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VA Reserve/Capital Reform and Hedging Considerations

Tao Wang
Jerry Mao

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Tao Wang
Jerry Mao
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Agenda

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Variable Annuity Guarantees

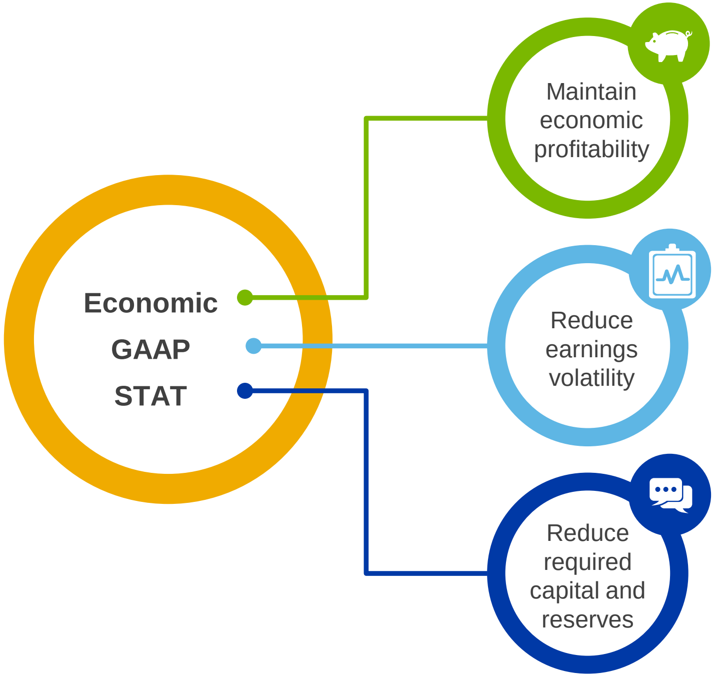
Variable Annuity Guarantees

- Guarantee Minimum Death Benefit (GMDB)
- Guarantee Minimum Income Benefit (GMIB)
- Guarantee Minimum Accumulation Benefit (GMAB)
- Guarantee Minimum Withdrawal Benefit (GMWB) / Guarantee Lifetime Withdrawal Benefit (GLWB)

Why is hedging important?

- VA guarantees are complex options
- Exposed to capital market risks
- Policyholder behavior assumptions
- Rollup and ratchet features
- Long term nature

Conflicting Hedging Objectives



- These are three conflicting hedging objectives due to different market sensitivities to interest rates and equity.
- In terms of market sensitivity,

  Economic > GAAP > Statutory
- Full economic hedge means over hedge Statutory and GAAP. Full economic hedge is penalized by current statutory framework and creates GAAP volatility.
- Statutory or GAAP hedge means under hedge economic. It may hurt economic profitability.

Economic Perspective

Fair Market Value

- FAS157 defines fair value and provides guidance on how to measure assets and liabilities at fair value.
- A risk neutral policyholder would be indifferent to invest in any other financial instruments or in a variable annuity with GMxB riders.
- Suppose both cash flows on the liability side and on the income side are tradable assets,

$$\text{Fair Market Value} = \mathrm{E}^{\mathrm{Q}}[\text{PV Rider Fees}] - \mathrm{E}^{\mathrm{Q}}[\text{PV Claims}]$$

US GAAP Perspective

FASB Targeted Improvement for Long Duration Contracts

Scope

All long duration contracts including Whole Life, Universal Life, Variable Annuity, Fixed Income Annuities, etc.

Timeline

Jan 1st, 2022 for Calendar-year public companies, and Jan 1st, 2024 for all other calendar-year companies

Key Changes to VA

Current		New
GMDB, GMIB, Lifetime GWB **SOP 03-1** **Insurance Accrual**	→	**Market Risk Benefit** **(All GMxBs in VA)** A benefit offered by an insurer that protects a contract holder from capital market risk (for example, investment losses due to market downturns) **FAIR VALUE**
GMAB, non-lifetime GWB **FAS 157** **FAIR VALUE**		

Hedging Implications

- Current standard makes it challenging to hedge exposures related to SOP riders.
- New standard eliminates the mismatch and encourages more hedging.
- The accounting methodologies are more aligned among guarantees. GAAP is more aligned with economic.

Statutory Perspective

NAIC Variable Annuity Reserve and Capital Reform

Scope: Variable Annuity

Timeline: Effective Jan 1st, 2020, with a three-year Phase-in period

Changes:

- Align TAR and reserve, remove non-economic volatility in C3
- Align hedge assets with liability valuation
  - ✓ Align market sensitivity with fair value if hedging fully
- Reform Standard Scenario calculation
  - ✓ Remove from C3 Phase II calculation
  - ✓ Refresh prescribed policyholder behavior assumptions
  - ✓ Align standard scenario calculation more closely to the CTE framework
- Promote consistency across companies and products
  - ✓ Follow VM-20 guidance on ESG
  - ✓ Follow VM-20 guidance on general account asset projection assumptions

Statutory Framework

Current VA Statutory Framework

Stat Reserves = Max (**AG43 CTE Amount** (1-E) x **CTE 70 Best Effort (Reflect Hedging)** + E x **CTE 70 Adjusted (No rebalance)** Min E factor 30% , **AG43 Std Scenario**) + **Voluntary Reserve**

TAR = Max (**C3P2 CTE Amount** (1-E) x **CTE 90 Best Effort (Reflect Hedging)** + E x **CTE 90 Adjusted (No rebalance)** Min E factor 5% , **C3P2 Std Scenario**)

C3 = **TAR** - **Stat Reserves**

Issues with current framework:

- Four components.
  Different sensitivities.
  C3 is volatile.
- Discontinuous sensitivity when switching regime under max calculation.
- Standard Scenario Amount uses locked-in at-issue discount rates and is not sensitive to interest rates.
- Min E Factor = 30%.
  Full hedging is often penalized.

Statutory Framework

Proposed VA Statutory Framework

Stat Reserves = **AG43 CTE Amount** **(1-E) x** CTE 70 Best Effort (Reflect Hedging) **+ E x** CTE 70 Adjusted (No rebalance) Min E factor 5% + **AG43 Additional Reserve** + **Voluntary Reserve**

TAR = **C3P2 CTE Amount** **(1-E) x** CTE 98 Best Effort (Reflect Hedging) **+ E x** CTE 98 Adjusted (No rebalance) Min E factor 5%

C3 =25%x (**TAR** + **AG43 Additional Reserve x (1-Tax)** - **Stat Reserves**)

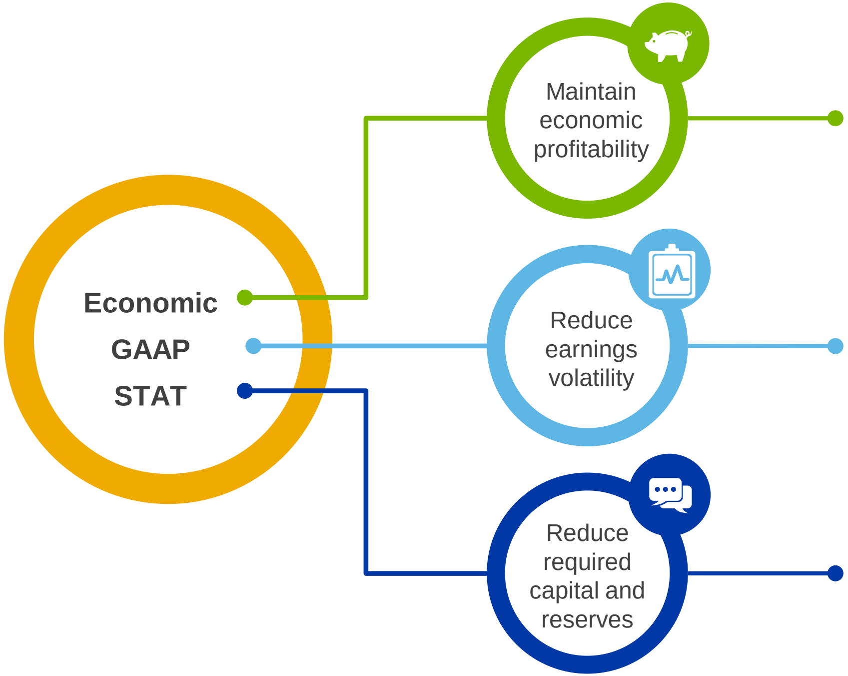
Key Changes:

- Change max function to add on factor
- Remove C3P2 standard scenario
- Align C3P2 CTE amount with AG43.
  - ❑ Change CTE90 to CTE98.
  - ❑ Revenue sharing guidance
  - ❑ Same error factor for reflection of hedging
  - ❑ Tax treatment
- Align AG43 standard scenario with CTE adjusted
  - ❑ Starting Assets + GPVAD
  - ❑ Revenue sharing guidance
  - ❑ Only currently held hedges are reflected
  - ❑ Aggregate basis
- Min E Factor = 5%.
  Higher credit for CDHS.
  More incentive to hedge.

Statutory Framework – Computation Implications

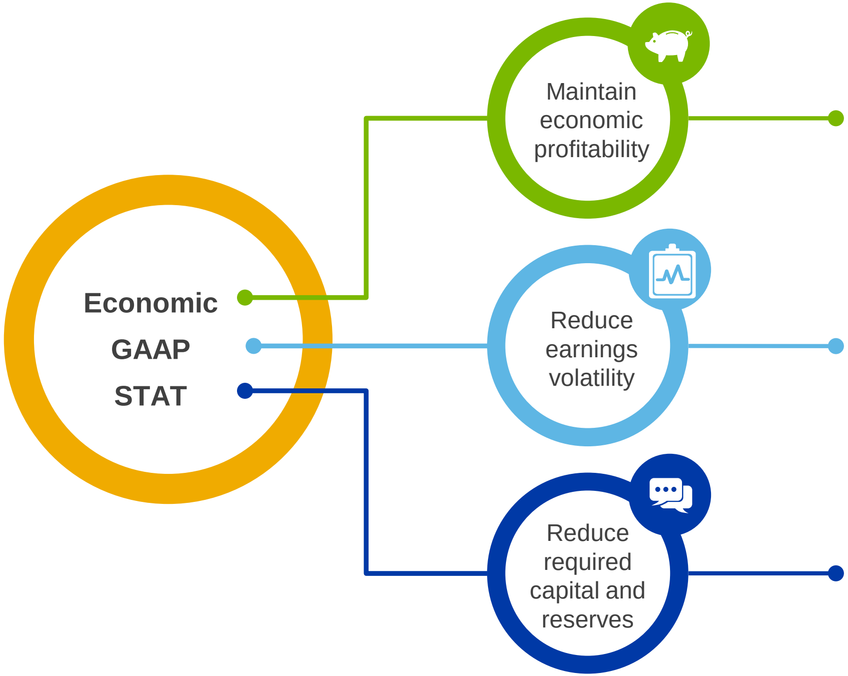
<table>
<tr><th></th><th colspan="2">AG43</th><th colspan="2">C3P2</th></tr>
<tr><td></td><td>CTE Amount
(Best Effort/Adjusted)</td><td>Standard Scenario</td><td>CTE Amount
(Best Effort/Adjusted)</td><td>Standard Scenario</td></tr>
<tr><td>Current</td><td>By stochastic scenarios
By time step</td><td>By prescribed scenarios
By time step
By policy</td><td>By stochastic scenarios
By time step</td><td>By prescribed scenarios
By time step</td></tr>
<tr><td rowspan="2">Proposal</td><td rowspan="2">By VM-20 scenarios
By time step</td><td><u>CSMP Method</u>
(Company Specific Market Path)
By prescribed scenarios
By time step
By different withdrawal election</td><td rowspan="2">By VM-20 scenarios
(more scenarios may be needed to calculated C3P2 CTE98)
By time step</td><td rowspan="2">N/A (Removed)</td></tr>
<tr><td><u>CTEPA Method</u>
(CTE with Prescribed Assumptions)
By VM-20 scenarios
By time step
By different withdrawal election</td></tr>
</table>

Current Valuation Regimes



ECON	Risk neutral valuation. Fair value sensitivity.
FAS 157	Risk neutral valuation. Fair value sensitivity.
SOP 03-1	Real world valuation. Not mark to market.
AG43 CTE	Min E factor 30%. Partial credit for hedging.
AG43 STD	Not sensitive to interest rates. Discontinuous sensitivity when switching regimes under max function.
C3P2 CTE	Numerous differences compared to AG43 CTE Amount.
C3P2 STD	Same issues as AG43 STD

New Valuation Regimes



ECON	Risk neutral valuation. Fair value sensitivity.
FAS 157	Risk neutral valuation. Fair value sensitivity.
SOP 03-1	Removed
AG43 CTE	Min E factor changed from 30% to 5%. Higher credit for hedging. If hedging fully, market sensitivity is more aligned with fair value.
AG43 STD	More aligned with AG43 CTE Amount.
C3P2 CTE	More aligned with AG43 CTE Amount.
C3P2 STD	Removed

Summary of Hedging Implications

Current valuation regimes:

- Competitive hedging objectives
- Some companies do not hedge SOP riders because of the inconsistent methodology.
- Full hedging is penalized while partial hedging produces more optimal results

New valuation regimes:

- Convergence of valuation regimes creates incentive for fair value hedging.
- Companies may consider hedging those SOP riders because they are now considered as Market Risk Benefits and are measured at fair value.
- Higher credit for CDHS. More incentive to hedge.

