returns between Barclays Bloomberg US Treasury Index and S&P 500 Index using daily data from 1994 to 2020

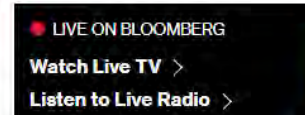
# Importance of Understanding Assumptions in Risk Models

## Risk Model From 2008 Crash Loses AIMCo \$1.5 Billion During Covid

By [Kevin Orland](#)

July 10, 2020, 1:25 PM EDT

- ▶ Value-at-risk measure understated peril of volatility strategy
- ▶ Alberta pension fund manager releases review of losses



Volatility wagers that lost Alberta Investment Management Corp. about C\$2.1 billion (\$1.5 billion) were being assessed by a legacy value-at-risk model that breaks down when risks are non-linear and outside of its 95% confidence interval, the pension manager said in the review released Thursday.

1. <https://www.bloomberg.com/news/articles/2020-07-10/risk-model-from-2008-crash-loses-aimco-1-5-billion-during-covid?sref=KDvG5sgc>

# Key Takeaways for Surplus Risk Modeling

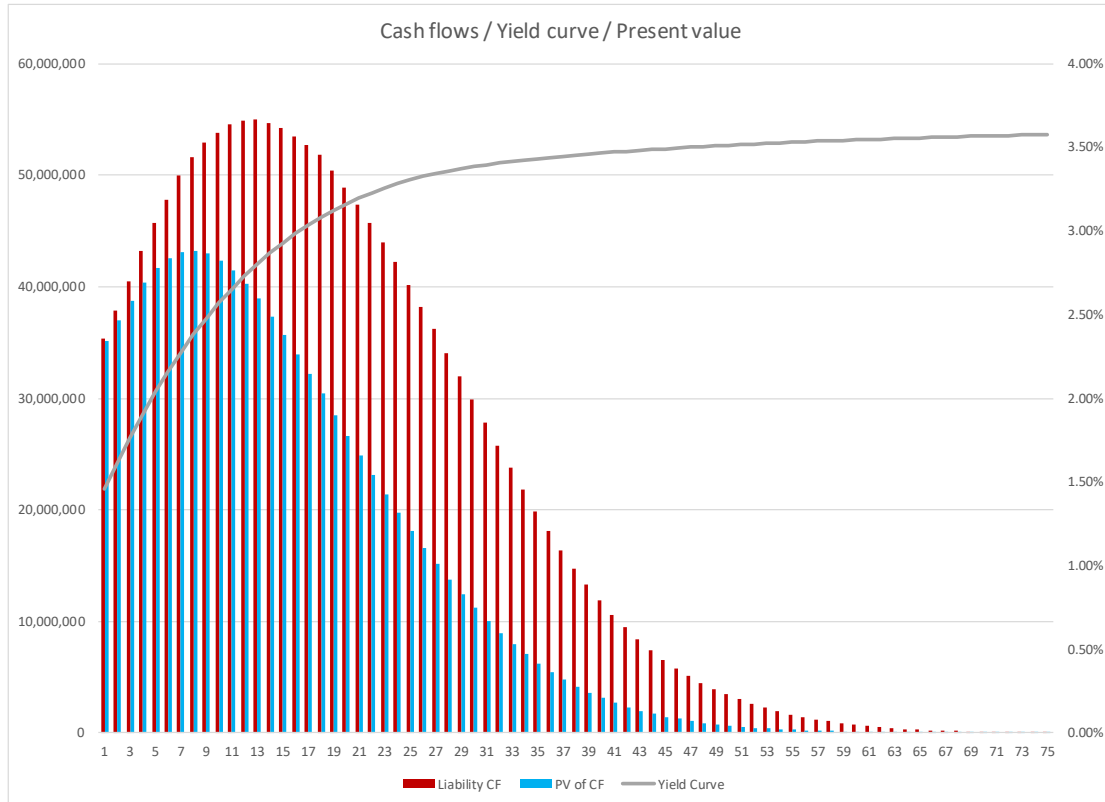
- Understand limitation of the modeling approach
- Understand the assumptions used
- Stress test key assumptions (e.g., correlation)
- Know when model will not work

# Measuring liability risk and its implications

# Identifying the main sources of liability risk

- Time to payment – short vs. long dated liabilities
- Yield curve movement – rates, spreads and shape
- Understanding the main sources of liability risk allows the sponsor to direct a limited amount of assets

