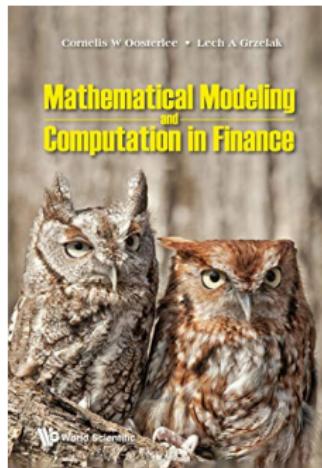


# Materials for the course

The course is based on book “*Mathematical Modeling and Computation in Finance: With Exercises and Python and MATLAB Computer Codes*”, by C.W. Oosterlee and L.A. Grzelak, World Scientific Publishing Europe Ltd, 2019. For more details go [here](#).



- ▶ Youtube Channel with courses can be found [here](#).
- ▶ Slides and the codes can be found [here](#).

# Course road map



# Understanding of Filtrations and Measures

Length: **2h40m**

- 2.1. Filtration
- 2.2. Conditional Expectations
- 2.3. Conditional Expectations in Python
- 2.4. Option Pricing Using Conditional Expectation
- 2.5. Convergence Experiment in Python
- 2.6. Concept of Numeraire
- 2.7. From P to Q in the Black-Scholes Model
- 2.8. Change of Numeraire: Stock Measure
- 2.9. Change of Numeraire: Dimension Reduction
- 2.10. The T-Forward Measure
- 2.11. The Summary of the Lecture + Homework



# The HJM Framework

Length: **2h**

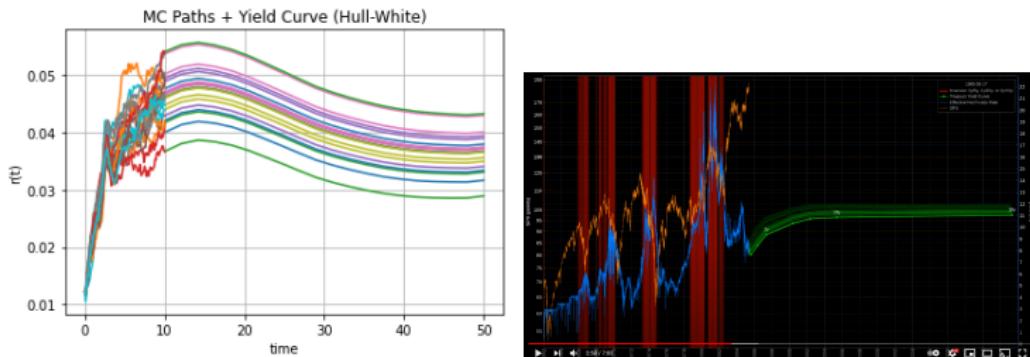
- 3.1. Equilibrium vs. Term-Structure Models
- 3.2. The HJM Framework
- 3.3. The Instantaneous Forward Rate
- 3.4. Arbitrage Free Conditions under HJM
- 3.5. Ho-Lee Model and Python Simulation
- 3.6. Hull-White Model
- 3.7. Hull-White Model and Simulation in Python
- 3.8. The Summary of the Lecture + Homework



# Yield Curve Dynamics under Short Rate

Length: **2h10m**

- 4.1. Exact Solution for the HW Model
- 4.2. Affinity of the Hull-White Model
- 4.3. Brief Introduction to Yield Curves
- 4.4. Limitations of the 1Factor Model and Yield Curve Dynamics
- 4.5. Gaussian 2F Model
- 4.6. The Summary of the Lecture + Homework