Agenda

Hedging Laboratory

Test different hedging strategies under the new statutory framework:

- Dynamic hedging (delta-rho)
- Macro hedging (static)
- A combination of dynamic and macro hedging

Using:

- CDHS
- Explicit hedging

Compare:

- Hedging effectiveness
- Reserve and capital implications (stochastic components only)

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Definitions: CDHS

Clearly Defined Hedging Strategy

> A strategy undertaken by a company to manage risks through the future purchase or sale of hedging instruments and the opening and closing of hedging positions that meet the criteria specified in the applicable requirement.

The strategy must identify:

a) The specific risks being hedged (e.g., delta, rho, vega, etc.).
b) The hedge objectives.
c) The risks not being hedged (mortality, withdrawal, etc.).
d) The financial instruments that will be used to hedge the risks.
e) The hedge trading rules, including the permitted tolerances from hedging objectives.
f) The metric(s) for measuring hedging effectiveness.
g) The criteria that will be used to measure hedging effectiveness.
h) The frequency of measuring hedging effectiveness.
i) The conditions under which hedging will not take place.
j) The person or persons responsible for implementing the hedging strategy.

Definitions: Explicit Hedging

- **Explicit hedging:** Hedging positions and their resulting cash flows are included in the stochastic cash-flow model used to determine the scenario reserve.

- **Implicit Hedging:** The effectiveness of the current hedging strategy on future cash flows is evaluated, in part or in whole, outside of the stochastic cash-flow model.

- We choose the **explicit hedging** method because
  - Explicit hedging is easy with the right technology
  - Explicit hedging is more realistic and transparent
  - Implicit hedging is a shortcut without an agreed upon approach and process
  - Implicit hedging cannot accurately reflect the inner workings of dynamic hedging
  - Implicit hedging may require a higher error factor

Definitions: Stochastic Reserve Component

- Weighted average of the CTE 70 Best Effort and CTE 70 Adjusted quantities.
- “Best Effort” reflects actual hedging practices; “Adjusted” reflects no hedge rebalancing.
- The weight applied to the “Adjusted” run is referred to as the error factor (E).

- Stochastic Reserve Component = $(1 – E) * CTE_{70,\ Best\ Effort} + E * CTE_{70,\ Adjusted}$

- Minimum Error Factor (old): 30% for explicit hedging; 70% for implicit hedging
- Minimum Error Factor (new): 5%

→ Expect larger impact from hedging due to reduction of minimum error factor

Definitions: Stochastic Total Asset Requirement (TAR) Component

- Weighted average of the CTE X (Best Effort) and CTE X (Adjusted) quantities.
- "Best Effort" reflects actual hedging practices; "Adjusted" reflects no hedge rebalancing.
- The weight applied to the "Adjusted" run is referred to as the error factor (E).

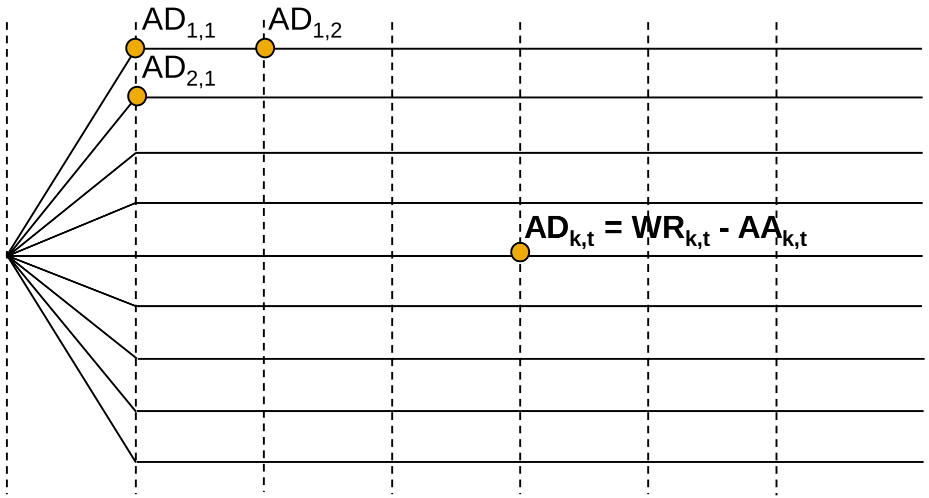
- Stochastic TAR Component = $(1 – E) * CTE_{X,\ Best\ Effort} + E * CTE_{X,\ Adjusted}$

- Minimum Error Factor: 5%
- X (old): 90
- X (new): 98

→ Due to the increase in the CTE level from 90 to 98, it requires running a larger number of scenarios.

Methodology: GPVAD Calculation

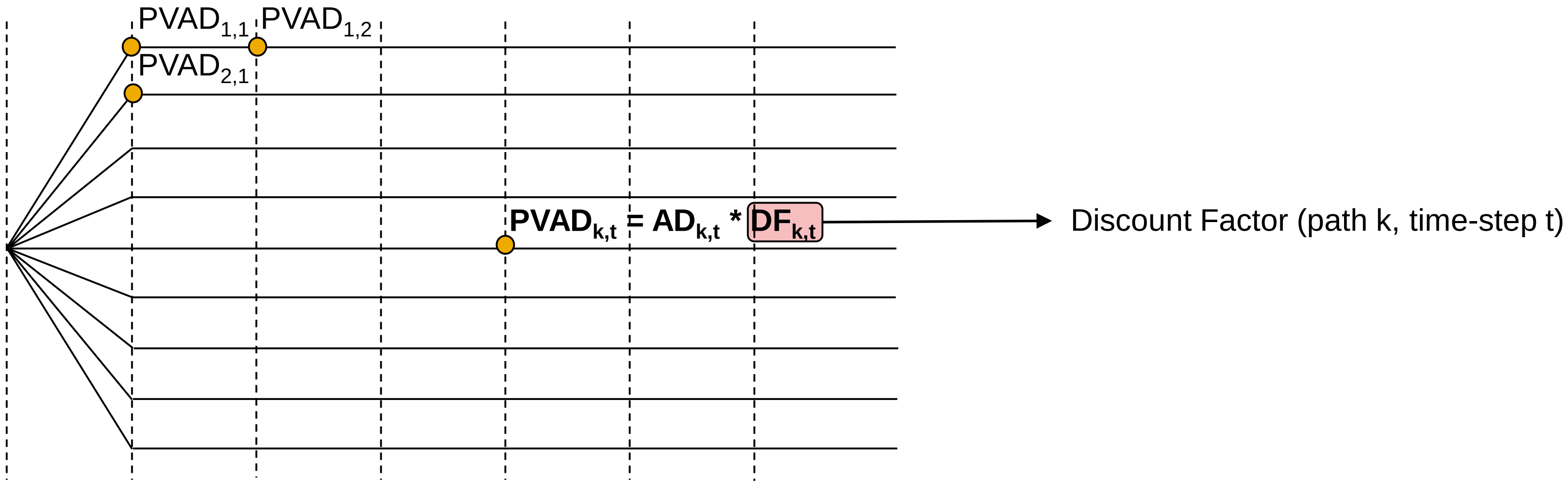
- At each point in the grid (path k, time-step t), compute the Accumulated Deficiency (AD).



	Old	New
Working Reserve ($WR_{k,t}$)	$CSV_{k,t}$	0
Accumulated Assets ($AA_{k,t}$)	$GA_{k,t}+SA_{k,t}$ + $Hedge\_Portfolio_{k,t}$	
$Hedge\_Portfolio_{k,t}$	$Cash\_Account_{k,t}$ + $Futures\_FV_{k,t}$ + $IRS\_FV_{k,t}$ - $Liability\_FV_{k,t}$	

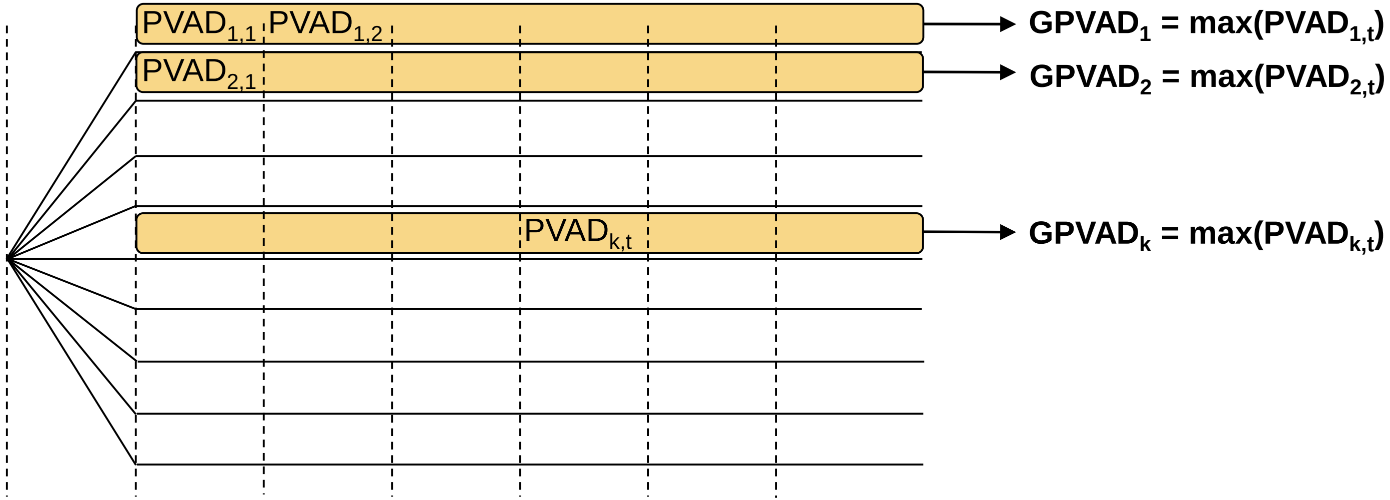
Methodology: GPVAD Calculation

- Discount each AD to the valuation date at the NAER (net asset earned rate), to determine the Present Value of Accumulated Deficiency (PVAD).