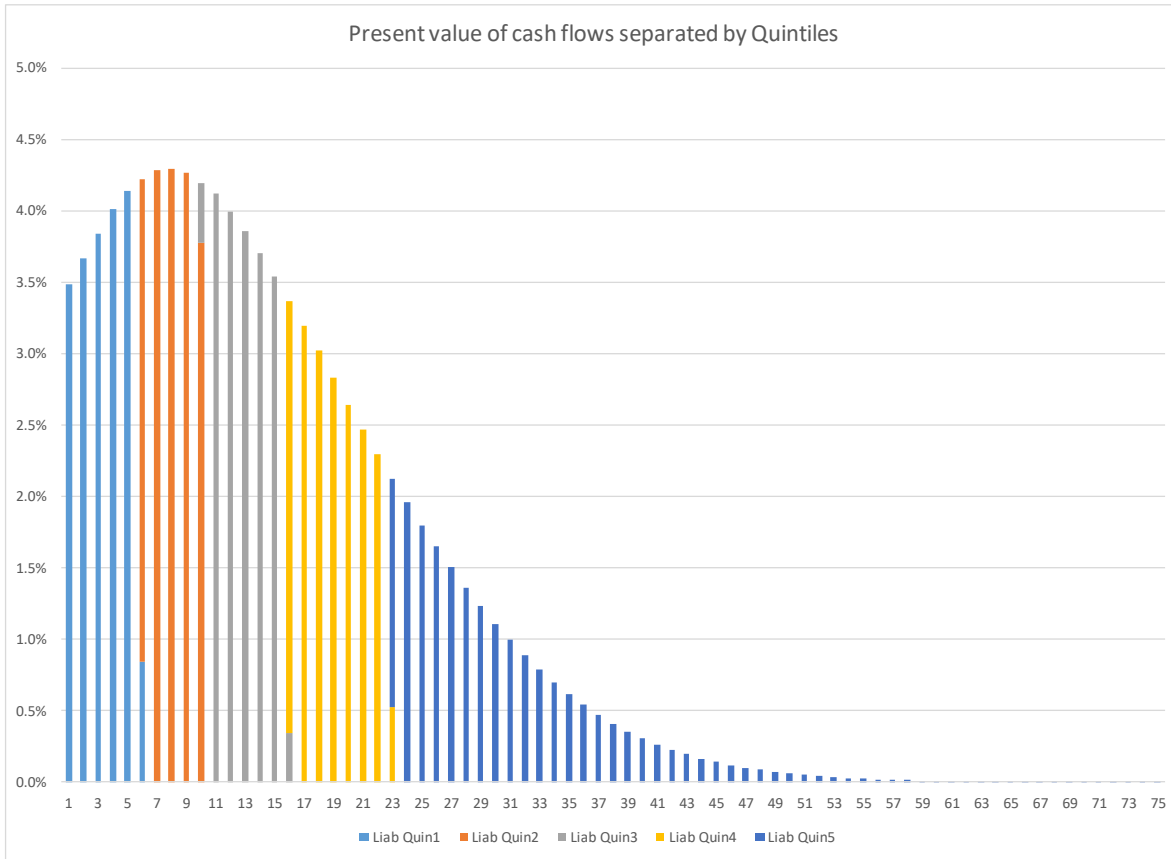
# Cash flows/Yield curve/Present value



- **Cash flows** are estimated benefit payments based on the plan’s benefit formula, participant data, and assumptions
- **Yield Curve** is a series of spot yields on high quality corporate bonds
- **Present value** the discounted value of each cash flow using the appropriate time and appropriate spot rate
  - $PV_n = CF_n * (1 + y_n)^{-n}$
  - $L = \sum_{n=0}^{100} PV_n$
- **Liability** is the sum of individual present values, think of the liability as a “portfolio” of partial liabilities

Effective liability discount rates are based on the FTSE Pension Discount Curve. Liability profile is based on sample pension plan, results may vary for pension plans with different liability profiles.

# “Portfolio” of partial liabilities



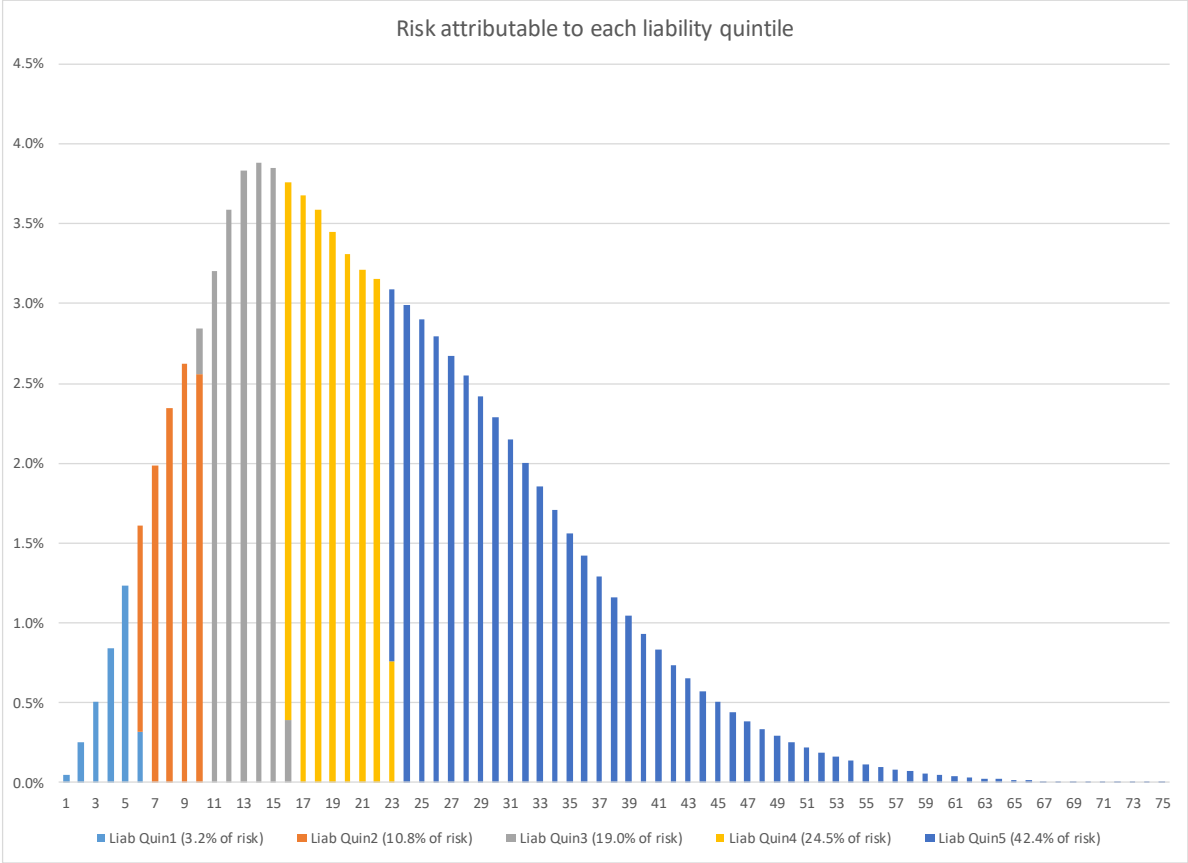
- The allocation to each partial liability is the present value of each partial liability divided by the total liability, or  $PV_n / L$
- The allocation to the first partial liability is 3.5%, the second is 3.7%, etc.
- The sum of all partial liability allocation is 100%, or all the liability
- It is our assertion that the **value** liability is front loaded

| Quintiles | Years   | Percentage of liability present value |
|-----------|---------|---------------------------------------|
| 1         | 1 – 5   | 20%                                   |
| 2         | 6 – 10  | 20%                                   |
| 3         | 11 - 15 | 20%                                   |
| 4         | 16 – 22 | 20%                                   |
| 5         | 23 +    | 20%                                   |

