

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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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.) This

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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.

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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.

Topics: ADR and variance measures of risk. Linear and quadratic programming methods for portfolio management and asset allocation. The indexation problem and multiple linear regression. Surplus optimization. Mean-variance analysis with transaction costs. Testing and implementation issues.

Session 10

Multiperiod Portfolio Analysis.

Finally, we address the multiperiod investment problem and the problem of choosing among efficient portfolios.

Topics: Multiperiod portfolio models. Kelly's criterion. Portfolio insurance strategies.

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.

Topics: Bond spreading and hedging. Spot rates, forward rates, term structure estimation. Modes of fluctuation of the yield curve - a principal components analysis. Applications to bond pricing. Volatility of interest rates.

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.

Topics: Interest rate tree and the yield curve. Interest rate models: Ho-Lee, Black-Derman-Toy, Hull-White, and Heath-Jarrow-Morton. Callable bond pricing. Interest rate swaps and swaption pricing. Introduction to the MBS market. Prepayment modeling.

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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.

Against the Gods: The Remarkable Story of Risk, Peter Bernstein, Wiley, New York, 1998.

Asset & Liability Management: A Synthesis New Methodologies, Risk Publications/Kamakura, London, 1998.

Black-Scholes and Beyond: Option Pricing Models, Chriss Neil, Irwin Professional Publishing, Burr Ridge, Illinois, 1997.

Bond Markets, Analysis and Strategies, 6rd edition, Fabozzi and Fabozzi, Prentice Hall, Englewood Cliffs, NJ, 2006.

Capital Ideas: the Improbable Origins of Modern Wall Street, Peter Bernstein, Wiley, 2nd edition, New York, 2005.

Corporate Hedging in Theory and Practice: Lessons from Metallgesellschaft, Eds. C. Culp and M.H. Miller, Risk Publications, 1999.

Credit Derivatives: Application for Risk Management, Investment, and Portfolio Optimisation, Risk Publications, London, 1998.

Derivative Credit Risk, RISK Publications/Renaissance Software, London, 1995.

Derivatives Pricing: The Classic Collection, Peter Carr (Editor), Risk Books, 2004.

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

Efficient Asset Management: A Practical Guide to Stock Portfolio Optimization and Asset Allocation, Richard O. Michaud, HBS Press, 1998.

Financial Futures Markets: Structure, Pricing and Practice, John Merrick, Jr., Harper and Row, New York, 1990.

Fixed Income Analytics: State-of-the-Art Debt Analysis and Valuation Modeling, Ravi Dattatreya, ed., Probus Publishing, Chicago, 1991.

Fixed-Income Portfolio Strategies, Frank Fabozzi, ed., Probus Publishing Company, Chicago, 1989.

Flash Boys: A Wall Street Revolt, Michael Lewis, W. W. Norton & Company, 2014

Fooled by Randomness: the Hidden Role of Chance in Life and in the Markets, Nassim Nicholas Taleb, Random House, 2nd edition, 2005.

From Black-Scholes to Black Holes, RISK Publications/FINEX, London, 1992.

Handbook of Mortgage Backed Securities, 5th edition, F. Fabozzi McGraw-Hill, 2001

Hedging with Trees: Advances in Pricing and Risk Management Derivatives, Eds. M. Broadie and P. Glasserman, Risk Publications, London, 1998.

Inventing Money: The Story of Long-Term Capital Management and the Legends behind It, Nicholas Dunbar, John Wiley & Sons, 2001

Liar’s Poker, Michael Lewis, Norton, New York 1989.

Monte Carlo: Methodologies and Applications for Pricing and Risk Management, Ed. Bruno

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Dupire, Risk Publications, London, 1998.

My Life as a Quant: Reflections on Physics and Finance, Emanuel Derman, Wiley, 2004

Over the Rainbow, RISK Publications/Fuji, London, 1996,

Rubinstien on Derivatives, Mark Rubinstein, Risk Publications, London, 1999.

Stocks for the Long Run: the Definitive Guide to Financial Market Returns and Long-Term Investment Strategies, Jeremy Siegel, McGraw-Hill; 3rd edition, 2002.

The Big Short: Inside the Doomsday Machine, Michael Lewis, Norton & Company, 2010

The Black Swan: The Impact of the Highly Improbable, Nassim Nicholas Taleb, Random House, 2007

The Complete Guide to Option Pricing Formulas, Haug Espen Gaader, McGraw-Hill, 2nd edition, 2006.

The Concepts and Practice of Mathematical Finance, Mark S. Joshi, Cambridge University Press, 2003

Fortune's Formula: The Untold Story of the Scientific Betting System that Beat the Casinos and Wall Street, William Poundstone, Hill and Wang, 2006

The Handbook of Exotic Options: Instruments, Analysis, and Applications, ed.: Israel Nelken, Irwin, Chicago, 1995.

The Handbook of Fixed Income Options, Frank Fabozzi, ed., Irwin Professional Publishing, Burr Ridge, Illinois, 1996.

The Handbook of Fixed Income Securities, 5th edition, Frank Fabozzi, ed., Irwin Professional Publishing, Burr Ridge, Illinois, 1997.

The Winner's Curse: Paradoxes and Anomalies of Economic Life, Richard Thaler, Princeton University Press, Princeton, NJ, 1994.

Trading and Investing in Bond Options, M. Anthony Wong, John Wiley, New York, 1991.

Volatility and Correlation: the Perfect Hedger and the Fox, Riccardo Rebonato, John Wiley & Sons; 2nd edition, 2004.

Volatility: New Estimation Techniques for Pricing Derivatives, ed. Robert Jarrow, Risk Publications, London, 1998.

When Genius Failed: The Rise and Fall of Long-Term Capital Management, Roger Lowenstein, Random House, 2000.

Finance Textbooks

Cox and Rubinstein, *Options Markets*, Prentice Hall, Englewood Cliffs, NJ, 1985.

Dixit and Pindyck, *Investment Under Uncertainty*, Princeton University Press, Princeton, NJ, 1994.

Elton and Gruber, *Modern Portfolio Theory and Investment Analysis*, 5th edition, Wiley, New York, 1995.

Garbade Kenneth, *Fixed Income Analytics*, MIT Press, Cambridge, MA, 1997.

Hull John, *Options, Futures, and other Derivatives*, 10th edition, Prentice Hall, NJ, 2017.

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Jarrow and Turnbull, *Derivative Securities*, 2nd edition, South-Western College Pub., 1999.

Luenberger David, *Investment Science*, Oxford University Press, 1998.

Markowitz, *Mean-Variance Analysis in Portfolio Choice and Capital Markers*, Blackwell, New York. 1987.

Rebonato Riccardo, *Interest-Rate Option Models: Understanding, Analysing and Using Models for Exotic Interest-Rate Options*, 2nd edition, Wiley, NY, 1998.

Rodriguez and Carter, *International Financial Management*, 3rd edition, Prentice Hall, Englewood Cliffs, NJ, 1984.

Shreve Steven, *Stochastic Calculus Models for Finance: Continuous Time Models*, Springer 2005.

Sundaresan, Suresh, *Fixed Income Markets and their Derivatives*, 2nd edition, South-Western, Cincinnati (2002).

Tuckman, Bruce, *Fixed Income Securities: Tools for Today's Markets*, 2nd edition, Wiley, NY, 2002.

Wilmott Paul, *Paul Wilmott on Quantitative Finance*, 2nd edition, John Wiley & Sons, 2006