Derivatives
Module 4, Academic Year 2021-2022

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Course description

This course is introduction to financial derivatives. We will have a look at some most common classes, such as foreign exchange forwards, interest rate swaps, vanilla and exotic options, credit default swaps. Every time we will be interested in two questions: what is economic purpose of a derivative (who are natural buyers and sellers), and how do we price it?

Main goal of the course is to give you an idea of risk-neutral pricing and replication. Every reasonable derivative can be replicated as a combination of some underlying assets (probably with dynamic, but mechanical, trading). If you are trying to price a derivative by forecasting the future, then probably you are doing something wrong.

After the course you will understand major classes of derivatives. You will learn which class of derivatives can hedge which risk. You will also understand how market-makers price derivatives and risk-manage their positions.

Course requirements, grading, and attendance policies

Prerequisites:
- Basic calculus (you know what is derivative of a function)
- Basic probability theory (you know what is expectation and standard deviation)
- Programming in any language (preferably, in Python)

Grading:
- Three quizzes in a classroom: 5% each
- Three homework assignments: 15% each
- Final written exam: 40%

Course contents

1. Basic interest rates. Foreign exchange forwards. Hedging and speculation. Arbitrage-free price of a forward. Non-deliverable forwards.

2. Floating interest rates. Interest rate swaps and futures. Bootstrapping a yield curve from market instruments. Managing interest rate risk. Overnight index swaps curve and discounting. LIBOR-gate.

3. Vanilla options. Vanilla strategies. Single-step and multi-step binomial trees. Dynamic replication (also known as delta-hedging). Geometric Brownian motion and Black-Scholes formula as the limit of binomial tree.

4. Implied volatility and volatility smile. Market risk and option greeks: delta, gamma, vega, rho, theta. Link between gamma and theta, gamma and vega.

5. Monte-Carlo method. Risk-neutral probability and fundamental theorem of asset pricing.

6. Credit default swaps. Connection between bonds, probabilities of default, and credit default swaps. Wrong-way risk. Risk-neutral and real-world probabilities revisited.

7. Value at Risk (VaR) and Expected Shortfall (ES). Methods to compute aggregate risk of a derivatives portfolio: analytical formulas, historical simulations, Monte-Carlo method.

Course materials

Required textbooks and materials
Rule of thumb in derivatives: if you aren't sure where to start, check Hull's book.

John C Hull. *Options, Futures, and Other Derivatives*. 11th ed. Pearson, 2022. ISBN: 9780136939979.

Additional materials
These books go into depths of some particular topics. You do not have to read them to pass the course. However, they demonstrate how deep is the rabbit hole, and how many aspects one needs to take into account.

1. In case you are interested in theoretical foundations and mathematical proofs, have a look at two Steven Shreve's books.

Steven Shreve. *Stochastic Calculus for Finance I: The Binomial Asset Pricing Model*. Springer; 2004. ISBN: 9780387249681.
Steven Shreve. *Stochastic Calculus for Finance II: Continuous-Time Models.* Springer, 2004. ISBN: 9780387401010.

2. Some people prefer Tomas Bjork's book about mathematical foundations:

Tomas Bjork. *Arbitrage Theory in Continuous Time*. 3rd ed. Oxford University Press, 2009. ISBN: 9780199574742.

3. Interest rate swaps may appear simple to someone, compared to options. Marc Henrard's book demonstrates how complex this area is, and how different it is from what is described in textbooks.

Marc Henrard. *Interest Rate Modelling in the Multi-curve Framework*. Palgrave Macmillan, 2014. ISBN: 9781137374660.

4. Iain Clarke describes complex stochastic volatility models that are frequently used on foreign exchange market.

Iain Clarke. *Foreign Exchange Option Pricing: A Practitioner's Guide.* Wiley, 2010. ISBN: 9780470683682.

5. This course does not cover credit valuation adjustment (CVA) and other specific adjustments. However they are extremely important. If you are not aware of them, you are risking losing money in the long run.

Jon Gregory. *The xVA Challenge: Counterparty Risk, Funding, Collateral, Capital and Initial Margin*. 4th ed. Wiley, 2020. ISBN: 9781119508977.

Academic integrity policy

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