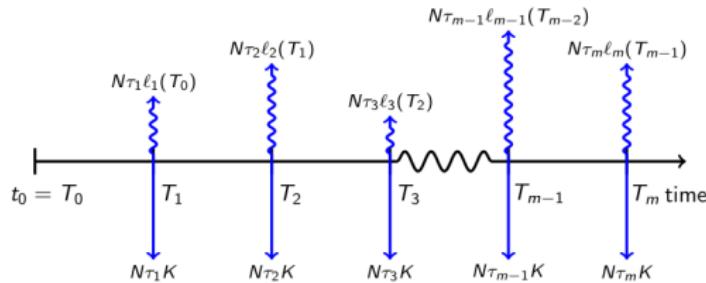


**Figure:** Dynamics of the yield curve for random market scenarios under the 1F Hull-White model.

# Interest Rate Products

Length: **2h**

- 5.1. Simple Compounded Forward Rate
- 5.2. Forward Rate Agreement
- 5.3. Floating Rate Note
- 5.4. Interest Rate Swap
- 5.5. The Hull-White model under the T-Forward Measure
- 5.6. Options on Zero-Coupon Bond
- 5.7. Caplets and Floorlets
- 5.8. Pricing of Caplets/Floorlets Under the HW Model
- 5.9. The Summary of the Lecture + Homework



# Construction of Yield Curve and Multi-Curves

Length: **3h**

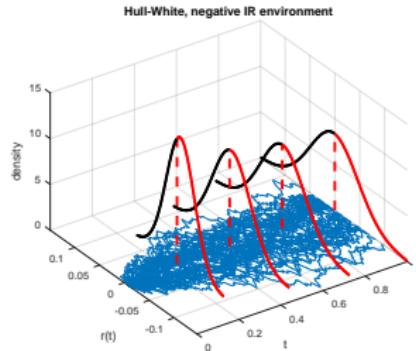
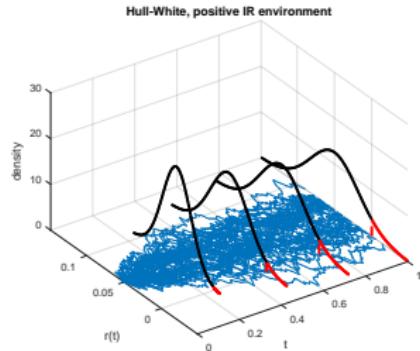
- 6.1. Yield Curve and its Dynamics
- 6.2. Mathematical Formulation
- 6.3. From Implied Volatilities to Building of YC
- 6.4. Spine Points and Optimization Routine
- 6.5. Analytical Example of YC Construction
- 6.6. Python Experiment
- 6.7. Different Interpolations and Impact on Hedging
- 6.8. Introduction to Multi-Curves
- 6.9. Multi-Curves and Connection to Default Probabilities
- 6.10. Python Experiment for Multi-Curves
- 6.11. The Summary of the Lecture + Homework

Date	1 Mo	2 Mo	3 Mo	6 Mo	1 Yr	2 Yr	3 Yr	5 Yr	7 Yr	10 Yr	20 Yr	30 Yr
06/01/21	0.01	0.01	0.02	0.04	0.04	0.16	0.31	0.81	1.28	1.62	2.22	2.30
06/02/21	0.01	0.01	0.02	0.04	0.05	0.13	0.30	0.80	1.26	1.59	2.21	2.28
06/03/21	0.00	0.01	0.02	0.04	0.04	0.16	0.34	0.84	1.30	1.63	2.22	2.30
06/04/21	0.01	0.02	0.02	0.04	0.05	0.14	0.32	0.78	1.23	1.56	2.16	2.24
06/07/21	0.01	0.02	0.02	0.04	0.05	0.16	0.33	0.79	1.24	1.57	2.17	2.25
06/08/21	0.01	0.02	0.02	0.04	0.05	0.14	0.32	0.77	1.20	1.53	2.13	2.21
06/09/21	0.01	0.02	0.03	0.04	0.05	0.16	0.31	0.75	1.17	1.50	2.10	2.17

# Pricing of Swaptions and Negative Interest Rates

Length: **2h**

- 7.1. Pricing of Caplets/Floorlets
- 7.2. Pricing of Interest Rate Swaps
- 7.3. Pricing of Swaptions under the Black-Scholes Model
- 7.4. Jamshidian's Trick
- 7.5. Swaptions under the Hull-White Model
- 7.6. Negative Interest Rates
- 7.7. Shifted Lognormal, Shifted Implied Volatility
- 7.8. The Summary of the Lecture + Homework



