

A Specialized Capital Markets Assumptions Framework and Strategic Asset Allocation for US Life Insurers

Giga Nozadze

Instructor: James Conklin

Focusing on the Wrong Measure of Risk

Long term allocators like life insurers, pensions, endowments, and sovereign wealth funds operate in different investment worlds. Endowments and SWFs can afford long dated, illiquid bets with alternatives. Life insurers, by contrast, operate under capital rules, manage long dated liabilities, and keep most of their money in fixed income. Their investment is ten or twenty years, so they need capital market assumptions that actually fit that horizon.

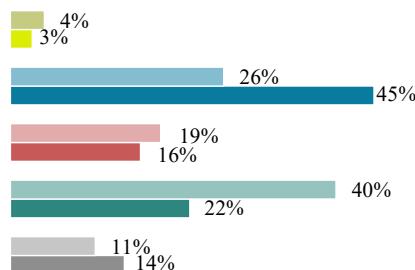
This project steps back from the usual toolkit to ask: what do we really need to know about risk and return over the long run? For fixed income, the answer is starting yield adjusted for credit loss, because it consistently explains the bulk of future returns, while private assets are modeled from fundamental economic and financial drivers.

Most importantly, in this paper I argue that, instead of return volatility, the appropriate risk measure to use in this context is the forecast error around long run return assumptions. That distinction matters. Insurers usually hold assets to maturity, so mark to market noise is not as important as in other investment worlds, which leads to my suggested optimal allocations for six US life insurers that are different from their current portfolios:

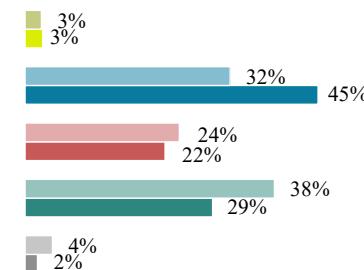
Current allocations (transparent) are different from optimal weights (solid)

■ Government ■ Public Corporates ■ Structured ■ Private Credit ■ PE and RE

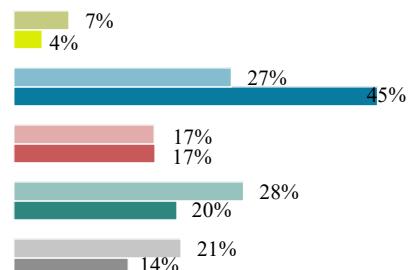
Brighthouse



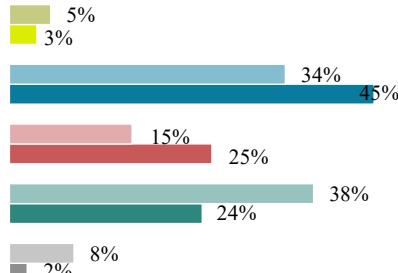
Corebridge



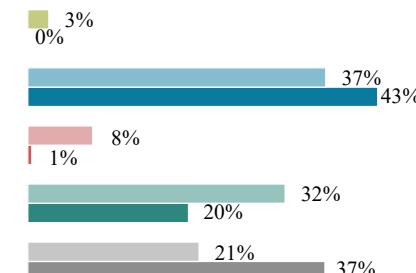
Metlife



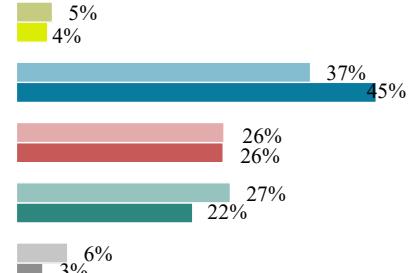
Principal



Prudential



Voya

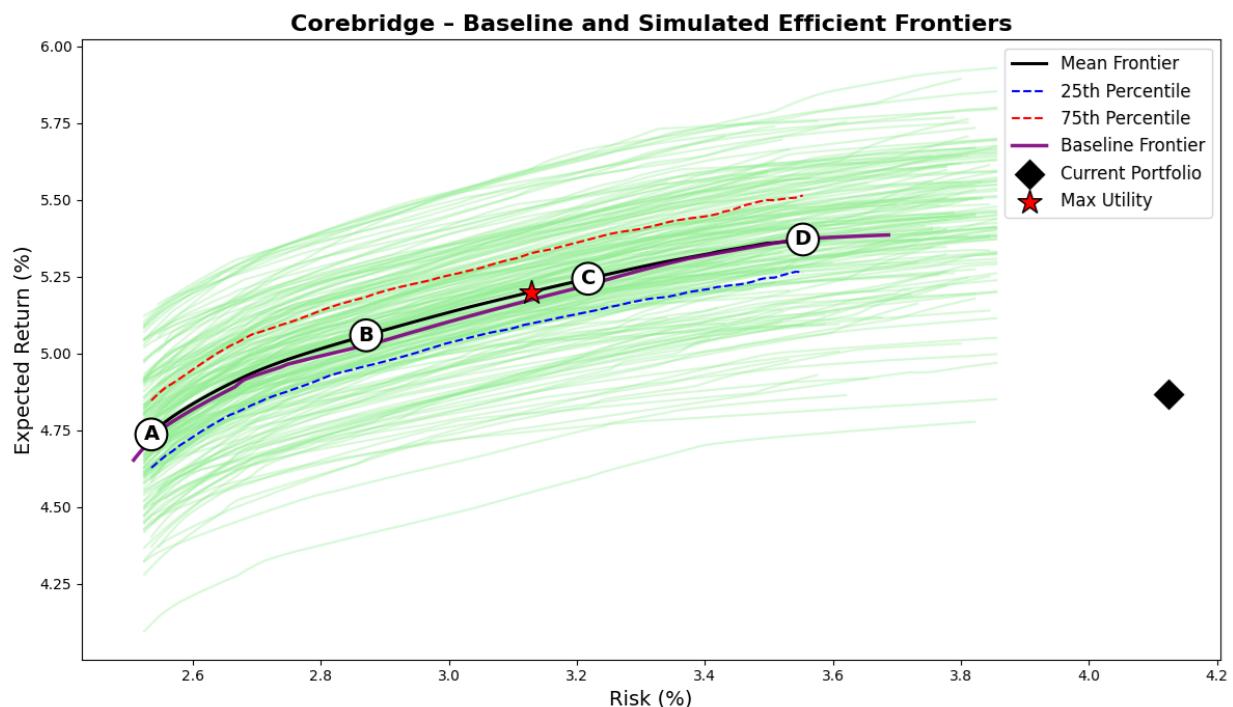


Source: Company 10-K and 10-Q files

Corebridge

Corebridge Financial, formerly AIG's life and retirement division, has a diversified liability structure that spans retail annuities, workplace retirement, and institutional spread-based products. Its balance sheet combines individual annuities with group retirement and funding agreements, which gives it a balanced mix of short, medium, and long-term obligations. The resulting liability structure has moderate duration, steady exposure to payout and deferred annuity claims, and a meaningful share of institutional contracts that reset at intermediate horizons.

To reflect this mix, I modeled Corebridge's liability term structure using a blend of short and medium buckets with a smaller allocation to long-dated exposures. The implied liability duration is close to eight years and sits between the shorter profiles of DC-heavy insurers and the longer payout-driven profiles of firms like Prudential or MetLife. This structure requires a portfolio that can provide stable spread income while maintaining enough duration to anchor long-term guarantees.



On the asset side, Corebridge's current portfolio is built around spread-oriented fixed income. Public investment-grade corporates account for roughly one third of assets, with a large share concentrated in BBB credits. Structured products such as RMBS, CMBS, and ABS contribute another significant portion of the book, and the firm holds meaningful private placements across both A and BBB ratings. Mortgage loans, private credit, and alternative investments round out the allocation. This mix produces an average fixed-income rating of A+, a duration of 6.18 years, and a net duration gap of negative 0.69 years, which indicates that assets are shorter than modeled liabilities. Capital use of 1.72 percent reflects a portfolio that leans heavily on public BBB credit and higher capital intensity mortgage loans.

The optimization results show that Corebridge's current allocation is functional but not as efficient as the frontier allows. The current portfolio delivers an expected return of 4.87 percent with 4.12 percent volatility and a Sharpe ratio of 0.21, which places it outside the main efficiency envelope. Portfolios B through D reach expected returns between 5.00 and 5.29 percent while keeping risk between 2.85 and 3.49 percent. The maximum utility portfolio

achieves a 5.13 percent expected return with only 3.09 percent risk, increasing the Sharpe ratio to 0.36 and closing most of the duration mismatch.

The composition of the optimized portfolios highlights where the improvements come from. The optimizer removes the entire 18.8 percent allocation to BBB public corporates and reallocates this weight to higher quality A and AA-rated corporates, private placements, and structured products. Exposure to RMBS rises to around 14 percent across the frontier, and CMBS increases to 7 percent or more. Residential mortgage whole loans reach their cap at roughly 15 percent, replacing commercial mortgage whole loans, which fall from 15.6 percent in the current portfolio to almost zero. Allocations to high yield credit remain small and controlled. Treasury and global sovereign exposures are modest but present, supporting liquidity and interest rate sensitivity without diluting spread income.

Metric/Asset	Current	Port A	Port B	Port C	Port D	Max Utility
Expected Return (%)	4.87	4.71	5	5.17	5.29	5.13
Risk (%)	4.12	2.53	2.85	3.18	3.49	3.09
Sharpe Ratio	0.21	0.28	0.35	0.37	0.37	0.36
Avg FI Credit Rating	A+	AA-	AA-	A+	A+	AA-
FI Duration (years)	6.18	6.43	6.7	6.81	7.09	6.76
Net Duration (years)	-0.69	-0.44	-0.17	-0.06	0.22	-0.11
Capital Use (%)	1.72	0.81	1.3	1.74	2.1	1.62
US Treasuries, Short/Intermediate	0.2	12	1	0.9	0.3	1
US Treasuries, Long	0.3	0	0.1	1.3	5.2	0.8
US Taxable Munis	1.9	0.4	0.1	0	0	0.1
Global ex-US Government, hedged	1.8	0	0	0	0	0
US Public Corporates IG AAA	2.8	15	11.3	8.8	2.4	9.8
US Public Corporates IG AA	5.5	6.2	1.8	1.8	1	1.7
US Public Corporates IG A	8.3	7.6	11.7	11.7	12.3	11.6
US Public Corporates IG BBB	18.8	0	0	0	0	0
US Public Corporates, HY Intermediate	1.3	0	0.3	0.8	0.8	0.7
US Public Corporates, HY Long	1.6	0	0.8	3.3	4.1	2.8
Global ex-US Corporates, hedged	0	10	5.8	1.3	0.2	2.2
Residential Mortgage-Backed Securities (RMBS)	6.8	0.4	13	13.7	13.8	13.7
Commercial Mortgage-Backed Securities (CMBS)	4.1	2.9	6.8	7.7	9.2	7.4
Asset-Backed Securities (ABS)	12.8	0	0.2	0.6	1.2	0.4
Corporate IG Private Placement A	4.5	15	15	15	15	15
Corporate IG Private Placement BBB	5.1	15	15	15	15	15
Corporate HY Private (Leveraged Loans)	0.8	0	0.1	0.1	0.1	0.1
Residential Mortgage Whole Loans	5.5	15	15	14.8	14.5	14.8
Commercial Mortgage Whole Loans	15.6	0	0	0.1	1	0.1
Private Equity	2.5	0.6	2	3	4.1	2.7
Real Estate (via partnerships, equity)	0	0	0	0	0	0

Private placements play a central role in the optimized results. Both A and BBB-rated private corporate allocations rise to their full 15 percent limits, reflecting favorable capital treatment and strong risk-adjusted spreads. Structured products complement this position by delivering yield with relatively moderate capital charges, which helps move the frontier outward. Non-core assets such as global ex-US government bonds, taxable municipal bonds, and real estate are effectively eliminated in the optimized portfolios due to weak capital-adjusted returns. Capital use falls from 1.72 percent in the current mix to about 1.62 percent in the maximum utility allocation and as low as 0.81 percent in the most conservative portfolios along the frontier.

Mean Reversion and Time Diversification

Returns are not random draws from a hat each year. They are linked over time, hence serial correlation (SC). Positive SC means strength tends to follow strength, called short term momentum, while negative SC means weak periods tend to be followed by stronger ones, called mean reversion. Time diversification shows up when there is enough mean reversion, and when that self-correction is present, the average outcome over many years becomes more stable than a single year volatility snapshot suggests.

A simple way to see this is to compare two measures, namely standard deviation (traditional vol) and standard deviation of *average* return CAGRs (kind of like standard error) scaled by square root of horizon (to put them on the same footing).

First is the standard deviation of one year returns. This is the usual volatility statistic that captures mark to market movement. It is helpful for a sense of noise, but it overstates uncertainty for a hold to maturity investor because a weak year can be followed by stronger years and income keeps compounding.

$$R_{t,1y} = \frac{I_{t+1}}{I_t} - 1 \rightarrow \sigma_{1y} = \text{stdev}_t(R_{t,1y})$$

Second is the dispersion of ten year compounded returns (CAGRs), which is like standard error (standard deviation of *average* returns). To get this, I build many overlapping ten year (assumed investment horizon) windows through history and compute the compounded annual growth rate in each window. Then look at how those CAGRs are spread out and scale it by square root of 10 to put it on the same footing as standard deviation itself.

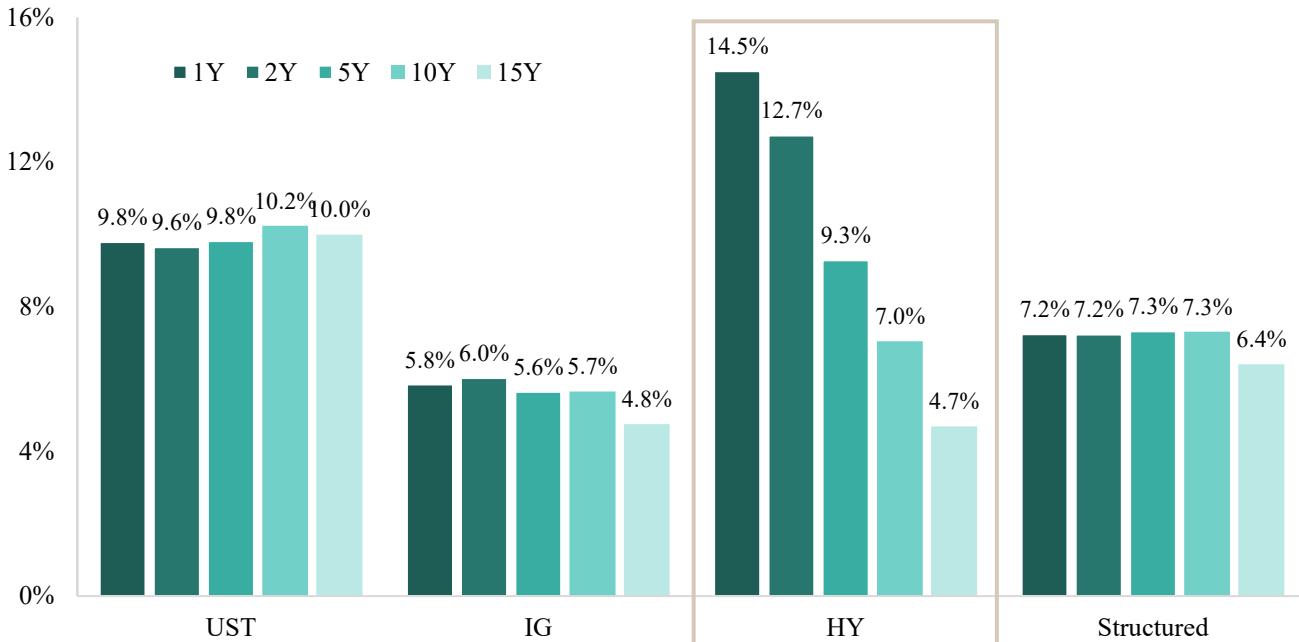
$$\text{CAGR}_{10}(t) = \left[\frac{I(t+10)}{I(t)} \right]^{1/10} - 1 \rightarrow \sigma_{\text{ann}}(10) = \sqrt{10} \text{ stdev}_t(\text{CAGR}_{10}(t))$$

If yearly returns were completely independent and had the same volatility, the standard deviation of the 10 year average (CAGR) would shrink with the square root of 10, and after the scaling described above we would end up right back at the one year volatility. In real bond markets years are not independent. Mean reversion in spreads and the pull of income make weak periods more likely to be followed by stronger ones. That negative linkage tightens the distribution of long horizon outcomes even after scaling. If momentum dominated instead, the distribution would not tighten and could even widen.

What's more, for certain types of asset classes such as HY, hybrids, preferreds, and REITs, the longer the horizon, the lower the standard deviation of CAGRs (scaled), which points to the very fact that due to mean reversion, the volatility of 1-year returns overstates the true risk over the long run.

To see this, I take every start month for time series of indices, compute the compounded return to a fixed future date (after T years), and convert each one to an annual rate. That number is the T year CAGR for that start month. Across all start months this gives a distribution of T year CAGRs. The standard deviation of that distribution tells how uncertain the long run *average* outcome is at horizon T. Since CAGRs are averages across T years and are naturally less noisy than one year returns (like standard error (stdev of average) vs standard deviation itself), I multiply the standard deviation of the T year CAGRs by the square root of T, to put all horizons on the same annual footing.

Time diversification effect is most pronounced in HY securities

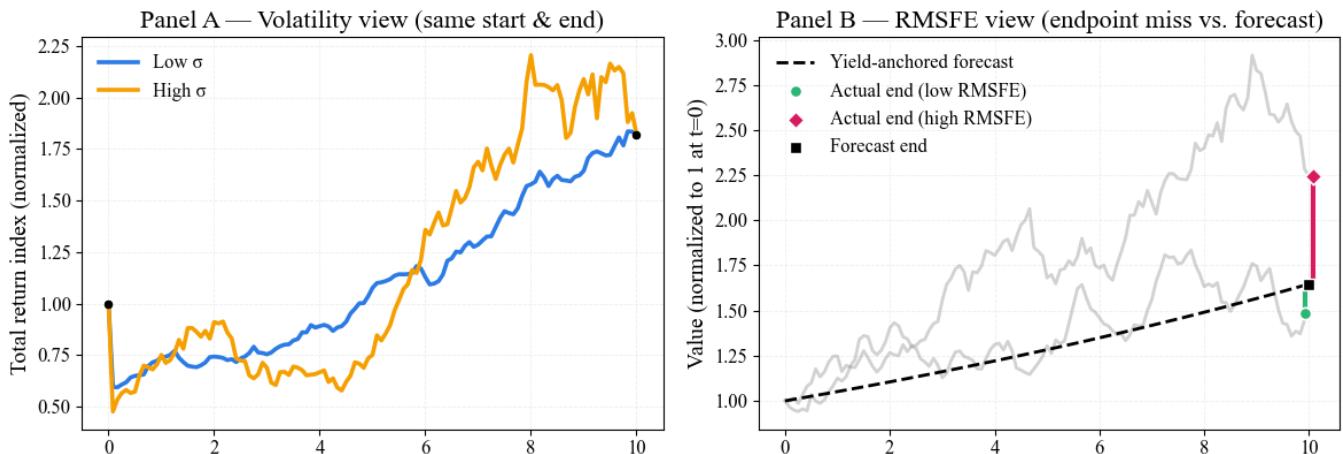


Source: Bloomberg. Historical data for all 36 individual indexes covers periods ranging from 25 to 40 years.

As mentioned above, high yield shows strong time diversification, because credit spreads tend to overshoot during stress and then grind back as defaults peak and recoveries come through, which is also, mildly but still, pronounced in investment grade securities. That pattern is reliable over business cycles. Structured indexes improve a little, while Treasuries move the other way, which is consistent with long swings in real yields and inflation that do not quickly mean revert.

