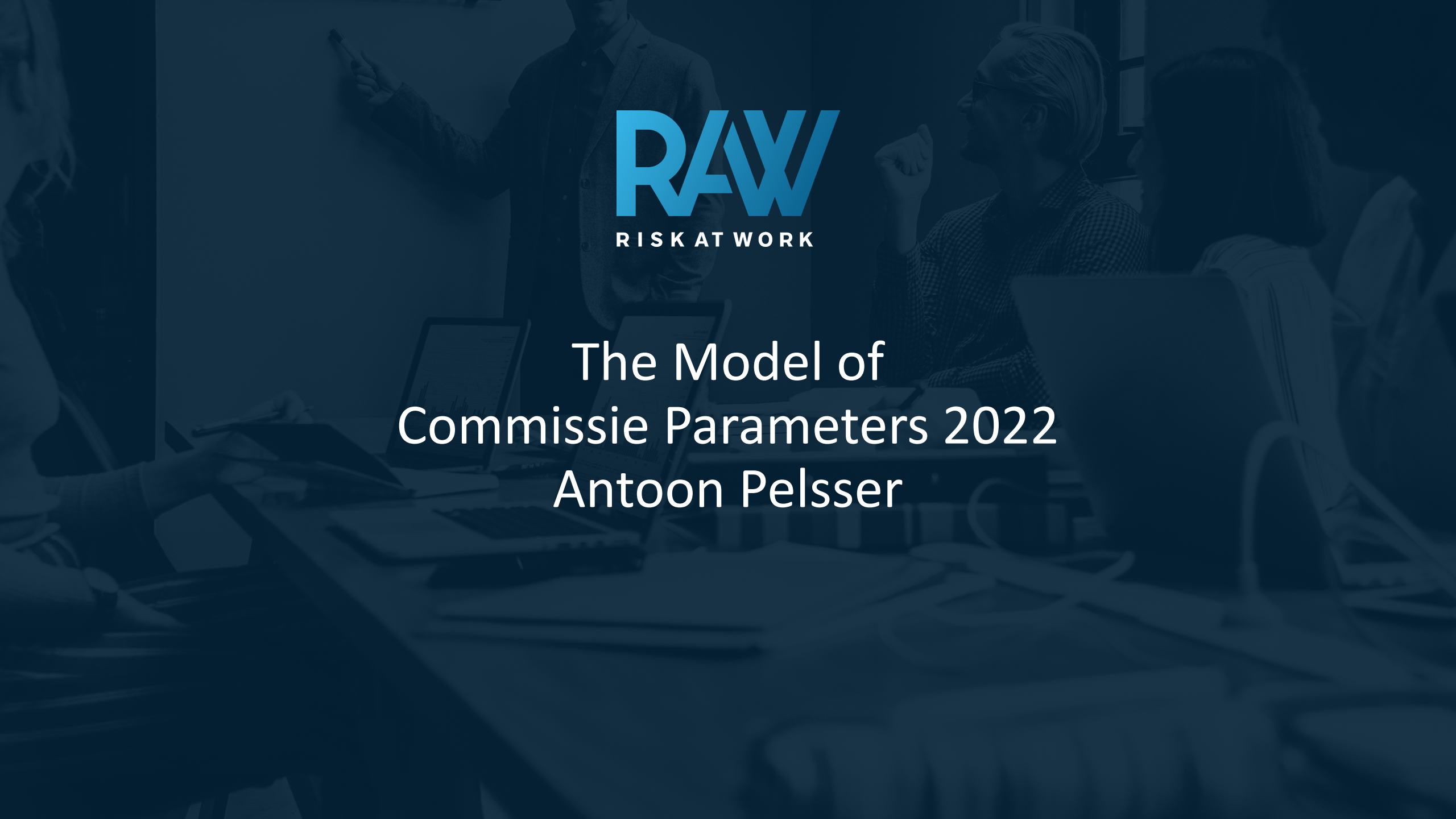

The Model of Commissie Parameters 2022

Antoon Pelsser

Outline of Presentation

- Introduction:
  - What is the Commissie Parameters?
- Structure of CP2022 model:
  - Affine model for stock, nominal rates, inflation & stoch.vol.
- Results of P and Q fit of CP2022 model:
  - Good fit for historical data & observed prices of derivatives

RISK AT WORK

Introduction

The numbers on your UPO

- You receive an annual overview of your (projected) pension income
  - Uniform Pensioenoverzicht (UPO)