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# Time to payment – short vs. long dated liabilities

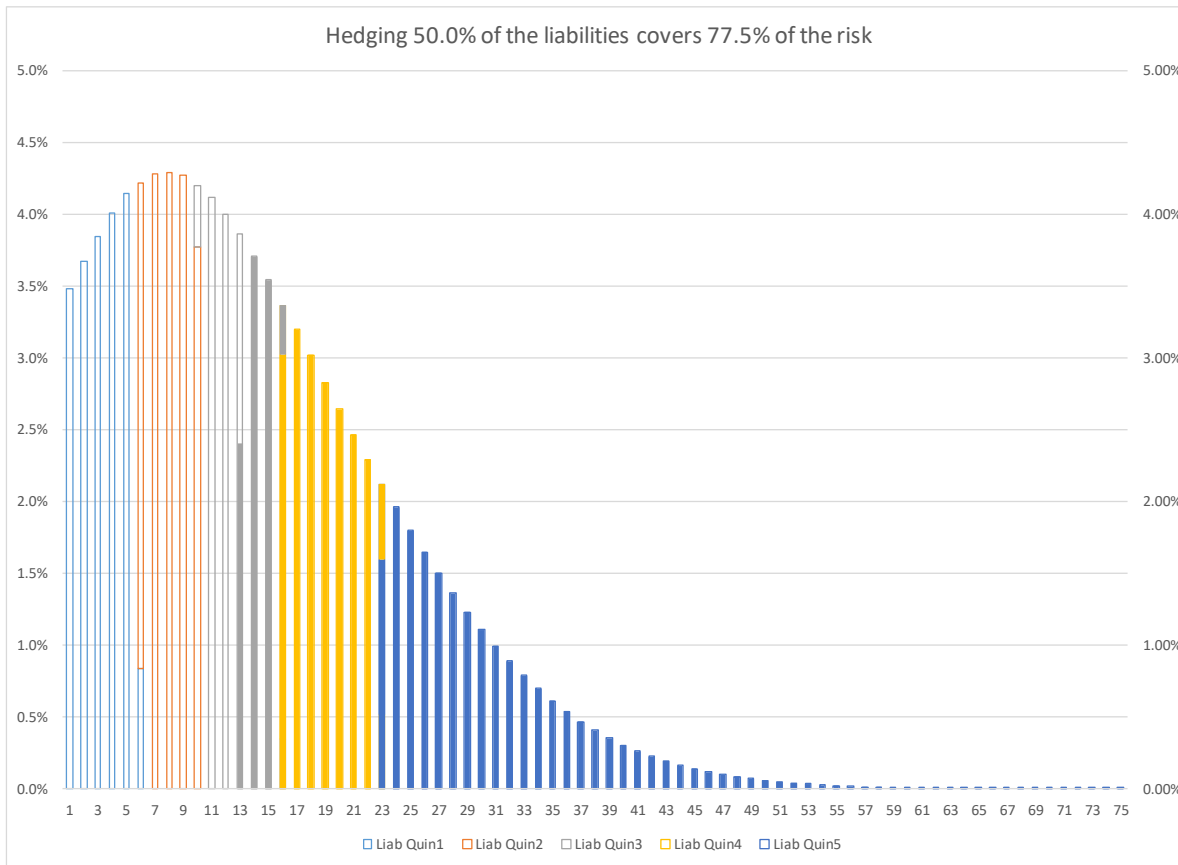


- Here we measure the contribution to risk of each partial liability, with the total equaling 100%
- Using historical yield curve volatility and correlations
- The first partial liability is contributing 3.5% of the liability **value** but 0.05% of the liability **risk**, the fifteenth partial liability is contributing 3.5% of the liability **value** but 3.85% of the **risk**.
- It is as valuable but 77x more risky
- So while **value** of the liability is front loaded, the **risk** is back loaded

| Quintiles | Years   | Percentage of liability present value | Percentage of liability Risk |
|-----------|---------|---------------------------------------|------------------------------|
| 1         | 1 – 5   | 20%                                   | 3%                           |
| 2         | 6 – 10  | 20%                                   | 11%                          |
| 3         | 11 - 15 | 20%                                   | 18%                          |
| 4         | 16 – 22 | 20%                                   | 24%                          |
| 5         | 23 +    | 20%                                   | 44%                          |

Effective liability discount rates are based on the FTSE Pension Discount Curve. Liability profile is based on sample pension plan, results may vary for pension plans with different liability profiles.

