Every quarter DNB publishes a set of economic scenarios (P-scenarios) and risk neutral scenarios (Q-scenarios) which pension funds must use as per regulations for risk management [1]. Furthermore, these scenarios serve more purposes for pension funds, such as but not limited to: defining risk attitudes, valuation of pension contracts, quantifying transition effects and pension fund communication with participants. The set of economic scenarios are generated by an economic model, which gets revised every 5 years by the Commission Parameters. In the previous model, the economic scenarios were generated by the Koijen-Nijman-Werker (KNW) model [2]. The pension transition and the Wet toekomst pensioenen (Wtp) mandated an extension of the model which can generate Q-scenarios as well besides only P-scenarios. This new model is called the CP 2022 model [3]. The key modifications and extensions to the KNW model are:

* Using a stochastic volatility parameter that drives the risk factors instead of a deterministic volatility parameter.
* Generating equivalent P- and Q-scenarios.

The introduction of the new pension law necessitates a transition from the old system, involving the transfer of approximately 1500 billion EUR. Decision-making heavily relies on scenario-calculations mandated by law, highlighting the importance of the models generating these scenarios.

CP 2022 was designed to be affine, which is an important property that allows for tractability in many ways. During calibration, option prices are computed under the dynamics stated by CP 2022 by using Monte Carlo, which is time-consuming. There exist alternative methods in the literature which use the affinity property to derive the characteristic function. Using this property, options can be priced using Fourier inversion techniques [4][5][6] that are faster than Monte Carlo. This could accelerate the calibration process by a significant margin. A faster calibration implies the following advantages:

* The scenarios can be published online at an earlier date. At the moment the scenarios are typically published online in the second week of each quarter. It would be beneficial for pension funds to have quicker access to the scenarios for a smoother decision making process.
* With a faster calibration there is more time left to improve accuracy of the estimations.
* Quick calibration allows policymakers to rapidly test and implement policy changes.

For academia, it is of great benefit to publish one of the first literature on a newly developed model, improve the model using existing methods and research new methods for fast option valuation.

The research question entails: Can the COS method outperform the Monte Carlo method in the CP 2022 model?

Hypothesis: The COS method is computationally more efficient and thus faster than Monte Carlo for valuing options. Per optimization step during calibration, we compare the option prices and computation times from the Monte Carlo method (which is the benchmark method) and the COS method.

We divide the research question into 2 parts: evaluating European style options and path-dependent options.

1. Can the COS method outperform the Monte Carlo method in the CP 2022 model in evaluating European style options?
2. Can the COS method outperform the Monte Carlo method in the CP 2022 model in evaluating the path-dependent options: swaptions and/or year-on-year inflation caps and floors?

The COS method is already proven to be superior than Monte Carlo in evaluating European style options [6]. In these cases the Fourier coefficients are analytically available. We generalize the COS method to evaluate option prices when the interest rates are stochastic in the CP 2022 model.

The second part is much more involved in the CP2022 model and is an open question for research. In this case Fourier coefficients need to be calculated numerically at each step and we thus run into the curse of dimensionality. In this case it is not immediately clear which method is computationally more efficient, although, based on the results in [7], the COS method is expected to be more efficient than Monte Carlo simulation for path-dependent options. Or a different approach can be used, such as deriving the forward characteristic function and using the COS method under a different measure. It will be a major contribution of this thesis to the existing literature to investigate and extend the COS method to one or two path-dependent options used in the calibration within the new pension framework.

We first start with a literature review and create documentation on the CP 2022 to make it more accessible and understandable to a wider audience. Then we implement and generalize the COS method for calculating one or more European type of options needed for the calibration and benchmark the results against the Monte Carlo method that is being used and include error convergence tests. Lastly we work out the COS method for pricing swaptions and/or year-on-year inflation caps and floors.

“Expected” planning:

July 2024 – mid-August 2024: literature study + documentation CP 2022, particularly the mathematical derivations of needed characteristic function.

Mid-August 2024 – Mid-October 2024: work out the COS method for European style option(s) used in the calibration, including error convergence tests.

Mid-October 2024 – February 2025: investigate and work out the COS method for pricing swaptions and/or year-on-year inflation caps and floors, including error analysis.

Defense: March 2025 (to be determined)

Relevant literature

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3. Commisie Parameters 2022. Technical appendix: Specification of the CP2022 model. Technical report, Commisie Parameters 2022, 2022. https://www.rijksoverheid.nl/documenten/rapporten/2022/11/29/ bijlage-2-technische-appendix.
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6. Junike, Gero, and Hauke Stier. "The multidimensional COS method for option pricing." arXiv preprint arXiv:2307.12843 (2023).
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