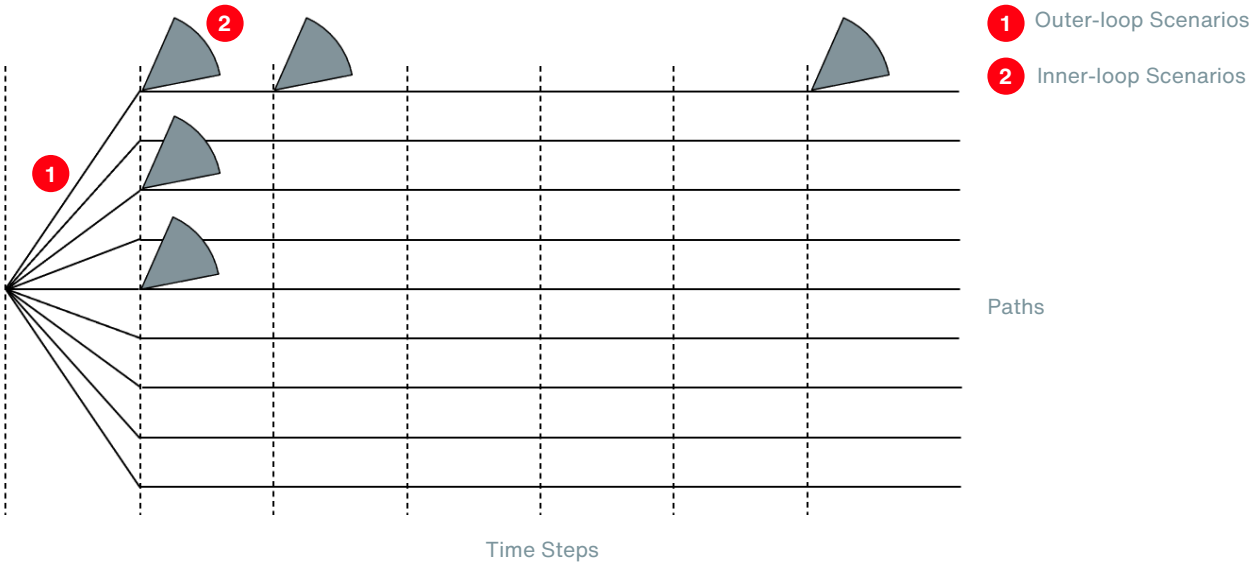
PATHWISE

Stochastic-on-Stochastic Simulation

As equity-linked products become more popular and their risk management becomes critical, the need for stochastic-on-stochastic (SoS) simulation in several areas has become more important. A SoS simulation involves two steps: an outer-loop projection and an inner-loop projection. The outer-loops are often used to project the real-world economic scenarios over time, while the inner-loops are used to value interest rate sensitive products with other values of interest – such as Greeks – at each outer-loop scenario timestep.

Illustration of the SoS simulation



SoS simulations have shown to be extremely useful in the following four areas:

Hedging | Valuation | Pricing | Business Planning

Hedging

Dynamic hedging: nested SoS simulations can be used to assess the hedging efficiency, cost, and profit and loss impacts for different hedging strategies and frequencies.

Macro-hedging: since the establishment of the VM-21 regulation, major US variable annuities writers have implemented macro-hedging programs, whose goal is to hedge Total Asset Requirement (TAR) instead of economic values. In this context, nested SoS simulations can be used to predict the future TAR and earnings movements to find the optimal macro-asset allocation.

Valuation

Capital relief: once the dynamic hedging strategy is developed, the SoS simulation is used to predict the profit and loss distribution, to calculate the hedged capital, and to obtain hedging credits from regulatory bodies. For example, under the Quebec capital adequacy guideline, only an insurance company that has a well-defined dynamic-hedging strategy is allowed to obtain significant capital relief.

xVA: the calculation of X-valuation adjustments (XVA) in counterparty credit risk is computationally intensive because of the number of trade valuations needed, typically proportional to several factors such as the size of the portfolio, the number of future exposure dates, the number of simulation paths needed to obtain a certain level of accuracy, the number of sensitivities needed to hedge the risk, and the high dimensionality of the risk factor space due to the joint modelling of a multitude of risk factors. SoS simulation is used to fulfill these requirements.