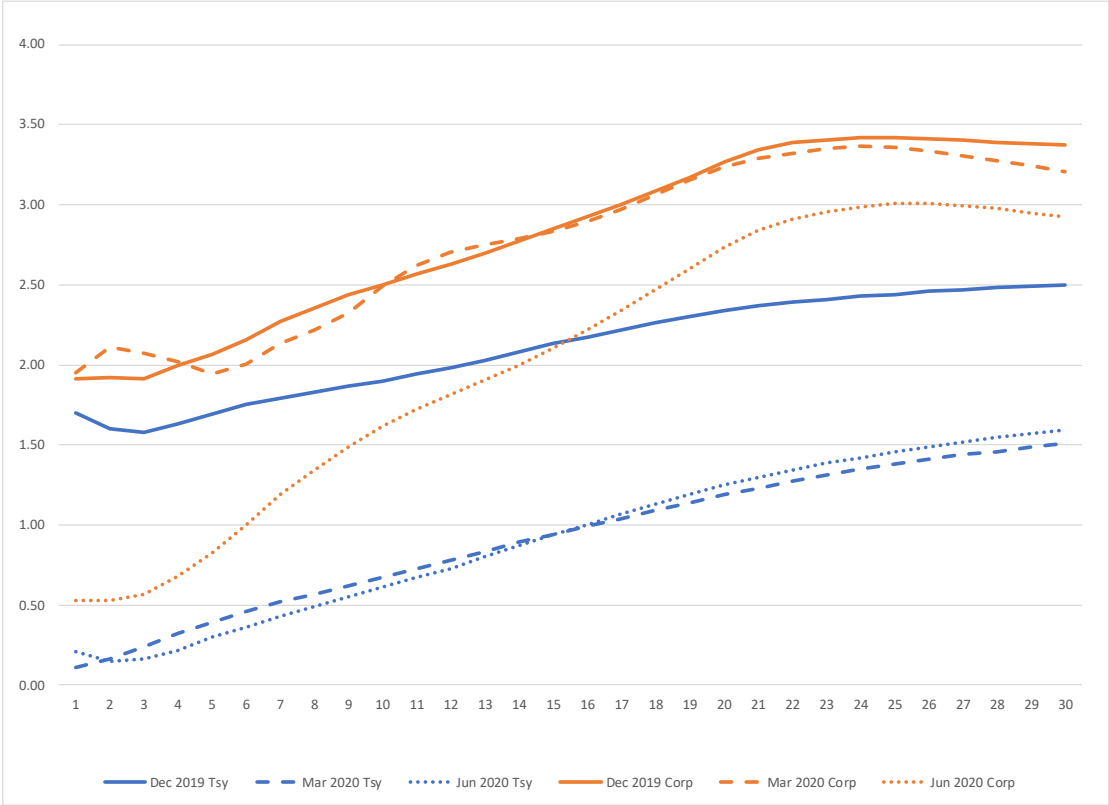
# What are the implications?



- Typical situation - \$ in LDI < size of liability
- Not all liability contributes equally to volatility
- Many LDI programs are set to hedge all partial liabilities equally (duration of assets = duration of liabilities)
- Capital efficiency – using the limited dollars to hedge the liability that is the riskiest
- If I have enough assets to hedge half the liability, hedging the longest liability can hedge nearly 75 to 80% of the risk, as opposed to 50% of the risk when using a traditional method

Effective liability discount rates are based on the FTSE Pension Discount Curve. Liability profile is based on sample pension plan, results may vary for pension plans with different liability profiles.

# Yield curve movement – rates, credit, and shape



| Factor                                 | December 2019 to March 2020                                  | March 2020 to June 2020  |
|--|--|--|
| Interest rate Impact                   | Decrease 1 bps   | Decrease 88 bps  |
| Interest rate Impact                   | Decrease 123 bps   | Decrease 6 bps   |
| Credit spread impact                   | Increase 122 bps   | Decrease 82 bps  |
| Impact of changes in yield-curve shape | Short end down 12 bps and long end down 16 bps (“butterfly”) | Short end down 112 bps and long end down 29 bps (“steepening”) |

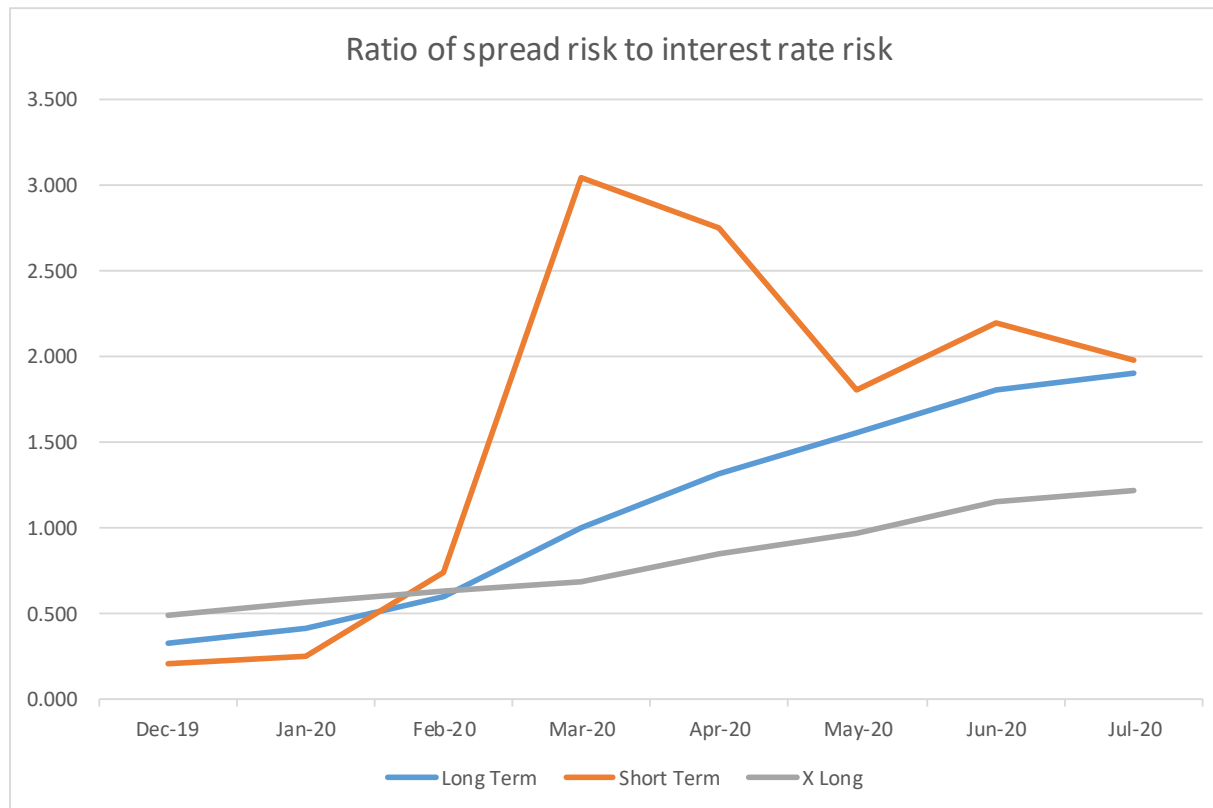
Corporate bond yield curve is based on the FTSE Pension Discount Curve. Treasury yield curve is based on spot yields from US Treasuries.