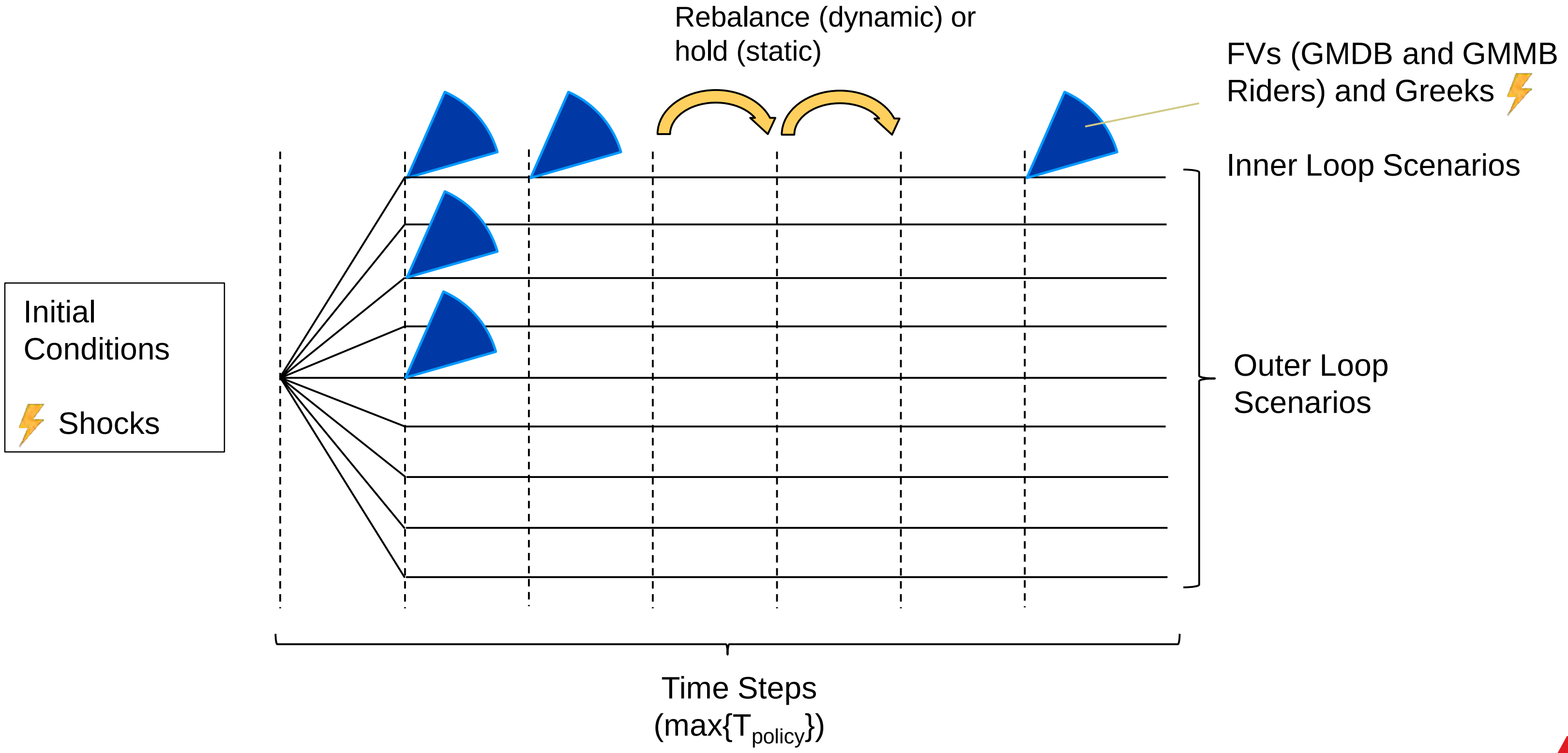


Methodology: GPVAD Calculation

- The scenario reserve is determined for each path k by computing the maximum PVAD across all time-steps t, and adding it to the starting asset amount.

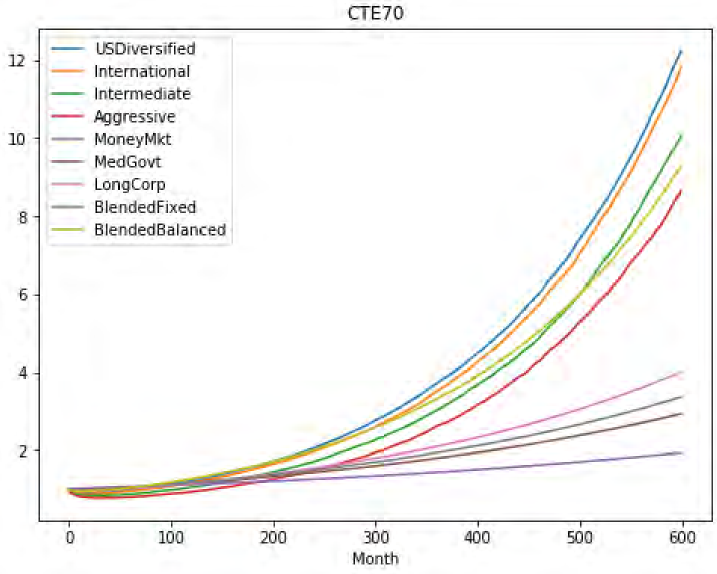


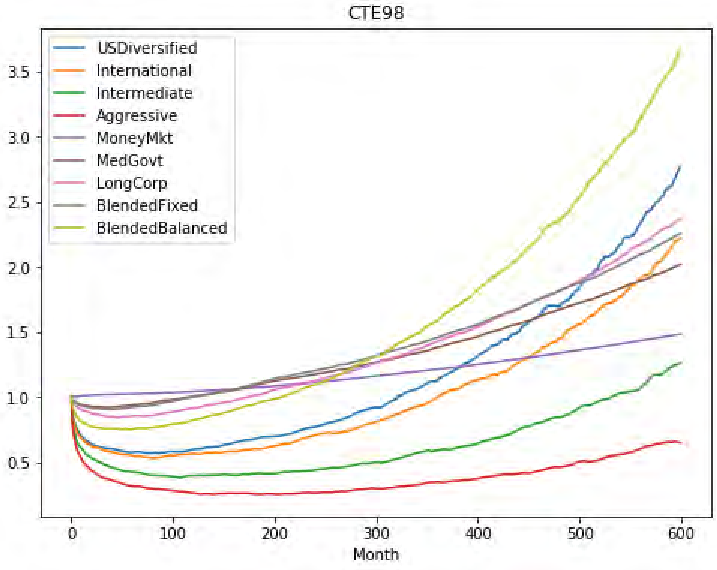
Methodology: Hedge Overlay



Methodology: Economic Scenarios

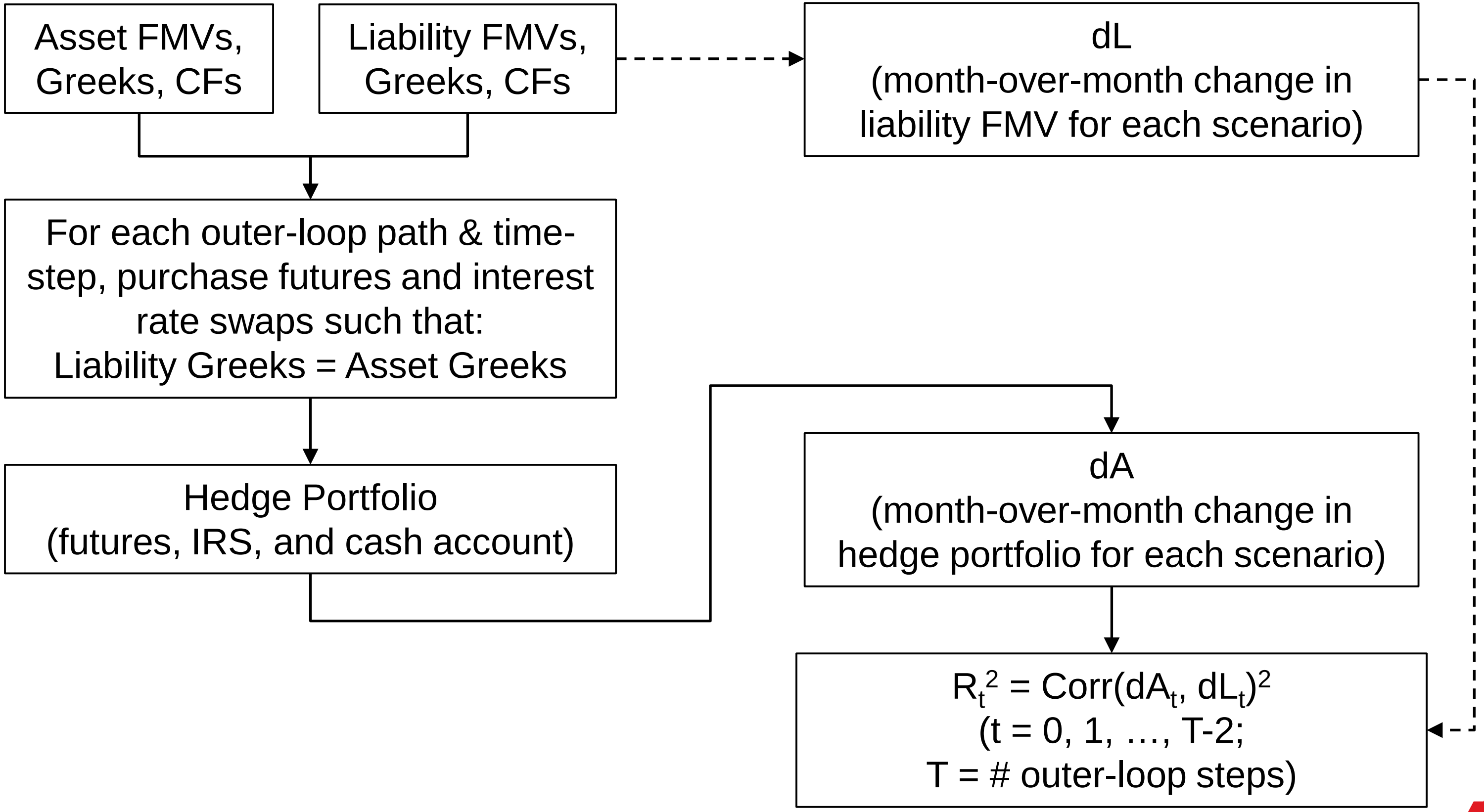
- VM-21 outer-loop uses the AAA ESG





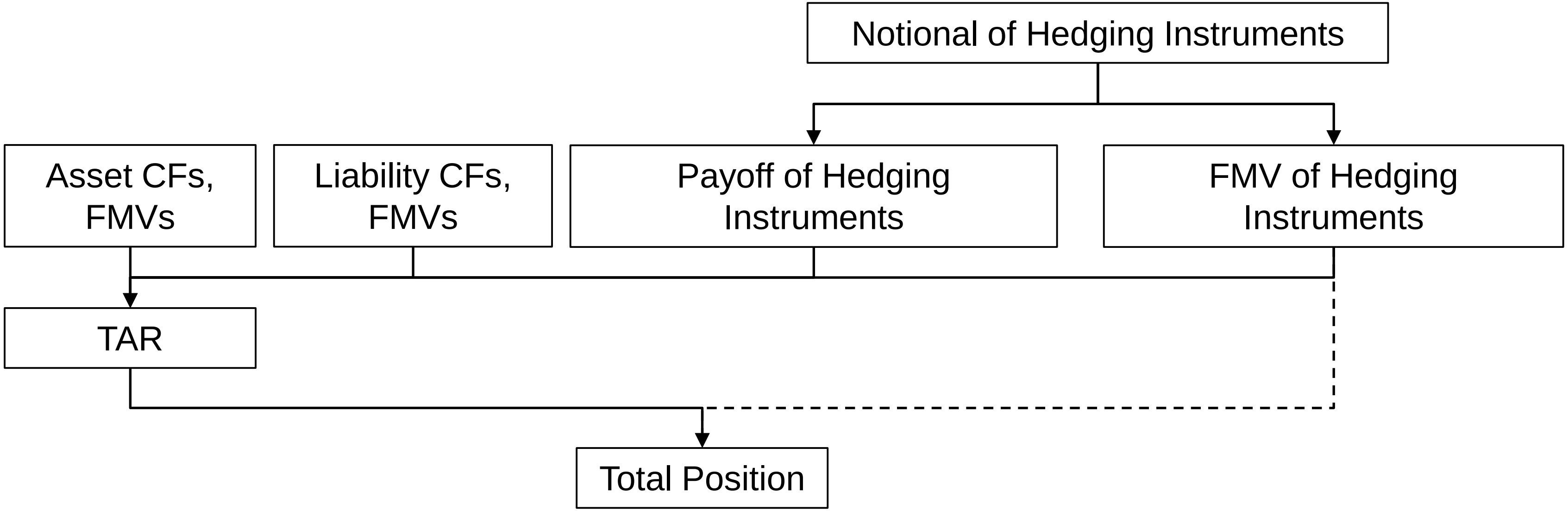
- FV inner-loop scenarios consisted of the following risk-neutral models:
  - o Interest Rate: Hull-White Two Factor (HW2F)
  - o Equity: Geometric Brownian Motion (GBM)

Methodology: Dynamic Hedging



Methodology: Macro Hedging

Macro hedging intends to stabilize capital over time. We wish to identify the notional of the hedging instruments such that the sensitivity of the Total Position is minimized.



