UNIVERSITY OF PENNSYLVANIA
The Wharton School

FNCE 392/892:
FINANCIAL ENGINEERING

Prof. Domenico Cuoco Spring 2011

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Course Description:

This class covers advanced derivative pricing models. It aims at introducing the main models used in practical applications, understanding their comparative advantages and limitations, as well as how they are calibrated and applied. To allow sufficient breadth of scope, the class will not place any special emphasis on models leading to explicit valuation formulas for specific derivatives, relying instead on the generality afforded by Monte Carlo simulation.

Students will be asked to calibrate and apply the models introduced in the class using software of their choice. The use of *Mathematica* 8.0 is strongly recommended.

Although every effort will be made to introduce the 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 this prerequisite 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*, 7th edition, Prentice Hall, 2008.
- Paul Glasserman, *Monte Carlo Methods in Financial Engineering*, 1st edition, Springer, 2003.
- Riccardo Rebonato, *Volatility and Correlation*, 2nd edition, Wiley, 2004.

- Damiano Brigo and Fabio Mercurio, *Interest Rate Models - Theory and Practice*, 2nd edition, Springer, 2007.
- 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.

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:

Part I. Technical Background and First Applications

1. Review of the Binomial Model
Recursive and non-recursive risk-neutral valuation of path-independent and path-dependent derivatives. Monte Carlo simulation. First examples of *Mathematica* implementation.

2. Introduction to Continuous-Time Stochastic Processes
Martingales. Brownian motions. Ito processes. Diffusions and stochastic differential equations. Ito's lemma. Girsanov's theorem. Monte Carlo Simulation of the Black-Scholes model.

3. 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. The martingale property of forward and futures prices. The risk-neutral martingale measure and the forward martingale measure.

4. First Applications of the FTAP
The Black-Scholes model once again. Forward and futures prices. Black's model. Quantos.

5. Monte Carlo Simulation in General Models
Euler discretization. Choleski decomposition. Estimating the greeks through Monte Carlo simulation.

Part II. Pricing Models for Equity Derivatives

6. The Volatility Surface
Key features of empirical volatility surfaces for equity derivatives. Implications for price distributions.

7. Local Volatility Models
The constant elasticity of variance (CEV) model. The implied volatility function (IVF) model.

8. Stochastic Volatility Models
The Heston model. Calibration and Monte Carlo implementation of stochastic volatility models. Hedging.

9. Jump Models
The Poisson process. The Merton jump-diffusion model. Monte Carlo implementation of jump models. Hedging.

10. Stochastic Volatility Jump Models
The affine stochastic volatility jump (ASVJ) model. Further extensions.

11. American Derivatives
The least-squares Monte Carlo (LSM) algorithm.

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
Basic instruments (swaps, caps and floors, swaptions). The market pricing formulas and quoting conventions. Pricing caps, floors and swaptions as bond options.

14. The Extended Vasicek Model
Spot rate models and the extended Vasicek (Hull-White) model. Calibration and Monte Carlo simulation. Pricing swaptions in one-factor models: the Jamshidian decomposition.

15. The Extended Cox-ingersoll-Ross (CIR++) Model
Calibration and Monte Carlo simulation.

16. Multi-Factor Spot Rate Models
Limitations of one-factor models. Factors in bond returns and principal component analysis. Multi-factor spot-rate models: the extended two-factor gaussian (G2++) model.

17. The standard LIBOR Market Model
Modeling forward rates: key advantages. The Heath-Jarrow-Morton (HJM) approach and the Brace-Gatarek-Musiela (BGM) approach. The standard LIBOR market model. Parametric volatilities and correlations versus non-parametric calibration. Calibration and simulation of the standard LIBOR market model.

18. Nonstandard LIBOR Market Models
The volatility surface for bond derivatives. The CEV and Displaced Diffusion LIBOR market models. Calibration and Monte Carlo simulation. Other extensions.

Part IV. Pricing Models for Credit Derivatives

19. Introduction to Credit Derivatives
The market for credit derivatives. Key instruments.

20. Pricing Defaultable Bonds and Credit Default Swaps
Hazard rates and credit spreads. Hazard rate curves implied by Credit Default Swaps.

21. Dynamic Credit Risk Models
Structural Models. Merton's model and first passage models. Shortcomings of structural models. Intensity models. The shifted square root diffusion (SSRD) model: calibration and simulation. Recovery risk.

22. Correlated Defaults
Modeling correlated defaults: correlated default intensities, joint default events and default contagion. Dynamic copula-based models. Monte Carlo simulation.