- Graph shows three numbers:
  - Expected result after retirement date
    - Includes inflation and indexation
  - Positive scenario (=95% percentile)
  - Negative scenario (= 5% percentile)

- All Dutch pension funds must use the same scenarioset for these projections
  - Model of the so-called “Commissie Parameters”

New Dutch Pension System

- Pressure on the Dutch Pension System
  - Labour market factors
    - ageing population, higher employee turnover in the labour market, early retirement
  - Financial Crises
    - interest rates

- Changes to the Dutch Pension System
  - defined benefit → defined contribution
  - individual accounts
  - better measurement and matching of risk profiles and preferences

- CP 2022 model will help to facilitate this transition

Transition to the New Pension System

- "Fair and Balanced" transition

- In the current system, participants have no entitlements
  - Participate in general fund
  - Receive monthly payout after retirement

- In the new system, participants will have individual "pots"
  - Redistribute pension fund assets over individuals
  - Transition Calculation → Use (risk-neutral) valuation of CP2022 model

P and Q Model

$\mathbb{P}$ **model** → prognosis
$\mathbb{Q}$ **model** → risk neutral valuation

General Affine (Term Structure) Models

CP 2022 Affine Model:

- **Stocks**
- **Nominal Rates**
- **Inflation & CPI**
- **Stochastic Volatility**

Background

- Every 5 years CP report with advice on a number of parameters and scenario-sets that are needed for calculations in Dutch pension system
- Includes extrapolation method for term structure of interest (based on UFR), and a set of economic scenarios
- Wet Toekomst Pensioenen:
  - new applications of existing parameters and scenarioset (P-set) and
  - new risk-neutral scenarioset (Q-set) needed for transition

Commissie Parameters 2022

Video from Technical Briefing 6 Dec 2022

- Timeline:
  - Feb 2022: Committee installed by Minister of Pensions (Carola Schouten)
    - Bi-weekly meetings by the committee members
  - 29 Nov 2022: Report presented to the Minister
  - Dec 2022: Technical briefing with Dutch Parliament (Tweede Kamer)
    - Dec 2022: Parliament votes in favour
  - Mar 2023: Technical briefing with Dutch Senate (Eerste Kamer)
    - May 2023: Senate votes in favour
  - 1 July 2023: WTP officially in power

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Structure of CP2022 Model

Scenario Generator 2019

- Model CP2019 is based on Koijen, Nijman & Werker (2010): affine model for short rate r_t , expected inflation rate π_t , stock index S_t and price index Π_t
- Calibration based on (only) historical data 1999-2018 for
  - monthly historical spot rates based on swap data,
  - historical stock index values (MSCI World Index), and
  - Eurozone inflation index (HICP)
- Maximum likelihood estimation, under restrictions on long term value of
  - expected inflation, expected stock returns and probability of negative interest rates.

New Scenario Generator of CP2022

- Requirement that new sets should aim to be consistent with historical and current market data, led to number of adjustments:
  - joint (continuous time) model to generate scenarios
    - guarantees equivalent $\mathbb{P}$-/$\mathbb{Q}$-scenario-sets
  - calibration includes derivatives on equity, interest and inflation
    - incorporates market price of protection against risks
  - time-varying future risk premia
    - allows perfect fit nominal/real term structures
  - stochastic volatility process
    - parameters describing financial uncertainty not constant
  - two price index processes
    - allows distinction Eurozone and Dutch inflation

Dynamic Model Specification

- The factor processes corresponding to (squared) volatility v_t , short rate r_t and expected inflation rate π_t satisfy

$$
\begin{aligned}
d\mathbf{X}_t^s &= \begin{bmatrix} K_{vv} & 0 & 0 \\ K_{vr} & K_{rr} & K_{\pi r} \\ K_{v\pi} & K_{r\pi} & K_{\pi\pi} \end{bmatrix} \left(\begin{bmatrix} \mathbb{E}v_\infty \\ \mathbb{E}r_\infty \\ \mathbb{E}\pi_\infty \end{bmatrix} - \mathbf{X}_t^s \right) dt \; + \; \begin{bmatrix} \omega & 0 & 0 & 0 & 0 \\ \sigma_{vr} & \sigma_{r1} & \sigma_{r2} & 0 & 0 \\ \sigma_{v\pi} & \sigma_{\pi 1} & \sigma_{\pi 2} & 0 & 0 \end{bmatrix} \begin{bmatrix} v_t & 0_{1\times 4} \\ 0_{4\times 1} & I_4 + v_t\Gamma_1 \end{bmatrix}^{\frac{1}{2}} dW_t^{\mathbb{P}}, \\
&=: K(\mathbb{E}\mathbf{X}_\infty^s - \mathbf{X}_t^s)\, dt \; + \; \Sigma^{r\pi}(\Gamma_0 + (\mathbf{X}_t^s)_1\Gamma)^{\frac{1}{2}}\, dW_t^{\mathbb{P}},
\end{aligned}
$$