# Yield curve movement – rates, credit, and shape

| Factor                       | Defined as:   | Changes in the value of the liability explained by changes in the ...                               | % of risk (long term historical assumptions) |
|------------------------------|---|---|--|
| Interest rate changes        | Parallel shifts in the U.S. Treasury yield curve                                  | ... 10-year zero-coupon Treasury yield  | ~65%   |
| Credit spread changes        | Parallel shifts in the credit spread component of the corporate bond yield curve  | ... 10-year point on the FTSE pension discount curve, net of the estimated impact of interest rates | ~25%   |
| Changes in yield-curve shape | Non-parallel shifts in the underlying yield curves (flattening, steepening, etc.) | .. other movements in movements in the yield curve beyond the above parallel changes                | ~10%   |

- A lot risk can be managed buying a STRIP equal to the duration of your liability
- Corporate bonds begin to have an advantage because they combine treasury risk, credit spread risk and yield curve changes (because of principle and interest)
- Mismatch between implied liability rating (AA) and an investible asset portfolio (lower quality than AA) as well as correlations with equity markets work against an all credit portfolio
- Yield curve changes are best to match through derivatives by looking at the residual different between asset and liability key rate durations

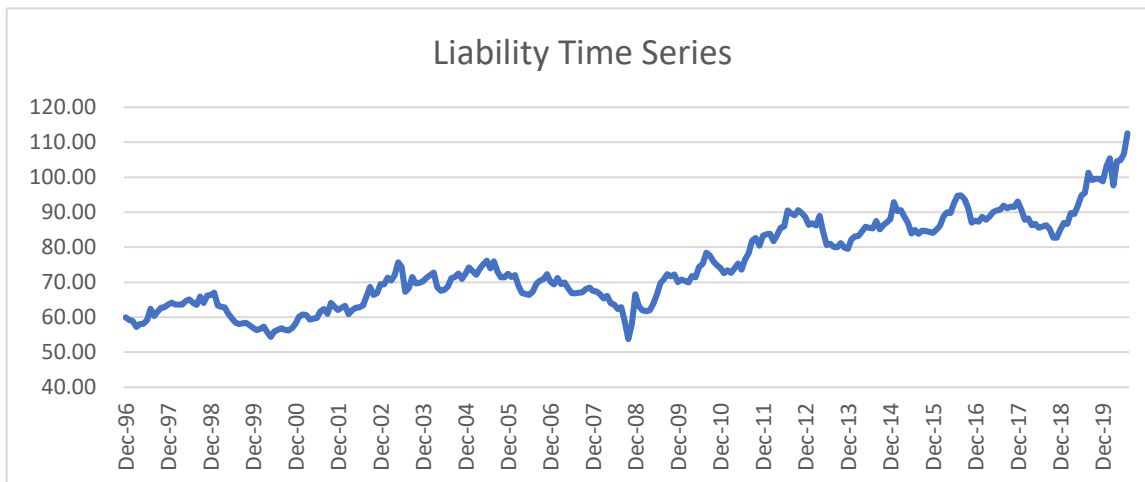
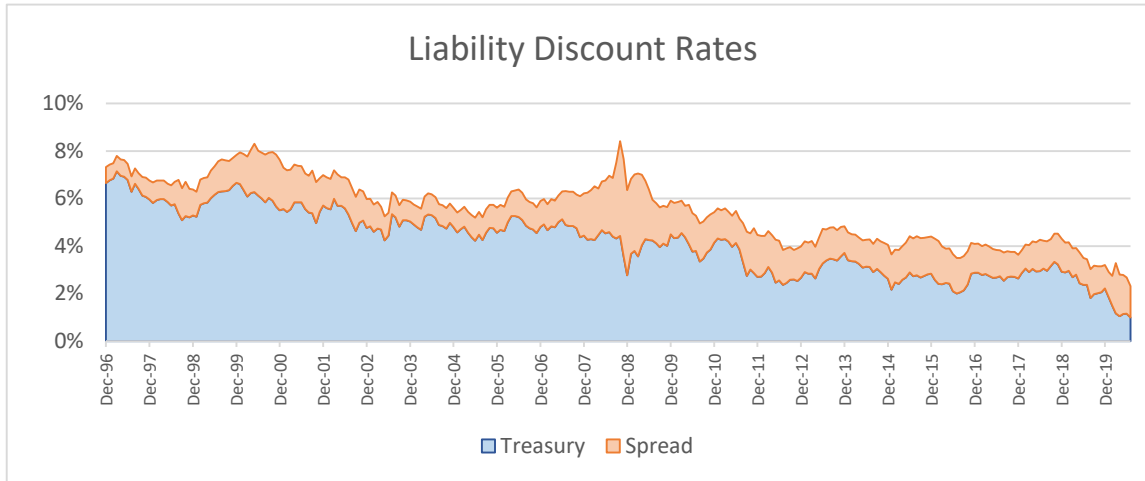
# Yield curve movement – conditional assumptions