# Mortgages and Prepayments

Length: **4h**

- 8.1 Introduction to Mortgage Contracts
- 8.2 Bullet Mortgage
- 8.3 Bullet Mortgage: Python Experiment
- 8.4 Annuity Mortgage
- 8.5 Annuity Mortgage: Python Experiment
- 8.6 Prepayment determinants
- 8.7 CPR: Constant Prepayment Rate
- 8.8 Index Amortizing Swap
- 8.9 Inclusion of Refinancing Incentive
- 8.10 Stochastic Prepayment: Python Experiment
- 8.11 Stochastic Prepayment and Swaptions
- 8.12 Pipeline Risk
- 8.13 The Summary of the Lecture + Homework

# Hybrid Models and Stochastic Interest Rates

Length: **2h20m**

- 9.1 Hybrid Models for xVA and VaR
- 9.2 The Black-Scholes Hull-White Model
- 9.3 Implied Volatility for Models with Stochastic Interest Rates
- 9.4 Stochastic Vol Models with Stochastic Interest Rates
- 9.5 Example of a Hybrid Payoff: Diversification Product
- 9.6 The Heston Hull-White Hybrid Model
- 9.7 Monte Carlo for Hybrid Models
- 9.8 Monte Carlo for the Heston-Hull-White Model
- 9.9 The Summary of the Lecture + Homework

# Foreign Exchange (FX) and Inflation

Length: **2h50m**

- 10.1 Introduction to Foreign Exchange
- 10.2 Forward FX Contract
- 10.3 Cross-Currency Swaps
- 10.4 Pricing of FX Options, the Black-Scholes Case
- 10.5 The Heston FX Model
- 10.6 Pricing of FX Options with Stochastic Interest Rates
- 10.7 Introduction to Inflation
- 10.8 Pricing of Inflation Forwards and Swaps
- 10.9 Modeling of Inflation with SDEs
- 10.10 The Summary of the Lecture + Homework

# Market Models and Convexity Adjustments

Length: **2h30m**

- 11.1 A bit of History
- 11.2 Libor Market Model Specifications
- 11.3 Libor Rate Dynamics, from  $\mathbb{P} \rightarrow \mathbb{Q}^T$
- 11.4 Lognormal Libor Market Model and Measure Changes
- 11.5 LMM Under the Terminal and Spot Measures
- 11.6 Stochastic Volatility LMM
- 11.7 Smile and Skew in the LMM (Displaced Diffusion)
- 11.8 Freezing Technique
- 11.9 Convexity Correction
- 11.10 Convexity and Inclusion of Volatility Smile and Skew
- 11.11 The Summary of the Lecture + Homework



# Valuation Adjustments- xVA (CVA, BCVA and FVA)

Length: **3h**

- 12.1. Introduction and Basics of CVA
- 12.2. Exposures and Potential Future Exposure
- 12.3. Expected Exposures
- 12.4. Expected Exposures and Closed Form Solutions
- 12.5. Generation of Exposures with Python (1D Case)
- 12.6. Exposure Generation for Portfolio of Assets
- 12.7. Unilateral Credit Value Adjustment (CVA)
- 12.8. Approximations in Calculation of CVA
- 12.9. Bilateral Credit Value Adjustment (BCVA)
- 12.10. Funding Value Adjustment (FVA)
- 12.11. Trade Attributions in (B)CVA
- 12.12. The Summary of the Lecture + Homework

# Value-at-Risk and Expected Shortfall

Length: **2h**

- 13.1. Value at Risk (VaR), Stressed VaR (SVaR)
- 13.2. Coherent Risk Measures
- 13.3. Expected Shortfall
- 13.4. Historical VaR (HVaR) and Python Experiment
- 13.5. Missing Data, Arbitrage and Re-Gridding
- 13.6. VaR Computation with Monte Carlo
- 13.7. Backtesting
- 13.8. The Summary of the Lecture + Homework

# The Summary of the Course

## 14.1. The Summary of the Course.

