

UNIVERSITY OF PENNSYLVANIA
The Wharton School

FNCE 392/892:
FINANCIAL ENGINEERING

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Course Description

This class covers advanced pricing models for equity, fixed income and credit derivatives. It aims at:

- Introducing the main models used in practical applications to price and hedge derivatives;
- Understanding their comparative advantages and limitations, as well as how they are calibrated and applied.

As part of two team assignments, students will be asked to calibrate and implement the models introduced in the class using software of their choice. The use of *Mathematica* is recommended but not required for this purpose: *Matlab*, *R* or other software packages with similar capabilities are viable alternatives, although I will be using *Mathematica* in class to illustrate the calibration and implementation of the different models.

In spite of the fact that every effort will be made to introduce the various pricing models and techniques as intuitively as possible, the class is by its nature very quantitative and will require a significant amount of work.

Prerequisites

The prerequisites are Fixed Income and Financial Derivatives, with a grade of A- or higher in each of these two classes. Students who do not satisfy these prerequisites must obtain the instructor's permission to enroll.

Course Material

The course will be based primarily on lecture notes (copies of the overheads used in class). These notes will be made available ahead of each class through webCafé.

Although there is no required textbook for the class, the following books are useful key references:

- John C. Hull, *Options, Futures, and Other Derivatives*, 8th edition, Prentice Hall, 2011.
- Paul Glasserman, *Monte Carlo Methods in Financial Engineering*, 1st edition, Springer, 2010.
- Riccardo Rebonato, *Volatility and Correlation*, 2nd edition, Wiley, 2004.
- Damiano Brigo and Fabio Mercurio, *Interest Rate Models - Theory and Practice*, 2nd edition, Springer, 2006.
- Riccardo Rebonato, *Modern Pricing of Interest-Rate Derivatives: The LIBOR Market Model and Beyond*, 1st edition, Princeton University Press, 2002.
- Philipp J. Schönbucher, *Credit Derivatives Pricing Models*, 1st edition, Wiley, 2003.

Class Format

The main class format will be lectures.

Team Information

The maximum size of the teams for the team assignments will be determined based on total enrollment in the class. Teams can span across different sections of the course and their composition can vary across different assignments. When forming the teams, students are advised to ensure that at least one member in each team has some familiarity with one of the software packages mentioned in the Course Description.

Requirements and Grading

Final grading will be based on group assignments, a final exam and class participation, with the following weights: 60% group assignments, 30% final exam, 10% class participation.

Office Hours

MW 4:30-5:30 or by appointment.

Course Outline

Below is an outline of the course illustrating the progression of topics. Please note that some of the topics might require more or less than a class.

Part I. Technical Background

1. Monte Carlo Valuation in the Binomial Model

Recursive and non-recursive risk-neutral valuation of path-independent and path-dependent derivatives in the binomial model. Introduction to Monte Carlo simulation and comparison with alternative valuation techniques.

2. Continuous-Time Stochastic Processes: Terminology and Key Results

Martingales. Brownian motions. Ito processes. Diffusions and stochastic differential equations. Ito's lemma. Girsanov's theorem. Euler discretization.

3. Generalizing Risk-Neutral Valuation: the Fundamental Theorem of Asset Pricing (FTAP)

Arbitrage, numeraire and martingale measures. The martingale property of asset prices. Pricing derivatives with the FTAP.

Part II. Pricing Models for Equity Derivatives

4. Basic Models

The Black-Scholes model. Forward and futures prices. The Black model. Calibration and Monte Carlo simulation.

5. The Volatility Surface

Key features of empirical volatility surfaces for equity derivatives. Implications for option pricing models.

6. Local Volatility Models

Empirical motivation for local volatility models. The constant elasticity of variance (CEV) model. The implied volatility function (IVF) model. Calibration and Monte Carlo simulation.

7. Stochastic Volatility Models

Empirical motivation for stochastic volatility models. The Heston model. Calibration and Monte Carlo simulation.

8. Hybrid Stochastic Volatility Models

The SABR model. Calibration and Monte Carlo simulation.

9. Jump-Diffusion Models

Empirical motivation for jumps. The Poisson and jump-diffusion processes. The Merton jump-diffusion model. Calibration and Monte Carlo simulation.

10. Stochastic Volatility Jump-Diffusion Models

The affine stochastic volatility jump-diffusion model. Calibration and Monte Carlo simulation. Further extensions.

11. American Derivatives

Monte Carlo valuation of American derivatives: the least-squares Monte Carlo (LSM) al-

gorithm.

12. Derivatives on Foreign Assets

Foreign market derivatives. Composite derivatives. Quantos.

13. Volatility Derivatives

Variance swaps: pricing and synthetic replication. The VIX.

Part III. Pricing Models for Fixed Income Derivatives

14. Introduction to Fixed Income Derivatives

Vanilla fixed income derivatives: caps, floors and swaptions. The market pricing formulas and quoting conventions. Vanilla fixed income derivatives as bond options.

15. One-Factor Spot Rate Models

Introduction to one-factor spot rate models. The extended Vasicek (Hull-White) model. The extended Cox-Ingersoll-Ross (CIR++) model. Calibration and Monte Carlo simulation. Pricing swaptions and options on coupon bonds in one-factor spot rate models: the Jamshidian decomposition.

16. Multi-Factor Spot Rate Models

Limitations of one-factor models. Factors in bond returns: principal component analysis. Multi-factor spot-rate models. The extended gaussian two-factor (G2++) model.

17. Forward Rate Models

Modeling forward rates instead of spot rates: key advantages. The Heath-Jarrow-Morton (HJM) models and the LIBOR market models. The standard LIBOR market model. Calibration and Monte Carlo simulation. Extensions of the standard LIBOR market model.

Part IV. Pricing Models for Credit Derivatives

18. Introduction to Credit Derivatives

The market for credit derivatives. Key instruments: credit default swaps (CDS's), CDS indices and CDS index tranches. Hazard rates and the pricing of single-name CDS's. Copulas and the pricing of multi-name CDS's.

19. Dynamic Credit Risk Models

Motivation. Structural models: the Merton model and first passage models. Shortcomings of structural models. Single-name intensity models: the shifted square root diffusion (SSRD) model. Calibration and Monte Carlo simulation. Multi-name intensity models: conditionally independent defaults, joint default events and default contagion.