Product and Assumptions

Consider hedging VA policies with GMDB and GMAB riders.

Product settings:

- Total Account Value (time 0): 10,000 (scaled)
- Book Guarantee Value: close to ATM
- Number of policies: 50,000
- Average policyholder age: 53

Run settings:

Parameter	Value
# outer-loop steps (monthly)	241
# outer-loop paths	5000
# of inner-loop paths	1000

Dynamic Hedging Strategy

Delta-Rho Hedging Strategy

- Delta-hedging instrument: 3-month futures
- Rho-hedging instrument: vanilla interest rate swaps
- Rebalancing frequency: monthly

Computation of Greeks

- Delta is computed for each equity index as follows:

$$\frac{FMV(AV_{+1\%}) - FMV(AV_{-1\%})}{AV_{+1\%} - AV_{-1\%}}$$

- Rho is computed for each rho bucket as follows:

$$\frac{FMV(Segment\ of\ Forward\ Curve_{+10bps}) - FMV(Segment\ of\ Forward\ Curve_{-10bps})}{20bps}$$

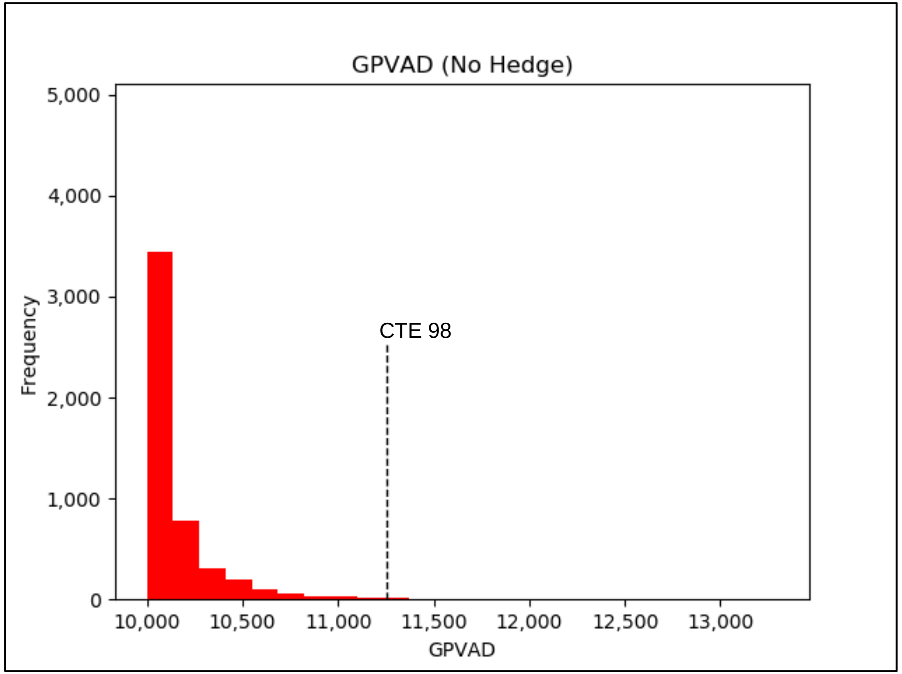
- The segment of the forward curve is dependent on the rho bucket.

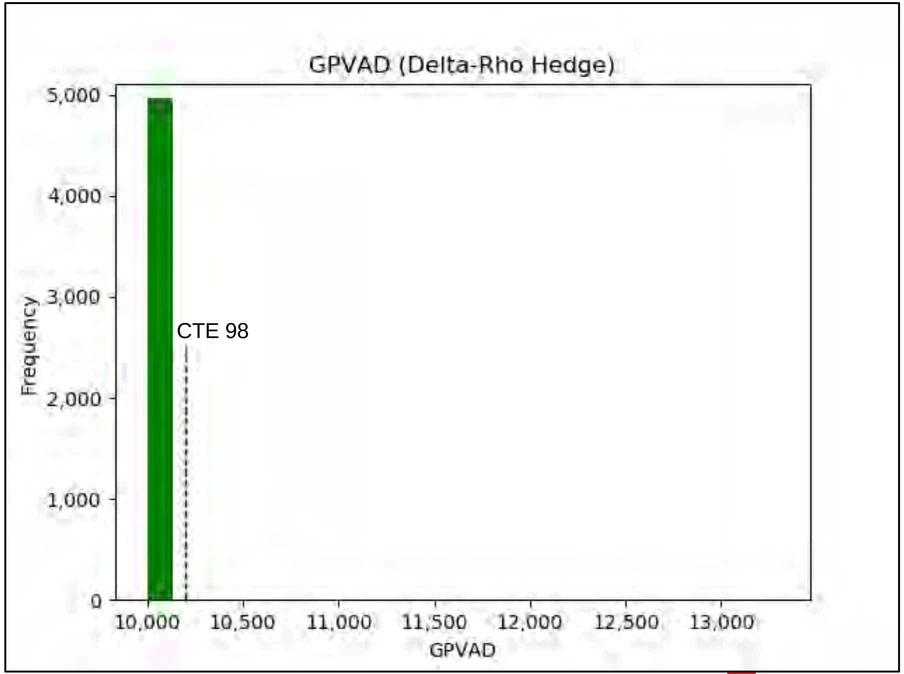
Dynamic Hedging Strategy: CDHS Checklist

Item	Description
Specific risks being hedged	Delta, Rho
Hedge objectives	Hedge the economic value of the underlying liability
Risks not being hedged	Mortality, withdrawal, etc.
Hedging instruments	3-month futures, IRS
Trading rules	Dynamic hedging (5% risk limit for rebalancing)
Measure of hedging effectiveness	R^2
Frequency of measuring hedging effectiveness	Monthly
Conditions under which hedging will not take place	N/A

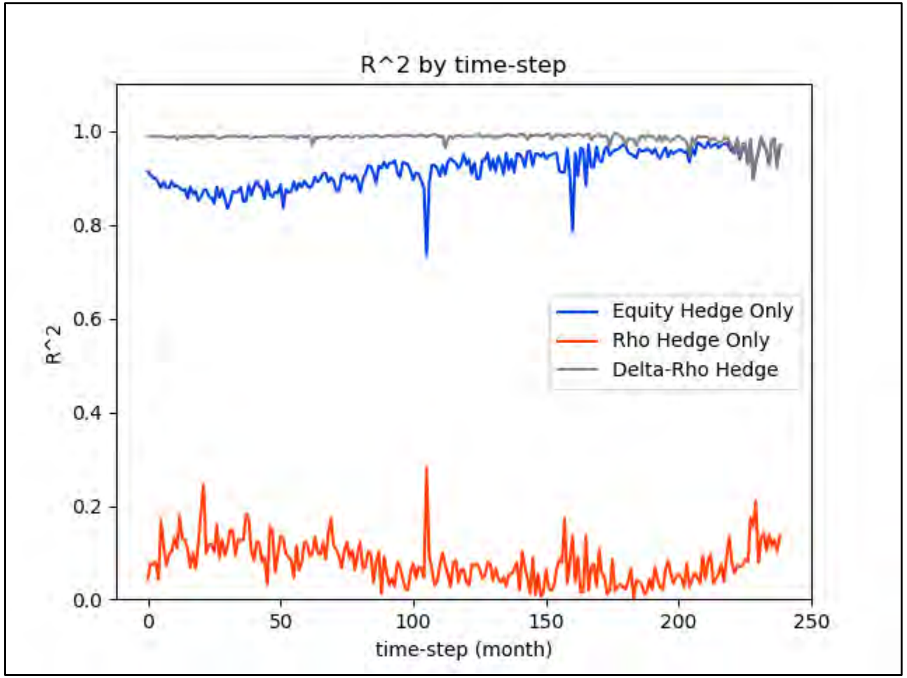
Dynamic Hedging: GPVAD Distribution

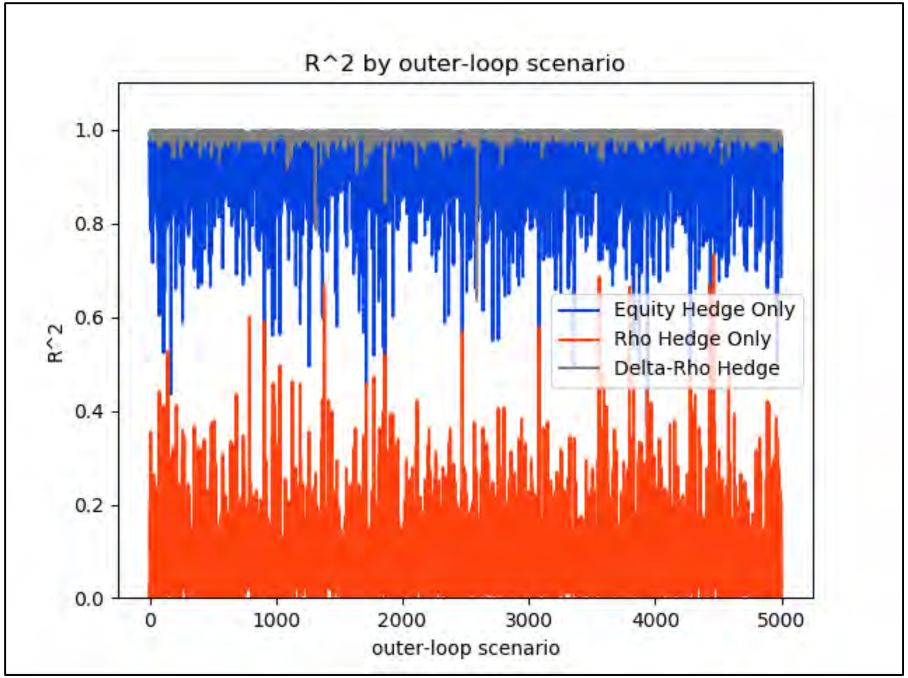
Distributions under the new framework:





Dynamic Hedging: Hedging Effectiveness





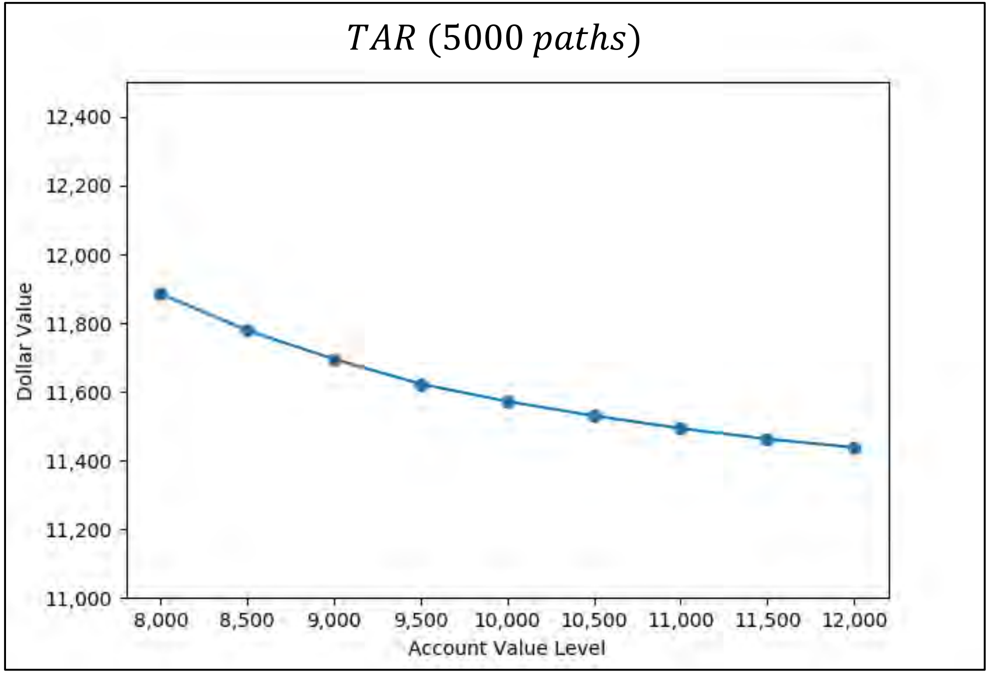
Macro Hedging Strategy: CDHS Checklist

Item	Description
Specific risks being hedged	Delta of TAR
Hedge objectives	Minimize Net Delta to maintain stability of Total Position
Risks not being hedged	Rho, mortality, withdrawal
Hedging instruments	Put options
Trading rules	Static hedge (i.e. no rebalancing)
Measure of hedging effectiveness	Average change in Total Position over 1-year horizon
Frequency of measuring hedging effectiveness	Annually (as it is a static hedge)
Conditions under which hedging will not take place	N/A

Macro Hedging: TAR Sensitivity

- Firstly, we observe how the TAR varies with the account value. In this case, no options are reflected in the calculation of the TAR.

- In this plot the TAR value is calculated at different Account Value Levels, the base case is an Account Value Level of 10,000.



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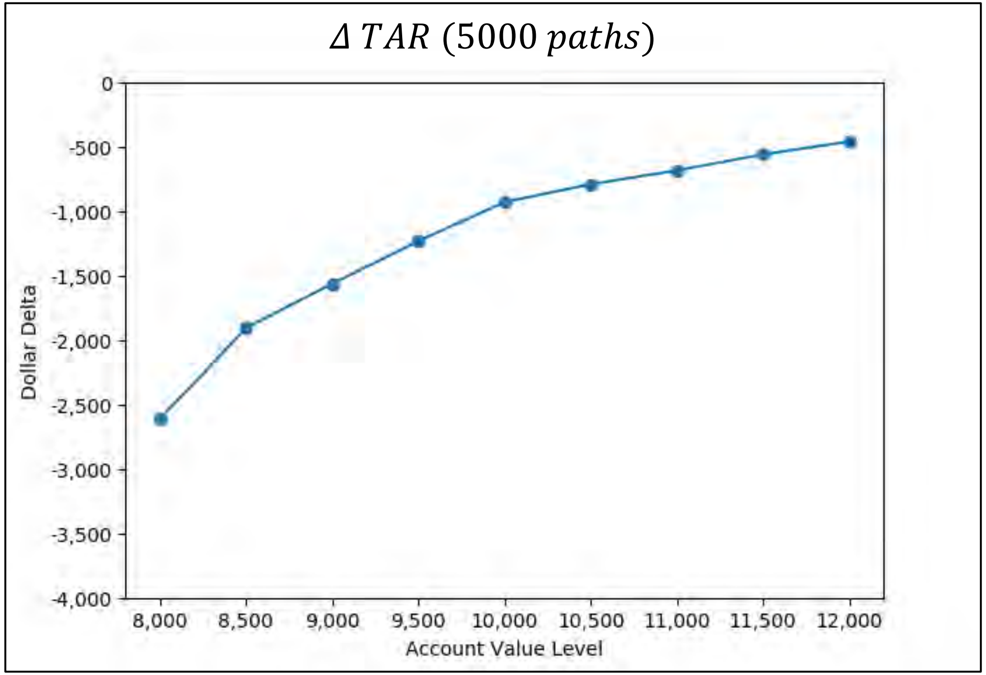
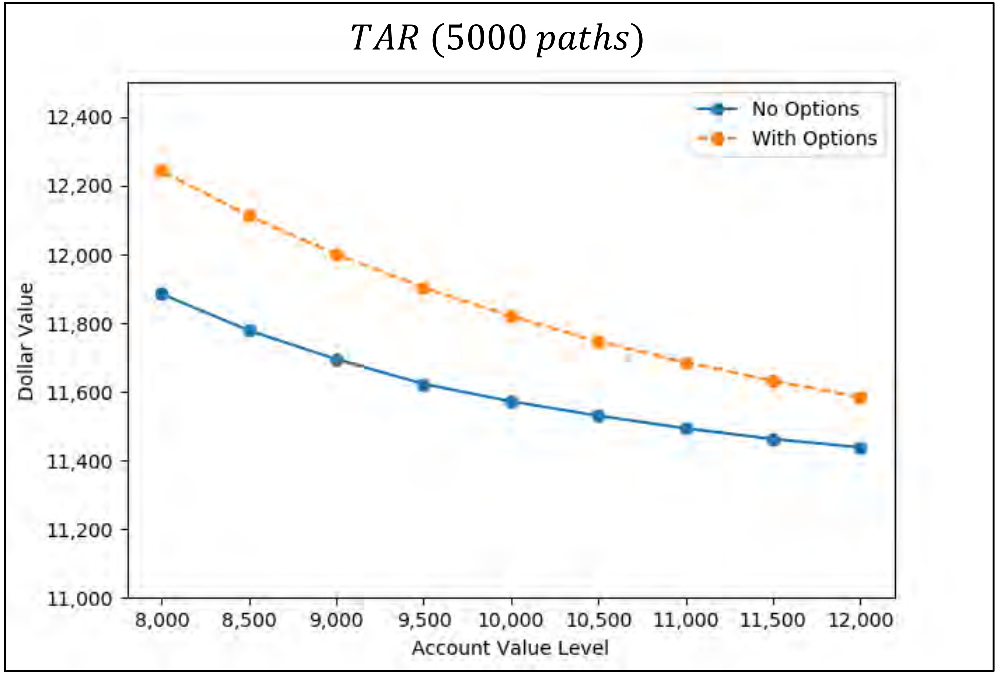
Macro Hedging: Sensitivity of TAR Delta

- Next, we observe how the Delta of the TAR varies with the account value.
- Dollar Delta is computed as: $\frac{TAR(AV_{+5\%}) - TAR(AV_{-5\%})}{AV_{+5\%} - AV_{-5\%}} * AV_{+0\%}$
- Dollar Delta is computed at each point in the plot.
- It is important to note that the shock size, in our case +/-5%, impacts the stability of the Dollar Delta.
- As the TAR is a CTE measure, as opposed to an FMV measure, larger shocks provide more stable plots of Dollar Delta.
- Note as the Account Value Level increases, the TAR Delta increases.



Macro Hedging: Include Put Options in GPVAD

- This plot depicts how the TAR value varies with the account value (including 1 long 20-year ATM-Spot put option).
- We have purchased a put option at time zero, at different account values, with a strike price set at 10,000.
- Note how the TAR value increased across all Account Value Levels by incorporating the option.



Macro Hedging: GPVAD Cashflow Sensitivities

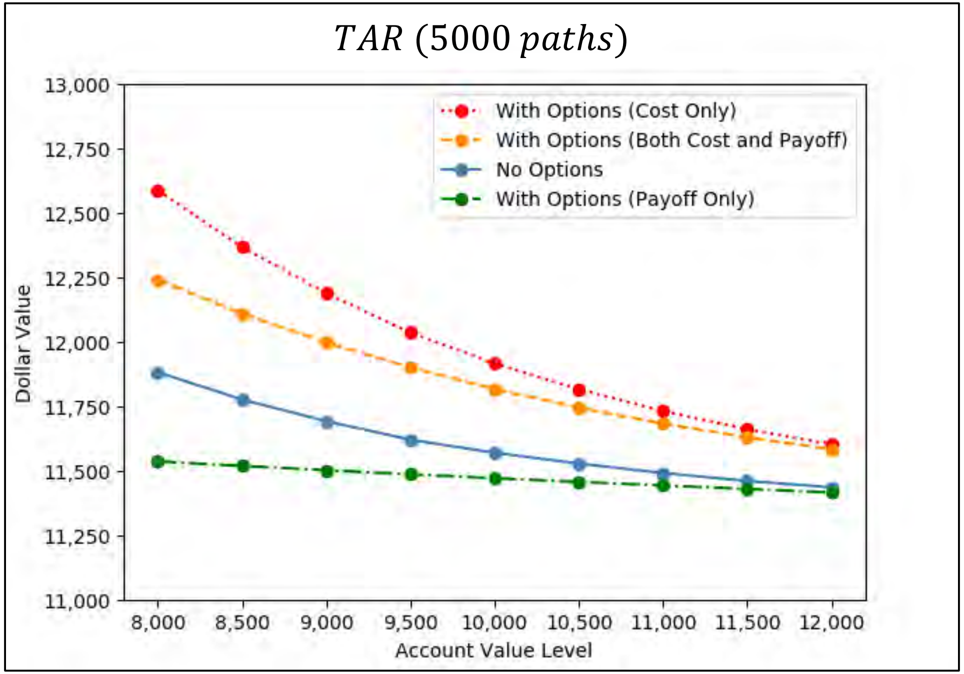
- Next, we examine how the TAR varies with the account value, including buying 1 long 20-year ATM-Spot put option, at different account value levels.

- The plot illustrates that the cost of the option has a larger impact than the payoff.

- The cost occurs at time 0 and is not scenario-dependent.

- As the cost of the option increases the AD, and consequently the GPVAD, the TAR increases in magnitude.

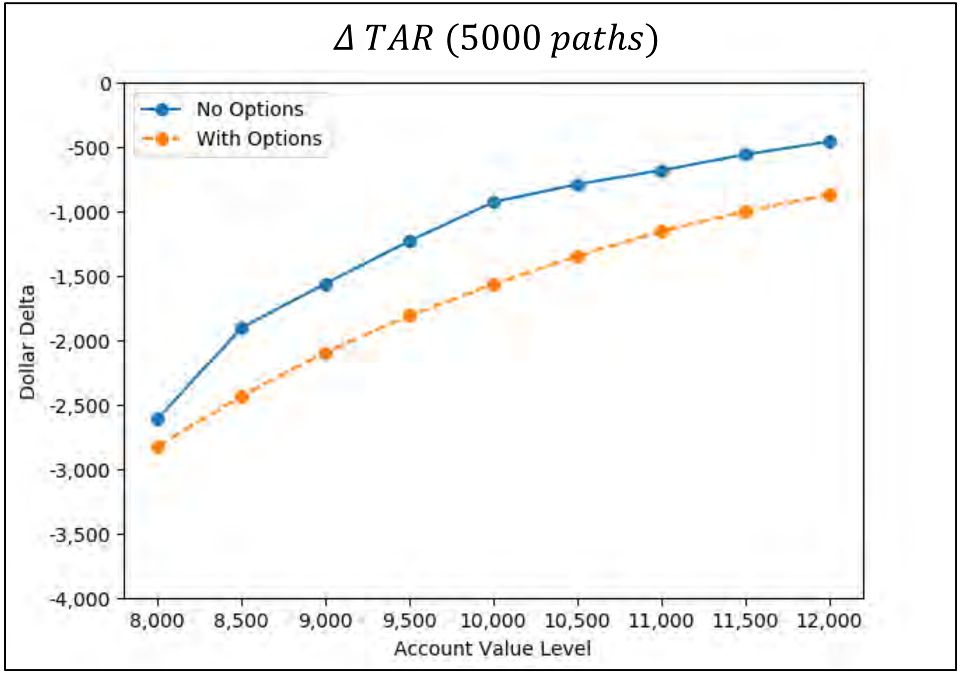
- In contrast, as the payoff of the option decreases the AD, and consequently the GPVAD, the TAR decreases in magnitude.