Enter Starting Yield

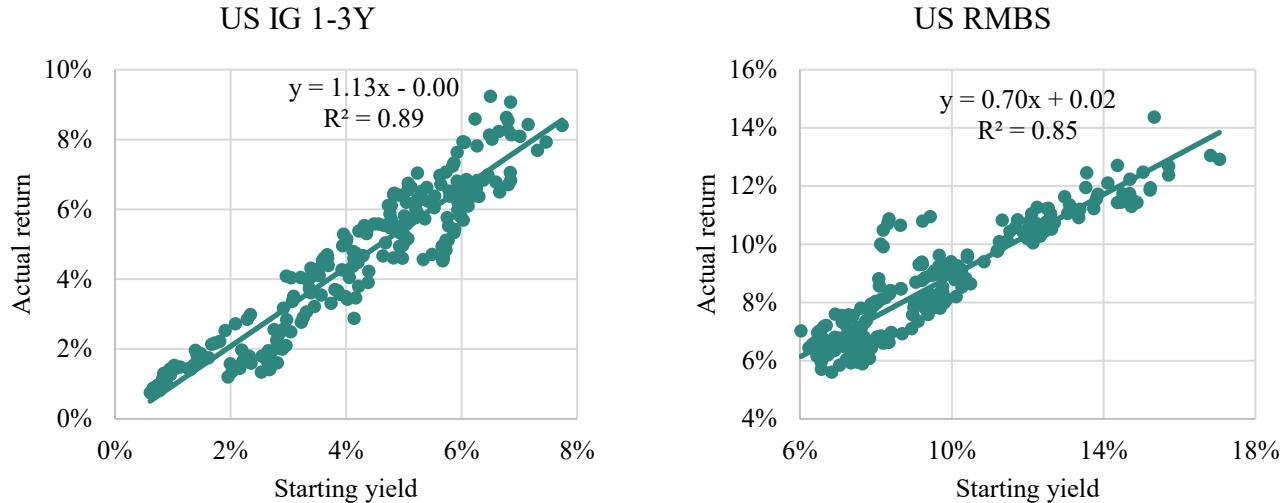
Life insurers mostly hold bonds to maturity and book them at amortized cost. Over a ten year horizon, the thing that drives results is the cash yield collected, adjusted for credit losses. Day to day price swings matter far less. For that reason the natural forecast for a ten year compounded return is simply the starting yield minus expected credit loss (ECL).



The charts above show this difference. In panel A, the difference between two time series is their variance, with the same starting and ending points, while panel B emphasizes the difference between ending points, which, as I argue here, should be the focus and the risk measure used in portfolio optimization analytics for long-term allocators.

Each scatter below compares the starting yield on the x axis (not adjusted for ECL) with the realized ten year return (CAGR) on the y axis. The relationship is tight for the given indexes as well as ones not shown here. Slopes are close to one and R squared values are high, which means that over decade horizons the entry yield explains most of what ultimately happens.

Starting yield is a good indicators of actual returns



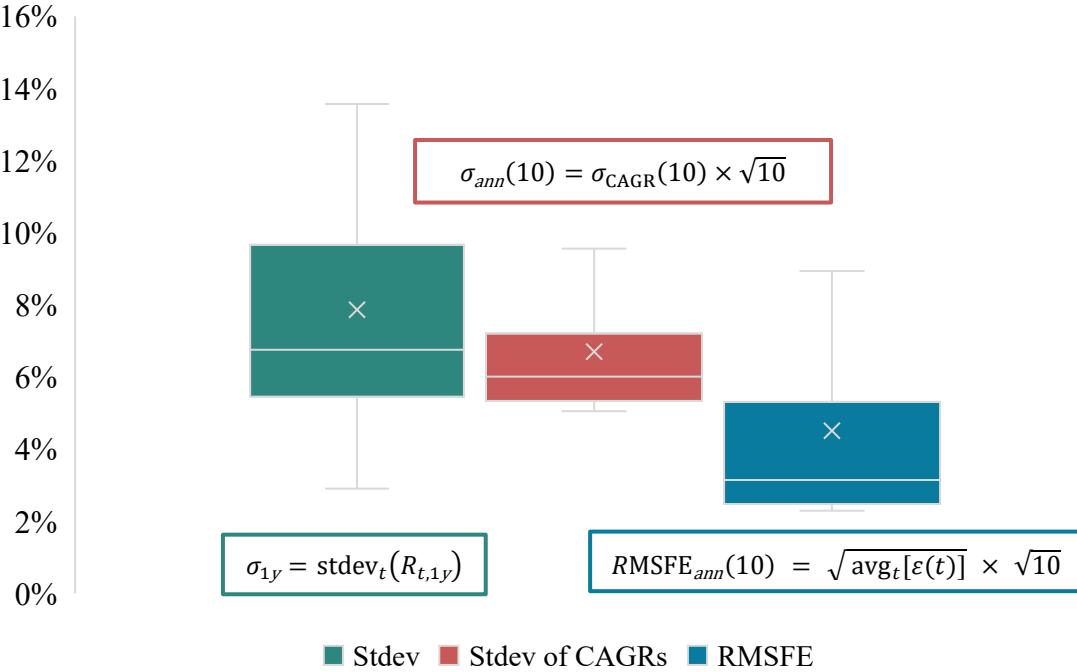
With returns anchored, the next step is to define risk in a way that matches how insurers actually experience it. Here risk means how far the realized ten year outcome can end up from the forecast that comes from the entry yield, not how bouncy prices are month to month.

Third and, in my opinion, the most useful measure of risk is the root mean square error around a very simple forecast (starting yield). For every start date, I take the forecast ten year CAGR (starting yield) and compare it with the realized ten year CAGR. The difference is the forecast error. Then I square these errors, average them, and take the square root. That is Root Mean Squared Forecast Error (RMSFE), which I then multiply by the square root of 10 again to put it on the same footing as standard deviation. Basically, I'm doing the same as above where I computed standard deviation of *average* returns (CAGRs) and scaled it by the square root of 10, but here, instead of deducting the mean of average returns in the formula (volatility formula), I deduct actual starting yields, because I argue that they contain useful information, which effectively decreases the long-term risk and uncertainty the asset allocators actually experience (and should care about). In plain words, RMSFE is the typical miss of the yield based forecast. It bundles the two uncertainties a buy and hold bond investor really faces over time, which are reinvestment risk and credit loss risk. Because RMSFE is an error on a ten year average, I report it on an annual scale by

$$\text{Forecast}_{10}(t) = Y_{\text{start}}(t) \rightarrow \varepsilon(t) = \text{CAGR}_{10}(t) - \text{Forecast}_{10}(t)$$

$$\text{RMSFE}_{\text{ann}}(10) = \sqrt{\text{avg}_t[\varepsilon(t)^2]} \times \sqrt{10}$$

Lower deviation in CAGRs compared to annual returns suggest mean reversion in returns, mainly driven by HY bonds, hybrids, and long-term indexes, with even lower RMSFE measure



The second (blue) bar demonstrates mean reversion: the distribution of multi-year CAGRs has a noticeably lower volatility (mean and median) than 1-year returns. Intuitively, extreme short-term shocks (e.g., a sudden yield spike) wash out over longer horizons as bonds gravitate back toward par and reinvestment rates stabilize. Statistically, the standard deviation of CAGRs shrinks relative to 1-year volatility because past deviations are gradually reversed, i.e., mean reversion at work.

In the textbook model, returns are independent and identically distributed (i.i.d.). Under i.i.d., the volatility of an *average annual* return over T years declines by the square-root-of-time rule, i.e. $\sigma_{TY,\text{avg}} = \sigma_{1Y}/\sqrt{T}$. This underpins results like Samuelson's Invariance Theorem (optimal allocation independent of horizon). But square-root-of-time i.i.d. scaling overstates strategic-horizon uncertainty, whereas RMSFE is a better proxy for the risk of missing long-term targets. Practically, risk should be defined as the uncertainty of hitting the plan, not year-to-year noise, which can justify allocations that look “aggressive” under traditional σ metrics. The key distinction is conditional vs. unconditional: the stdev of 10-year CAGRs is an unconditional spread around a sample average, while RMSFE compares each start date’s realized 10-year CAGR to the plan we could have made then (starting yield), bundling reinvestment and credit-loss risk and filtering out variation already explained by the known entry yield.

Viewed through this horizon lens, high-yield, hybrids, and long-duration assets often dismissed as “too volatile”, look attractive for strategic allocations because their returns stabilize over time as spreads mean-revert and coupons compound. Finally, I combine horizon uncertainty with near-term noise:

$$\sigma = 0.7 \text{ RMSFE}_{\text{ann}} + 0.3 \sigma_{1Y}$$

The 70% weight reflects long-term target risk (meeting the decade plan). The 30% weight preserves a practical allowance for capital/liquidity constraints and life insurers’ relatively lower tolerance for short term drawdowns compared to endowments and wealth funds.

Private Equity

$r_u = y_u + g_u$			$r_l = r_u + (D/E)*(r_u - k_d)$		$r_g = r_l + m_f$						$r = r_g + i$
Income Yield	Real Growth Rate	Unlevered Return	Debt to Equity	Real Cost of Debt	Real levered Return	Multiple Expansion	Gross Real Expected Return	Fees	Net Expected Real Return	Expected Inflation	Net Expected Return
3.6%	+ 3.0%	= 6.6%	52.0%	3.1%	8.4%	+ 3.0%	= 11.4%	-4.0%	= 7.4%	+ 2.3%	= 9.7%

Income Yield - I collected data on recent private equity transactions from Bloomberg and focused on last-twelve-month deal multiples. Since direct earnings yields weren't available, I used transaction value to EBIT (TV/EBIT) ratios as a proxy. For most deals, these figures weren't automatically downloadable, so I retrieved them manually for around 200 companies. I then averaged the inverse of these ratios to estimate an income yield for PE, which came out to about 3.6%.

Growth Rate - To capture the real growth potential of PE portfolios, I assumed an unlevered real growth rate of 3.0%, which is about twice as high as the same metric for public markets (Russell 2000 estimated EPS growth rate). The reasoning is that private equity managers can add value through operational improvements, margin expansion, and concentration in higher-growth sectors.

Leverage - I applied a debt-to-equity ratio of 52%, interpolated from post-2008 LBO data and reflecting today's more conservative financing because of high cost of debt. Leveraging the unlevered return (6.6%) with this D/E and a real cost of debt of 3.1% raises the real levered equity return to about 8.4%. The logic is standard corporate finance: equity holders benefit from borrowing so long as operating returns exceed the interest cost.

Real Cost of Debt - I estimate the real cost of debt as real cash rate (nominal SOFR-expected inflation) + one-third of the HY OAS, averaged over the last year to match how I average purchase multiples. The logic is: most LBO debt is floating-rate secured bank debt; a practical proxy for its spread is about two-thirds of the HY OAS, but issuers don't effectively pay the full stated spread once we account for default losses borne by lenders. So I haircut the spread by half, which leaves ~one-third of HY OAS added to real LIBOR. I also ignore the interest tax shield (jurisdictions vary), which biases k_d slightly up, but that's offset by the conservative haircut I already apply to the spread.

Multiple Expansion - I added an adjustment of +3.0% for multiple expansion. This reflects the possibility that PE managers, through active ownership and timing of exits, can sell companies at somewhat higher valuation multiples than entry. I floor this component at zero, consistent with AQR's skeptical stance, and only allow for a small partial convergence toward public market multiples.

Fees - I subtracted 4.0% to reflect management and performance fees. This haircut is somewhat below AQR's 5.7% historical average, since I expect net performance fees to be lower going forward as returns compress. Even so, the fee drag remains the single largest deduction in the framework.

Inflation Adjustment - Finally, I added back expected inflation of 2.3% to convert from real to nominal returns, yielding a net nominal expected return of roughly 9.7%.

I view the expected return profile of private equity relative to public markets through the lens of factor exposures. Buyout strategies, which dominate the private equity universe, systematically load more heavily on certain risks

than public equities. Because leverage is central to the buyout model, PE portfolios effectively run at higher equity betas, closer to 1.2-1.5 in practice rather than the sub-1.0 estimates implied by smoothed NAVs. This means the true risk is higher than what reported returns suggest, and that risk tends to show up in prolonged bear markets rather than in short, sharp drawdowns.

The illiquidity angle is more nuanced. In theory, locking capital for 5-10 years should command a premium, but in practice, much of it is competed away. Many investors seem content to trade off some economic compensation in exchange for smoother reported returns and the reduced headline volatility that comes with appraisal-based valuations. As a result, the realized illiquidity premium often looks small or even nonexistent.

The industry track record also points to little evidence of persistent net alpha. Several large-sample studies find that, once we control for leverage, small-cap exposure, and fees, private equity returns are largely explained by traditional risk factors. In other words, the outperformance often attributed to manager skill or illiquidity premia is better understood as compensation for bearing higher equity beta and structural tilts. Fees in particular eat up much of the gross excess return, making it difficult to justify a positive “alpha” at the asset-class level.

Beyond leverage, private equity tends to tilt toward smaller and historically cheaper companies. The small-cap bias is visible in the typical characteristics of buyout targets, while the value bias has become less consistent in recent years as entry multiples have risen. Taking these exposures together, I think it is most realistic to treat private equity as a leveraged small-cap equity exposure, with higher sensitivity to the equity risk premium, some residual size tilt, and no persistent net alpha after fees.

For my expected return modeling, I primarily use a discounted cash-flow framework similar to AQR’s yield-based approach: I start from an estimate of the unlevered return (income yield plus real growth), then add the effects of financial leverage, conservatively account for potential multiple expansion, and subtract fees. This makes the drivers of PE returns more transparent and allows me to stress-test assumptions around valuations, leverage costs, and growth. That said, I also supplement this analysis with a simpler public-equity-based comparison, where I treat private equity as a leveraged small-cap exposure with no net alpha. Using this as a cross-check provides an additional perspective and helps ensure that my forward-looking assumptions remain grounded against public market benchmarks.

In constructing my CMA inputs, I use arithmetic mean expected returns rather than geometric, since arithmetic returns are the appropriate measure for portfolio optimization and strategic asset allocation, they represent the expectation of a one-period return and avoid deducting variance drag, which the optimizer already accounts for through the volatility input. Reported geometric means, while more intuitive for compounding, understate the inputs required for allocation modeling. For the cash or risk-free rate, I do not rely on today’s short-term SOFR or T-bill yield, which are cyclical and unsuitable for a strategic horizon. Instead, I assume a long-run real cash rate (anchored by historical averages and central bank estimates of the neutral rate) combined with long-term inflation expectations from breakeven markets, ensuring consistency with a 10-year investment horizon.

Real Estate

NOI Yield	CapEx (~NOI/3)	Cashflow Yield	Real Growth	Unlevered Real Expected Return	Expected Inflation	Unlevered Nominal Expected Return
4.7%	- 1.6%	= 3.1%	+ 0.0%	= 3.1%	+ 2.3%	= 5.4%

NOI Yield - I begin with the net operating income yield, which reflects rental income as a percentage of property market value. This is the steady income stream that properties generate before accounting for maintenance costs. It is analogous to a gross yield, similar in spirit to a dividend yield in equities but based on property-level cashflows.

CapEx Deduction - From NOI, I subtract recurring capital expenditures. These are the costs required to maintain and preserve the property's income-generating capacity. Empirical work (e.g., Pagliari 2017) shows that these expenditures typically average about one-third of NOI. In my case, that adjustment reduces the yield by 1.56%.

Cashflow Yield - The result is the free cashflow yield, representing the actual income available to investors after maintaining the property. This measure is more relevant than raw NOI because it accounts for the fact that real estate is capital-intensive and requires continual upkeep. At this stage, my unlevered real cashflow yield is 3.13%.

Real Growth - For growth assumptions, I use a conservative real growth rate of zero. While rents may rise with GDP or demographics, long-term evidence suggests that real estate income growth has often barely kept up with inflation, or, in some cases, underperformed it. This assumption is consistent with AQR's treatment of private real estate, where the long-run real growth contribution is taken as negligible.

Unlevered Real Expected Return - By combining the free cashflow yield and the real growth assumption, I arrive at an unlevered real expected return of 3.13%. This reflects the baseline compensation investors can expect before inflation and leverage, directly from property-level economics.

Inflation - To convert to nominal terms, I add expected inflation. Here, I assume 2.28%, which captures the anticipated erosion of purchasing power over time. This step aligns real estate projections with nominal return frameworks used in portfolio construction.

Unlevered Nominal Expected Return - Finally, adding inflation to the unlevered real expected return yields a nominal expected return of 5.41%. This is the figure I use for strategic asset allocation purposes, providing a consistent basis of comparison with public equities and fixed income.

Correlations and Variance/Covariance

I build the variance-covariance matrix from the risk measures I discussed above, which are weighted average of RMSFE (long-term uncertainty) and traditional standard deviation, which for public fixed income comes from excess-return distributions. For private equity, I use a yield-based build (income yield + growth - fees, adjusted for leverage) and a public proxy, levered Russell 2000 excess returns to reflect buyout beta. For private real estate, I pair a cash-flow model (NOI - CapEx + inflation) with a listed REIT proxy for volatility and co-movement, since appraisal series are too smooth. To capture co-movement, I form monthly excess-return proxies for each sleeve and estimate the correlation matrix empirically. I then combine these correlations with my custom risks via the standard identity:

$$Cov_{i,j} = \rho_{i,j} * \sigma_i * \sigma_j$$

This produces a covariance matrix whose off-diagonals reflect realistic market correlations, while the diagonals embed the long-term, economics-based risk I believe matters for strategic allocation across public markets, private equity, and private real estate.

The full correlation matrix is given in the appendix.

	Asset	NAIC Schdl.	Rating	NAIC Rating	Capital Charge	Mat. (years)	Dur. (years)	Starting Yield	ECL	Expected Return	ER (Cap-Adjusted)	Standard Deviation	Long-term Uncertainty	Weighted Avg Risk
Government	US Treasuries, Short/Intermediate	D-1	AAA	1A	0.00%	4.0	3.7	3.83%	0.00%	3.83%	3.83%	6.01%	2.93%	3.86%
	US Treasuries, Long	D-1	AAA	1A	0.00%	22.1	13.8	4.80%	0.00%	4.80%	4.80%	13.57%	6.36%	8.52%
	US Taxable Munis	D-1	AA	1C	0.00%	13.3	10.6	3.96%	0.10%	3.86%	3.86%	8.21%	2.41%	4.15%
	Global ex-US Government, hedged	D-1	AA	1C	0.42%	9.7	8.3	3.07%	0.10%	2.97%	2.80%	3.99%	4.24%	4.17%
Public Corporates	US Public Corporates IG AAA	D-1	AAA	1A	0.16%	5.4	5.0	4.23%	0.00%	4.23%	4.16%	4.45%	2.29%	2.94%
	US Public Corporates IG AA	D-1	AA	1C	0.42%	7.8	6.8	4.36%	0.10%	4.26%	4.09%	5.48%	2.45%	3.36%
	US Public Corporates IG A	D-1	A	1F	0.82%	10.3	8.3	4.87%	0.07%	4.80%	4.48%	6.27%	2.82%	3.85%
	US Public Corporates IG BBB	D-1	BBB	2B	1.52%	10.5	8.2	5.21%	0.49%	4.72%	4.11%	7.23%	3.20%	4.41%
	US Public Corporates, HY Intermediate	D-1	BB-	3C	6.02%	4.5	3.9	7.04%	0.67%	6.37%	3.96%	12.46%	12.80%	12.70%
	US Public Corporates, HY Long	D-1	BB-	3C	6.02%	16.3	9.5	7.87%	0.67%	7.20%	4.79%	18.04%	8.94%	11.67%
	Global ex-US Corporates, hedged	D-1	A	1F	0.82%	7.0	6.2	3.92%	0.07%	3.85%	3.52%	5.99%	1.12%	2.58%
Structured	Residential Mortgage-Backed Securities	D-1	AA	1C	0.00%	7.8	6.7	4.93%	0.10%	4.83%	4.83%	8.15%	3.09%	4.61%
	Commercial Mortgage-Backed Securities	D-1	AA	1C	0.00%	4.4	4.1	4.69%	0.10%	4.59%	4.59%	7.74%	3.69%	4.90%
	Asset-Backed Securities	D-1	AA	1C	0.42%	3.6	3.3	4.41%	0.10%	4.31%	4.14%	5.82%	5.49%	5.59%
Private Credit	Corporate IG Private Placement A	D-1	A	1F	0.82%	10.3	8.1	5.52%	0.07%	5.45%	5.13%	5.34%	2.78%	3.55%
	Corporate IG Private Placement BBB	D-1	BBB	2B	1.52%	10.5	8.0	6.14%	0.49%	5.65%	5.05%	5.70%	3.20%	3.95%
	Corporate HY Private (Leveraged Loans)	D-1	B+	4A	7.39%	4.7	3.9	7.99%	2.42%	5.57%	2.62%	14.43%	8.94%	10.58%
	Residential Mortgage Whole Loans	B	AA	1C	0.68%	7.7	6.4	4.90%	0.10%	4.80%	4.52%	2.86%	3.09%	3.02%
	Commercial Mortgage Whole Loans	B	AAA	1A	0.90%	4.4	4.1	4.76%	0.00%	4.76%	4.40%	13.15%	6.62%	8.58%
Illiquid	Private Equity	BA	-	-	30.00%	-	-	9.68%		9.68%	6.68%	-	-	25.27%
	Real Estate (via partnerships, equity)	BA	-	-	30.00%	-	-	5.40%		5.40%	2.40%	-	-	17.5%

Liability Term-Structure Modeling

Because insurers do not publicly disclose the exact timing of their future liability cash flows, I construct a stylized liability term structure for each company that is consistent with the economic nature of their business lines. The goal is not to reproduce statutory projections, but to create a realistic, product-driven shape for each insurer's liability curve so that the strategic asset allocation problem incorporates duration, convexity, and liquidity characteristics that genuinely differ across Brighthouse, Corebridge, MetLife, Principal, Prudential, and Voya.