- The log-stock index S_t and Eurozone log-price index Π_t satisfy

$$
\begin{aligned}
d\mathbf{X}_t^o &= \begin{bmatrix} r_t + \eta_S \\ \pi_t + \eta_\Pi \end{bmatrix} dt \; - \; \tfrac{1}{2}\mathcal{D}\left(\begin{bmatrix} \sigma_S' \\ \sigma_\Pi' \end{bmatrix} \begin{bmatrix} v_t & 0_{1\times 4} \\ 0_{4\times 1} & I_4 + v_t\Gamma_1 \end{bmatrix} \begin{bmatrix} \sigma_S' \\ \sigma_\Pi' \end{bmatrix}' \right) dt \; + \; \begin{bmatrix} \sigma_S' \\ \sigma_\Pi' \end{bmatrix} \begin{bmatrix} v_t & 0_{1\times 4} \\ 0_{4\times 1} & I_4 + v_t\Gamma_1 \end{bmatrix}^{\frac{1}{2}} dW_t^{\mathbb{P}}, \\
&=: (\mu^o + K^o\mathbf{X}_t^s)dt \; + \; \Sigma^{S\Pi}(\Gamma_0 + (\mathbf{X}_t^s)_1\Gamma)^{\frac{1}{2}}\, dW_t^{\mathbb{P}},
\end{aligned}
$$

Affine Model Structure

- Motivation choices:
  - Affine model allows us to characterize future term structures in terms of few state variables, since nominal and real spot rates are affine in state-vector X_t^s
  - Asymmetric distributions for economic variables under $\mathbb{P}$ and $\mathbb{Q}$:
    - More realistic scenarios and better fit for market prices derivatives
  - Scenarios are generated using simulation of monthly increments; only annual values published in sets.

Extrapolation of Term-Structures

- Explicit request for advice on extrapolation of long-term interest rates
- In CP2022 model:
  - First smoothing point at maturity of 50 years (was 30 years)
  - After maturity of 50 years constant forward rate equal to

$$UFR = \frac{50\ y_t^{obs}(50) - 30\ y_t^{obs}(30)}{50 - 30}$$

- Motivation:
  - Sufficiently liquid market prices after 30 years
  - Small market impact, for market share Dutch pension funds

Estimation/Calibration of CP2022 Model

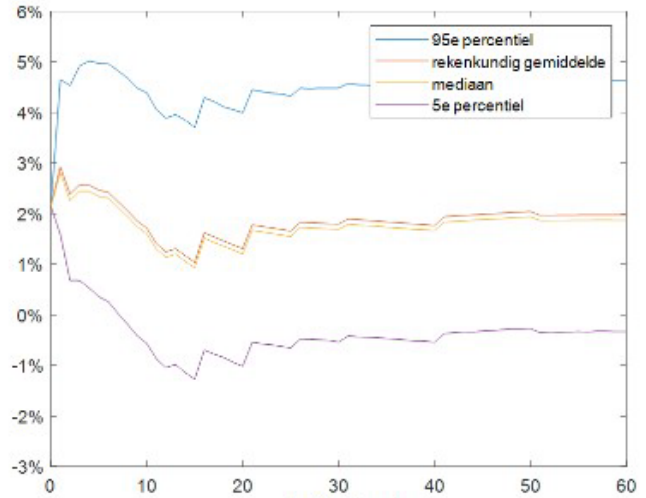
- Simultaneous $\mathbb{P}$ and $\mathbb{Q}$ calibration
- Goal of optimization:
  - Constrained maximum likelihood for historical data
  - Constrained by fit of equity, interest rate and inflation derivative prices
    - (mean square error for implied volatilities)
- Other parameter constraints during optimization:
  - Expected (log) growth stock index in equilibrium is ln(1 + 5.2%)
  - Expected (log) growth price index in equilibrium is ln(1 + 2.0%)
  - Ultimate Forward Rate given by 30/50 observed rates
  - Spot rates for 10 years to maturity, 60 years from now, are 2.0% (nominal spot) and 0.0% (real spot).
- Nominal and real term structures fitted exactly by appropriate choice of market price of risk functions

