Course Syllabus

University of Pennsylvania
The Wharton School
Operations, Information and Decisions

Mathematical Modeling and its Application in Finance
OIDD 353/653 – Spring 2018

Tuesday & Thursday, 3:00pm - 6:00pm
January 11 – February 27, 2018
Room: TBD JMHH
Office Hours: Tue & Thu 1:30-2:45pm or by appointment

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Teaching Assistant: TBD

Modern financial markets are marked by the widespread prevalence of new financial products, the importance of risk management, and the availability of powerful computational technology. Quantitative methods have become fundamental tools in the analysis and planning of financial operations. There are many reasons for this development: the emergence of a whole range of new and complex financial instruments, innovations in securitization, the increased globalization of the financial markets, the proliferation of information technology, and so on.

In this class, we develop financial models and computational methods to solve pricing, hedging, and portfolio optimization problems that appear every day in financial markets. The emphasis is on a practical approach: we apply models and methods in a hands-on fashion to real problems, and simultaneously highlight their limitations in real situations. We develop techniques to price a wide array of equity derivatives, including path-dependent options and multi-asset options. We explore the related problems of hedging and risk management, and we address issues that arise in short and long term portfolio optimization. We construct models for the evolution of interest rates, to allow for the pricing and hedging of interest rate derivatives.

The grade for the course will be based on homework assignments and a take-home final exam. The homework will count for 60% of the final grade. There will be about five homework assignments during the term. The final exam will count for 40% of the final grade. Students may work on the homeworks in groups of three or less. Details of the final exam will be discussed later in class.

The course is intended for students who have a strong interest in finance. Prospective students of this course should be comfortable with quantitative methods, such as basic statistics and the methodologies (math programming and simulation) taught in OIDD 612 (Business Analytics.)
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course is quantitative and will require extensive computer use. The models will be implemented in spreadsheets or a high-level modeling environment, MATLAB. (Each student will receive a copy of the student version of Matlab; details will be discussed in class.)

Most of the reading for the course will be in the form of lecture handouts that will be distributed in class and be available on the course Canvas site. The Options, Futures, and other Derivatives book by John Hull (10th edition, Prentice Hall, NJ, 2017 or earlier editions) is optional and will supplement the lecture notes.

**Tentative Schedule**

**Session 1**

*Course Overview & Hedging for Risk Management.*

The course begins with an introduction to hedging. We discuss some basic concepts in hedging. The issue of hedging will be addressed later in the course when pricing models are developed for specific securities.

Topics: Formulation of the hedging problem, Regression hedging. Examples and applications; in-sample versus out-of-sample performance.

**Session 2**

*Numerical Option Pricing I – Option Pricing Theory*

We first give some brief background on option pricing theory

Topics: Risk neutral valuation, Review of the Black&Scholes Model; Geometric Brownian process and the lognormal distribution of stock prices;

**Sessions 3-5**

*Numerical Option Pricing II – The Binomial Method.*

We start with the binomial pricing method for simple European calls and puts, and then extend it to American options. We continue with binomial pricing methods for exotic options; Exotics include options with path-dependent payoffs and options on multiple underlying assets (rainbow options).

Topics: The CRR binomial model. European and American options. Path independent and path dependent securities. Barrier options, Options on multiple assets.

**Sessions 6-7**

*Numerical Option Pricing III – Monte Carlo Simulation.*

We discuss Monte Carlo Simulation. Pricing path independent and dependent options. Variance Reduction Techniques.

Topics: Random number generator; Pricing path independent and dependent securities by simulation; Variance reduction techniques: control variate techniques

**Session 8**

*Option Pricing IV – Beyond Black & Scholes*

We apply the B&S models to traded securities and observe the volatility smile. We discuss the deviations of real markets from the assumptions of the Black-Scholes Model and extensions of the Black-Scholes model, including Merton jump-diffusion model and stochastic volatility models. Finally, we discuss structured option portfolio.

Topics: Historical simulation, stress test, stochastic volatility, jump-diffusion process.
Session 9

**Portfolio Optimization**
In this part of the course, the risk-reward tradeoff is explored for a portfolio with multiple securities. First, we study the standard mean-variance quadratic programming model, variations of the model based on alternative definition of risk, and several applications and extensions.


Session 10

**Multiperiod Portfolio Analysis.**
Finally, we address the multiperiod investment problem and the problem of choosing among efficient portfolios.


Session 11

**Bond Analytics.**
We give a brief background on bond mathematics. We study the pricing of U.S. Treasury bonds and introduce some of the taxonomy used for fixed-income securities such as yield and duration.

*Topics:* Review of discounting, present value and yield. Duration and convexity measures. Immunization and hedging applications. The discount factor and the spot yield curve.

Session 12

**Yield Curve Fluctuations.**
We investigate changes in the Treasury yield curve and its implication for bond portfolio management.


Sessions 13 - 14

**Interest Rate Models and Pricing Interest Rate Sensitive Securities.**
Finally, we will discuss models for the pricing of interest-rate sensitive securities, including single factor models (e.g., Ho-Lee, Black-Derman-Toy) and multi-factor models (e.g., Heath-Jarrow-Morton). Model calibration to market data, and applications including the pricing of caps, floors, swaptions, callable bonds, mortgage-backed securities, and other interest-rate sensitive securities.

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Course-Related Books

“Industry” Books

The following books are widely read on Wall Street. Some books are edited compilations of research reports from the major investment banks.


Derivatives Trading and Option Pricing, Nicholas Dunbar (Editor), Risk Books, 2005.


Monte Carlo: Methodologies and Applications for Pricing and Risk Management, Ed. Bruno
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*My Life as a Quant: Reflections on Physics and Finance*, Emanuel Derman, Wiley, 2004
*Over the Rainbow*, RISK Publications/Fuji, London, 1996,


**Finance Textbooks**


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