I begin by defining a set of generic product "archetypes" that represent the broad categories of business written by large U.S. life insurers. Each archetype has a characteristic maturity profile describing when the associated benefit payments tend to occur. Group benefits and defined-contribution recordkeeping business produce very short-dated liabilities because the underlying obligations are liquid, frequently reset, and mostly paid within the first few years. Stable-value contracts and funding-agreement-backed notes extend slightly further, but still concentrate their cash flows in the front half of the horizon. Variable annuity accumulation and fixed deferred annuities have a different shape: most of their liability mass falls in a medium-term "hump" reflecting typical surrender behaviour, reset features, and the timing of common annuitization windows. Payout annuities and pension risk transfer blocks are the opposite, they behave like long, level coupon streams with significant weight far out the maturity spectrum. Finally, universal life and lifetime protection products have the longest and thickest tails due to long-duration guarantees, slow runoff dynamics, and mortality-driven cash flows that extend well beyond 20 years.

Each of these archetypes is associated with a simple five-bucket maturity structure (0-3, 3-7, 7-12, 12-20, and 20-30 years). The exact weights are not meant to be precise forecasts; rather, they are intentionally distinct so that short-liability products genuinely look short and long-liability products generate long and meaningful tail exposure. What matters for the asset allocation problem is not perfect accuracy, but that the term structures reflect the economic differences between product types and therefore create different duration requirements across companies.

After defining the archetypes, I assign each insurer a mixture of them based on publicly disclosed business composition. Brighthouse is dominated by retail variable annuities and universal life, with an additional block of payout annuities. Corebridge has a more balanced mix of annuities, FIAs, retirement products, and funding agreements. MetLife's business is split between large pension-risk-transfer transactions, institutional contracts, and extensive group benefits. Principal is heavily retirement-platform-oriented with a strong DC focus. Prudential combines significant PRT business with a diversified individual annuity franchise. Voya is concentrated in workplace retirement and stable-value/funding-agreement products with only a small long-dated insurance tail. These mixes produce a company-specific five-bucket liability profile for each insurer.

To convert these high-level buckets into a continuous annual 30-year liability curve, I spread each bucket's weight uniformly across the years it represents, concatenate the segments, and normalize the resulting vector so that it sums to one. This yields a smooth, interpretable sequence of projected liability weights from year 0 to year 30. From this curve, I compute the Macaulay duration of liabilities using a 4% discount rate, along with a convexity-type second moment and simple liquidity measures such as the proportion of cash flows arriving within the first one and five years. These statistics allow me to compare insurers along dimensions that matter for asset allocation: for example, PRT-heavy firms exhibit higher liability duration and thicker tails, while retirement-platform insurers have sharply front-loaded curves.

In the optimization itself, the liability curve enters through a duration-matching condition that restricts the portfolio's duration to lie within one year of the modeled liability duration. This ensures that insurers with long-tailed payout or UL exposures cannot be assigned unrealistically short asset portfolios, and conversely that DC-heavy insurers are not forced into unnecessary long-duration assets. The curve also provides the economic backdrop for interpreting the allocation results: insurers with more long-dated liabilities naturally tilt toward long corporates,

long Treasuries, mortgages, and other assets that supply term exposure, while insurers with short, liquid liabilities remain concentrated in shorter credit, ABS, front-end Treasuries, and other assets aligned with near-term runoff.

The strength of this approach is that it is transparent, intuitive, and produces materially different liability shapes across the six insurers. Earlier attempts that relied on a single exponential decay function produced nearly identical liability curves for every company, which in turn forced the optimal portfolios to converge to similar shapes. By basing the liability term structures on product-level differences and company-specific business mix, the method generates realistic dispersion in liability duration, convexity, and tail thickness, leading to genuinely differentiated strategic asset allocations for each insurer.

Company	DC & Group	Stable-Value	AA / Deferred	Lifetime Payout / PRT	Universal Life / Protection	Avg Duration	Convexity	Share 1Y	Share 5Y
Brighthouse	0.10	0.00	0.35	0.25	0.30	9.53	53.07	0.05	0.28
Corebridge	0.25	0.15	0.30	0.15	0.15	6.87	40.92	0.10	0.47
MetLife	0.20	0.00	0.15	0.40	0.25	9.51	57.39	0.06	0.29
Principal	0.50	0.20	0.20	0.05	0.05	4.89	24.42	0.16	0.64
Prudential	0.10	0.00	0.15	0.45	0.30	10.70	58.67	0.04	0.22
Voya	0.50	0.25	0.15	0.05	0.05	4.75	23.71	0.16	0.66

Optimization

Objective

To analyze and compare the strategic positioning of U.S. life insurers, I developed a robust surplus optimization framework designed to simulate forward-looking efficient frontiers under parameter uncertainty, regulatory capital frictions, and liability-aware portfolio constraints. The model aims to evaluate how each insurer's existing general account allocation compares to the theoretically optimal mix given the same investment opportunity set, liability duration profile, and regulatory capital environment. At the core of the framework is a surplus-based objective function, which maximizes the expected return on assets net of both surplus volatility and capital consumption:

$$\max_w \mu^T w - \lambda(w^T \Sigma w) - \phi(c^T w)$$

where w represents portfolio weights, μ is the vector of expected returns, Σ is the covariance matrix of asset returns, and c is a vector of capital charges approximating NAIC risk-based capital (RBC) factors. The parameter λ captures risk aversion to surplus volatility, while ϕ penalizes capital-intensive allocations.

Constraints

The optimizer embeds several layers of realistic institutional constraints that reflect both regulatory and portfolio management practices of life insurers:

1. $\sum w_i = 1$, with individual asset weights bounded between 0% and 15% to prevent excessive concentration.
2. The portfolio's duration must remain within ± 1 year of the company's liability duration estimate. When KRD matching is active, bucket exposures must stay within $\pm 30\%$ of liability weights in the 5-year, 10-year, and 20-year key-rate zones.

3. Average fixed-income credit quality must remain at or above A+. Exposure to BBB-rated assets is capped at 15%, and exposure below investment grade is capped at 5%. These limits ensure credit discipline consistent with regulatory and internal policy guidelines.
4. The model introduces granular constraints to reflect insurer investment policies:
 - o Private equity $\leq 5\%$
 - o Leveraged loans $\leq 5\%$
 - o Global ex-US corporates $\leq 10\%$
 - o Real estate equity $\leq 5\%$
 - o Commercial and residential mortgage whole loans $\leq 25\%$ combined
 - o Direct lending / private credit $\leq 25\%$
 - o All alternative and strategic assets combined $\leq 35\%$

Robust Scenario Simulation

To address estimation uncertainty in expected returns and correlations, the framework incorporates a Monte Carlo resampling procedure that generates 100 independent capital market scenarios for each insurer. In each scenario:

- Expected returns (μ) are perturbed with both a common market forecast error and an idiosyncratic component, scaled to 4% and 5% of the median asset volatility, respectively.
- Volatilities are jittered by $\pm 2\%$, and correlations are perturbed by ± 1 percentage point, with the resulting matrices projected back to the nearest positive semi-definite correlation structure.
- Each simulated covariance matrix is then shrunk 40% toward the base matrix for numerical stability.

This produces 100 feasible (μ_s, Σ_s) pairs per insurer, from which I solve the optimization across 60-80 risk-aversion levels (λ grid) to trace each scenario's efficient frontier. All frontiers are interpolated to a common volatility grid, and only points with at least 80% scenario coverage are retained. The resulting mean, interquartile curves form the robust frontier envelope, representing the range of plausible efficiency outcomes under forecast uncertainty.

Modeling Assumptions and Limitations

It is important to note that some elements of this framework are stylized representations rather than direct empirical observations. Since insurer liability structures are not publicly disclosed in detail, I approximate each firm's liability term structure using informed assumptions based on its business mix, product composition, and reported average asset durations. Similarly, the constraints used in the optimization reflect typical U.S. life insurer investment policies and RBC considerations, not necessarily the exact internal limits of the firms studied. Finally, while the optimization framework is designed to reflect the economic objectives and balance-sheet logic of life insurers, preserving surplus stability, maximizing capital-adjusted yield, and maintaining liability alignment, it does not claim to reproduce the exact optimization algorithms or governance processes used by these institutions. Rather, the model serves as a conceptual and quantitative approximation of how a rational, surplus-focused life insurer would behave under the same market conditions and regulatory environment.

Factor Analysis and Asset/Liability Simulation

This stage extends the analysis beyond static optimization to evaluate how portfolios perform under changing economic and market conditions. The goal is to connect each asset's risk and return characteristics to common systematic drivers, simulate their joint evolution with liabilities, and assess long-term surplus outcomes.

First I estimate a multi-factor framework using monthly historical data on macro-financial variables and asset excess returns. Each asset was regressed on four standardized factors:

1. changes in the risk-free rate level (ΔL)
2. changes in the yield-curve slope (ΔS)
3. changes in investment-grade credit spreads (SprIG)
4. equity market excess returns (E).

These factors capture the main channels through which macro conditions affect insurers' portfolios, interest rate shifts, curve movements, credit spread behavior, and equity risk sensitivity.

Multicollinearity diagnostics ensured factor stability before estimation. Ordinary least squares regressions with Newey-West (HAC) standard errors were then used to correct for serial correlation in monthly returns. Only statistically significant coefficients ($p < 0.10$) were retained, ensuring that the estimated betas reflect robust and economically meaningful relationships. Residual standard deviations were stored as idiosyncratic volatilities to be used in the simulation stage.

To account for changing macro-financial environments, factor covariances were estimated separately for two regimes defined by the 36-month rolling correlation between ΔL and E. Periods with positive correlation were classified as *normal* (typical disinflationary conditions), while periods with negative correlation were classified as *inflationary* (stock-bond co-movement). This captures how diversification benefits vary across market states, a key consideration for insurers exposed to both rate and credit risk.

Expected asset returns from the optimization stage were combined with the estimated betas and regime-dependent covariances to form the stochastic simulation model. Asset returns were generated according to:

$$r_{asset} = \mu + \beta' F + \varepsilon$$

where μ is the expected monthly return, β is the vector of significant factor loadings, F represents factor shocks drawn from regime-specific covariance matrices, and ε is the idiosyncratic noise term.

Liability returns were modeled as a function of accrual rate and sensitivity to rate level and slope changes:

$$r_{liability} = accrual + \beta_{AL} \cdot \Delta L + \beta_{AS} \cdot \Delta S$$

Liability parameters were company-specific, derived from each firm's duration and liquidity profile. This ensures that asset and liability movements are internally consistent within each simulation path.

The model simulated asset and liability values jointly over 10,000 Monte Carlo paths and a 10-year horizon (120 months). Each simulation randomly transitioned between normal and inflationary regimes based on their historical probabilities, producing realistic distributions of asset, liability, and surplus outcomes. Three metrics summarize the results:

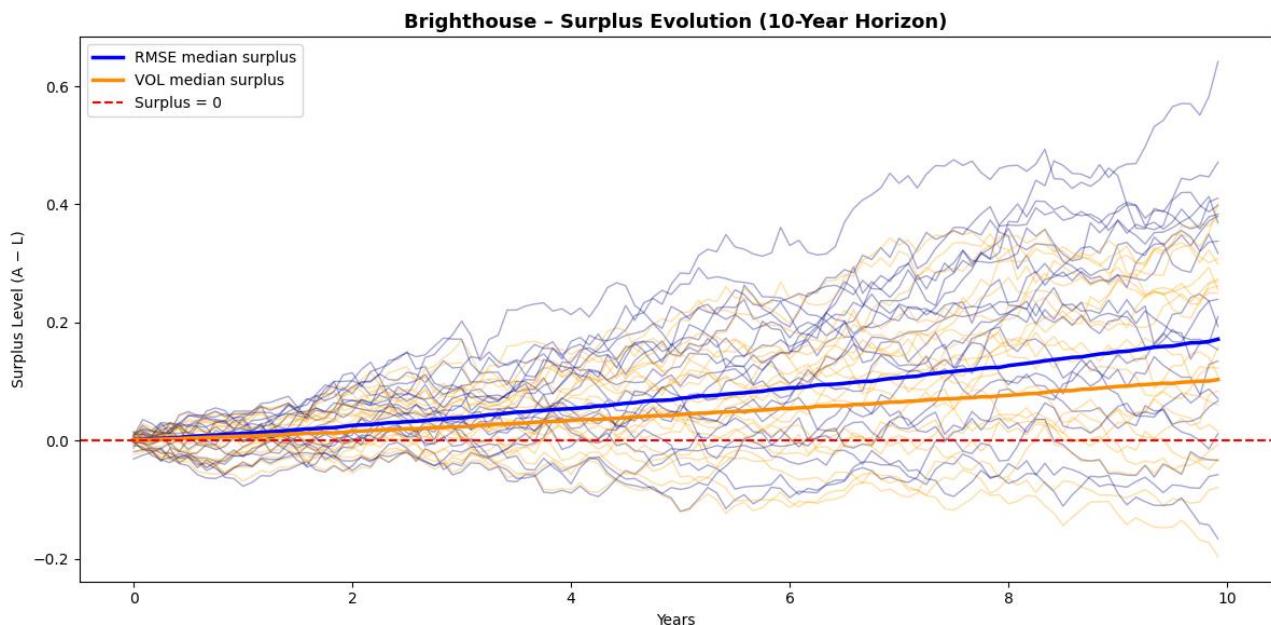
- H1 (surplus growth): Median surplus compound annual growth rate (CAGR) over the 10-year horizon
- H2 (shortfall risk): Probability that surplus becomes negative, and probability that surplus CAGR falls below the liability discount rate
- H3 (RBC efficiency): Median surplus CAGR per unit of regulatory capital, measuring surplus generated per unit of required capital

Results across all six insurers show consistent patterns. RMSFE-based (robust) optimized portfolios achieve higher surplus growth, lower shortfall risk, and greater RBC efficiency compared with volatility-minimizing portfolios.

Company	Δ Surplus CAGR (RMSFE-VOL)	$\Delta P(\text{Surplus} < 0)$	Δ Surplus/RBC
Brighthouse	+0.42%	-7.79%	+0.03
Corebridge	+0.14%	-0.63%	+0.11
MetLife	+0.30%	-6.32%	+0.07
Principal	+0.16%	-2.03%	+0.08
Prudential	+0.10%	-2.26%	+0.02
Voya	+0.15%	-2.14%	+0.07

The observed improvement in surplus efficiency stems from the way the RMSFE-based risk measure captures long-term uncertainty alongside short-term volatility. While both approaches use the same optimization framework and constraints, the RMSFE metric penalizes persistent deviations from expected returns more heavily than short-term fluctuations. As a result, portfolios optimized under this measure favor assets with more stable long-horizon performance and lower parameter sensitivity, such as high-quality spread assets and diversified securitized exposures. In contrast, optimization based solely on standard deviation tends to overweight assets that appear low-risk in the short term but may exhibit higher uncertainty or drawdown potential over time.

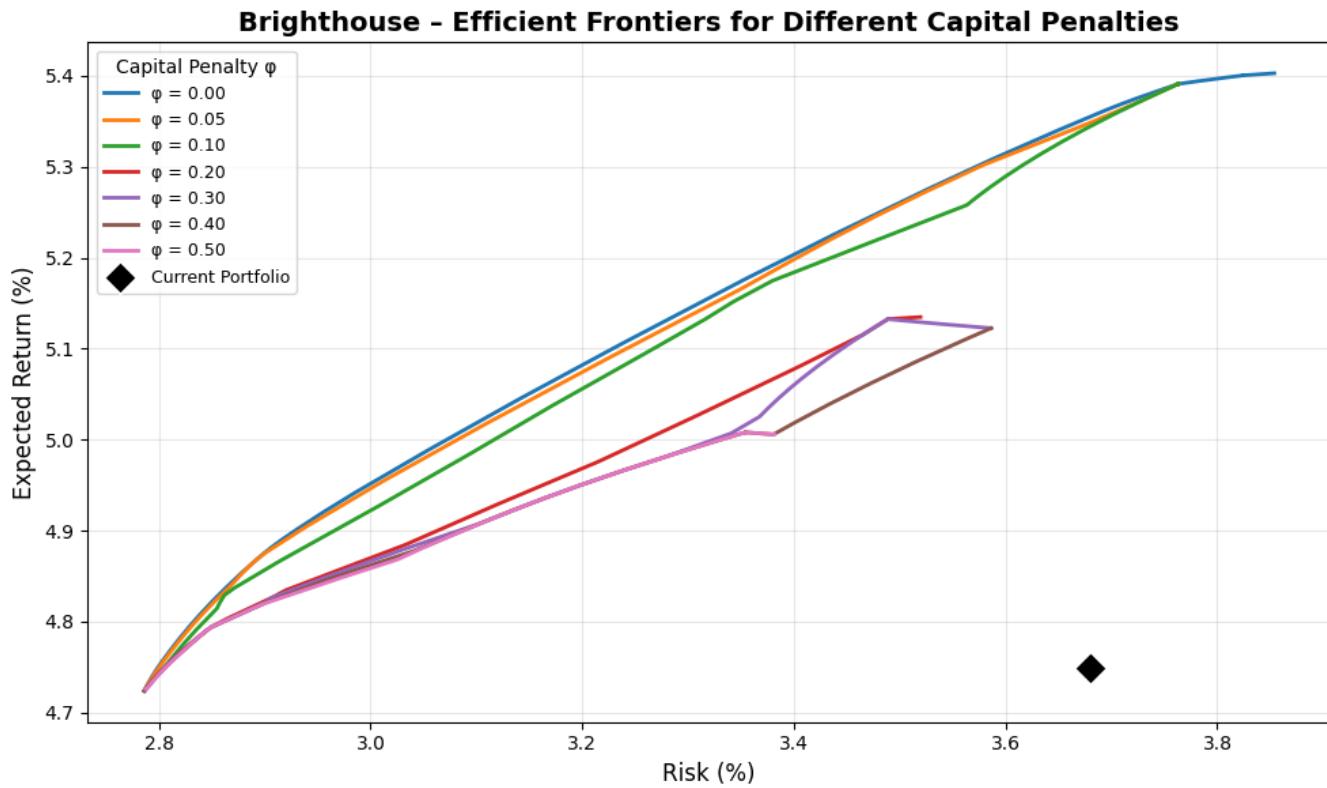
By integrating long-term model uncertainty into the risk definition, the RMSFE framework produces portfolios that are better aligned with liability horizons and more resilient to shifts in the underlying return distribution. Mathematically, this also leads to smoother and more stable frontier shapes, as the RMSFE term dampens extreme sensitivity to parameter estimation error while still preserving mean-variance efficiency.