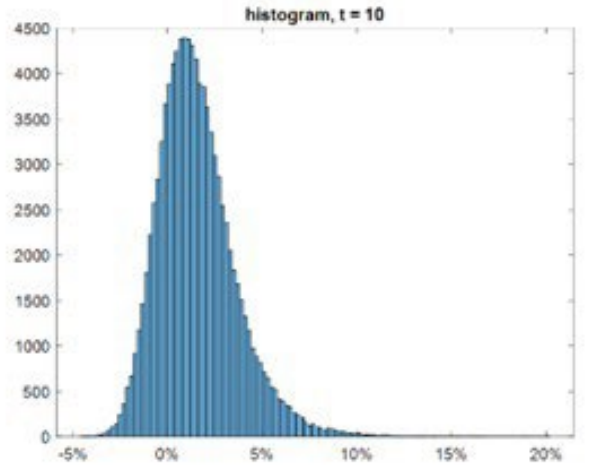
RISK AT WORK

Fit of the CP2022 Model

Nominal Rates (ℙ-scenario's)

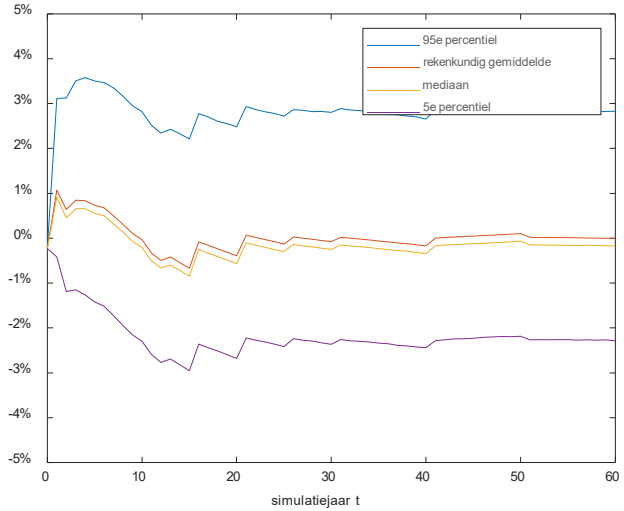
- Nominal rates (maturity 10)
  - Quantiles (top)
  - Distribution (t=10, bottom)
  - Probability distribution skewed to the right:
    - More likely to have high interest rates than low interest rates
    - In line with historical data

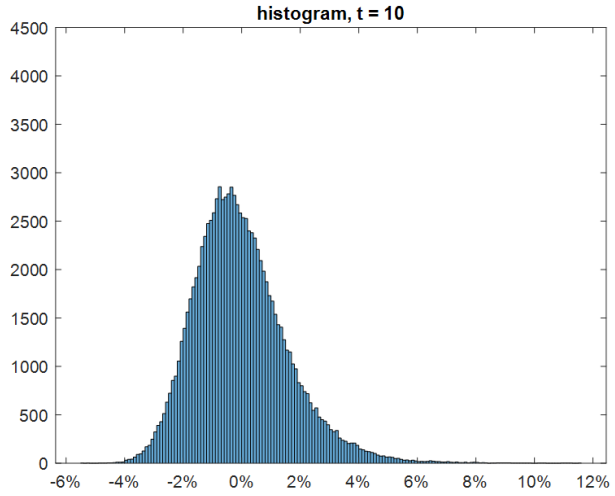




Real Rates ($\mathbb{P}$-scenario's)