- Conditional assumptions use more recent market risk data to arrive at volatility and correlations (inputs are not stable)
- Spread risk was ~30% of interest rate risk in early 2020, similar to the long term relationship from the previous page
- As coronavirus impacted markets this relationship flipped and spread risk was equal to or larger than interest rate risk
- The shorter term the model history the higher the relationship of spread risk to interest rate risk during the crisis
- Which do you believe more? – longer term inputs (equilibrium model) where relationships don't change or shorter term inputs (market model) where output is much more volatile

# Joining asset risk with liability risk for surplus

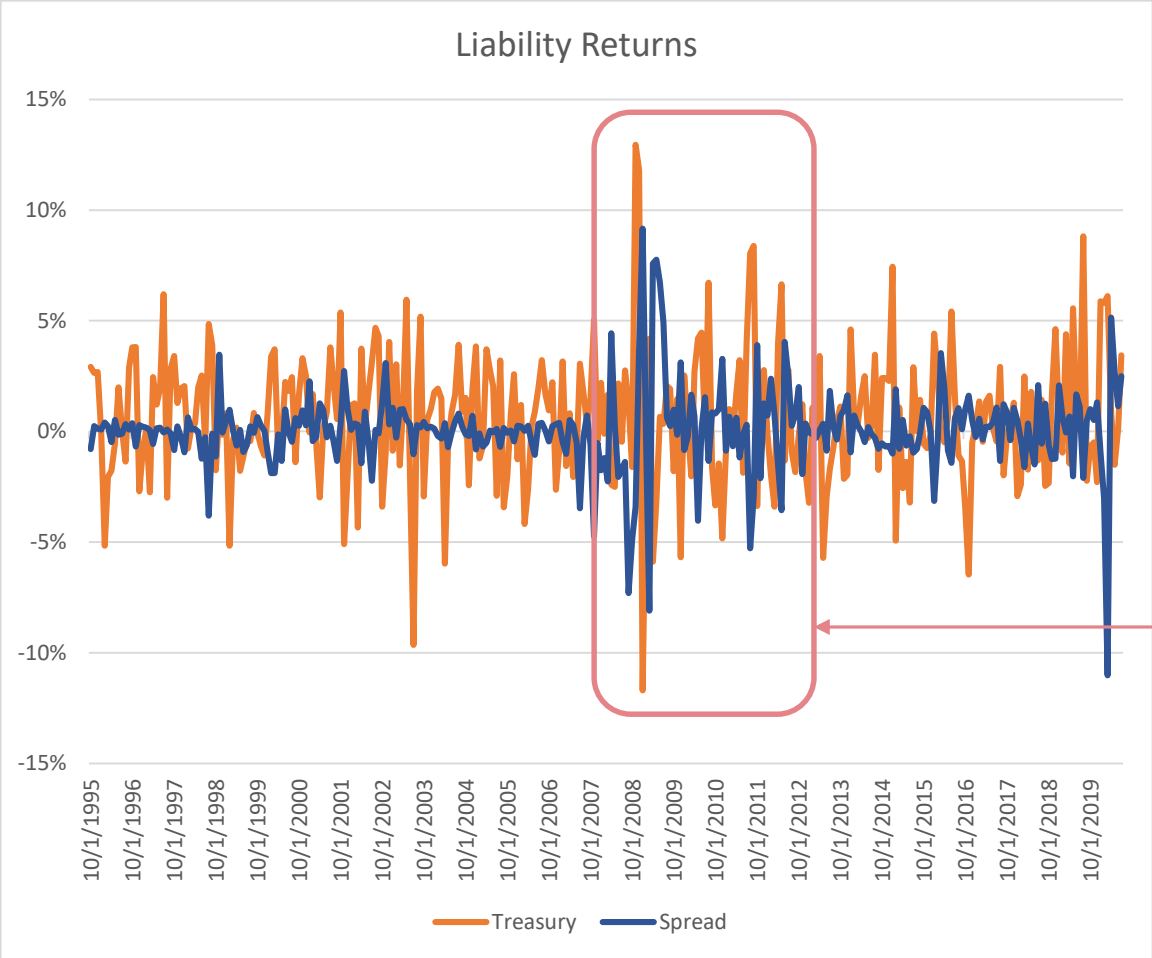
# Investing: Start with Liabilities



- Liability discounting yield curves have demonstrated significant volatility through time
  - Credit spreads have narrowed and widened through time, with larger blowouts in times of market stress
  - Treasury rates have fallen over the years
  - Spreads and rates across the yield curve behave differently
- Using the same projected pension cash flows, we see that the value of the liability, or PV of cash flows, has also demonstrated significant volatility through time
  - Not unexpected as volatile yield curves drive this behavior
  - Liabilities using discount rates today are almost twice what they would have been 25 years ago
  - Impact of rates versus spreads on liability values depends on the market environment
- **Bottom Line: Liabilities move with both Treasury Rates and Credit Spreads**

Effective liability discount rates are based on the FTSE Pension Discount Curve.

# Treasury Rates and Credit Spread Returns



- Correlation of Total Liability Returns is higher compared to Treasury Liability Returns than Credit Spread Liability Returns, indicating that treasury rates are driving liability returns more than credit spreads
- This behavior changes through time, as you can see from the 4-year period beginning in 2008
  - We've seen this behavior recently with COVID-19, as well
- Volatility of rates and spreads also play an important role in the relative impact on Total Liability Returns
  - Credit Spread Liability returns during 4-year period beginning in 2008 are almost double those over a 25-year period

|                       | 10/31/1995-7/31/2020 |          |        | 12/31/2007-12/31/2012 |          |        |
|-----------------------|----------------------|----------|--------|-----------------------|----------|--------|
|                       | Total                | Treasury | Spread | Total                 | Treasury | Spread |
| Total                 | 1.00                 | 0.78     | 0.20   | 1.00                  | 0.64     | 0.30   |
| Treasury              | 0.78                 | 1.00     | -0.46  | 0.64                  | 1.00     | -0.54  |
| Spread                | 0.20                 | -0.46    | 1.00   | 0.30                  | -0.54    | 1.00   |
| Annualized Volatility | 9.4%                 | 10.4%    | 6.5%   | 13.4%                 | 14.9%    | 12.1%  |

Liability returns are based on changes in the FTSE Pension Discount Curve.