Prepayment options: prepayment is usually priced as an American call option on a defaultable debt owned by the borrower. Modeling of prepayment options in mortgage portfolios is important since prepayments truncate the timing and amount of expected cash flows. The SoS simulation is typically used for the valuation of these options and the hedging of these portfolios thereafter.

Pricing

Profit margin calculation: SoS simulation is frequently needed to calculate the profit margin for an insurance product over time. Here, the outer loops are used to project real-world cashflows to the end of policyholder lifetime. Two important cash flows include the change of reserve and cost of capital, which are obtained from inner loop simulations at each time step across all outer loops.

The SunLife pricing team utilized PathWise to develop a fast and transparent pricing process with nested simulation. A Co-Presentation with SunLife was presented in 2020 SOA Annuity Symposium.

Business planning

Own Risk and Solvency Assessment (ORSA): Solvency II requires insurance companies to perform ORSA at least once a year in order for insurers to assess their business strategies, the associated risk profile and the solvency position for the coming years. Recovery plans are often part of this exercise. Doing so requires a quantification of the impact of several scenarios (deterministic outer-loop) on the financial position (stochastic inner-loop for the market consistent valuation for each reporting period).

Asset Liability Management (ALM): this involves determining the efficient frontier in order to optimize the risk-return profile of the asset portfolio given the risk characteristics of the liability portfolio over time of the insurance company. Non-linear and linear restrictions are imposed on the optimization problem. For pension liabilities benefits indexation, asset re-balancing and embedded options are part of the ALM framework, which requires a nested simulation approach. PathWise has a build-in library for ALM.

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Bottlenecks and challenges with SoS simulations

Though widely applicable, the long compute times required by legacy systems have always been a bottleneck when the nested simulation is implemented in practice. Due to the stochastic-on-stochastic nature of the algorithm, the number of projections can quickly grow in magnitude. For instance, suppose a nested simulation algorithm is used to project the total quarterly FMVs of a VA portfolio containing 100,000 policies for the next 10 years with 1,000 outer-loops and 1,000 inner-loops. The total number of required projections is:

$$4 \times 100{,}000 \times 1{,}000 \times 1{,}000 \times 10 = 4 \times 10^{12}$$

With a legacy computing system that can process 10^7 projections per second, this calculation alone will take around five days. The long compute time not only slows down the valuation process but also brings in additional operational risks to the business, such as system failures.

Due to the aforementioned challenges, short-cut techniques such as inforce compression and scenario clustering have always been a necessary component in the algorithm. However, these short-cut techniques lack theoretical justification, hence their performance and quality of results cannot be guaranteed for all cases, resulting in potentially large approximation errors that are difficult to explain in the financial statement figures.

Parallel computing is an alternative to the short-cut methods to speed-up the simulations. However, there are some practical barriers that usually stop insurers from adopting modern computing platforms such as Graphics Processing Units (GPUs), which are best-suited for such calculations:

- The development of the complex parallel GPU-enabled code such as CUDA, can be challenging to maintain.
- Model ownership, controllability, vendor legacy technology lock-in due to the lack of transparency in third-party software.
- Lower than expected computing performance due to inefficient IT infrastructure, such as separated computing systems and input/output (I/O) inefficiencies.

Leveraging PathWise for the SoS simulation

Some of the advantages of adopting PathWise for your SoS calculations include:

- PathWise offers a fully transparent, intuitive, spreadsheet-like application (PathWise Modeling Studio), in which the cashflow valuation logic is implemented.
- No CUDA or C++ code development is required. The PathWise Modeling Studio has built-in GPU logic generation to execute the valuation logic on high performance computing (HPC) hardware in the cloud.
- Customers can secure the ownership of the model so that the valuation logic is not disclosed.
- Job scheduling, intelligent automation, customized middleware technology.
- Controllability and trackability are ensured through the transparency of PathWise.
- Adaptive GPU resource allocation to minimize operational risks such as system outage.
- Specialized GPU grid optimization for different types of valuation, such as CTE, GPVAD, SoS, for maximum computing efficiency.
- Ready for Machine Learning (ML)/Deep Learning (DL): PathWise offers expertise and the required computing power that can help customers explore ML/DL models to further speed-up valuation when necessary.
- Reduction in energy cost and environmental footprint by moving from local to cloud computing: https://energydigital.com/smart-energy/cloud-computing-saves-energy-and-co2-emissions

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About

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