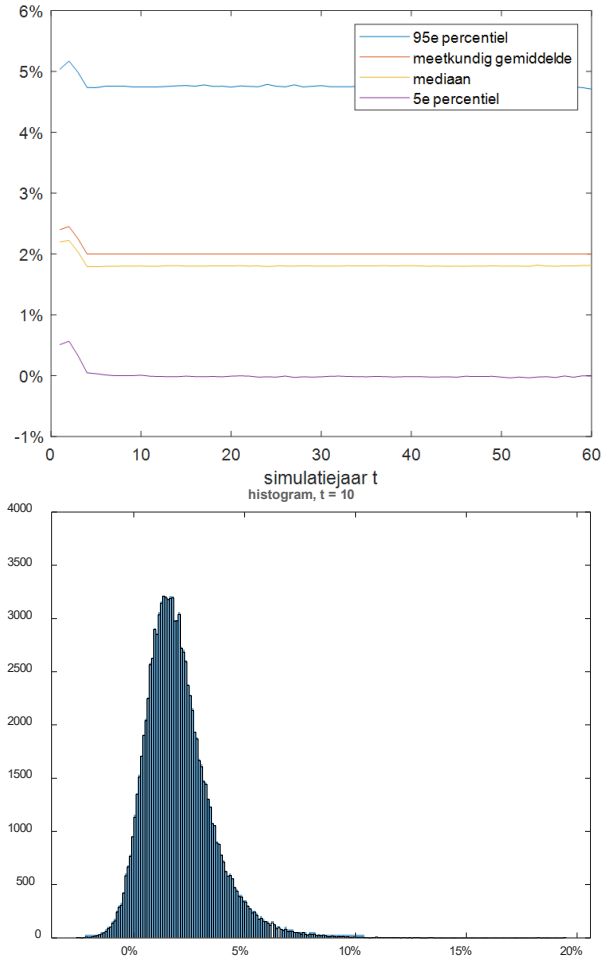
- Real rate (maturity 10)
  - Quantiles (top)
  - Distribution (t=10, bottom)
  - Probabilities skewed to the right:
    - More likely to have high interest rates than low interest rates
    - In line with historical data





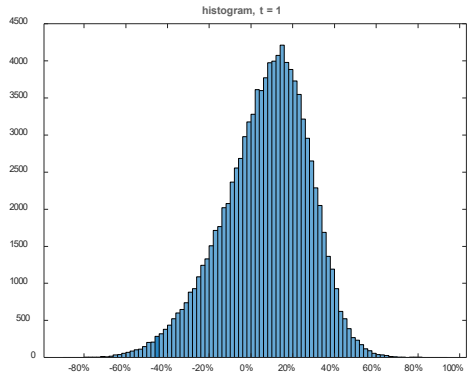
NL Inflation (ℙ-scenarios)

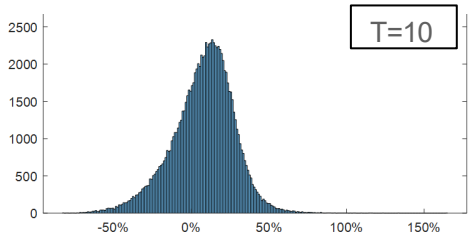
- NL inflation
  - Quantiles (top)
  - Distribution (t=10, bottom)
  - Probabilities skewed to the right:
    - More likely to have high inflation than low inflation
    - In line with historical data
  - Difference between euro-HICP and NL inflation

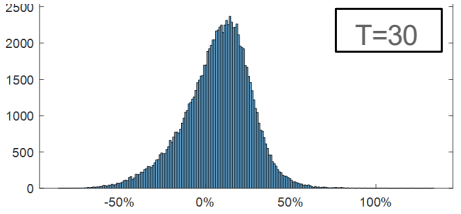


Equity returns ($\mathbb{P}$-scenarios)

- Stock returns
  - Distribution (t=1, 10, 30)
  - Probability distribution skewed to the left:
    - More chance of low returns than high returns
    - In line with historical data