# Assets' Rates & Spreads Exposure

- When thinking about investment choices, it is helpful to consider their relationship to rates & spreads

Corporate bonds are somewhat related to treasuries and somewhat related to equities—they are somewhat of a hybrid

- Decomposing the return into spread and treasury rates clarifies the level of exposure

Equities behave like spread returns because they spreads are based on credit quality which should be tied to the success of the company, like equity prices

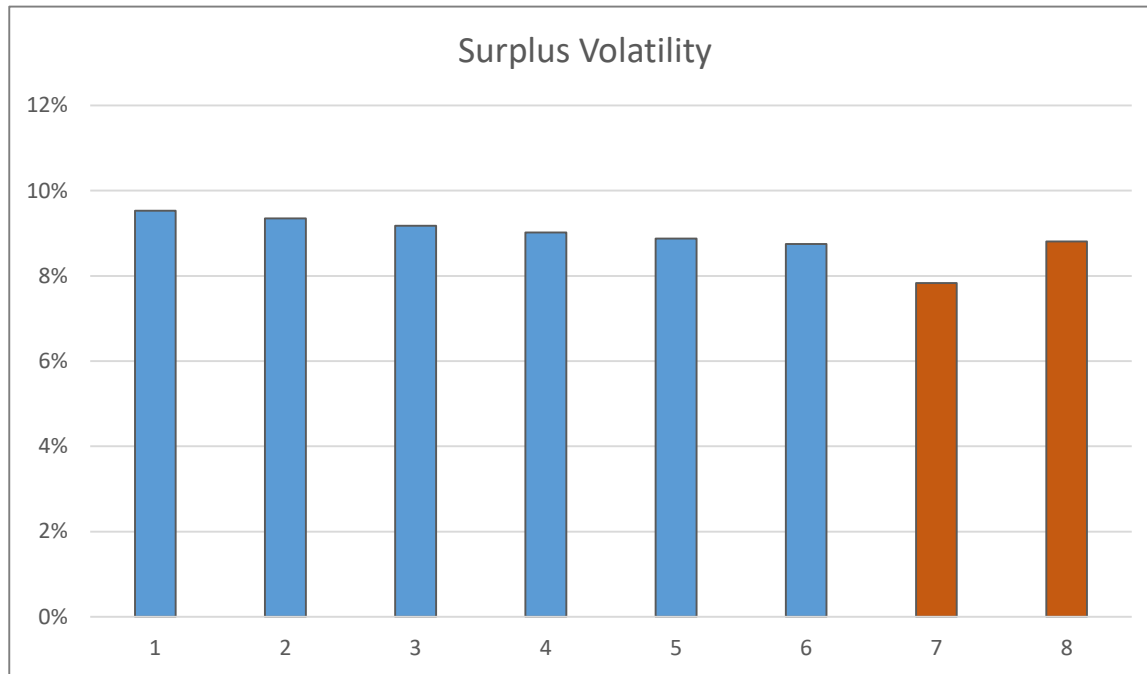
- Over periods where spreads don't change a lot, the correlation is relatively low
- When spreads are changing a lot, the correlation grows

| Correlation of returns 1/31/1995-9/30/2020 |           |       |              |                 |              |             |
|--|-----------|-------|--------------|-----------------|--------------|-------------|
|  | MSCI EAFE | SP500 | BB Long Corp | BB LCorp Excess | BB LCorp Tsy | BB Long Tsy |
| MSCI EAFE                                  | 1         | 0.84  | 0.29         | 0.65            | -0.26        | -0.26       |
| SP500                                      | 0.84      | 1     | 0.26         | 0.60            | -0.25        | -0.24       |
| BB Long Corp                               | 0.29      | 0.26  | 1            | 0.46            | 0.64         | 0.65        |
| BB LCorp CSpd                              | 0.65      | 0.60  | 0.46         | 1               | -0.39        | -0.38       |
| BB LCorp Tsy                               | -0.26     | -0.25 | 0.64         | -0.39           | 1            | 0.99        |
| BB Long Tsy                                | -0.26     | -0.24 | 0.65         | -0.38           | 0.99         | 1           |

Treasuries, obviously are entirely driven by treasury rates and so any correlation different than 1 is because of different exposures across the yield curve

Correlations of returns are for MSCI EAFE, S&P 500, and Bloomberg Barclays Long Corporate indexes.

