UNIVERSITY OF PENNSYLVANIA
The Wharton School

FNCE 392/892:
FINANCIAL ENGINEERING

Prof. Domenico Cuoco   Spring 2008

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Course Description:

This class offers an analysis of advanced derivative pricing models. It aims at reviewing the main models and modeling techniques used in practical applications, understanding their applicability and limitations, and at building an integrated framework allowing students to: 1) decide what stochastic factors (e.g., volatility, jumps, one or more interest rate factors, default intensities) should be incorporated in a reasonable pricing model for a given derivative; 2) formulate a consistent model incorporating the chosen factors; 3) calibrate the model using market data; 4) price the derivative and identify a hedging strategy. To allow sufficient flexibility in the choice of the pricing model, the class will not place any special emphasis on closed-form valuation formulas, relying instead on the full generality afforded by the martingale approach to asset pricing as numerically implemented by Monte-Carlo simulation.

Students will be asked to implement and calibrate the models introduced in the class using software of their choice: Mathematica or Matlab, in conjuction with Crystal Ball (an Excel add-in for Monte Carlo simulation), are strongly recommended.

Although every effort will be made to introduce the models as intuitively as possible, the class will be 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 through Web Cafe.

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

- John C. Hull, *Options, Futures, and Other Derivatives*, 6th edition, Prentice Hall, 2005.

- Paul Glasserman, *Monte Carlo Methods in Financial Engineering*, 1st edition, Springer, 2004.

- 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.

Requirements and Grading:

TBA

Office Hours:

TBA

Course Outline:

I. Introduction to Stochastic Calculus
Martingales. Brownian motions. Ito processes. Diffusions and stochastic differential equations. Ito's lemma. Girsanov's theorem.

II. The Fundamental Theorem of Asset Pricing
Arbitrage, numeraires and martingale measures. The martingale property of asset prices. The martingale property of forward and futures prices. The risk-neutral martingale measure and the forward martingale measure.

III. Martingale Pricing and Monte Carlo Simulation
The martingale approach to derivative pricing. Examples: Black-Scholes and Black formulas. Monte Carlo simulation. Euler discretization. Choleski decomposition. Estimating the greeks through Monte Carlo simulation. First examples.

IV. Introduction to Equity Derivatives
Key features of empirical volatility surfaces for equity derivatives. Implications for price distributions. Time-series evidence from the VIX.

V. Modeling Volatility
Local volatility models: the constant elasticity of variance (CEV) model and the implied volatility function (IVF) model. Stochastic volatility models: the Heston model. Calibration and Monte Carlo implementation of stochastic volatility models.

VI. Modeling Jumps
The need for jumps. The Poisson process. The Merton jump-diffusion model. The affine stochastic volatility jump (ASVJ) model. Calibration and Monte Carlo implementation of jump models.

VII. Advanced Topics in Equity Derivatives
Volatility derivatives. Variance swaps: pricing and synthetic replication. The construction of the VIX. Quantos. Hedging with stochastic volatility and jumps.

VIII. Introduction to Fixed Income Derivatives
Basic instruments (swaps, caps and floors, swaptions). The market pricing formulas and quoting conventions. Empirical volatility surfaces for fixed income derivatives. Pricing caps, floors and swaptions as bond options.

IX. Modeling Spot Rates
One-factor models: The extended Vasicek (Hull-White) model and the extended Cox-Ingersoll-Ross (CIR++) model. Pricing swaptions in one-factor models: the Jamshidian decomposition. 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.

X. Modeling Forward Rates
Modeling forward rates: key advantages. The Heath-Jarrow-Morton (HJM) approach. Example: building a model with level and slope factors using the HJM approach. Limitations of the HJM approach. The Brace-Gatarek-Musiela (BGM) approach. Standard LIBOR market models. Parametric volatilities and correlations versus non-parametric calibration. Choosing the number of factors. Simulation of market model. Non-standard market models.

XI. Introduction to Credit Derivatives
Key instruments. Basic pricing relations. Hazard rates and credit spreads. Hazard rate curves implied by Credit Default Swaps. Calibration of intensity models. Modeling correlated defaults. Dynamic copula-based models. Stochastic Recovery. Monte Carlo implementation.