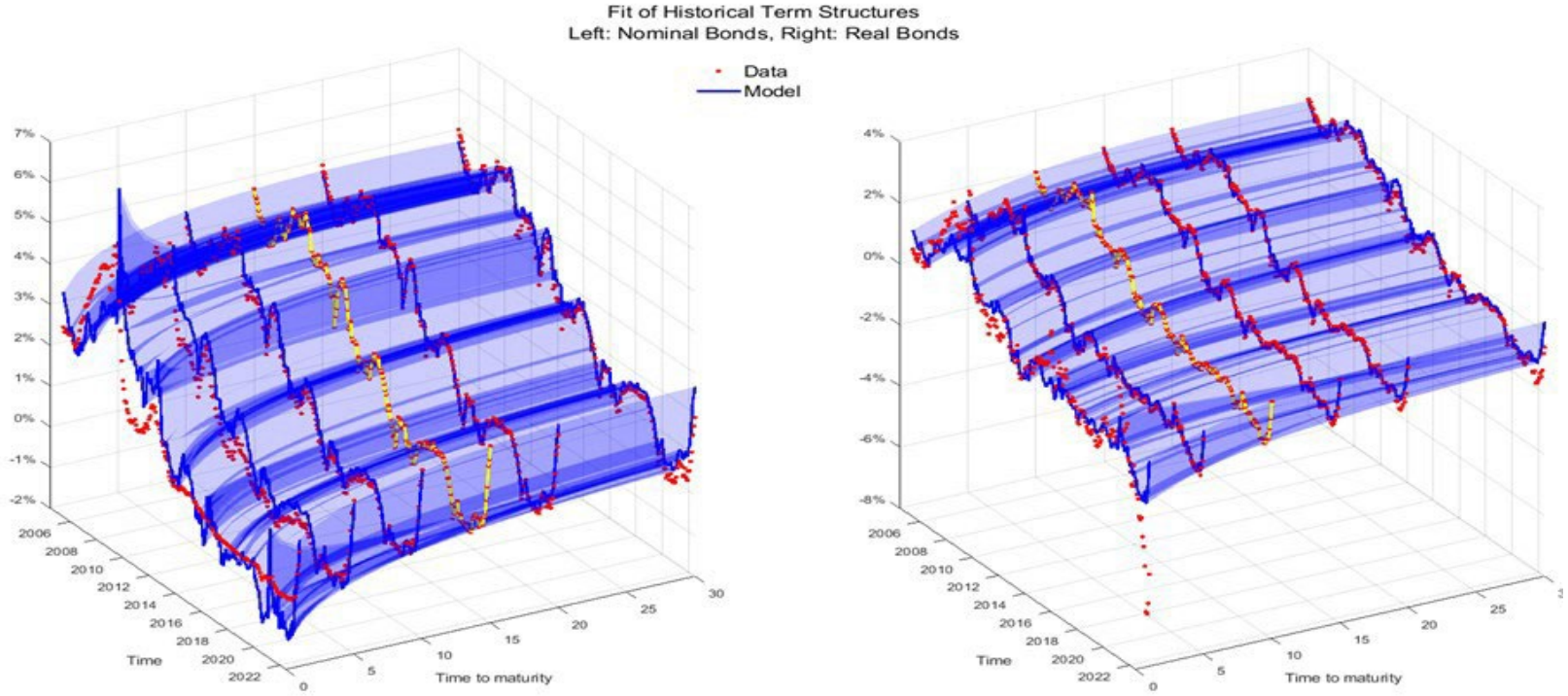
Correlations P-scenarios

- Correlations in year-on-year returns, in simulation year 10

	NomBond10 return	RealBond10 return	Stoch.Vol	NL inflatie	Aandelen return
NomBond10 return	100%				
RealBond10 return	96%	100%			
Stoch.Vol	15%	21%	100%		
NL inflatie	-39%	-25%	27%	100%	
Aandelen return	59%	57%	2%	-42%	100%