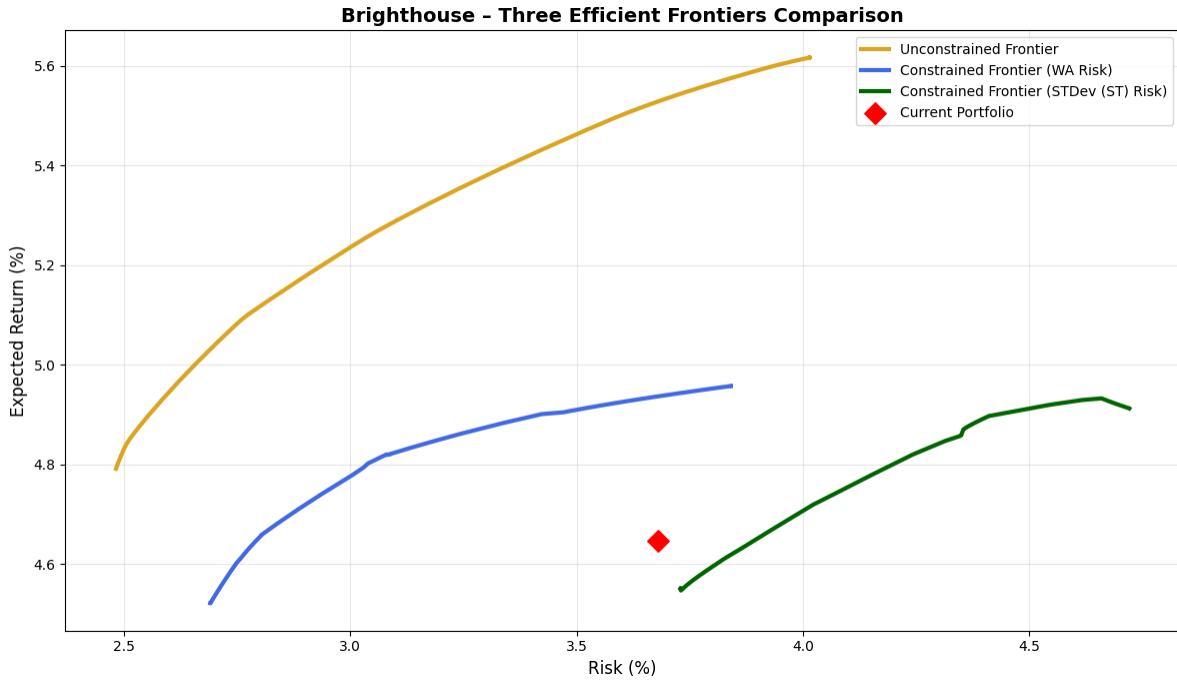
Appendix

- All the materials and sources used are located [on this drive](#).
- [This GitHub repository](#) contains all the files for the project.

Brighthouse



The impact of the capital penalty parameter (ϕ) further clarifies the relationship between regulatory friction and attainable efficiency. When the penalty is removed ($\phi=0$), the unconstrained frontier reaches expected returns near 5.15% at 4% volatility, primarily by allocating more heavily to higher-spread, capital-intensive assets such as high-yield credit and private equity. As ϕ increases, the frontier shifts downward and flattens, favoring capital-efficient sectors. At the realistic base case ($\phi=0.2$), the efficient frontier still dominates the current portfolio, with the utility-maximizing configuration around 3.0% risk and 4.9% return. Beyond $\phi=0.4$, expected returns decline by roughly 20-25 basis points at comparable risk, as the optimizer concentrates almost entirely in AAA/AA public credit, ABS, and high-grade private placements. The frontier also becomes visibly shorter and kinked as ϕ rises. This occurs because the capital penalty effectively removes the most capital-intensive assets from the feasible set, causing the optimizer to jump between a small number of discrete efficient combinations rather than tracing a smooth risk-return tradeoff. As higher- ϕ portfolios cluster around similar low-RBC fixed income segments, the range of feasible volatility narrows, producing a truncated, segmented frontier. This behavior is typical when regulatory capital constraints dominate portfolio dynamics, reinforcing how RBC frictions compress the efficient opportunity set even before liquidity or diversification limits are reached.



A final comparison between the unconstrained and realistically constrained frontiers quantifies the implementation gap. The unconstrained theoretical frontier lies roughly 70 basis points above the constrained one across the same risk range, largely due to the imposed 10% per-asset caps, the no-leverage condition, and the positive capital penalty. Despite these restrictions, Brighthouse's current allocation remains below even the constrained frontier, confirming that substantial improvement is achievable without relaxing policy limits or increasing balance-sheet risk. The second plot also introduces an additional constrained frontier constructed using the short-term standard deviation (STDEV) as the sole risk measure, in contrast to the weighted-average (WA) measure that combines short-term volatility with long-term uncertainty (RMSFE). The WA approach, as discussed earlier, better reflects the multi-horizon risk exposure of life insurers by integrating both market and liability-duration perspectives, while the STDEV frontier captures only short-term mark-to-market sensitivity. The two risk definitions lead to visibly different efficient sets: the WA-based frontier lies further left, emphasizing structural balance-sheet resilience, whereas the STDEV-based frontier appears steeper and more right-shifted, reflecting higher instantaneous volatility but limited duration exposure. Together, these frontiers highlight the tradeoff between short-term accounting volatility and long-term surplus stability. The constrained efficient portfolios, particularly those around 3.0-3.2% risk and 4.8% return under the WA metric, represent a realistic strategic target consistent with Brighthouse's liability structure and surplus-management philosophy.

From a strategic perspective, this analysis suggests that Brighthouse could materially enhance surplus efficiency through measured reallocation rather than structural transformation. The optimal adjustments would involve reducing reliance on commercial mortgage whole loans in favor of securitized exposures and private placements, modestly extending portfolio duration toward the seven-year range, and maintaining disciplined exposure to high-RBC sectors. The result is a portfolio that delivers roughly 20 basis points higher expected return, 60 basis points lower risk, and nearly one percentage point less capital usage, while maintaining strong credit quality and liability alignment. In short, Brighthouse's portfolio is prudently constructed but not positioned on the efficient frontier; by realigning toward the most RBC-efficient sources of yield, it could meaningfully improve long-term surplus generation without compromising solvency resilience.

Brighthouse

Brighthouse Financial's liability composition reflects its origins as a MetLife spin-off that retained a large block of variable annuities, universal life, and fixed deferred annuity products. These lines of business anchor its liability profile in long-dated, interest-sensitive exposures driven by policyholder behavior, guaranteed crediting mechanics, and the slow runoff of legacy contracts. Compared with insurers that have sizable group-benefits or pension-risk-transfer businesses, Brighthouse's liabilities are concentrated in individual retail contracts. This results in moderate liquidity needs but high duration sensitivity and a thick tail of long-horizon obligations.

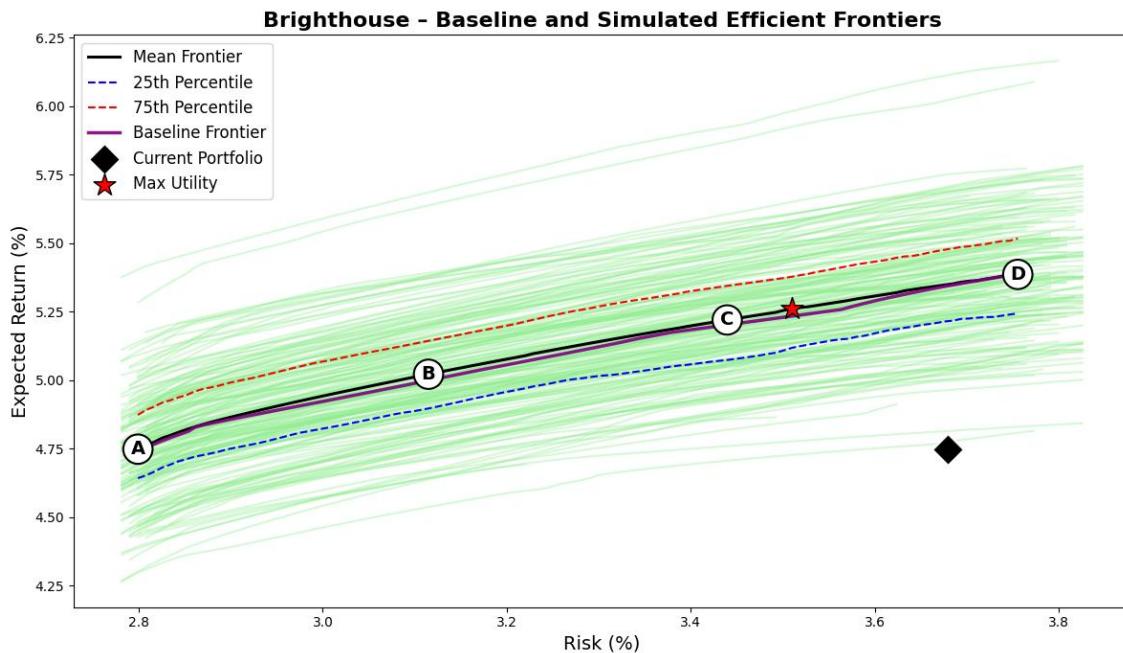
To approximate this structure, I modeled Brighthouse's liability curve using a mix of short, medium, and long buckets that produces an average liability duration slightly below eight years. Most of the projected cash flows fall within the medium and long segments, consistent with deferred annuity withdrawals, living benefit guarantees, and universal life reserves. Only a smaller share sits in the near-term bucket. This profile captures the interest rate sensitivity and long-horizon runoff patterns that are characteristic of Brighthouse's retail-focused balance sheet.

Metric/Asset	Current	Port A	Port B	Port C	Port D	Max Utility
Expected Return (%)	4.75	4.74	4.98	5.17	5.33	5.21
Risk (%)	3.68	2.8	3.09	3.41	3.71	3.48
Sharpe Ratio	0.2	0.27	0.32	0.34	0.36	0.35
Avg FI Credit Rating	AA-	A+	A+	A+	A+	A+
FI Duration (years)	6.2	8.03	8.03	8.03	8.04	8.03
Net Duration (years)	-3.33	-1.5	-1.5	-1.5	-1.49	-1.5
Capital Use (%)	1.92	0.72	1.14	1.56	2.14	1.66
US Treasuries, Short/Intermediate	3.7	0	0	0	0	0
US Treasuries, Long	2.6	3.5	6.1	10.1	13.8	11.1
US Taxable Munis	3.3	15	10.2	4	0.7	3
Global ex-US Government, hedged	0.9	0	0	0	0	0
US Public Corporates IG AAA	3.2	2.9	0.8	0.9	0.3	0.9
US Public Corporates IG AA	6.4	6.5	1.3	1.2	0.5	1
US Public Corporates IG A	9.6	14.9	14.4	14.4	14.2	14.4
US Public Corporates IG BBB	9.2	0	0	0	0	0
US Public Corporates, HY Intermediate	0.5	0	0.1	0.2	0.4	0.3
US Public Corporates, HY Long	0.3	0	2.1	4.2	4.5	4.3
Global ex-US Corporates, hedged	11.1	10	6.1	2.2	0	1.3
Residential Mortgage-Backed Securities (RMBS)	7.4	2.2	11.9	13.1	13.4	13.2
Commercial Mortgage-Backed Securities (CMBS)	5.8	0	0.9	2.3	2.3	2.7
Asset-Backed Securities (ABS)	5.4	0	0	0.1	0.3	0.2
Corporate IG Private Placement A	4.1	15	15	15	15	15
Corporate IG Private Placement BBB	2	15	15	15	15	15
Corporate HY Private (Leveraged Loans)	0.2	0	0	0	0	0
Residential Mortgage Whole Loans	6.7	15	15	14.9	14.6	14.9
Commercial Mortgage Whole Loans	13.4	0	0	0.1	0.7	0.1
Private Equity	3.6	0.1	1.3	2.3	4.2	2.7
Real Estate (via partnerships, equity)	0.6	0	0	0	0	0

On the asset side, Brighthouse holds a portfolio that is shaped by the need to generate stable spread income while managing the embedded options in its annuity guarantees. Public investment-grade corporates remain the largest sleeve, with meaningful allocations to private placements, structured securities, and both residential and commercial mortgages. Alternatives remain modest. This mix supports an average fixed-income rating of AA minus, a 6.20-

year duration, and a net duration gap of negative 3.33 years relative to the modeled liabilities. Capital use of 1.92 percent reflects a book that leans on public BBB credit, mortgage loans, and non-core structured assets that carry higher capital charges.

The optimization results indicate that Brighthouse's current portfolio is well constructed but still lies inside the efficiency envelope. The current mix produces an expected return of 4.75 percent with 3.68 percent risk, which is below both the baseline and mean frontiers. Portfolios A through D improve on this position by raising expected returns into the 4.98 to 5.33 percent range while keeping volatility between 2.80 and 3.71 percent. The maximum utility portfolio achieves a 5.21 percent expected return at 3.48 percent risk, improving the Sharpe ratio from 0.20 to 0.35 and bringing duration closer to the liability target. These results suggest that Brighthouse can reduce risk by roughly 50 to 80 basis points while adding at least 20 to 40 basis points of expected return.



The structure of the optimized portfolios shows a clear shift in composition. The optimizer eliminates the entire 9.2 percent BBB public corporate sleeve and redistributes this weight toward private placements, high-quality structured credit, and long Treasuries. Private placements in both A and BBB ratings rise to their caps at 15 percent, reflecting strong capital-adjusted spreads and favorable RBC treatment. RMBS and CMBS allocations rise sharply, reaching between 12 and 14 percent combined, while ABS plays only a minor role. Residential mortgage whole loans also reach their cap at about 15 percent, replacing a large portion of commercial mortgage loans, which fall from 13.4 percent to nearly zero. Long Treasuries rise meaningfully, from 2.6 percent to as high as 13.8 percent, helping to extend duration and stabilize surplus variability.

The optimizer reduces positions in global corporates, short Treasuries, and taxable municipals, reallocating toward domestic spread assets with lower capital intensity and higher efficiency ratios. High yield exposures remain minimal, as capital charges absorb much of the incremental return. Private equity and real estate remain small and controlled. Overall, the optimized portfolios maintain the same average credit quality at A plus, increase duration to roughly eight years, and reduce capital use to as low as 0.72 percent for the most conservative point on the frontier. Brighthouse's frontier is relatively tight, which reflects a portfolio that was already oriented toward stable spread income. Even so, the results confirm that Brighthouse can meaningfully improve its risk-return profile by shifting weight away from BBB public corporates and commercial mortgage loans and toward private placements, RMBS, and long-duration high quality credit that better aligns with its liability structure.

MetLife

MetLife's balance sheet reflects its position as one of the largest and most diversified global life insurers, with liabilities that span pension-risk-transfer contracts, corporate and group benefits, and a broad retail annuity platform. This combination produces a longer and more convex liability structure than most peers. Institutional pension obligations generate level long-dated payment streams, while group benefits and annuity guarantees add additional layers of medium-horizon exposure. The resulting liability curve has a modeled duration near eight years and a wide tail that extends past 20 years, consistent with MetLife's significant institutional and PRT business.

To approximate this structure, I modeled MetLife's liability profile with a balanced distribution of short, medium, and long buckets, which captures its mix of group, institutional, and individual lines. The curve reflects a noticeable long-duration bias and higher convexity than Corebridge or Brighthouse, indicating meaningful sensitivity to long-term rate shifts and reinvestment risk. This profile requires an asset strategy that balances long-duration exposure with spread efficiency and capital effectiveness.

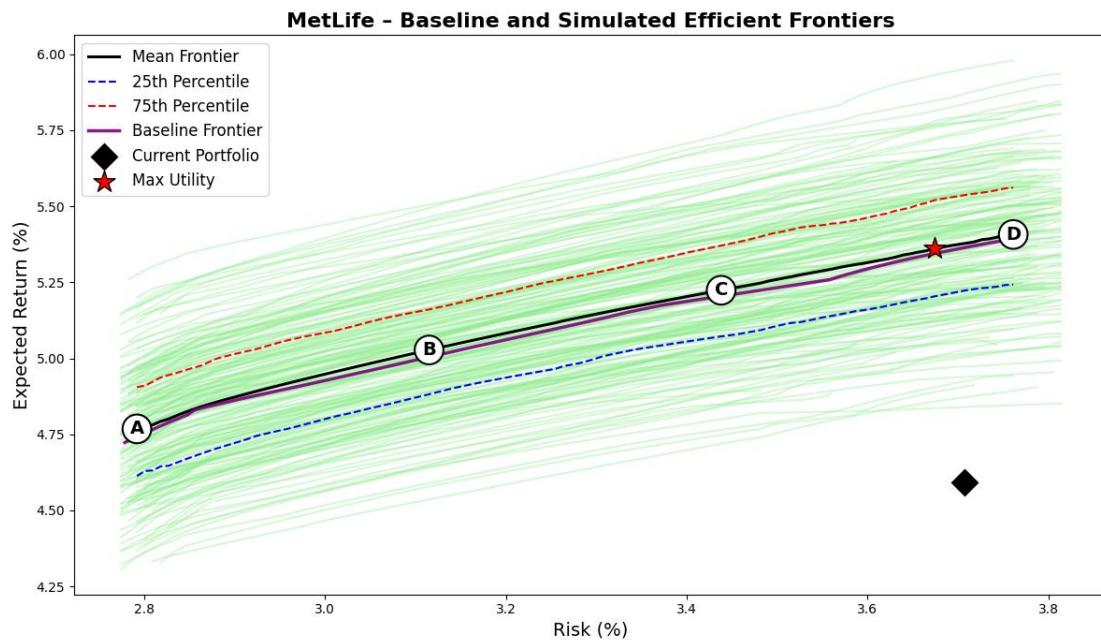
Metric/Asset	Current	Port A	Port B	Port C	Port D	Max Utility
Expected Return (%)	4.59	4.74	4.98	5.17	5.33	5.29
Risk (%)	3.71	2.79	3.09	3.41	3.71	3.64
Sharpe Ratio	0.16	0.27	0.32	0.34	0.36	0.36
Avg FI Credit Rating	AA-	A+	A+	A+	A+	A+
FI Duration (years)	6.15	8.01	8.01	8.01	8.02	8.02
Net Duration (years)	-3.36	-1.5	-1.5	-1.5	-1.49	-1.49
Capital Use (%)	2.63	0.72	1.11	1.47	2.1	1.93
US Treasuries, Short/Intermediate	4	0	0	0	0	0
US Treasuries, Long	3.9	3.3	6.4	10.4	13.9	13.2
US Taxable Munis	2.4	15	9.1	2.7	0.5	0.9
Global ex-US Government, hedged	10.3	0	0	0	0	0
US Public Corporates IG AAA	1.6	3.3	1.1	0.9	0.1	0.3
US Public Corporates IG AA	3.2	6.3	1.3	1.7	0.4	0.6
US Public Corporates IG A	4.8	15	14.9	14.7	14	14
US Public Corporates IG BBB	3.8	0	0	0	0	0
US Public Corporates, HY Intermediate	0.3	0	0	0.2	0.4	0.4
US Public Corporates, HY Long	0.3	0	2.2	4.3	4.6	4.6
Global ex-US Corporates, hedged	14.3	10	6.3	2.1	0	0.2
Residential Mortgage-Backed Securities (RMBS)	9.9	2	11.3	12.8	13.2	13.2
Commercial Mortgage-Backed Securities (CMBS)	2.3	0	1.3	3.2	3.8	4
Asset-Backed Securities (ABS)	5.1	0	0	0	0.2	0.2
Corporate IG Private Placement A	4	15	15	15	15	15
Corporate IG Private Placement BBB	1.6	15	15	15	15	15
Corporate HY Private (Leveraged Loans)	0.2	0	0	0	0	0
Residential Mortgage Whole Loans	7	15	15	14.9	13.9	14.4
Commercial Mortgage Whole Loans	14	0	0	0	0.6	0.4
Private Equity	3.4	0.1	1.1	2	4.1	3.5
Real Estate (via partnerships, equity)	3.4	0	0	0	0	0

MetLife's general account investments reflect that approach. The current portfolio includes a broad allocation across public investment-grade corporates, private placements, structured products, and global sovereign exposures. This mix produces an average fixed-income rating of AA minus, a 6.15-year duration, and a net duration gap of negative 3.36 years relative to the modeled liabilities. Capital use is 2.63 percent, higher than peers, reflecting the company's

material global sovereign allocations and its large commercial mortgage loan portfolio, both of which carry elevated capital charges relative to their incremental spread.

Under the optimization framework, MetLife's current allocation appears materially inside the efficient frontier. The current mix generates a 4.59 percent expected return at 3.71 percent volatility, which is below both the baseline and mean frontiers. Portfolios A through D show that expected returns between 4.74 and 5.33 percent are achievable while holding volatility between 2.79 and 3.71 percent. The maximum utility portfolio delivers a 5.29 percent expected return at 3.64 percent risk, raising the Sharpe ratio from 0.16 to 0.36 and closing most of the duration mismatch.

