Mathematical Finance and Complex derivatives

MAE, Module 4, 2021-2022

Vyacheslav Gorovoy, PhD

vgorovoy[at]nes.ru

Course information

Course Website: https://my.nes.ru

Instructor's Office Hours: by assignment

TAs: TBD

Course description

The course can be considered as a continuation of a Derivative course with the goal to provide training in financial mathematics, pricing complex derivatives and numerical methods. The first part of the course is the theoretical introduction to stochastic calculus and asset pricing based on an equivalent martingale measure approach. The second part is various applications for complex derivatives and structured products pricing. The material is mostly based on Hull "Options, Futures, and Other Derivatives" textbook (the second part of the book). The course is heavily using python, all lecture notes, hws and a project are in Jupyter notebook format.

Course requirements, grading, and attendance policies

Prerequisites:

1. Derivatives
2. Probability theory
3. Python

Grading:

Participation	**10%**
Homework 1	**20%**
Homework 2	**20%**
Project	**50%**

Software and tools: Jupyter notebook, Python

Course contents

- Diffusion processes and Black-Scholes model (Lecture notes L4 from Derivatives course)

- Stochastic calculus (Lecture notes L1)
  - Stochastic and Diffusion processes
  - Ito's Stochastic Calculus
  - The backward and forward Kolmogorov equations
  - The Feynman-Kac formula

- Equivalent Martingale Measure (Lecture notes L2)
  - Market price of the risk
  - Choice of numeraire
  - Girsanov theorem
  - Siegel's paradox

- Multi-asset derivatives (Lecture notes L2)
  - Modelling correlation between financial assets
  - Quanto. Application: Hedging risk exposure of oil company

- Monte Carlo (MC) simulation (Lecture notes L3)
  - Principles of Monte Carlo
  - Pricing Derivatives by MC
  - Variance Reduction
  - Applications: Derivatives pricing

- Path-dependent options on one asset (Lecture notes L4)
  - Asian options
  - Barrier options

- Models beyond Black-Scholes (Lecture notes L5)

  - Local volatility
  - Stochastic volatility
  - Models with jumps

- Interest rates derivatives. (Lecture notes L6)
  - Option on futures. Black's model.
  - Callable and putable bonds.
  - Interest rate swaps
  - Caps and floors
  - Interest rates models

- Credit Risk (Lecture notes L7)
  - Modeling Credit Risk. Default Probabilities.
  - Credit derivatives. Credit Default swap (CDS). Credit Linked note (CLN).
  - Modeling default correlations: the Gaussian Copula Model. First to default baskets.

- Structured products (SP) (Lecture notes L8)
  - Capital protected
  - Yield enhancement
  - Fixed Income structured notes. Range accrual and Step-up notes
  - Exotic

- ML in Finance
  - Bermudan and American option pricing using NN
  - Volatility surface dynamics based on ML

Description of course methodology

- Lectures
- Homeworks
- In-class quizzes

Sample tasks for course evaluation

Called Bond:
Consider a 5-year fixed rate bond with principle of $100 and coupon 4% per year payable semiannually. This bond is callable at 2-year time with a strike price of $100. Assuming that the quoted volatility for the forward yield over a period from 2 to 5 years is 20% and flat yield curve at 4% compounded continuously, compute the current price of the above callable bond.

Course materials

Textbooks and materials

- Lecture notes
- John Hull, “Options, Futures, and Other Derivatives”

Academic integrity policy

Cheating, plagiarism, and any other violations of academic ethics at NES are not tolerated.