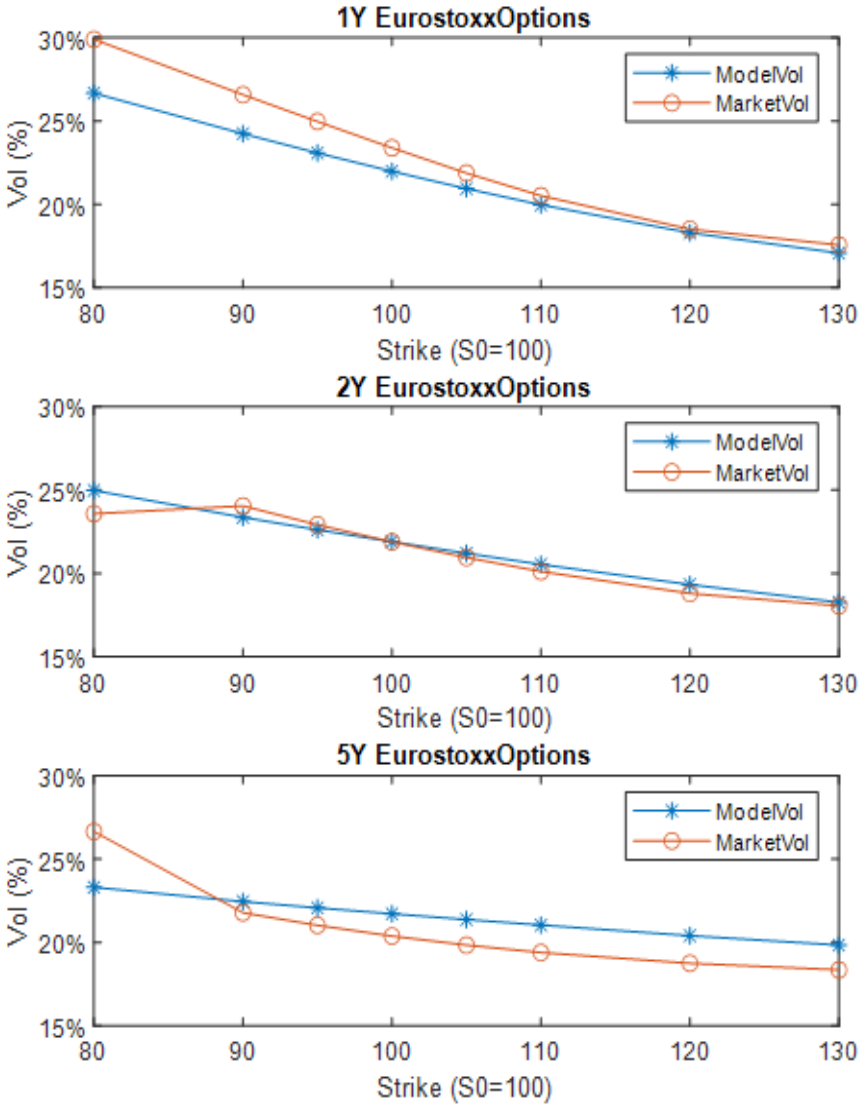
Fit of historical interest rate data

- Fit of model to observed nominal (left) and real interest rates (right)
  - Good fit for 10, 15, 20, 30 (red=data, blue=model)
  - Model cannot fit short maturities as well