The improvement in performance comes from significant reallocations. The optimizer reduces the entire global ex-US government allocation of 10.3 percent, which carries high capital cost and limited spread benefit. It also eliminates the 3.8 percent BBB public corporate allocation and cuts commercial mortgage whole loans from 14 percent to a negligible level. These positions are replaced with a combination of RMBS, CMBS, private placements, and long Treasuries. Both A and BBB private placements rise to their 15 percent caps, reflecting strong spread pickup with moderate capital intensity. RMBS and CMBS increase to around 13 and 4 percent respectively, and residential mortgage whole loans move to roughly 14 percent. Long Treasuries rise from 3.9 to more than 13 percent, helping align duration with long-horizon liabilities.



High yield credit remains minimal, and ABS plays a small role due to limited incremental benefit under capital constraints. Allocations to taxable municipals fall sharply, while global corporate exposures are reduced but retained in small amounts. Private equity remains below 4 percent and is used primarily for diversification rather than return maximization.

Overall credit quality remains anchored near A plus, while fixed-income duration increases from 6.15 to slightly above 8 years, reducing the liability duration gap from negative 3.36 years to about negative 1.5 years across most optimized portfolios. Capital consumption falls sharply from 2.63 percent to as low as 0.72 percent for the most conservative frontier points. Even higher-risk frontier portfolios manage to keep capital use below the current level while delivering higher Sharpe ratios and more balanced surplus risk.

Principal

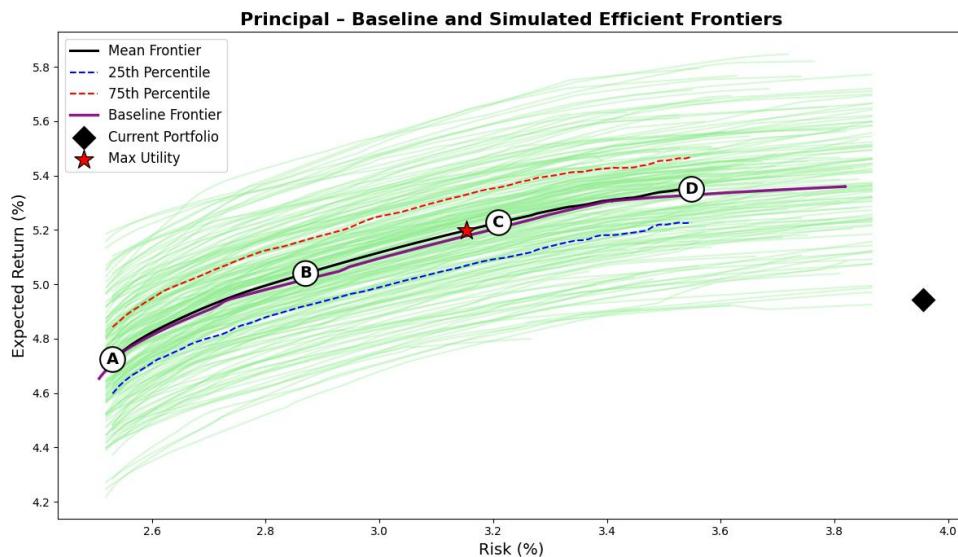
Principal Financial Group's balance sheet structure reflects its dual identity as both a U.S. life insurer and a global retirement and asset management platform. The company operates with a diversified liability mix that combines individual annuities, institutional retirement plans, and spread-based general account products. This results in a moderately long liability profile, though shorter and less convex than MetLife's due to Principal's emphasis on defined-contribution retirement and fixed deferred annuity businesses. In modeling the firm's liability structure, I allocated 30% of cash flows to the short bucket, 55% to the medium bucket, and 15% to the long bucket, implying an average liability duration of approximately 7.0 years. This reflects its relatively liquid liability base compared to more institutionally oriented peers such as MetLife and Corebridge.

Principal's general account asset mix exhibits a clear bias toward spread generation within a conservative credit risk framework. As of 2025, the company allocates roughly 34% of its portfolio to public investment-grade corporates, 25% to private placements, 15% to structured products (ABS, CMBS, RMBS), and 13% to commercial mortgage loans, with smaller positions in government securities and alternatives. The overall fixed-income portfolio carries an average rating of A+, a duration of 6.5 years, and a modestly positive net duration gap of 0.6 years relative to modeled liabilities. The capital utilization of 2.4% is somewhat elevated compared with Brighthouse or Corebridge, reflecting Principal's larger allocations to BBB-rated public credit and commercial mortgages, both of which attract higher RBC charges despite their stable cash flows.

Metric/Asset	Current	Port A	Port B	Port C	Port D	Max Utility
Expected Return (%)	4.94	4.71	4.99	5.16	5.27	5.13
Risk (%)	3.96	2.53	2.85	3.18	3.5	3.12
Sharpe Ratio	0.24	0.28	0.35	0.36	0.36	0.36
Avg FI Credit Rating	A+	AA-	AA-	AA-	A+	AA-
FI Duration (years)	6.49	6.36	6.38	6.38	6.39	6.38
Net Duration (years)	1.6	1.47	1.49	1.49	1.5	1.49
Capital Use (%)	2.42	0.82	1.36	1.88	2.25	1.79
US Treasuries, Short/Intermediate	0.7	12.8	2.4	1.9	0.7	2
US Treasuries, Long	0.8	0	0	0.2	0.8	0.2
US Taxable Munis	6	0.2	0	0	0	0
Global ex-US Government, hedged	0.5	0	0	0	0	0
US Public Corporates IG AAA	3	15	13.9	10.8	4.7	11.4
US Public Corporates IG AA	4.5	6.8	1.1	0.9	0.6	0.9
US Public Corporates IG A	9	6	5.9	6.8	8	6.7
US Public Corporates IG BBB	19.4	0	0	0	0	0
US Public Corporates, HY Intermediate	0.8	0	0.4	1.1	1.5	1
US Public Corporates, HY Long	1	0	0.6	2.5	3.1	2.2
Global ex-US Corporates, hedged	0	10	5.2	1.3	0.2	1.7
Residential Mortgage-Backed Securities (RMBS)	3.6	0.3	12.5	13.6	14	13.4
Commercial Mortgage-Backed Securities (CMBS)	5	3.3	9.5	10	10.9	9.9
Asset-Backed Securities (ABS)	6.6	0	1	2	4.4	1.8
Corporate IG Private Placement A	6.3	15	15	15	15	15
Corporate IG Private Placement BBB	7.4	15	15	15	15	15
Corporate HY Private (Leveraged Loans)	0.7	0	0.1	0.2	0.2	0.2
Residential Mortgage Whole Loans	6.6	15	14.9	14.7	14.1	14.8
Commercial Mortgage Whole Loans	13.2	0	0	0.3	2.2	0.2
Private Equity	3.4	0.6	2.4	3.7	4.6	3.4
Real Estate (via partnerships, equity)	1.7	0	0	0	0	0

Under the optimization framework, Principal's current portfolio is close to but still inside the efficient frontier. The current allocation delivers a 4.94 percent expected return with 3.96 percent risk and a Sharpe ratio of 0.24, which lies below both the baseline and mean frontiers. The optimized portfolios show that Principal can maintain or slightly increase expected return while reducing surplus volatility by more than one full percentage point. Portfolios B through D reach expected returns between 4.99 and 5.27 percent with volatility between 2.85 and 3.50 percent. The maximum utility portfolio produces a 5.13 percent expected return at 3.12 percent risk with a Sharpe ratio of 0.36, which is a notable improvement over the current configuration.

The improvement in efficiency comes from a systematic reallocation across spread assets. The optimizer removes the entire 19.4 percent allocation to BBB-rated public corporates and redeploys this weight into private placements, securitized credit, and mortgage whole loans. Both A and BBB private placements rise to their 15 percent caps, reflecting strong risk-adjusted spreads and favorable capital characteristics. RMBS and CMBS rise sharply, reaching between 12 and 14 percent and 9 to 11 percent respectively, while residential mortgage whole loans increase to about 15 percent across the frontier. Commercial mortgage whole loans fall from 13.2 percent to almost zero in the most efficient portfolios, as their capital intensity and concentration risk outweigh their yield advantage. Long Treasuries and short to intermediate Treasuries remain small but present to maintain liquidity and fine-tune duration. ABS exposures decline from 6.6 percent to much lower levels because their shorter duration limits their contribution to surplus efficiency once other structured sectors are utilized.



As a result of these reallocations, Principal's credit quality improves, with optimized portfolios exhibiting average ratings around AA minus, while fixed-income duration remains stable at roughly 6.38 years. Capital use drops substantially, from 2.42 percent in the current mix to 1.79 percent in the maximum utility portfolio and as low as 0.82 percent in the conservative allocations. These improvements occur without compromising expected return or reducing spread exposure.

Principal's efficient frontier is smooth and relatively steep, consistent with a portfolio that benefits from strong diversification across public corporates, private placements, structured securities, and mortgage assets. The interquartile range of simulated frontiers is tight, suggesting that the efficient solutions are robust to model uncertainty. The baseline and mean frontiers align closely, indicating that Principal's opportunity set is well balanced and not heavily dependent on specific return estimates. Strategically, the results imply that Principal can materially improve its surplus stability and capital efficiency by shifting away from BBB public credit and commercial mortgage loans and increasing reliance on private placements and structured credit. These adjustments move the company closer to the frontier while preserving its conservative risk posture.

Prudential

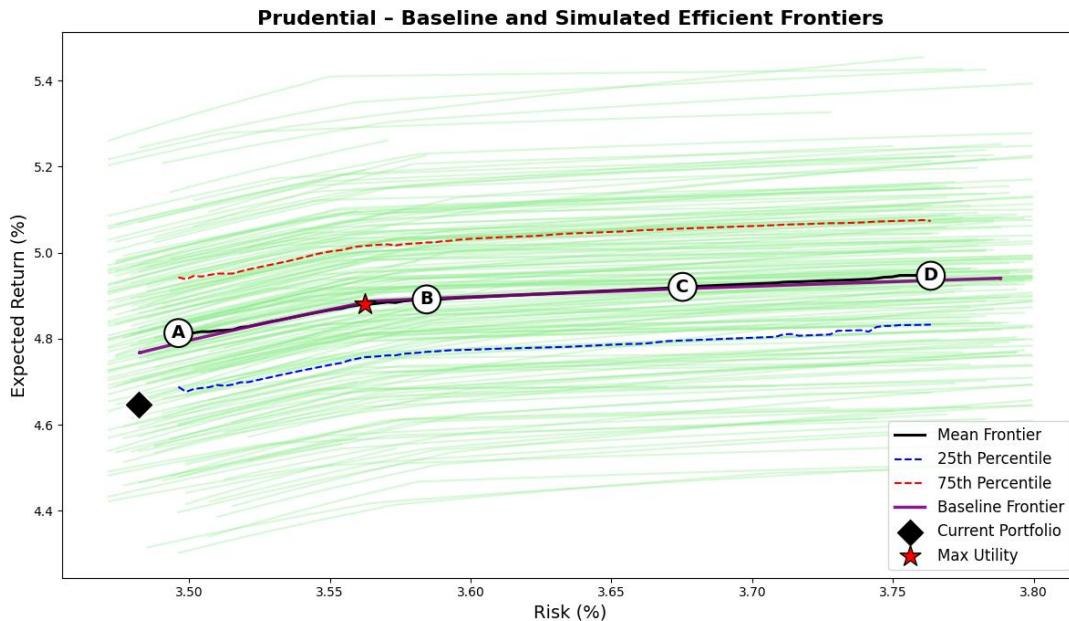
Prudential's balance sheet reflects its profile as a large diversified insurer with significant exposure to pension-risk-transfer contracts, institutional retirement solutions, and long-dated individual annuities. This mix produces one of the longer and more convex liability structures in the peer group. Pension and corporate benefit obligations create long, level payout streams, while individual annuities and universal life add additional medium-term and long-term components. In the liability model, I allocate a meaningful share of cash flows to the long bucket to reflect this structure, which yields an average liability duration comfortably above eight years and a thick tail extending well beyond twenty years.

Prudential's general account asset portfolio supports this liability mix with a diversified combination of public investment-grade credit, private placements, structured securities, commercial mortgages, and a sizable share of global sovereign exposures. The current portfolio carries an average fixed-income credit rating of AA minus, a duration of 6.84 years, and a negative net duration gap of 3.86 years, indicating that assets are shorter than the modeled liability curve. Capital use of 1.66 percent is low compared with peers because the firm holds a high share of high-grade capital-efficient exposures, although global sovereigns and taxable municipals still contribute meaningfully to capital consumption.

Metric/Asset	Current	Port A	Port B	Port C	Port D	Max Utility
Expected Return (%)	4.65	4.79	4.89	4.91	4.93	4.88
Risk (%)	3.48	3.5	3.58	3.66	3.74	3.56
Sharpe Ratio	0.19	0.23	0.25	0.25	0.25	0.25
Avg FI Credit Rating	AA-	AA-	A+	A+	A+	A+
FI Duration (years)	6.84	9.2	9.2	9.2	9.2	9.2
Net Duration (years)	-3.86	-1.5	-1.5	-1.5	-1.5	-1.5
Capital Use (%)	1.66	0.79	0.88	0.85	0.82	0.88
US Treasuries, Short/Intermediate	2.5	0	0	0	0	0
US Treasuries, Long	2.6	15	15	15	15	15
US Taxable Munis	1.4	15	15	15	15	15
Global ex-US Government, hedged	14.6	9.2	6.2	5	4.2	6.6
US Public Corporates IG AAA	2.7	0	0	0	0	0
US Public Corporates IG AA	5.4	0	0.1	0.5	0.6	0
US Public Corporates IG A	8.2	15	15	15	15	15
US Public Corporates IG BBB	7.7	0	0	0	0	0
US Public Corporates, HY Intermediate	0.8	0	0	0	0	0
US Public Corporates, HY Long	0.9	3.2	5	5	5	4.8
Global ex-US Corporates, hedged	6	0	0	0	0	0
Residential Mortgage-Backed Securities (RMBS)	1	0	1.5	7.1	11.8	0.5
Commercial Mortgage-Backed Securities (CMBS)	2.4	0	0	0	0	0
Asset-Backed Securities (ABS)	4.6	0	0	0	0	0
Corporate IG Private Placement A	13.4	15	15	15	15	15
Corporate IG Private Placement BBB	6.3	15	15	15	15	15
Corporate HY Private (Leveraged Loans)	1.4	0	0	0	0	0
Residential Mortgage Whole Loans	5.2	12.5	12.3	7.4	3.4	13.1
Commercial Mortgage Whole Loans	10.4	0	0	0	0	0
Private Equity	2.1	0	0	0	0	0
Real Estate (via partnerships, equity)	0.5	0	0	0	0	0

Under the optimization framework, Prudential's current portfolio is close to the efficient frontier but still exhibits room for improvement. The current mix delivers a 4.65 percent expected return at 3.48 percent risk, which places it slightly inside the frontier. Optimized portfolios show that Prudential can raise expected returns into the 4.79 to 4.93 percent range while maintaining risk between 3.50 and 3.74 percent. The maximum utility allocation yields a 4.88 percent expected return at 3.56 percent volatility, increasing the Sharpe ratio from 0.19 to 0.25 while keeping capital use broadly unchanged. These results indicate that Prudential can moderately improve both return and surplus stability through targeted reallocations without altering the fundamental character of its balance sheet.

The optimizer's adjustments focus on reducing lower-efficiency holdings and redistributing weight toward private placements and structured spread assets. The model increases exposure to long Treasuries up to the 15 percent cap, which helps close the liability duration gap and stabilizes surplus dynamics. Taxable municipal bonds, which currently represent 1.4 percent of the book, rise significantly across the optimized set because of their combination of yield, credit quality, and capital efficiency. The optimizer also reallocates away from global ex-US sovereign exposures, which fall from 14.6 percent to between 4 and 9 percent depending on the point along the frontier. These positions have limited incremental spread for their capital charge, so replacing them unlocks additional efficiency.



Structured credit plays a major role in the optimized portfolios. RMBS increases from 1 percent to as high as 11.8 percent in the higher-return portfolios, while CMBS and ABS are removed entirely. Residential mortgage whole loans rise to more than 13 percent in the maximum utility allocation, replacing the entire 10.4 percent exposure to commercial mortgage whole loans, which are eliminated in all optimal configurations because of their capital intensity and concentration risk. Private placements become a central component, with both A and BBB rated tranches reaching their 15 percent caps across the frontier. Public corporate exposures shift toward higher quality A-rated holdings, while BBB-rated public credit is eliminated.

Across these optimized allocations, average credit quality remains at A plus to AA minus, portfolio duration increases to 9.20 years, and the net duration gap narrows substantially. Capital use remains stable between 0.79 and 0.88 percent, which reflects Prudential's already efficient baseline. The improvement in surplus efficiency arises from reallocating away from low-return global sovereign exposures and capital-intensive commercial mortgage loans into private placements, long Treasuries, and structured credit.

Voya

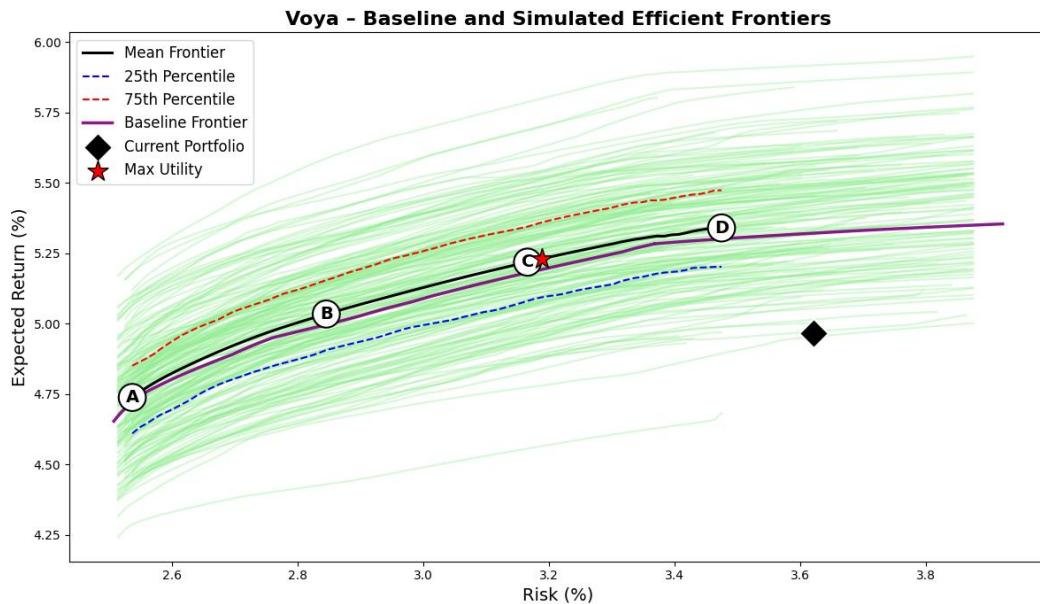
Voya Financial's general account structure reflects its evolution from a traditional life insurer into a retirement and asset management oriented institution. The company's liability profile is relatively short and liquid compared with other large U.S. life insurers, driven by its emphasis on defined contribution retirement plans, fixed annuities, and funding agreement backed securities. These business lines produce a liability term structure with modest convexity and a shorter average duration. In the liability model, I place most of the expected cash flows in the short and medium buckets, with a smaller long tail, which yields an average liability duration of about six and a half years. This captures Voya's liquidity sensitive funding model and its lower exposure to long dated guarantees compared with peers such as Prudential or MetLife.

Voya's general account is diversified across fixed income sectors but is designed primarily for capital efficiency and liquidity management rather than maximizing yield. The portfolio includes meaningful allocations to public investment grade corporates, private placements, structured credit, and commercial mortgage loans, along with a moderate allocation to government securities. Alternatives remain a small component. This mix results in an average fixed income credit rating of AA minus, a duration of 6.20 years, and a positive net duration gap of 1.45 years relative to the modeled liabilities. Capital use of 2.16 percent reflects Voya's reliance on BBB public credit, structured credit, and commercial mortgages, all of which carry appreciable capital charges relative to their incremental spread.