Macro Hedging: Sensitivity of TAR Delta with Options

- This plot depicts how the TAR Delta varies with the account value (including 1 long 20-year ATM-Spot put option).

- Note how the TAR Delta decreased across all Account Value Levels by incorporating the option.



Macro Hedging: Net Delta

- Next, we try different notional values of 20-year ATM-Spot put options and observe how the Net Delta behaves. The Net Delta is computed as the difference between the TAR Delta and the Option Delta.

- We wish to identify the notional for which the Net Delta is close to zero. A Net Delta of zero means that changes in the TAR are effectively offset by changes in the option position.

Notional (% of AV)	TAR Delta	Option Delta	Net Delta
0	-923	0	-923
25	-890	-316	-573
50	-947	-633	-314
75	-1245	-949	-295
100	-1,561	-1,266	-295

Macro Hedging: Net Delta

- As the notional increases, the magnitude of the Net Delta initially decreases and then remains level.
- Notional values of 75% and 100% minimize the magnitude of the Net Delta.
- The optimal strategy is to use a 75% notional value as it has a lower option cost as compared to the 100% notional value.

Hedge Projection: Base Case

- Next, we analyze the stability of the Total Position over a 1-year horizon.
- Specifically, we wish to see the difference between the Total Position at time 0 and time 1.
- We define the Total Position to be: TAR – Option Value.
- Firstly, let’s examine the case with no options.

TAR (T0)	Total Position (T0)		TAR (T1)*	Total Position (T1)*		Difference in Total Position*
11,572	11,572		11,867	11,867		295

** Quantities at time 1 represent an average across 100 scenarios.*

Hedge Projection: Macro Hedging

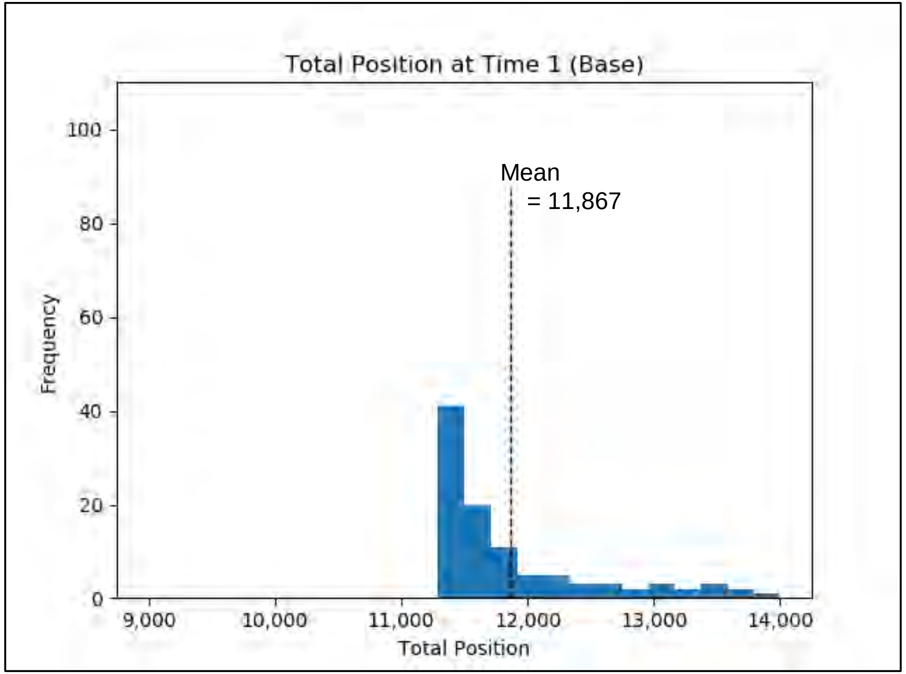
- Now, let's compare the analysis with no options and with options.
- Macro hedge case includes 1 long 20-year ATM-Spot put option with a 75% notional.

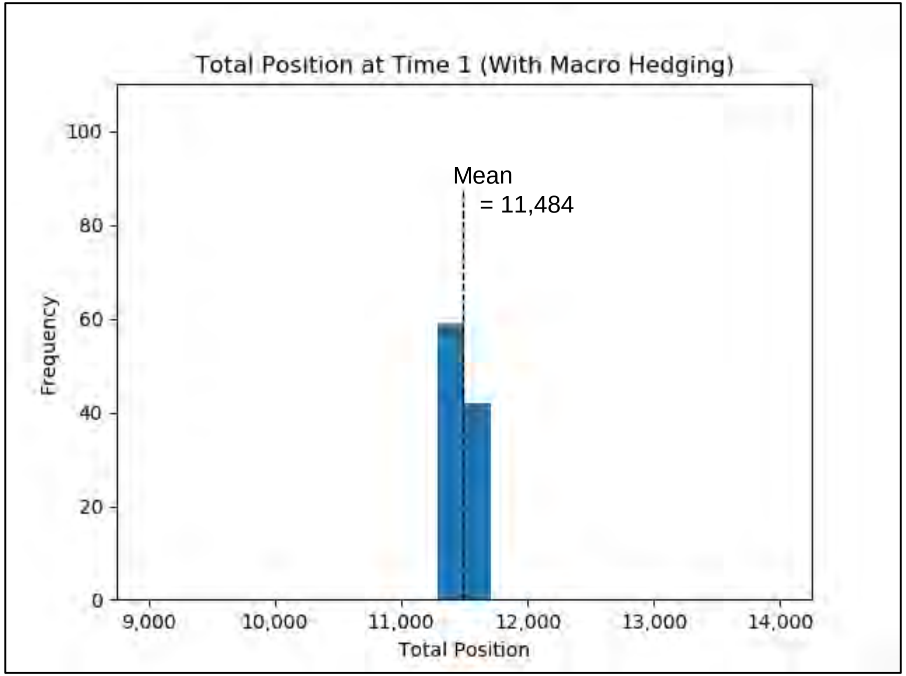
Macro Hedge	TAR (T0)	Total Position (T0)		TAR (T1)*	Total Position (T1)*		Difference in Total Position*
No	11,572	11,572		11,867	11,867		295
Yes	11,733	11,473		11,898	11,484		10

- Incorporating options reduces the "Difference in Total Position" from 295 to 10.
- Therefore, the incorporation of options improves the stability of the Total Position over a 1-year horizon in this situation.

Hedge Projection: Macro Hedging

- Effect of macro hedging:





Hedge Projection: Dynamic Hedging

- Next, let's incorporate dynamic hedging as well:

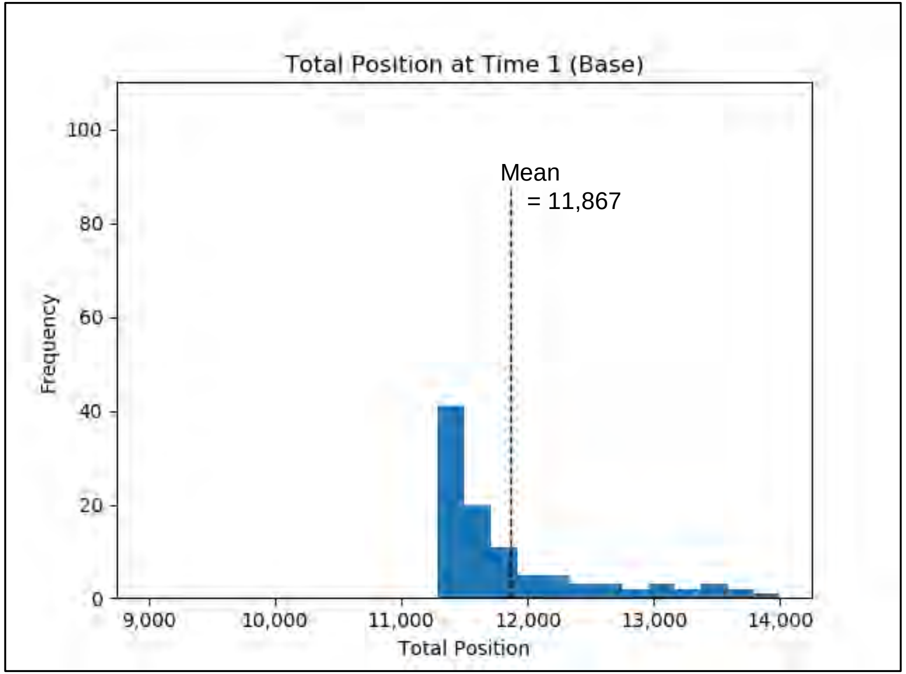
Dynamic Hedge	Macro Hedge	TAR (T0)	Total Position (T0)		TAR (T1)*	Total Position (T1)*		Difference in Total Position*
No	No	11,572	11,572		11,867	11,867		295
Yes	No	10,221	10,221		10,537	10,537		315
Yes	Yes	10,263	10,004		10,399	9,985		-18

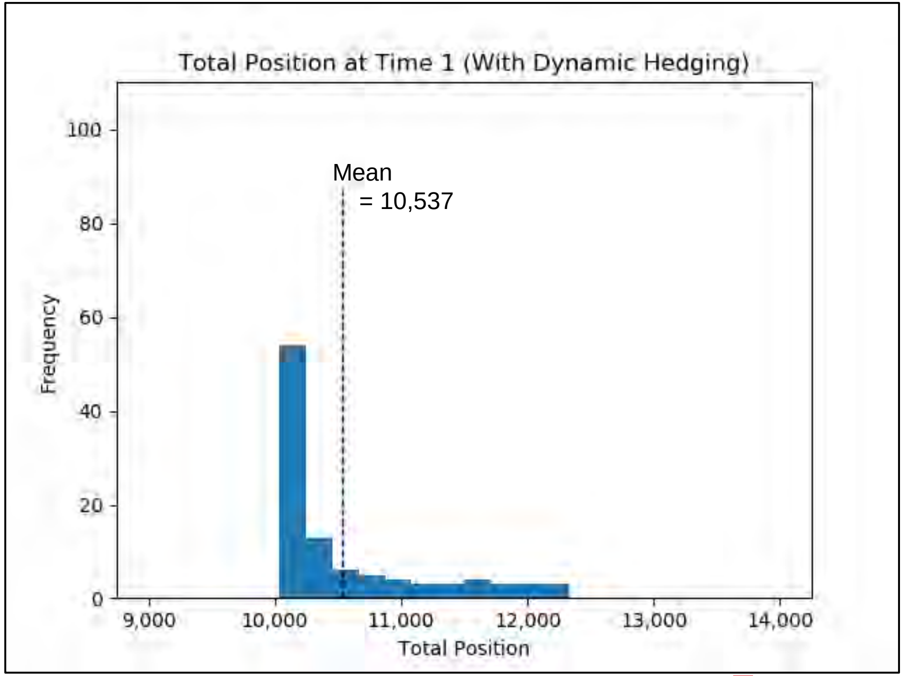
- We experience a similar reduction in the "Difference in Total Position" without and with dynamic hedging (295 and 315 without macro hedging; 10 and -18 with macro hedging).

- However, dynamic hedging lowers the TAR in this setting.

