UNIVERSITY OF PENNSYLVANIA
The Wharton School

FNCE 392/892:
FINANCIAL ENGINEERING

Prof. Domenico Cuoco Spring 2013

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Course Description

This class provides an introduction to advanced pricing models for equity, fixed income and credit derivatives, with a focus on understanding their comparative advantages and limitations, as well as how they are calibrated and applied.

As part of two or three 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 the software applications provided in class to illustrate the calibration and implementation of the different models will employ *Mathematica*.

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 Financial Derivatives and Fixed Income, 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 Canvas.

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, Wley, 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 will require more than a single class.

Part I. Technical Background

1. Generalizing Risk-Neutral Valuation: the Fundamental Theorem of Asset Pricing (FTAP)
Arbitrage, numeraires and martingale measures. The martingale property of asset prices. Pricing derivatives with the FTAP.

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.

Part II. Pricing Models for Equity Derivatives

3. Basic Models
The Black-Scholes model. Calibration. Introduction to Monte Carlo simulation and antithetic variates. Forward and futures prices. The Black model.

4. The Volatility Surface
Key features of empirical volatility surfaces for equity derivatives. Implications for option pricing models.

5. 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.

6. Stochastic Volatility Models
Empirical motivation for stochastic volatility models. The Heston model. Calibration and Monte Carlo simulation.

7. Hybrid Stochastic Volatility Models
The SABR model. Calibration and Monte Carlo simulation.

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

9. Stochastic Volatility Jump-Diffusion Models
The Bates model. Calibration and Monte Carlo simulation. Further extensions.

10. American Derivatives
Monte Carlo valuation of American derivatives: the least-squares Monte Carlo (LSM) algorithm.

11. Derivatives on Foreign Assets
Foreign market derivatives. Composite derivatives. Quantos.

12. Volatility Derivatives
Variance swaps: pricing and synthetic replication. The VIX.

Part III. Pricing Models for Fixed Income Derivatives

13. 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.

14. 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.

15. 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.

16. 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

17. 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.

18. Dynamic Credit Risk Models: Structural Models
Motivation. The Merton model. First passage models. Shortcomings of structural models. The role of imperfect information.

19. Dynamic Credit Risk Models: Intensity 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.