Metric/Asset	Current	Port A	Port B	Port C	Port D	Max Utility
Expected Return (%)	4.97	4.71	4.97	5.13	5.25	5.15
Risk (%)	3.62	2.53	2.82	3.14	3.44	3.16
Sharpe Ratio	0.27	0.28	0.34	0.36	0.36	0.36
Avg FI Credit Rating	AA-	AA-	AA-	AA-	AA-	AA-
FI Duration (years)	6.2	6.25	6.25	6.25	6.25	6.25
Net Duration (years)	1.45	1.5	1.5	1.5	1.5	1.5
Capital Use (%)	2.16	0.88	1.43	1.89	2.25	1.93
US Treasuries, Short/Intermediate	0.7	13.2	4.3	3.3	1.7	3.2
US Treasuries, Long	0.9	0	0	0.1	0.3	0.1
US Taxable Munis	1.4	0.1	0	0	0	0
Global ex-US Government, hedged	3.4	0	0	0	0	0
US Public Corporates IG AAA	1.4	15	13.5	11.6	7.4	11.4
US Public Corporates IG AA	4	6.5	1.1	1.3	0.8	1.3
US Public Corporates IG A	5.1	3.9	3.1	4.3	5.5	4.3
US Public Corporates IG BBB	8.3	0	0	0	0	0
US Public Corporates, HY Intermediate	0.5	0	0.5	1.1	1.5	1.2
US Public Corporates, HY Long	0.6	0	0.6	2.2	3.1	2.3
Global ex-US Corporates, hedged	6.8	10	6.8	1.7	0.1	1.5
Residential Mortgage-Backed Securities (RMBS)	9.9	0.7	11.5	12.9	13.6	13
Commercial Mortgage-Backed Securities (CMBS)	8.1	4.7	10	11.1	11.9	11.1
Asset-Backed Securities (ABS)	7.9	0	0.8	1.6	3.7	1.7
Corporate IG Private Placement A	11.6	15	15	15	15	15
Corporate IG Private Placement BBB	9.2	15	15	15	15	15
Corporate HY Private (Leveraged Loans)	1.2	0	0.1	0.2	0.2	0.2
Residential Mortgage Whole Loans	4.9	15	14.9	14.7	14.1	14.6
Commercial Mortgage Whole Loans	9.8	0	0	0.1	1.4	0.1
Private Equity	4.5	0.9	2.6	3.8	4.7	3.9
Real Estate (via partnerships, equity)	0	0	0	0	0	0

Under the optimization framework, Voya's current portfolio is reasonably well structured but lies inside the efficient frontier. The current mix produces a 4.97 percent expected return at 3.62 percent volatility, which is slightly below both the baseline and mean frontiers. The optimized frontier shows that Voya can maintain or slightly increase expected return while reducing risk by more than one full percentage point. Portfolios B through D deliver expected returns between 4.97 and 5.25 percent with risk between 2.82 and 3.44 percent. The maximum utility allocation achieves a 5.15 percent expected return at 3.16 percent volatility, raising the Sharpe ratio from 0.27 to 0.36 and significantly reducing surplus variability.

The optimization makes consistent and deliberate reallocations across fixed income sectors. The model removes the entire 8.3 percent allocation to BBB public corporates, which offers limited risk adjusted return for its capital charge. It also sharply reduces the 9.8 percent allocation to commercial mortgage whole loans, replacing this exposure with private placements and structured credit. Both A and BBB rated private placements rise to their 15 percent caps across all optimized portfolios, confirming their strong capital adjusted spreads. RMBS and CMBS allocations rise substantially, reaching 12 to 14 percent and 10 to 12 percent respectively, while residential mortgage whole loans increase to approximately 14 to 15 percent. These sectors combine attractive spreads, favorable capital treatment, and stable cash flow characteristics, making them natural building blocks for liability matched, capital efficient portfolios.



Allocations to global ex US corporates and sovereigns decline sharply or disappear entirely, as these exposures contribute little to surplus efficiency once the optimizer incorporates their correlations and capital costs. ABS exposures decline as well because their relatively short duration and more modest spreads limit their impact once RMBS and CMBS have been utilized. Small allocations to long Treasuries and high grade corporates are retained for duration management and liquidity needs. Private equity remains modest and controlled, consistent with Voya's capital discipline.

Across the frontier, credit quality stays anchored at AA minus, fixed income duration remains stable near 6.25 years, and the net duration gap moves slightly upward toward the liability target. Capital use falls meaningfully, from 2.16 percent in the current allocation to between 0.88 and 1.93 percent in the optimized portfolios, with the lowest capital requirements occurring in the most conservative configurations. The simulated efficient frontiers exhibit a fairly tight interquartile range, suggesting that Voya's opportunity set is robust to parameter uncertainty and largely driven by structural reallocation opportunities rather than estimation risk.

	US Treasuries, Short/Intermediate	US Treasuries, Long	US Taxable Munis	Global ex-US Government, hedged	US Public Corporates IG AAA	US Public Corporates IG AA	US Public Corporates IG A	US Public Corporates IG BBB	US Public Corporates, HY Intermediate	US Public Corporates, HY Long	Global ex-US Corporates, hedged	Residential Mortgage-Backed Securities	Commercial Mortgage-Backed Securities	Asset-Backed Securities	Corporate IG Private Placement A	Corporate IG Private Placement BBB	Corporate HY Private Placement (Leveraged Loans)	Residential Mortgage Whole Loans	Commercial Mortgage Whole Loans	Private Equity	Real Estate (via partnerships, equity)	
US Treasuries, Short/Intermediate	1.0	0.9	0.5	0.8	0.9	0.7	0.6	0.5	0.0	0.1	0.7	0.8	0.2	0.3	0.2	0.1	-0.2	0.8	0.2	0.0	0.0	
US Treasuries, Long	0.9	1.0	0.6	0.8	0.9	0.8	0.6	0.5	0.0	0.1	0.7	0.8	0.2	0.3	0.2	0.2	-0.1	0.8	0.2	0.0	0.0	
US Taxable Munis	0.5	0.6	1.0	0.7	0.7	0.7	0.7	0.7	0.5	0.5	0.8	0.7	0.4	0.6	0.3	0.3	0.2	0.7	0.8	0.4	0.0	0.0
Global ex-US Government, hedged	0.8	0.8	0.7	1.0	0.8	0.8	0.7	0.6	0.2	0.3	0.9	0.8	0.3	0.3	0.3	0.2	0.2	0.7	0.3	0.0	0.0	
US Public Corporates IG AAA	0.9	0.9	0.7	0.8	1.0	0.9	0.7	0.6	0.2	0.3	0.8	0.9	0.4	0.4	0.3	0.2	-0.1	0.9	0.4	0.0	0.0	
US Public Corporates IG AA	0.7	0.8	0.7	0.8	0.9	1.0	1.0	0.9	0.5	0.6	0.9	0.8	0.5	0.5	0.4	0.4	0.3	0.8	0.5	0.0	0.1	
US Public Corporates IG A	0.6	0.6	0.7	0.7	0.7	1.0	1.0	0.9	0.6	0.7	0.9	0.7	0.6	0.6	0.4	0.4	0.4	0.8	0.6	0.1	0.1	
US Public Corporates IG BBB	0.5	0.5	0.7	0.6	0.6	0.9	0.9	1.0	0.8	0.8	1.0	0.6	0.6	0.7	0.5	0.5	0.6	0.7	0.6	0.0	0.0	
US Public Corporates, HY Intermediate	0.0	0.0	0.5	0.2	0.2	0.5	0.6	0.8	1.0	0.9	0.7	0.3	0.7	0.6	0.5	0.5	0.5	0.8	0.4	0.7	0.0	0.1
US Public Corporates, HY Long	0.1	0.1	0.5	0.3	0.3	0.6	0.7	0.8	0.9	1.0	0.8	0.4	0.7	0.6	0.5	0.5	0.7	0.5	0.7	0.0	0.0	0.1
Global ex-US Corporates, hedged	0.7	0.7	0.8	0.9	0.8	0.9	0.9	1.0	0.7	0.8	1.0	0.8	0.9	0.8	0.4	0.4	0.5	0.7	0.9	-0.1	-0.1	-0.1
Residential Mortgage-Backed Securities	0.8	0.8	0.7	0.8	0.9	0.8	0.7	0.6	0.3	0.4	0.8	1.0	0.3	0.4	0.2	0.2	0.0	1.0	0.3	0.0	0.0	0.0
Commercial Mortgage-Backed Securities	0.2	0.2	0.4	0.3	0.4	0.5	0.6	0.6	0.7	0.7	0.9	0.3	1.0	0.4	0.5	0.4	0.4	0.8	1.0	0.0	0.2	0.2
Asset-Backed Securities	0.3	0.3	0.6	0.3	0.4	0.5	0.6	0.7	0.6	0.6	0.8	0.4	0.4	1.0	0.5	0.4	0.5	0.8	0.5	0.0	0.1	0.1
Corporate IG Private Placement A	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.4	0.2	0.5	0.5	1.0	1.0	0.2	0.3	0.5	0.2	0.2	0.2
Corporate IG Private Placement BBB	0.1	0.2	0.3	0.2	0.2	0.4	0.4	0.5	0.5	0.5	0.4	0.2	0.4	0.4	1.0	1.0	0.2	0.3	0.4	0.1	0.2	0.2
Corporate HY Private (Leveraged Loans)	-0.2	-0.1	0.3	0.2	-0.1	0.3	0.4	0.6	0.8	0.7	0.5	0.0	0.4	0.5	0.2	0.2	1.0	0.1	0.4	-0.2	-0.2	-0.2
Residential Mortgage Whole Loans	0.8	0.8	0.8	0.7	0.9	0.8	0.8	0.7	0.4	0.5	0.7	1.0	0.8	0.8	0.3	0.3	0.1	1.0	0.8	-0.1	-0.1	-0.1
Commercial Mortgage Whole Loans	0.2	0.2	0.4	0.3	0.4	0.5	0.6	0.6	0.7	0.7	0.9	0.3	1.0	0.5	0.5	0.4	0.4	0.8	1.0	0.0	0.2	0.2
Private Equity	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.2	0.1	-0.2	-0.1	0.0	1.0	0.7	0.7
Real Estate (via partnerships, equity)	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1	-0.1	0.0	0.2	0.1	0.2	0.2	-0.2	-0.1	0.2	0.7	1.0	1.0

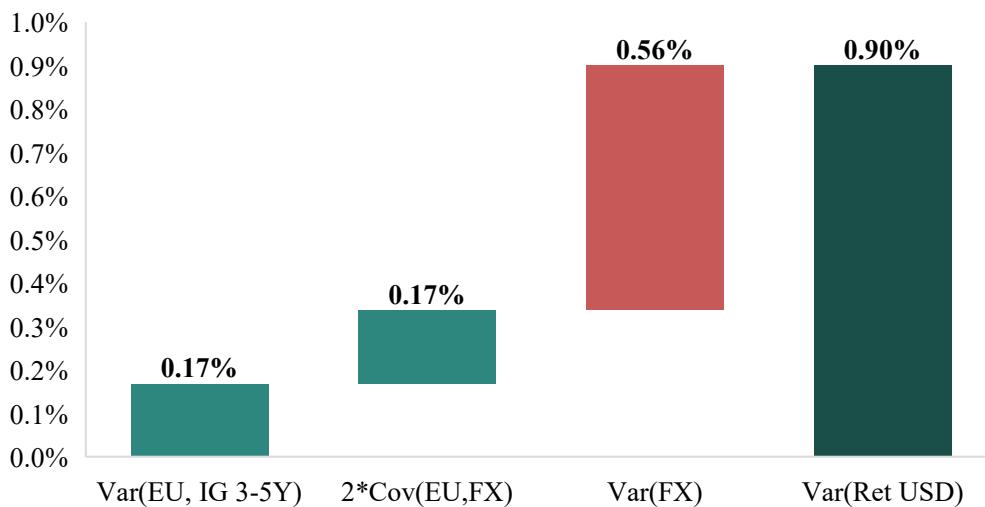
Cash and Foreign Currency Bonds

In this analysis, I intentionally exclude cash from the expected return modeling framework. Although cash is essential for liquidity management, it does not function as a strategic return driver over extended investment horizons. Empirical and industry research consistently demonstrates that cash historically underperforms risk-bearing assets such as bonds and equities across multi-year periods. Several factors underpin this long-term underperformance:

- **Structural return deficiency:** bonds allow reliable long-term return forecasting based on starting yields and embedded term premia. Cash, however, lacks such reliability, with short-term interest rates subject to significant fluctuations driven by central bank policy decisions rather than structural macroeconomic drivers such as long-term growth, inflation trends, or persistent risk premia.
- **Forecasting limitations:** empirically, the autocorrelation of cash return time series (1999-2025) is around 70% vs -10% for longer indices (long UST and corporate IG), the volatility and policy-dependent nature of short-term interest rates severely limits the stability and reliability of long-term cash return projections. Unlike longer-duration assets, cash has no term premium and responds predominantly to short-term monetary cycles rather than fundamental macroeconomic conditions.
- **Portfolio role:** from a portfolio construction standpoint, cash primarily serves as a liquidity buffer rather than a strategic asset. Institutional investors, particularly life insurers, typically maintain only minimal cash holdings (around 1-2%) to facilitate operational liquidity, meet transactional needs, or temporarily hold funds awaiting deployment into productive assets.

In my framework, foreign currency bonds are modeled using currency-hedged indexes rather than unhedged ones. The reason is that unhedged exposures introduce large amounts of uncompensated FX volatility, which in many cases dominates the bond return variance, as shown in the chart below. While one could make the case that foreign bonds provide diversification when domestic assets sell off alongside the currency, the evidence suggests that such offsets are weak (correlations are modest, around 0.25) and unstable over time. Moreover, correlation does not imply a reliable causal hedge.

Foreign currency volatility makes up the majority of the unhedged foreign currency bond risk



Life insurers and other institutional allocators do in practice allocate to foreign sovereign and corporate bonds, but on a hedged basis, since their mandate is to capture the bond risk premium rather than currency noise. Following

this logic, I include foreign bond exposures in my CMA framework through hedged indexes, ensuring comparability to domestic bonds and aligning with real-world institutional implementation.

Credit Loss Adjustments

While Yield to Worst (YTW) serves as a conservative base case for return expectations, assuming the earliest possible redemption scenario, it does not account for credit losses arising from defaults or downgrades. YTW assumes contractual cash flows will be honored, which makes it insufficient for realistic modeling of credit-sensitive portfolios. To reflect this, I apply expected credit loss adjustment, using 10-year cumulative default probabilities by rating tier and assumed Loss-Given-Default (LGD). The figures in the final table are based on long-run Moody's and S&P data, with assumed LGDs of 60% for corporates and lower for structured products. Sector-level estimates reflect a weighted average of underlying ratings.

Since the analysis is aimed at life insurers' portfolios, which face probably the highest number of regulations among large institutional asset allocators, I am also adjusting the yields by how much capital drag each asset has, which in public fixed income space is dependent on the credit ratings. The table below shows the list of assets along with their assigned schedule NAIC papers, ratings, NAIC designations, and capital charges (times portfolio adjustment factor which accounts for the number of issuers in a given index, and which I assume to be around 500 for each index I take, with PAF of ~1).

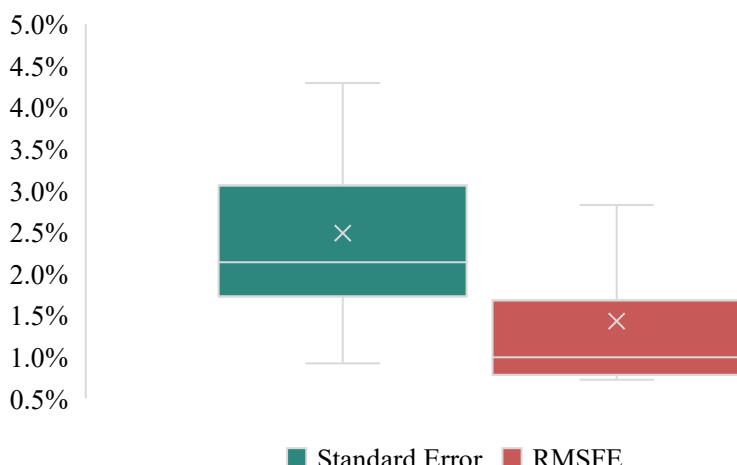
Capital Charge

The capital charge drags the expected return as it ties up the capital that could be invested at the hurdle rate for the given company, which is also its cost of capital and I assume to be 10%. The typical RBC ratio (how much capital above the required charge they typically hold for a given asset) for life insurers is 4. However, in my analysis, I deal with capital charges through the objective function, where one of the terms I deduct from the expected portfolio return is its capital drag.

Standard Error vs RMSFE

If we compare the traditional (standard error) vs novel (RMSFE, not scaled) approaches to how wrong we could be in average return estimation, RMSFE beats the Standard Error estimation, with both considerably lower average level and interquartile range.

As expected, RMSFE is lower than traditional measure of average return volatility STERR



Public Equity

This section provides a comprehensive explanation of the methodology, rationale, and data inputs used to estimate strategic long-term expected returns for U.S. public equities within the Strategic Asset Allocation (SAA) framework. Even though I don't include the public equity allocations for the optimal portfolios for life insurers (because they usually have <1% due to high RBC requirements), this analysis provides an important foundation for other types of allocators (endowments, SWFs) who allocate more to this asset class.

Unlike traditional top-down approaches, which often rely on index-level heuristics or aggregate macro projections, this analysis adopts a granular bottom-up structure, designed to be both cash-flow based and valuation-sensitive, while integrating structural economic insights and historical data patterns. Each step of the equity CMA construction reflects an effort to align financial modeling with the actual behaviors of public companies, equity markets, and sector-specific business models over time.

To begin with, the scope of the equity analysis is intentionally narrowed to U.S. large-cap equities only, and more specifically, to the eleven GICS sectors within the S&P 500 index. The rationale for this focused approach stems from both methodological and operational considerations:

- Bottom-up equity modeling at the sector level requires extensive historical data collection for constituent firms, including detailed variables such as dividends, buybacks, and growth estimates.
- Expanding this framework to multiple geographies or indices would have proven logically prohibitive and would risk compromising the rigor of the estimation.
- Restricting the analysis to the U.S. large-cap equity universe avoids the complications of FX forecasting and cross-border tax and liquidity assumptions.

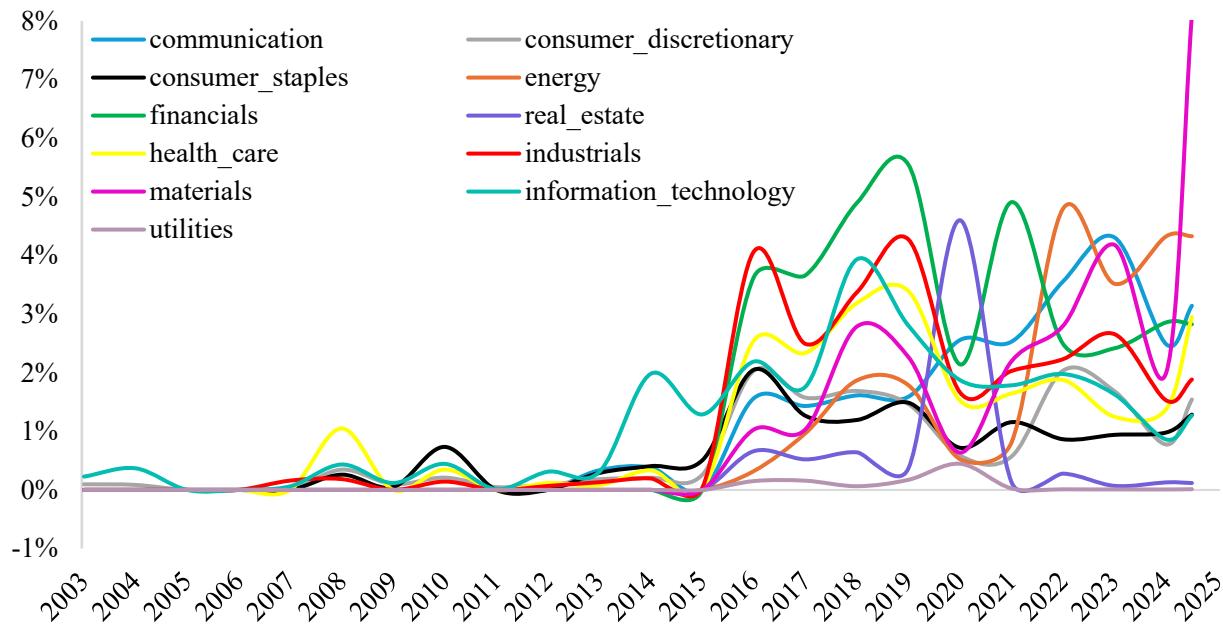
Historical data from Bloomberg were collected for all eleven sector-specific equity indices from 2003 to 2025, specifically the Bloomberg tickers corresponding to each sector such as B500CT (Consumer Staples), B500E (Energy), B500I (Industrials), and so forth. The monthly time series included index level prices, dividend yields, trailing-twelve-month (TTM) earnings per share (EPS), price-to-earnings (P/E) ratios, and net profit margins. This multi-decade data foundation ensures a sufficiently long observation window to capture both cyclical and structural patterns, including periods of economic expansion, contraction, and crisis.