Hedge Projection: Dynamic Hedging

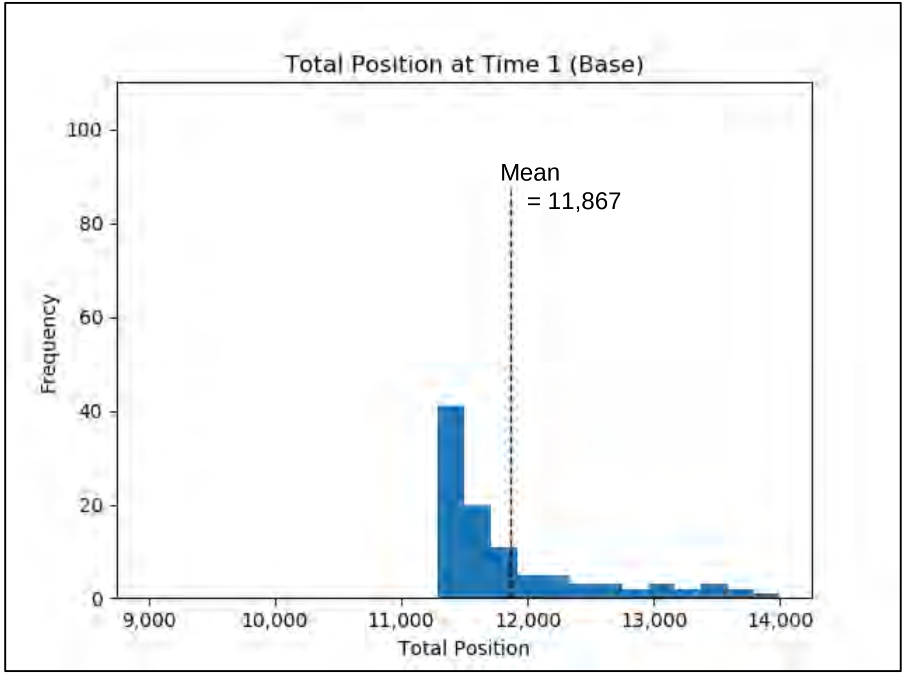
- Effect of dynamic hedging:

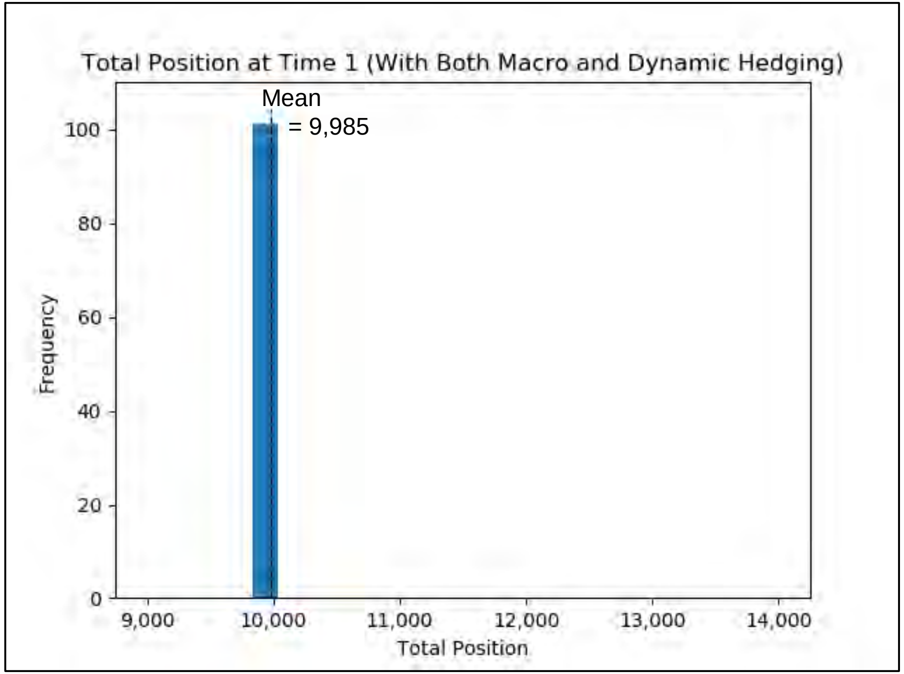




Hedge Projection: Combined

- Combined effect of macro hedging and dynamic hedging:





Summary

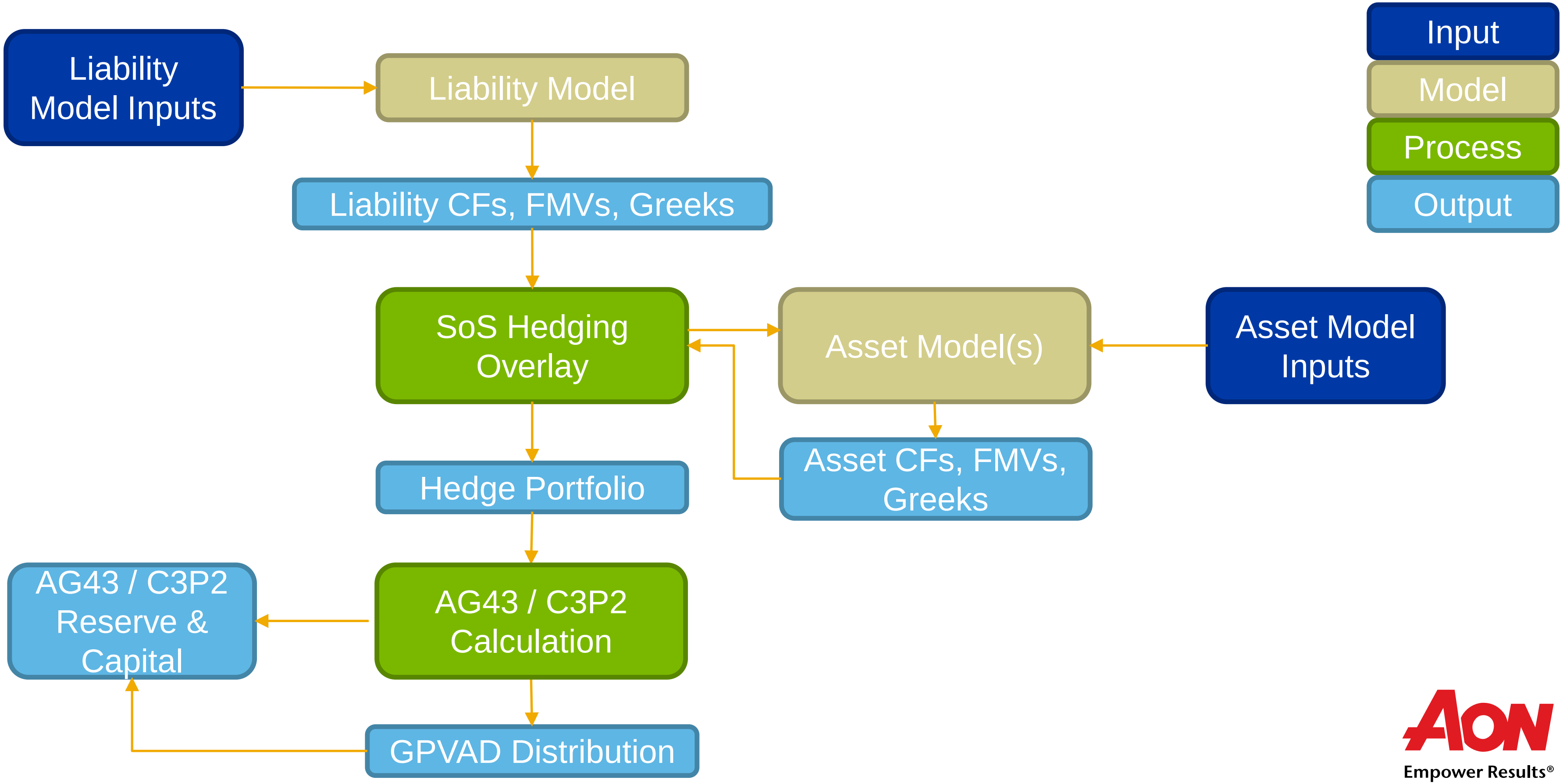
- Summary of strategies:

Dynamic Hedge	Macro Hedge	TAR (T0)	Total Position (T0)		TAR (T1)*	Total Position (T1)*		Difference in Total Position*
No	No	11,572	11,572		11,867	11,867		295
No	Yes	11,733	11,473		11,898	11,484		10
Yes	No	10,221	10,221		10,537	10,537		315
Yes	Yes	10,263	10,004		10,399	9,985		-18

- Based on this lab exercise, the optimal strategy is a combination of macro hedging and dynamic hedging. Dynamic hedging lowers the TAR, while macro hedging stabilizes the Total Position.

Agenda

Process Workflow



Challenges – Simulation

- CDHS requires SoS simulation as the Greeks need to be computed for each (path k, time-step t) combination.

- **Challenge**: SoS simulation is computationally and memory intensive.

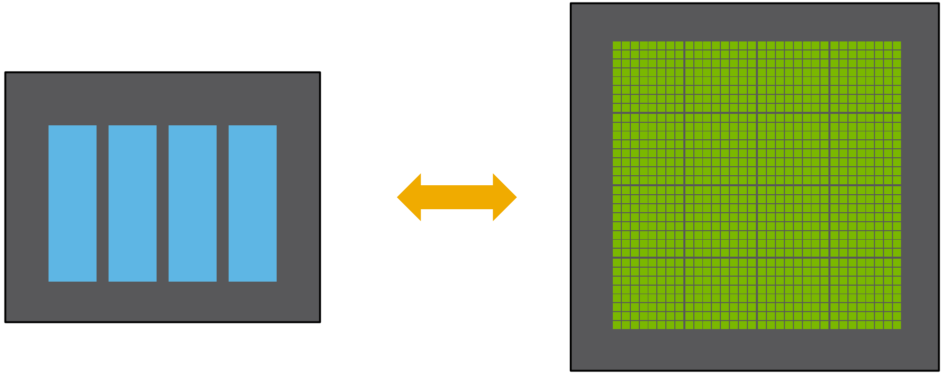
- Need to ensure current system can support the computational and memory requirements needed for SoS simulation if considering CDHS.

Total # of scenarios	**5,138,550,000,000**
# of policies	9,000
# outer-loop steps (monthly)	601
# outer-loop paths	1000
# of sensitivities	19
# of inner-loop paths (varying seed for each policy)	50

- Leveraging modern GPU (Tesla V100) and smart middleware, the above calculations can be completed in approximately 6 hours.