# Investment Illustration

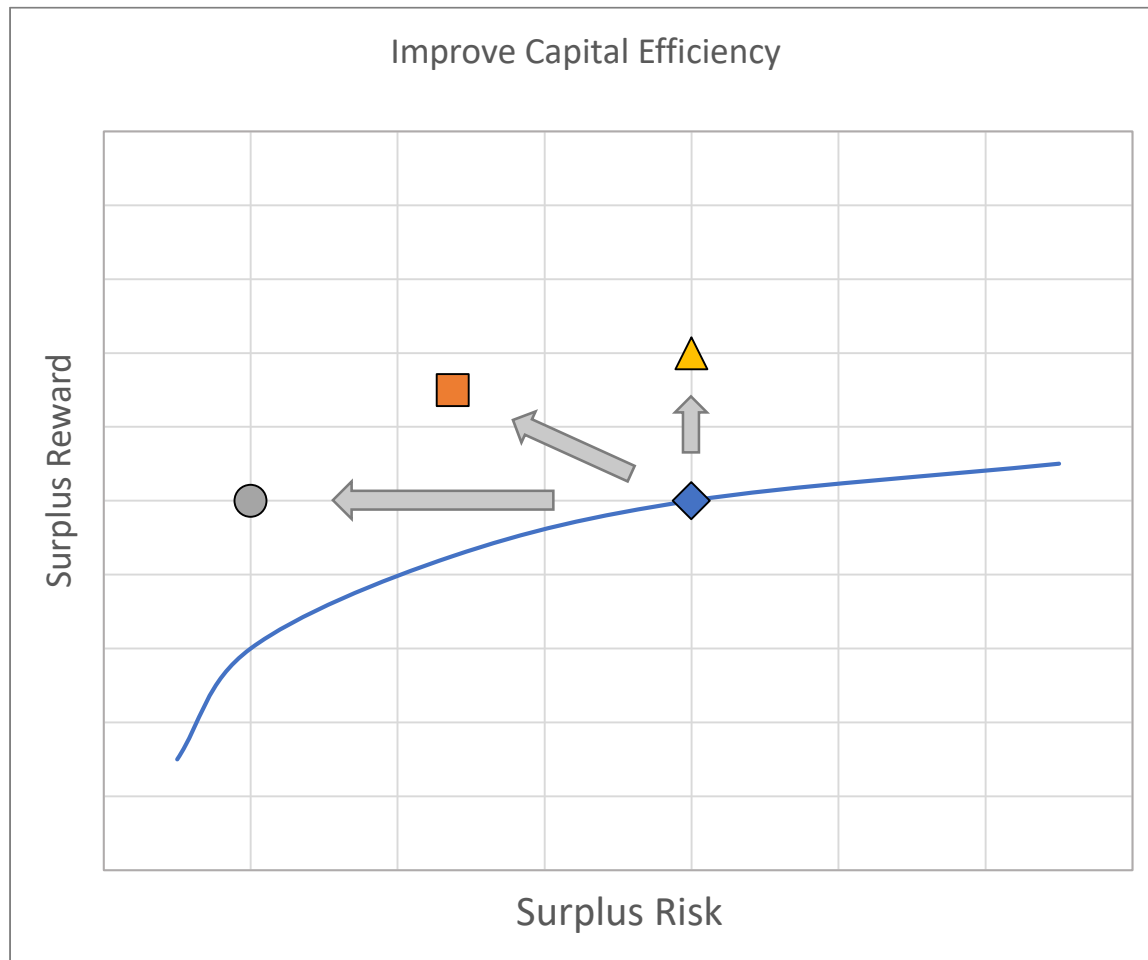


|                    | Portfolio Allocations (%) |    |    |    |    |    |    |    | Duration |
|--------------------|---------------------------|----|----|----|----|----|----|----|----------|
|                    | 1                         | 2  | 3  | 4  | 5  | 6  | 7  | 8  |          |
| Equities           | 60                        | 60 | 60 | 60 | 60 | 60 | 60 | 55 |          |
| Long Credit        | 40                        | 32 | 24 | 16 | 8  | 0  | 0  | 45 | 15.2     |
| Long Treasury      | 0                         | 7  | 14 | 20 | 27 | 34 | 17 | 0  | 17.0     |
| Intermediate Treas | 0                         | 1  | 2  | 4  | 5  | 6  | 3  | 0  | 5.6      |
| Extended Treasury  | 0                         | 0  | 0  | 0  | 0  | 0  | 20 | 0  | 25.5     |

- Every plan is different, so this is not necessarily a universal outcome, but...
- Assuming a 100% funded plan, the same cash flows, and using the BarraOne risk model as of the end of 2019:
  - If starting with 60% in global equity, more allocation to treasury bonds and less to credit results in lower surplus volatility (portfolios 1-6)
    - Long credit better tracks the liability in isolation, but fails to reduce risk from a total plan perspective
    - Equity acts as credit spread exposure, and more than offsets the liability exposure, so additional spread exposure from fixed income actually increases surplus volatility
  - Lengthening duration of treasuries offsets more liability duration and reduces risk (portfolio 7)
  - Many portfolios can get you to the same risk level, for example having less equity mixed with long credit (portfolio 8)
- Important to look at other measures as volatility may not tell the entire risk story

Equities consist of a mix of 60%/40% S&P 500 and MSCI EAFE, Fixed income indexes are Bloomberg Barclays Long Credit, Long Treasury, Intermediate Treasury and STRIPS 25+ indexes.

# Capital Efficiency



- Ultimately, the goal is to achieve the risk/reward tradeoff that is appropriate for a plan or investor
  - Identical plans may have different answers depending on the sponsors' financials and investors' risk tolerance
- Beginning with a given portfolio that is mismatched against liabilities, possibilities for better capital efficiency include
  - Reduce risk while maintaining reward by removing uncompensated risk
    - E.g. offset unhedged treasury exposure by hedging long cash flows that are responsible for more surplus risk by shifting duration to longer key rates through STRIPS
  - Shift risk characteristics to achieve higher rewards leaving overall risk the same, but expected reward higher
    - E.g. reduce hedging assets, but replace with longer duration to reduce overall risk, but then reallocate assets to return seeking assets that have a higher expected return and higher risk, leaving the total plan with the same level of risk with higher reward
  - Both of the above
    - E.g. mix above strategies to achieve a plan with less risk and more reward

# Practical implications for surplus risk market models

# Practical implications of surplus risk measurement

- Conditional vs unconditional forecasts – risk changes based on behavior or recent markets
- Normality of return distributions moving toward a long term equilibrium – falling interest rates
- Independent (simplistic) 5 x 5 boxes – correlated vs uncorrelated shock of single variables
- Transparency into investment management and holdings allow for better conversations with an investment manager and better visibility across managers and how they interact



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