The foundational component of the expected return estimation is the concept of a "cash yield," the equity market's closest analog to a bond's starting yield. Accounting earnings can be systematically manipulated and often diverge from the underlying economic reality that investors should rely on, making cash-based measures significantly more robust. Academic literature and regulatory commentary consistently highlight that companies frequently engage in earnings management through accrual adjustments, one-off items, or strategic timing of expenses and revenues, which distorts reported earnings quality. Earnings may reflect accounting judgment rather than actual cash flows, rendering traditional P/E or EPS-based return models vulnerable to these distortions. In contrast, empirical evidence suggests that shareholder yield components, dividends and buybacks, are harder to manipulate and better reflect real cash returned to investors. Dividend-paying stocks, on average, exhibit lower return volatility, even when controlling for firm size, indicating that cash distributions are associated with greater stability and transparency. Moreover, accrual-based earnings quality improves only when internal controls are strong, otherwise companies may still distort earnings figures even in ostensibly well-governed firms. These findings reinforce the superiority of using cash-based yields as forward return anchors in equity return modeling framework, dividends and buybacks cannot be fabricated, they reflect real value returned to shareholders, and they are less subject to managerial discretion or manipulation.

For equities, this is defined as the sum of dividend yield and share buyback yield. While dividend yield data are readily available at the sector index level, buyback data is not directly accessible in aggregated form. To overcome this, a bottom-up methodology was employed:

- For each year-end, the constituent companies of every sector index were retrieved via Bloomberg's Excel API.
- Key data included market capitalization, share prices, shares outstanding, and actual buyback amounts.
- These values were used to compute market-capitalization-weighted buyback yields at the sector level, creating a robust and replicable proxy for shareholder yield.

Buyback yields have considerably increased since 2012



Over the past two decades, share buybacks have become a structurally important component of shareholder return policy across nearly all U.S. equity sectors. As illustrated in the chart, buyback yields were negligible or even negative during the early 2000s but began rising meaningfully post-2010, with an especially sharp acceleration following the 2017 corporate tax reform and the COVID-19 recovery period. By 2022-2025, many sectors, including Financials, Technology, and Industrials, consistently delivered buyback yields in the 3% to 6% range, rivaling or exceeding their dividend yields. This shift reflects a broader transformation in corporate capital allocation strategies, where buybacks have become the preferred mechanism for returning cash to shareholders due to their flexibility, tax efficiency, and perceived signaling value. The growing prominence and persistence of buyback activity underscore the need to incorporate them explicitly into any forward-looking equity return model, particularly for sector-level strategic allocation analysis.

An important technical adjustment was made to both dividend and buyback yields to better reflect the timing of cash distributions. Specifically, raw dividend yield figures, which are calculated based on the year-end index level, were adjusted by dividing by the average index level over the course of the preceding year. This correction accounts for the fact that dividends and buybacks are distributed throughout the year rather than as a single lump sum at year-end, improving the fidelity of the cash yield as an annualized figure.

To estimate forward growth, 5-year consensus EPS growth forecasts were constructed using Capital IQ data. As these forecasts were not available in aggregate at the sector index level, another bottom-up process was employed:

- For each year-end in the historical period, EPS growth expectations were retrieved for all constituent companies in each sector, if available (they were available for majority of index constituents all of the time).
- These forecasts were then market-cap weighted to arrive at a sector-level forward growth rate.
- It is assumed that the growth in cash yield (dividends and buybacks) matches EPS estimated growth rate.

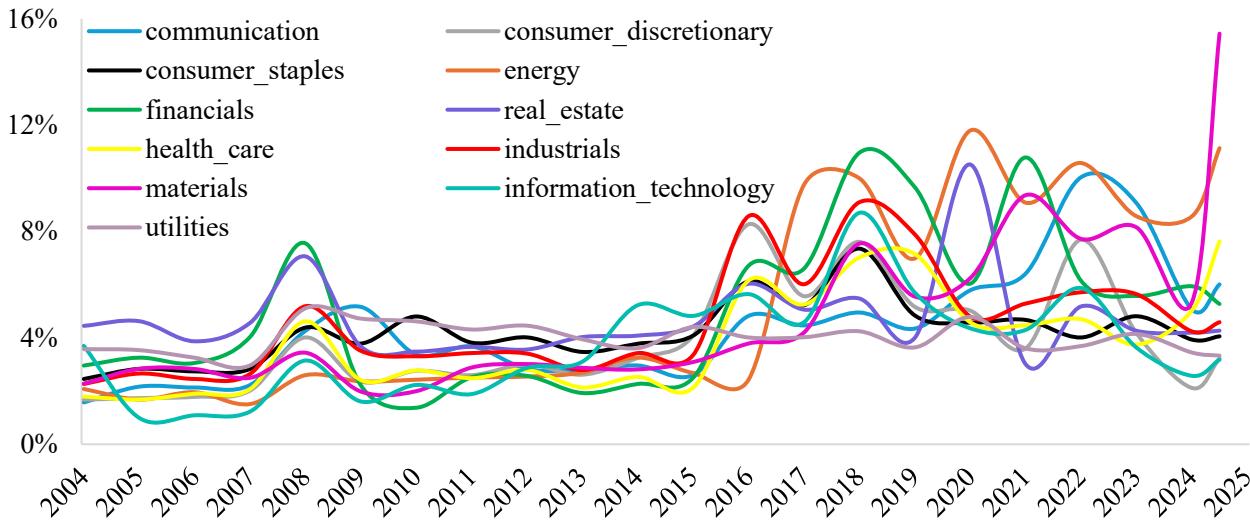
With both cash yield and expected growth in hand, the next step involved computing the implied cost of equity for each sector at each year using a two-stage dividend discount model, a version of the Gordon Growth Model. The structure of the model includes an initial five-year phase of elevated growth, followed by a perpetual growth phase at a lower terminal rate. The formula applied is as follows:

$$P = \sum_{t=1}^5 \frac{D_0(1+g)^t}{(1+r)^t} + \frac{D_0(1+g)^t(1+g_{terminal})}{(r-g_{terminal})(1+r)^5}$$

- P is the index level at year-end
- D_0 is the current cash yield (dividends + buybacks)
- g is the 5-year EPS growth rate
- rfr is the terminal growth rate (set equal to the long-term risk-free rate)
- r is the cost of equity to be solved for

This nonlinear equation was solved using a VBA-automated goal-seek macro to determine the implied cost of equity for each sector and year. After obtaining the implied cost of equity, the long-term risk-free rate was subtracted to derive the implied equity risk premium (ERP), the primary input into the SAA model. The choice of using the long-term rate (long treasury index) as the discount rate and terminal growth assumption is consistent with equity's long-duration nature, as equities represent claims on a very long stream of future cash flows.

Implied ERP levels have been more volatile in the last decade



The chart below plots the evolution of implied ERP by sector over the 2004-2025 period. The series are highly dynamic, influenced by fluctuations in valuation, payout behavior, and forward growth expectations. Notably, a pronounced upward shift in implied ERP levels is visible post-2015 across most sectors, with a further spike during periods of market stress, including 2020 and late 2023. These ERP movements capture not just investor sentiment and risk appetite, but also cyclical inflections in fundamentals and pricing.

Beliefs about market efficiency inherently shape how equity risk premiums are estimated. For long-horizon allocators, the choice of methodology reflects underlying assumptions about whether markets are efficiently priced. If one believes that public markets are broadly efficient over time, or at least that their direction is inherently unpredictable, then the current implied equity risk premium (ERP), derived from prevailing market prices and cash flows, offers the most rational anchor for return expectations. However, if one sees recurring valuation dislocations or structural inefficiencies at the sector or macro level, then using longer-term average implied ERPs or even historical realized premiums may be more appropriate. Survey-based ERPs, while occasionally used, may be preferred only by those who lack confidence in market-based signals altogether.

Since this framework is designed primarily with institutional allocators in mind, and I believe in general market efficiency with some sector-level inefficiencies, the implied ERP is adopted as the core signal, which is then refined through valuation-aware and structurally-informed adjustments, as described in the subsequent CAPE-based and profitability-based enhancements.

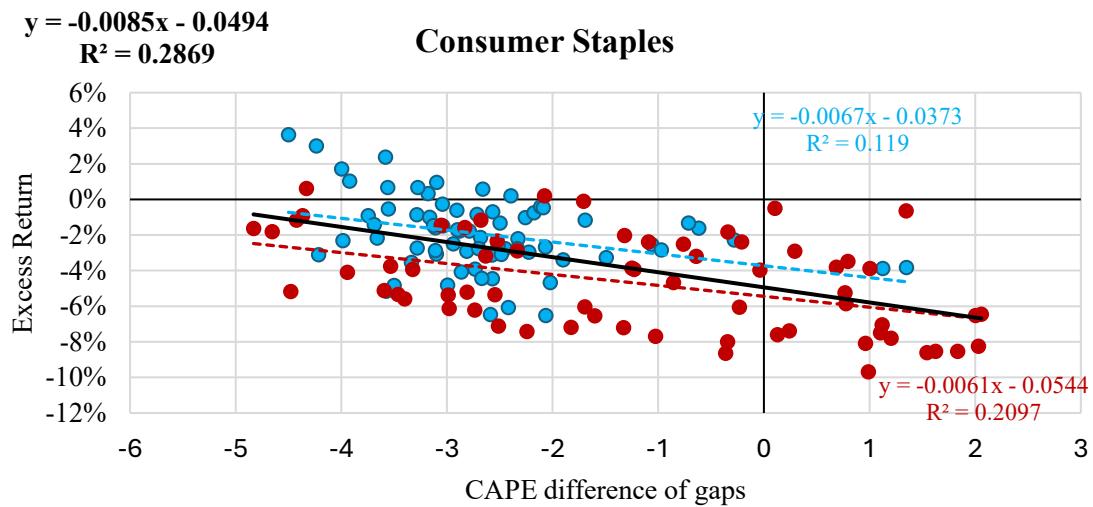
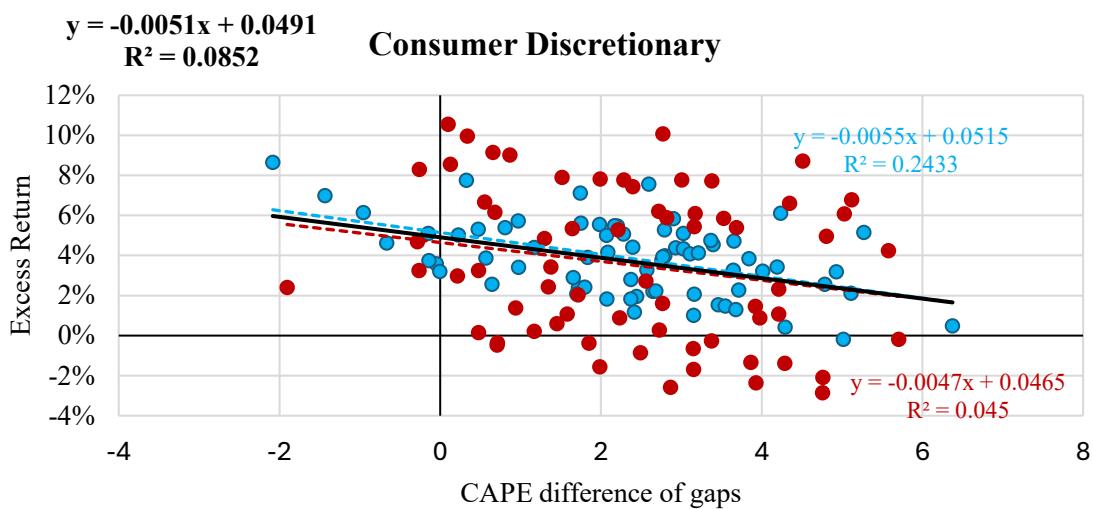
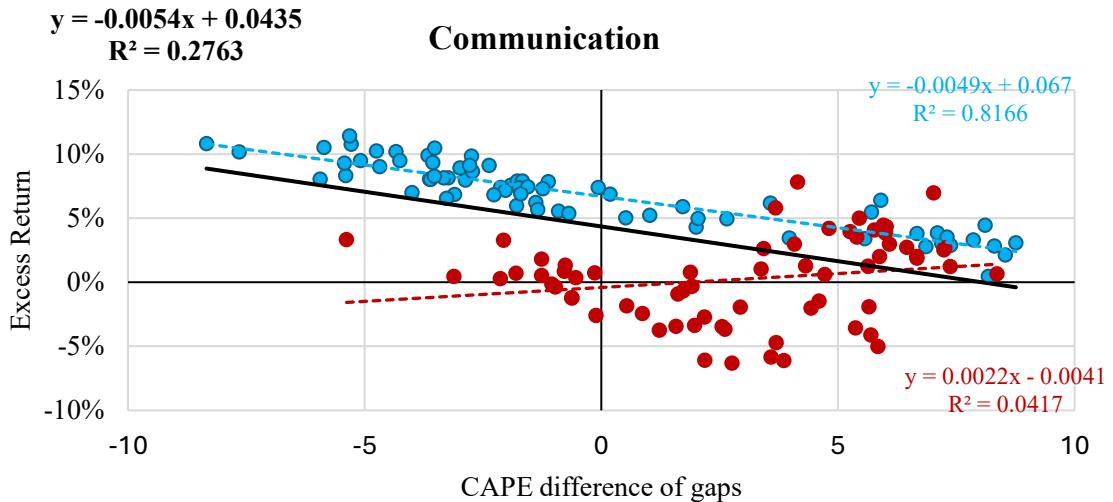
Having established base return expectations using implied cost of equity (implied ERP + long-term riskfree rate), the next step introduces a valuation-sensitive overlay via sector-specific CAPE adjustments. The cyclically adjusted P/E ratio (CAPE) serves as a signal of valuation deviation from historical norms. The methodology here avoids simplistic valuation heuristics and instead uses a regression-based framework to determine whether CAPE ratios have explanatory power for future sector-level excess returns. Rolling regressions were performed for each sector, regressing subsequent 5-year excess returns on CAPE deviations from historical norms. Three sub-periods were evaluated:

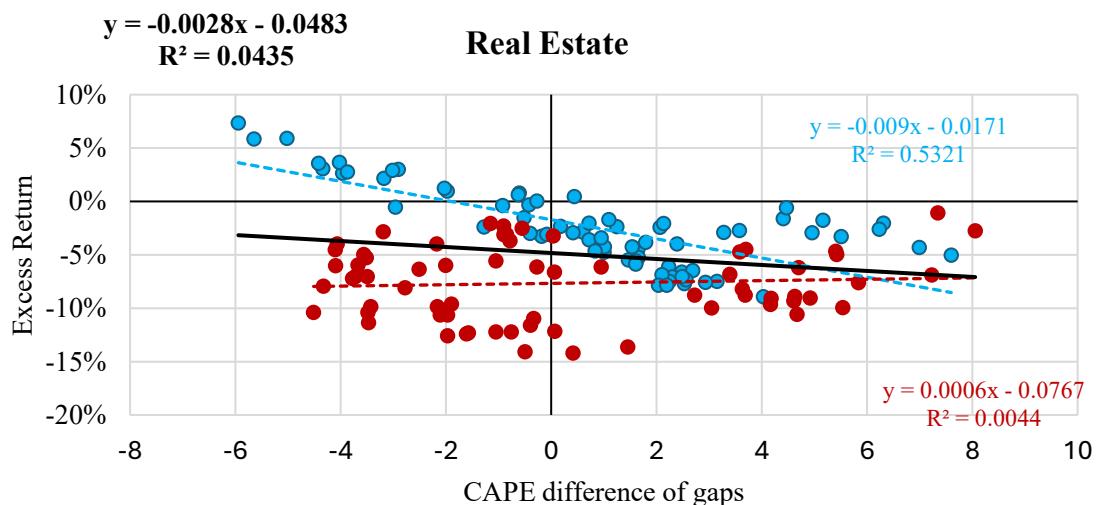
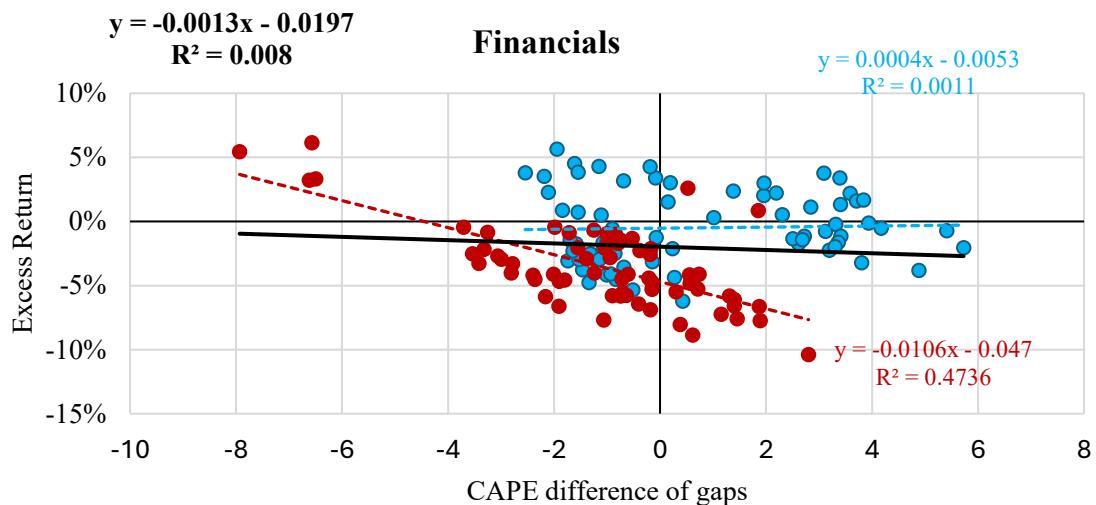
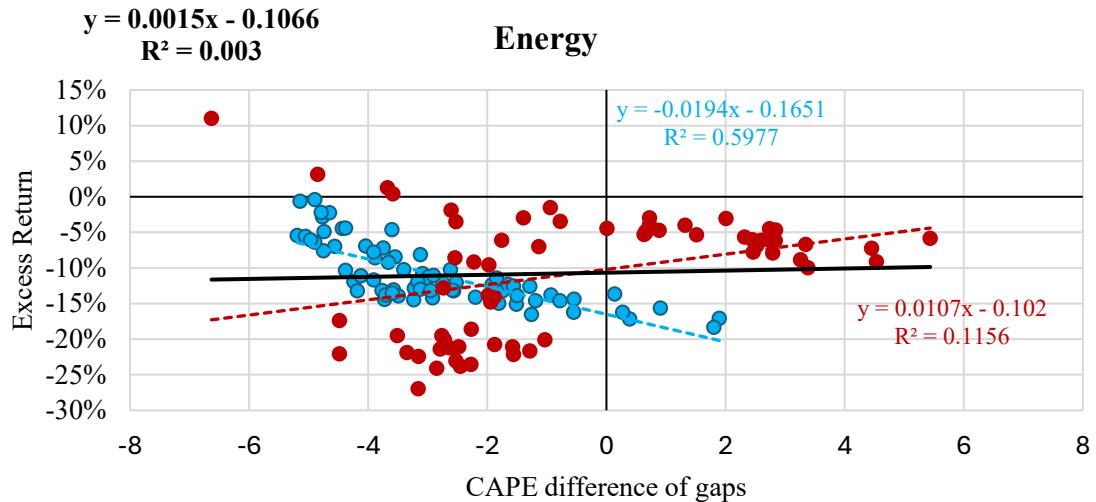
- The full historical sample
- The post-GFC expansion (2009-2015)
- The more recent cycle (2015-2020)