Calculation Efficiency

- Parallelism and GPU (Graphics Processing Unit)
- GPUs are designed to handle massively parallel tasks such as processing millions of insurance policies or thousands of scenarios



CPU
Several complex cores

GPU
Thousands of simpler cores

GPUs

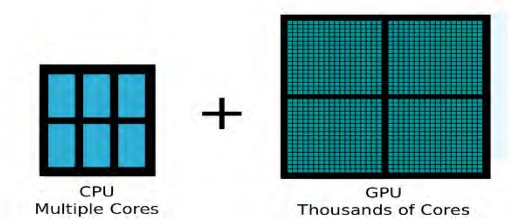
- GPU (Graphical Processing Unit) started in 1999, with the launch of GeForce 256, as an add in card used for 3d rendering in video games, which has now grown in 2017 to a $109B a year industry with over 600M users*

- Today GPUs are used in fields as diverse as artificial intelligence, machine learning, autonomous vehicles, oil exploration, image processing, statistics, algebra, 3D reconstruction, medical imaging, finance, etc

- Many processes that previously took days to be completed serially now can be done in minutes or seconds using GPUs because all the jobs can be done in **parallel.**

- CPUs (Central Processing Unit) are optimized for sequential tasks
- GPUs are optimized for compute intensive parallelizable (e.g. Monte Carlo simulation) tasks

- Mythbusters' Youtube video—GPU vs CPU
- https://www.youtube.com/watch?v=-P28LKWTzrI

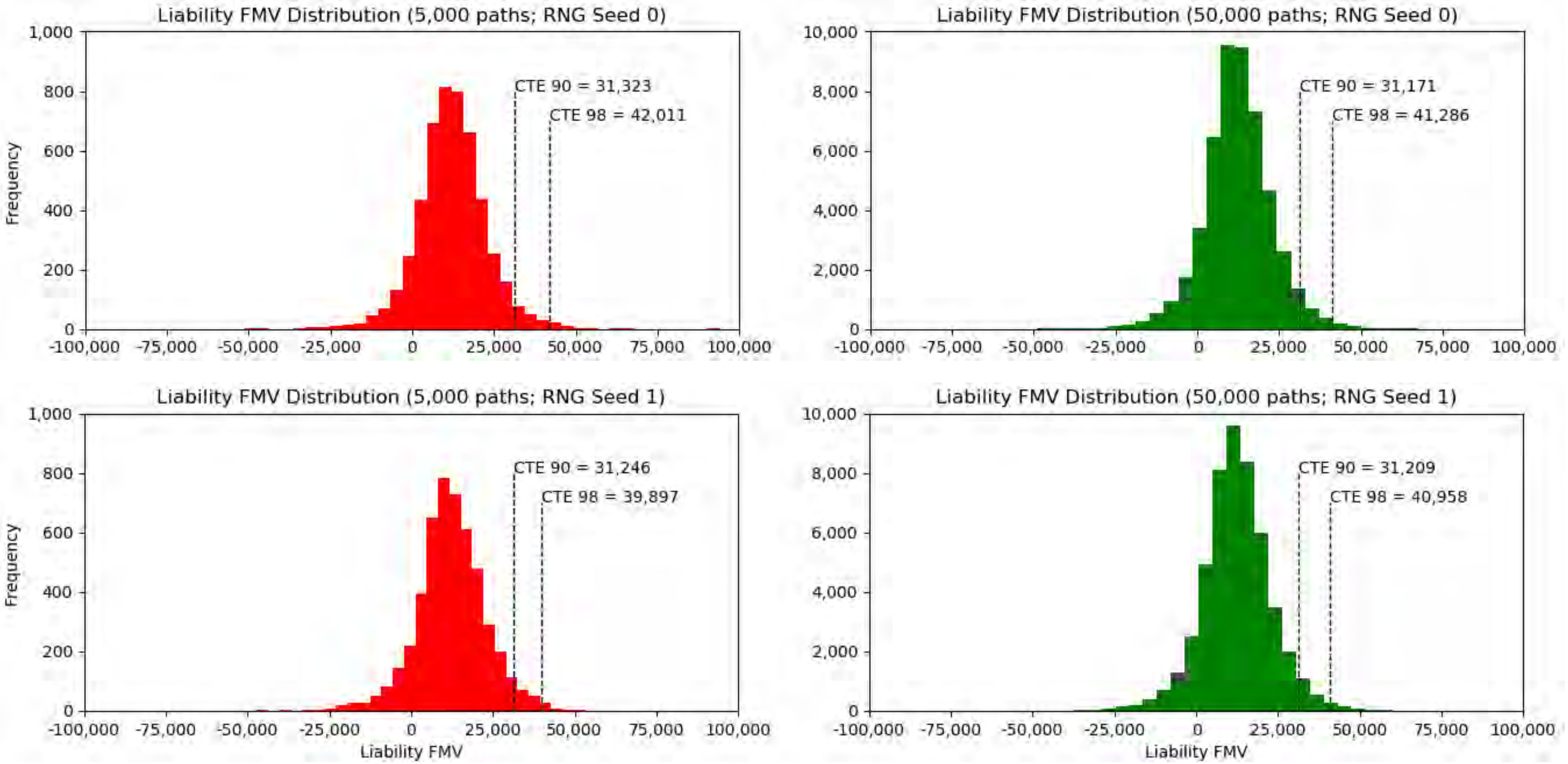


Challenges – Scenario Generation

- CTE level increase from 90 to 98 for the TAR.
- **Challenge**: Require running larger number of scenarios which will increase computation time and memory usage.
- Assuming N outer-loop scenarios, 0.1*N scenarios will be used in the computation of CTE 90, in contrast to 0.02*N scenarios for CTE 98.
- Therefore, to achieve the same level of accuracy, N needs to be increased by a factor of 5 when computing CTE 98 as opposed to CTE 90.
- Need to investigate if current system and associated processes can accommodate a 5X increase in the number of scenarios.

Example: CTEs Accuracy

- CTE98 sampling error is reduced from 5% to 0.8% when #scenarios increases from 5,000 to 50,000.



Challenge – Withdrawal Delay Cohort Method

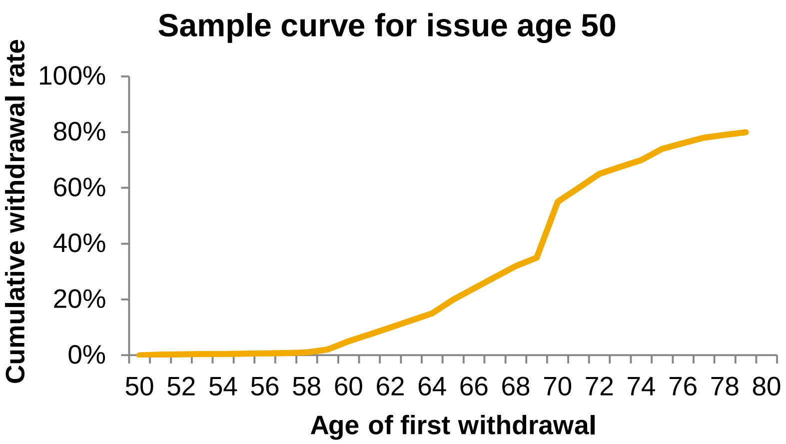
Standard Scenario - Withdrawal Delay Cohort Method

- Separate inforce by rider type, issue age, tax status
- For each group, construct cumulative withdrawal curve as of the issue year.
- Split the contract into several copies (cohorts), each of which has a different initial withdrawal period.
- Calculate weighted average of the cash flows from the cohorts
- At subsequent valuation date:

❑ For policies that begin withdrawals, it is modeled to continue withdrawing.

❑ For policies that remain non-withdrawing, adjust the cumulative withdrawal rate. For instance, a policy with issue age 50, at age 64 the remaining cohorts are scaled as:

$$F'(x) = \frac{F(x) - F(64)}{1 - F(64)}$$



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Challenge – Withdrawal Delay Cohort Method

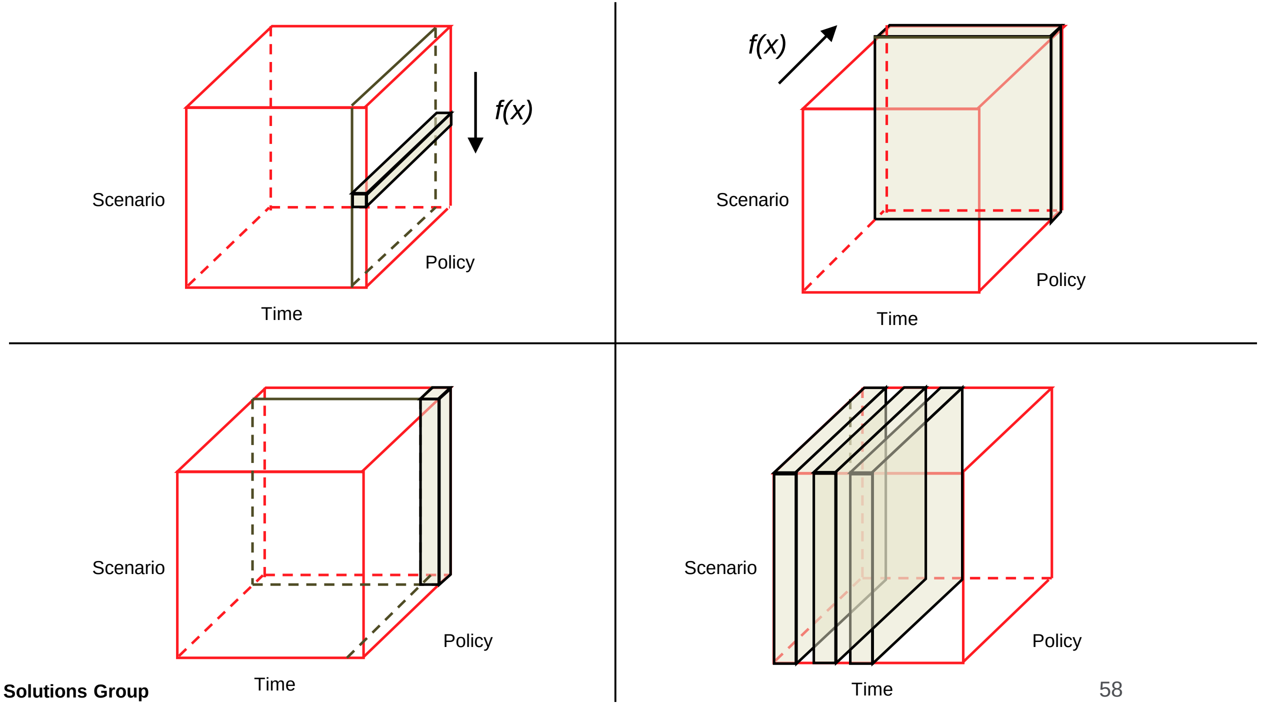
Standard Scenario - Withdrawal Delay Cohort Method

- CTEPA may be a preferred option over CSMP.
- CTEPA uses same scenarios as CTE Amount so it provides an intuitive comparison between company prudent and prescribed assumptions.
- CTEPA requires calculation under at least 1000 scenarios with withdrawal delay cohort method.
- GPUs are designed to handle massively parallel tasks such as processing millions of insurance policies or thousands of scenarios.

# of policies	1,000,000	1,000,000					1,000,000 x 5 cohorts	1,000,000 x 31 cohorts
Precision	Double	Single					Single	Single
# paths from VM20 ESG	1000	1000					1000	1000
# of GPUs	8	8					8	8
Run Time (hours)	1.87	0.46					2.3	14.26
Inforce Size	0.33G	0.2G					1G	6.2G
Age of first withdrawal	70	60	65	70	75	never	varies	varies
Std Scenario Amount	1,435,951	1,290,803	1,350,700	1,435,937	1,522,140	1,595,550	1,450,934	1,453,818

Example: Calculation Result (Hyper-)Cube

- Large-scale computations often result in big datasets with 3 or more dimensions (e.g. policies, steps, scenarios, sensitivities). Outputting the entire dataset incurs excessive memory and disk overhead.
- Alternatively, the system could produce "views" of the data on demand if re-calculation is fast.



Challenges - CDHS

- Back-testing disclosure for CDHS justification required over the past 12 to 36 months.

- **Challenge**: need to generate high quality performance attribution reports on a frequent basis.

- Performance attribution reports need to provide comprehensive analysis between actual and expected hedging performance.

- Conducting this analysis on a frequent basis will require dedicated resources. Alternatively, automated processes could be put in place to periodically generate the required reports.

- Need to determine availability of resources and/or feasibility of process automation to fulfill CDHS disclosure requirements.

Data Warehousing

- Data Warehouse
  - ✓ Integrated enterprise data warehousing solutions without the need for other 3rd party solutions
  - ✓ Only visible and accessible by authorized users/groups/departments
  - ✓ Wider range of data sources supported, including, but not limited to SQL database, Excel spreadsheets, flat files and XML
  - ✓ Data organized by topics, process date with clear audit trails

- Automation
  - ✓ Automation of the complete end-to-end process
  - ✓ Flexible triggers (time, file arrival, etc.)
  - ✓ Full logs and journals
  - ✓ Conditional execution of jobs and error handling

Conclusions

- Closer alignment with economic hedging.
- Benefit companies with robust hedging programs, give more incentive for hedging.
- Bringing together hedging, valuation, pricing and other departments.
- Integration can be more challenging than implementing the changes.

Thank You!

Questions?