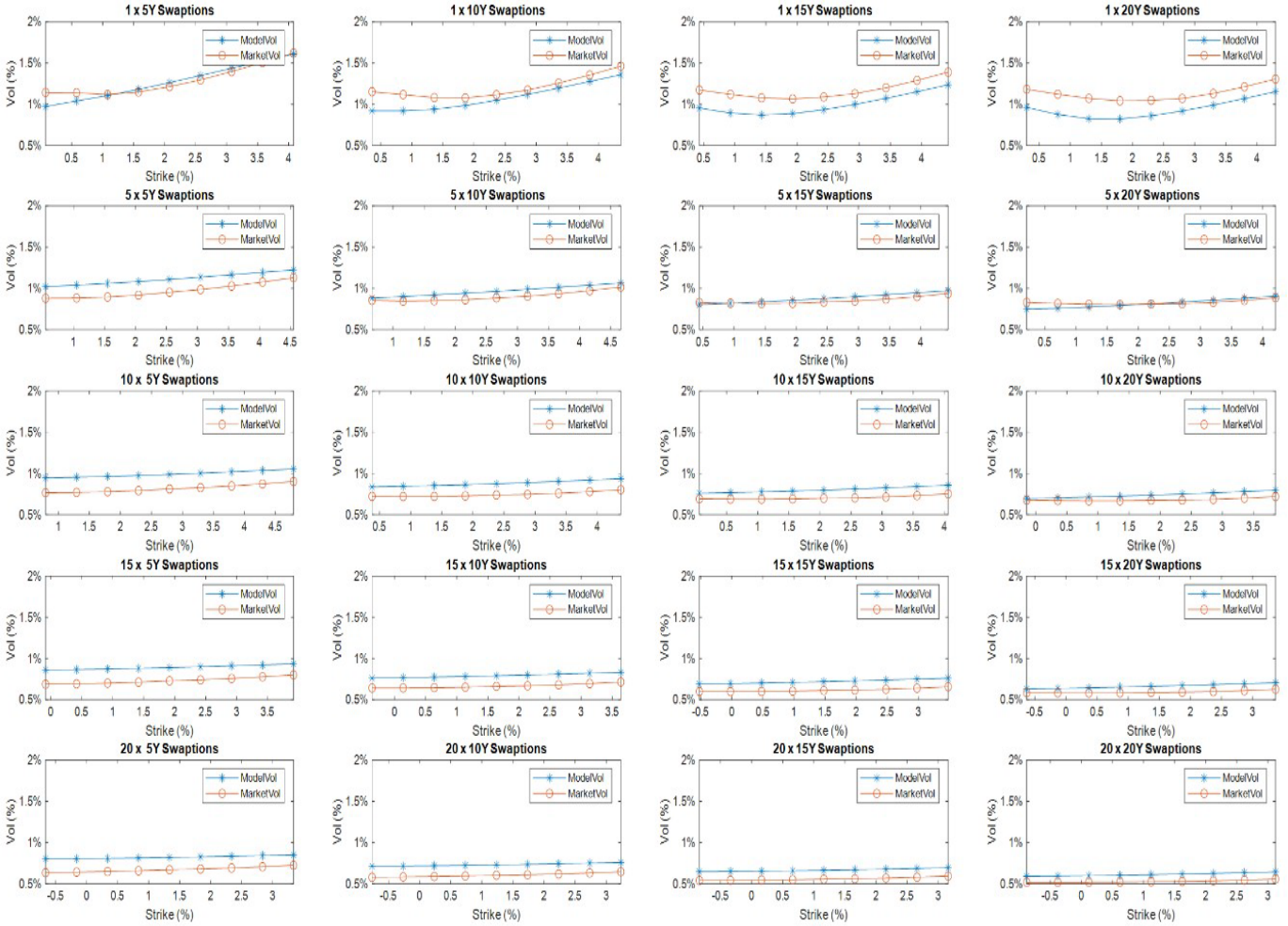
Stock options pricing

- Fit of stock options
  - Implied volatility
  - Option maturity: 1y 2y 5y
  - Skewness to the left: visible as declining vola
  - Model can reproduce the vol-smiles well



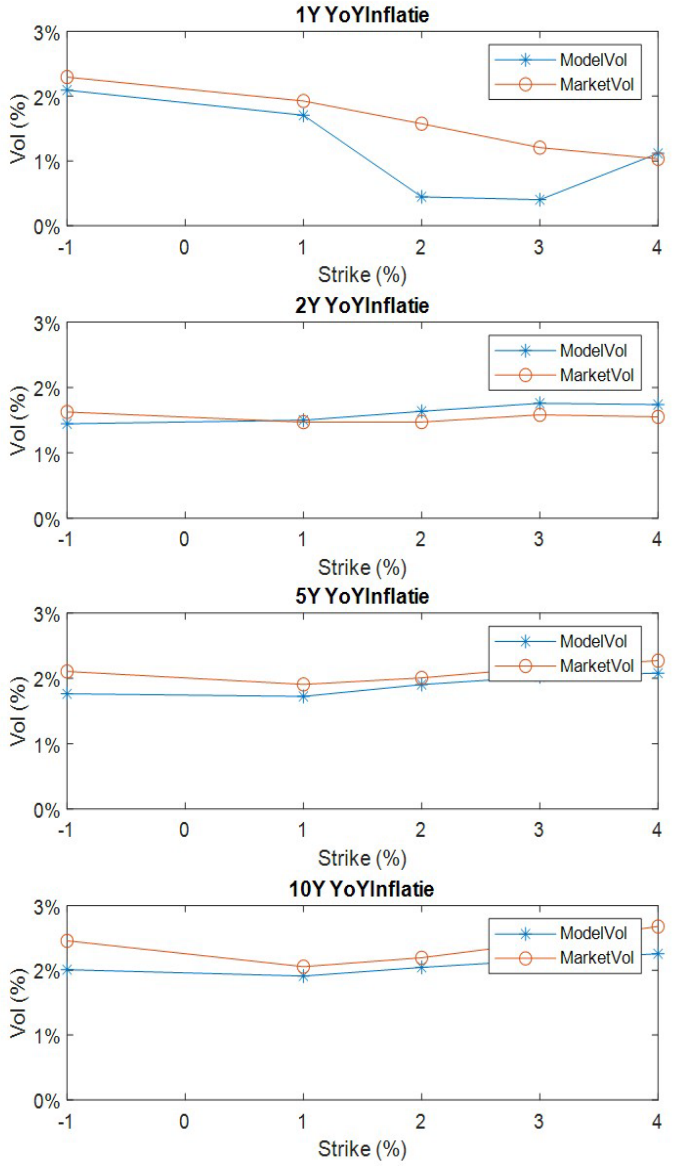
Prices interest rate options (swaptions)

- Fit of swaptions
  - Implied volatility “cube”
  - Option term per row
    - 1y, 5y, 10y, 15y, 20y
  - Swap-tenor per column
    - 5y, 10y, 15y, 20y
  - Skew to the right → increasing vola’s



Prices inflation options

- Fit to YoY HICP inflation options
  - Implied volatility
  - Option tenor: 1 2 5 10y
  - Model can reproduce the vol-smiles fairly well
    - Lesser fit for 1y options



Summary

- Structure of CP2022 model:
  - Affine model for stock, nominal rates, inflation & stoch.vol.

- Results of $\mathbb{P}$ and $\mathbb{Q}$ fit of CP2022 model:
  - Good fit for historical data & observed prices of derivatives