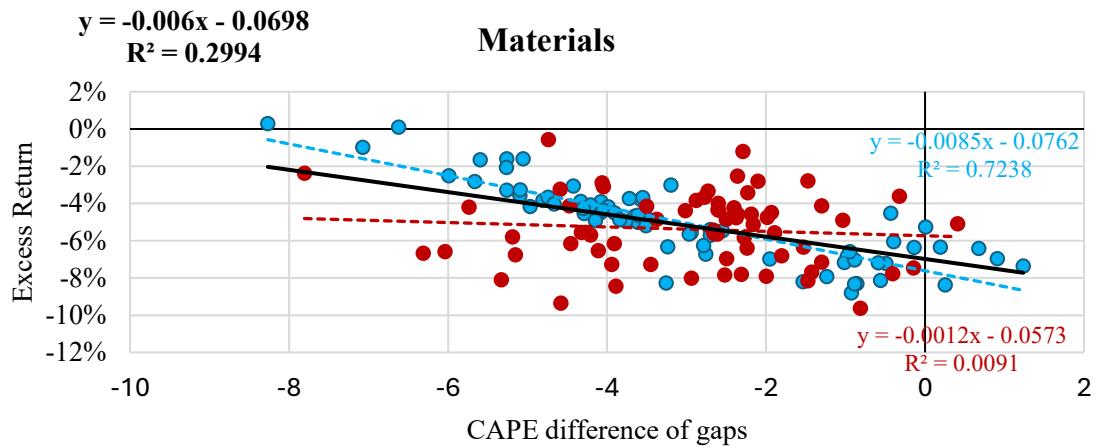
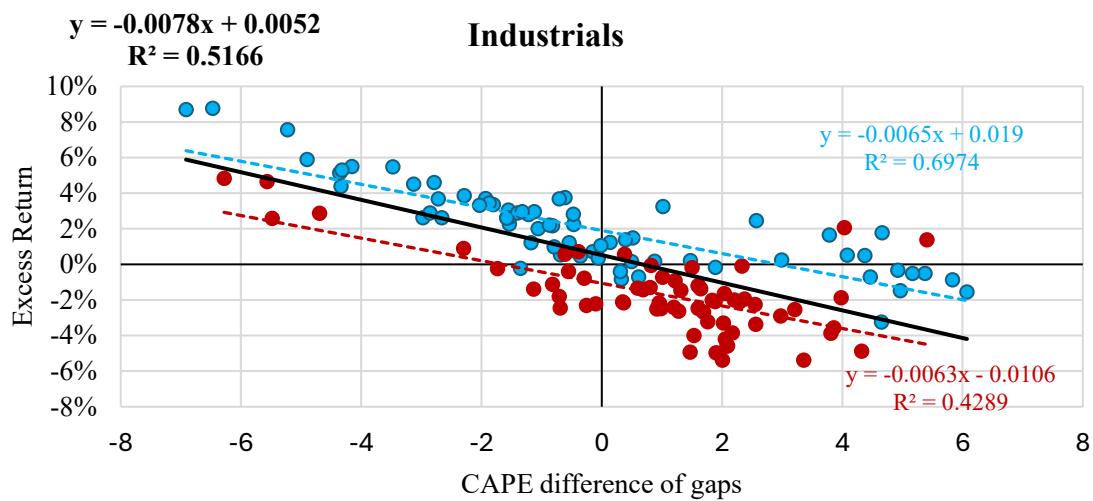
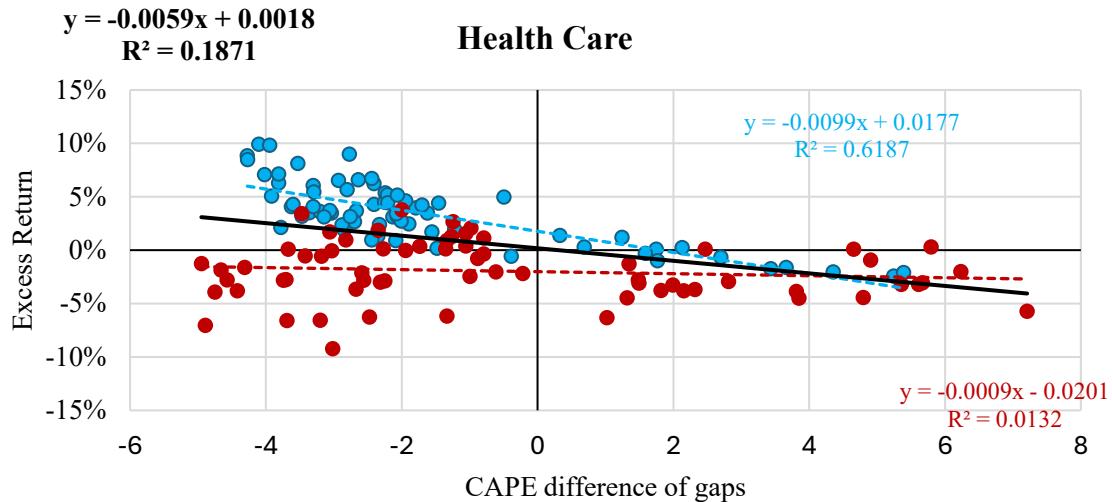
Only when these regressions exhibited meaningful explanatory power, defined as an R-squared above 0.2 in at least one sub-period, was an adjustment applied. The size of the adjustment was proportional to the statistical significance and stability of the relationship:

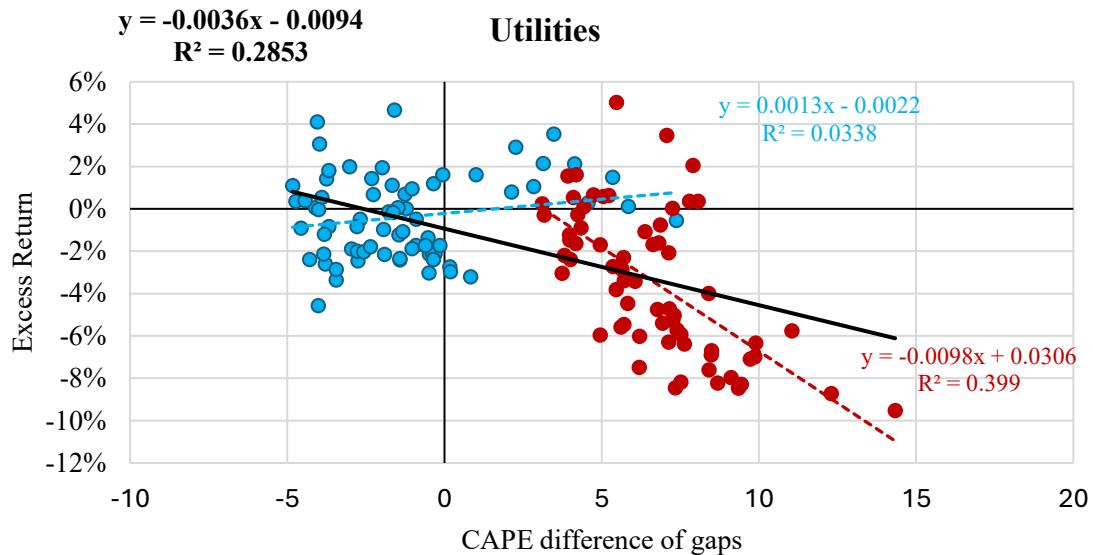
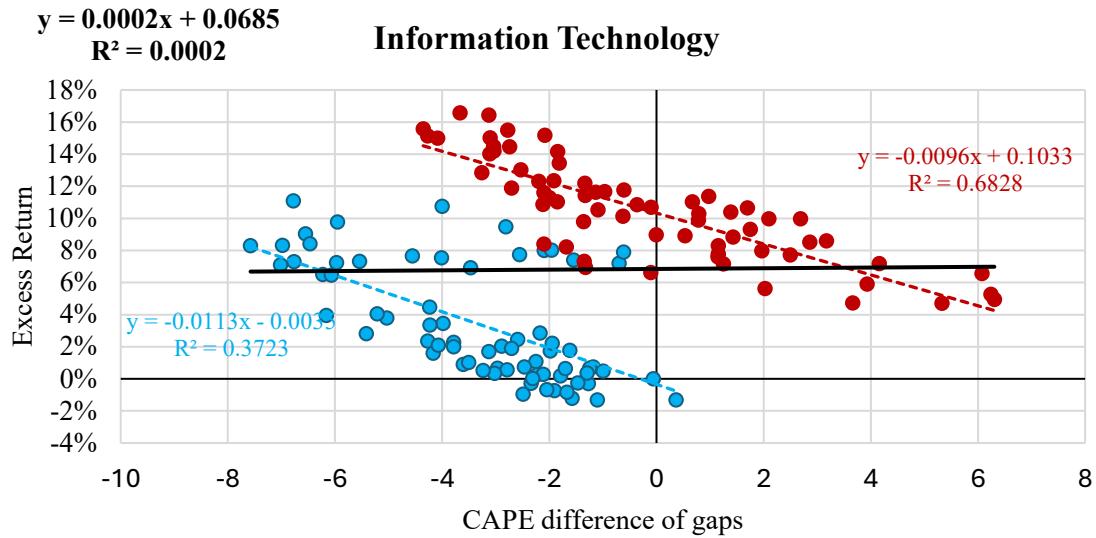
- If both long- and short-term regressions showed strong fit, a full adjustment of the implied excess return was imposed.
- If only one period met the criteria, a smaller 25 to 50% adjustment was applied.
- In sectors where CAPE-return linkages were weak or unstable, no adjustment was made.
- In sectors undergoing structural change, such as Information Technology, greater emphasis was placed on recent regressions to reflect evolving valuation paradigms.

The regression charts for each sector are given below (blue dots represent time period 2009-2015, red dots are for 2015-2020, while black line represents the full sample).









The CAPE adjustment process led to the following modifications:

- Technology and consumer staples received a slight upward adjustment due to persistent undervaluation relative to realized performance.
- Industrials and Utilities saw downward adjustments due to persistent overvaluation and a historically robust connection between high CAPEs and poor forward returns.

The output tables for all three testing period regressions are given below:

2009-2015	consumer_staples	industrials	information_technology	utilities
Alpha	-0.0373	0.0190	-0.0035	-0.0022
p-value	0.0000	0.0000	0.6075	0.3927
Beta	-0.0067	-0.0065	-0.0113	0.0013
p-value	0.0027	0.0000	0.0000	0.1227
R-squared	0.119	0.697	0.372	0.034
CAPE deviation (x)	0.00	0.00	0.00	0.00
Implied excess return (y)	-3.73%	1.90%	-0.35%	-0.22%

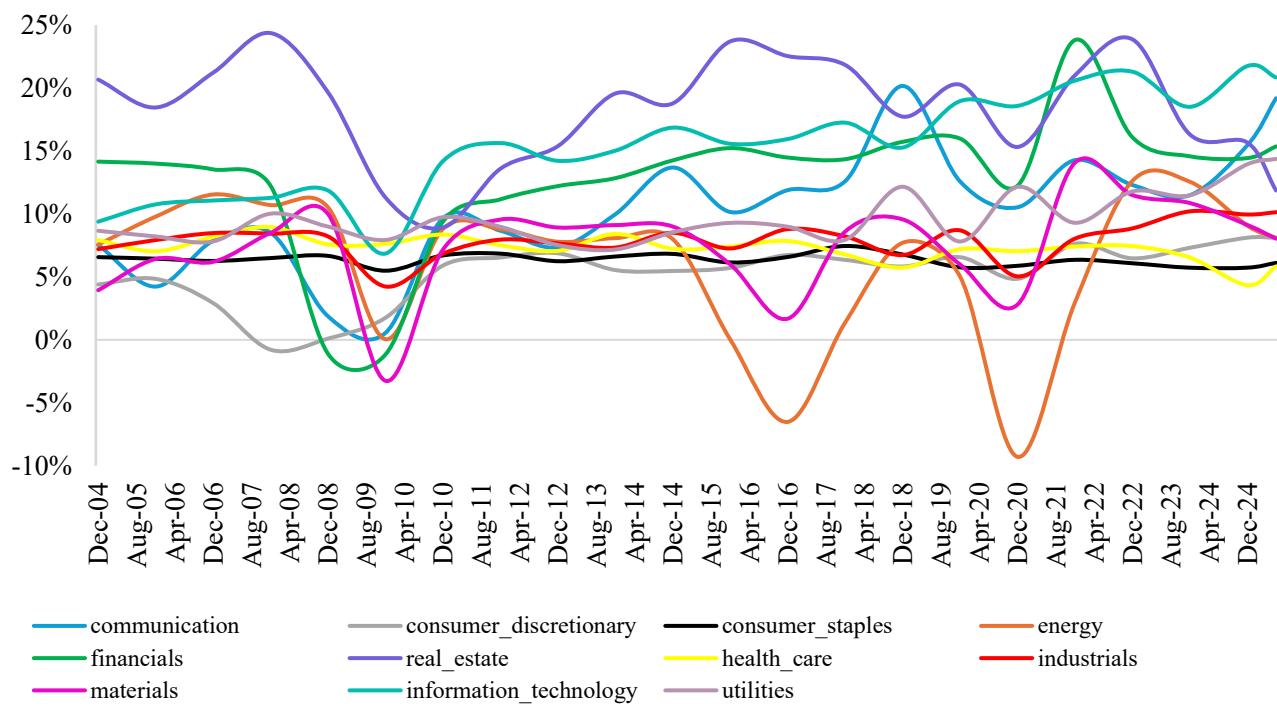
2015-2020	consumer_staples	industrials	information_technology	utilities
Alpha	-0.0544	-0.0106	0.1033	0.0306
p-value	0.0000	0.0000	0.0000	0.0042
Beta	-0.0061	-0.0063	-0.0096	-0.0098
p-value	0.0001	0.0000	0.0000	0.0000
R-squared	0.210	0.429	0.683	0.399
CAPE deviation (x)	0.00	0.00	0.00	0.00
Implied excess return (y)	-5.44%	-1.06%	10.33%	3.06%

Entire period	consumer_staples	industrials	information_technology	utilities
Alpha	-0.0494	0.0052	0.0685	-0.0094
p-value	0.0000	0.0038	0.0000	0.0005
Beta	-0.0085	-0.0078	0.0002	-0.0036
p-value	0.0000	0.0000	0.8855	0.0000
R-squared	0.287	0.517	0.000	0.285
CAPE deviation (x)	-9.84	9.84	9.71	7.46
Implied excess return (y)	3.41%	-7.12%	7.06%	-3.63%

Finally, a third layer of refinement was applied to expected returns based on structural sector-specific trends in profitability and margins. These adjustments recognize that valuation-based models such as CAPE, while informative, do not always capture evolving fundamentals, particularly when sector economics are undergoing transformation or degradation.

- **Real Estate** was adjusted downward by 50 basis points due to a sustained decline in sector-wide net profit margins, which have fallen to levels last seen during the Global Financial Crisis. Net margins now hover around 11.9 percent, down nearly 12 points from their 2015 peak, with a negative annual trend of minus 1.83 percent. Structural pressures include higher interest rates compressing cap rate spreads and secular weakening of office and retail segments.
- **Communication Services** received a 50 basis point upward adjustment. Net margins have expanded consistently, reaching 19.2% in 2025, nearly double the average from a decade prior. This improvement stems from a sectoral shift toward scalable, digital platform companies.
- **Utilities** were adjusted upward by 25 basis points, supported by a secular rise in profitability to 14.4 percent, driven by inflation-linked rate bases, electrification demand, and renewable energy investment.

Net profit margins by sector

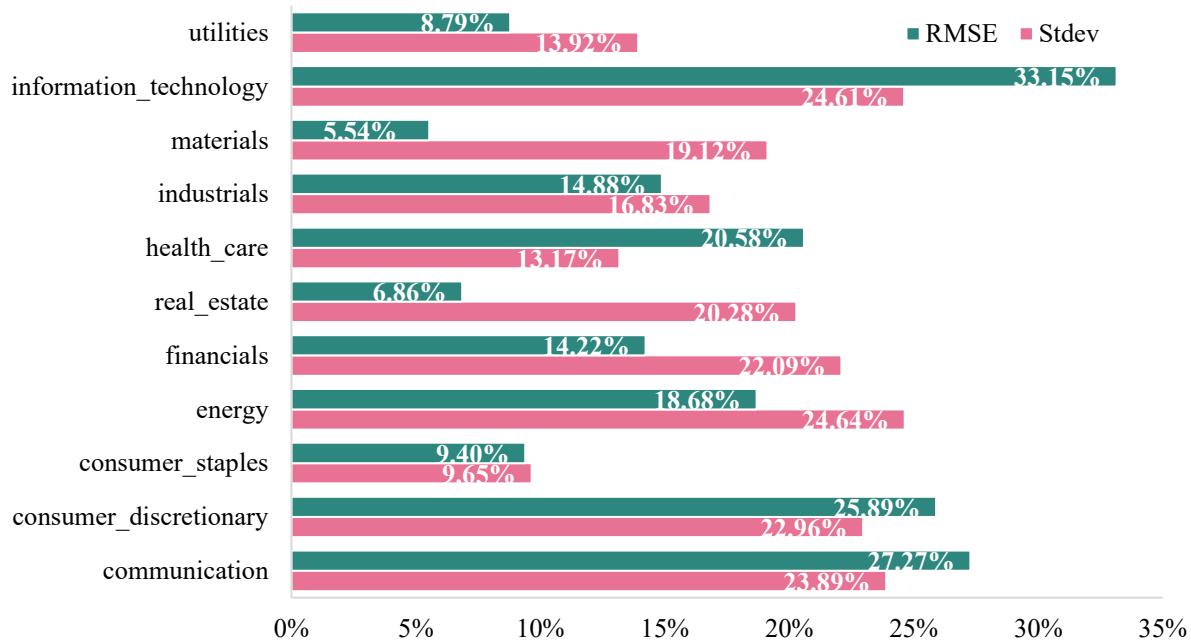


Together, the methodology outlined above represents a rigorous, data-intensive, and forward-looking approach to equity return forecasting. By anchoring expectations in actual cash flows, layering in valuation and structural considerations, and avoiding reliance on simplistic heuristics or backward-looking averages, this framework aims to produce credible, institutionally relevant return forecasts for use in long-horizon strategic allocation decisions.

Risk Estimation

The chart below compares the 10-year scaled root mean square error ($\text{RMSFE} \times \sqrt{10}$) of return forecasts to the historical standard deviation of total returns for each sector. RMSFE here is calculated based on the forecast error between the modeled expected return (implied cost of equity) and the realized return over rolling 5-year periods, and then scaled by $\sqrt{10}$ to represent volatility over a strategic 10-year horizon, consistent with the time frame of our SAA optimization. This scaling adjusts for the fact that forecast errors over time are not necessarily i.i.d., but it still offers a more forward-looking, model-anchored estimate of risk than raw historical volatility.

RMSFE vs Standard Deviation



Notably, in some sectors, specifically Communication Services, Consumer Discretionary, Health Care, and Information Technology, the RMSFE actually exceeds the observed standard deviation of returns. This counterintuitive outcome suggests that for these sectors, return forecasts have historically exhibited higher miss errors than the typical annual price fluctuation, which may reflect structural shifts, model misspecification, or simply the inherent difficulty in forecasting sectors undergoing rapid transformation. Conversely, more stable sectors like Consumer Staples, Utilities, and Real Estate exhibit RMSFEs that are meaningfully lower than their historical volatilities, underscoring the higher accuracy and reliability of forecast models in those segments.

Despite these nuances, RMSFE remains the preferred measure of risk in this SAA framework. It directly reflects the historical uncertainty of our modeled expected return inputs, rather than backward-looking price fluctuations, making it more consistent with a forward-driven optimization approach. This methodological choice ensures internal consistency between return assumptions and risk estimates.

Sector	Implied ERP	CAPE adjustment	Structural adjustment	Expected return	Risk
Communication	6.01%		0.50%	6.51%	27.27%
Consumer discretionary	3.22%			3.22%	25.89%
Consumer staples	4.06%	0.85%		4.91%	9.40%
Energy	11.13%		-0.50%	10.63%	18.68%
Financials	5.27%			5.27%	14.22%
Real estate	4.27%			4.27%	6.86%
Health care	7.62%			7.62%	20.58%
Industrials	4.59%	-3.56%		1.03%	14.88%
Materials	15.44%			15.44%	5.54%
Information technology	3.18%	5.16%		8.34%	33.15%
Utilities	3.33%	-0.91%	0.25%	2.67%	8.79%