15.450 Analytics of Financial Engineering

Course Description. This course covers the most important quantitative methods of financial engineering and computational finance. These methods include: (1) static and dynamic optimization; (2) Monte Carlo simulation; (3) stochastic (Itô) calculus; (4) financial econometrics; and (5) statistical inference for financial applications. Each of these techniques will be covered in some depth—along with its computer implementation—however, the emphasis will be on financial-engineering *applications*, not on methodology. In particular, quantitative methods are developed within the context of specific problems in financial engineering, problems that fall into one of the following four areas: (1) derivatives; (2) portfolio management; (3) risk management; and (4) proprietary trading. The correspondence between methods and applications is given in the following table:

Quantitative Method	Derivatives	Portfolio Management	Risk Management	Proprietary Trading
Optimization	✓	✓	✓	✓
Monte Carlo Simulation	✓	✓	✓	✓
Stochastic (Itô) Calculus	✓		✓	
Statistical Inference	✓	✓	✓	✓
Financial Econometrics	✓	✓	✓	✓

To ensure that the focus of the course is properly directed towards the practical application of these quantitative methods, the material will be presented in a unique way. The entire course will be devoted to solving successively more complex versions of a single problem: how should a rational investor decide to allocate his wealth among a collection of risky investments? By starting with a relatively simple static version of this problem (basic portfolio theory), and then adding more realistic features incrementally (dynamics, trading costs, securities with nonlinear payoffs, stochastic interest rates, non-Gaussian returns, etc.), students will have seen each of the five quantitative methods in the context of the four application areas listed above. In this way, the motivation for each method and how the method is applied follows naturally and immediately.

Pre-requisites. This course is intended for second-year Sloan Master's students in the Track in Financial Engineering (TFE). Therefore, the pre-requisites include 15.401 and all other requirements of the TFE; in particular, 15.437 is a recommended co-requisite. Some rudimentary programming skills will be necessary—projects will make use of Matlab and eViews programming languages (though prior exposure to these languages is not expected). Non-TFE students may enroll only with the permission of the instructor.

Course Requirements and Grading. Course requirements include: regular attendance and class preparation/participation in lectures and recitations (10 percent), three group projects involving extensive use of the Sloan Trading Lab (25 percent), a mid-term (25 percent) and a final (40 percent) examination. *The closed-book mid-term examination will be given during the first half of the regularly scheduled lecture meeting on Thursday April 3rd (from 4:00 to 5:30), and the closed-book final examination will be given during the MIT-scheduled final examination date—please reserve these dates immediately and schedule your interviews and travel plans accordingly.*

Course Materials. The following materials will be used in this course (required texts are indicated by asterisks):

- Lo*, 2003, *15.450 Lecture Notes.* MIT Graphic Arts.
- Bernstein, 1992, *Capital Ideas*, Free Press.
- Bernstein, 1996, *Against The Gods,* John Wiley & Sons.
- Bodie, Kane, and Marcus, 1999, *Investments* (4th Edition), Irwin.
- Campbell, Lo, and MacKinlay, 1997, *The Econometrics of Financial Markets*, Princeton.

Class Preparation and Participation. Class preparation and participation are important components of this course. Students are expected to come to each class well prepared to discuss the materials assigned (see the attached *15.450 Schedule of Classes and Assignments*). Assignments marked "Review" refer to material already covered in one of the prerequisites such as 15.401 or the Sloan core—students without such prerequisites should read this material thoroughly. Assignments marked "Read" should be read thoroughly with the expectation that it will be required for class discussion. In addition, there may be short assignments distributed in each class for discussion during the following class. Such assignments are to be treated like "case-study" assignments that require considerable advance preparation, and students should expect to be "cold-called" in class to present their analyses of these assignments.

Group Projects. There are three group projects that will provide students with additional opportunities to apply the methods covered in the lectures to new problems in financial engineering. Each project covers a broad application area and involves both quantitative analysis and industry research. Students will be assigned to project groups based on computer skills, industry experience, etc. so that each group will have a good balance of quantitative expertise and institutional background. The three projects and their distribution and due dates are:

Project	Topic	Distributed	Due
A	Portfolio Management	February 13	March 6
B	Monte Carlo Methods and Risk Management	March 6	April 3
C	Derivatives, Fixed-Income, and Trading	April 3	May 8

Projects are due at the start of class (4:00pm) on the due date. Projects submitted after the due date will be subject to a 25% grade-deduction for each 24-hour period they are late. There will be no exceptions to this policy.

15.450 Schedule of Classes and Assignments

Thursday	February 6	Part 1: Preferences, Risk, and the Investment Problem Part 2: Means, Variances, and Basic Statistical Inference • Review 15.060 Classes 4–7 • Read BKM* Appendix A • Read Merton (1994)	Class 1
Thursday	February 13	Part 1: Modern Portfolio Theory Part 2: Mean-Variance Analysis and Static Optimization • Review BKM Part 2 (Portfolio Theory) • Read BKM Chapter 28 • Read Treynor and Black (1973) • Project A Distributed	Class 2
Thursday	February 20	Part 1: Basic Properties of Financial Data Part 2: Cross-Sectional and Time-Series Models of Returns • Read CLM† Chapter 1 • Read Lo (1994)	Class 3
Thursday	February 27	Part 1: The CAPM/APT and Linear Factor Models Part 2: Performance Attribution • Review BKM Chapters 9–11 • Read BKM Chapter 24 • Read Black (1993) • Read Jagannathan and McGrattan (1995)	Class 4
Thursday	March 6	Part 1: Stochastic Processes and Financial Time Series Part 2: Monte Carlo Simulation and Statistical Inference • Read CLM Chapter 2 • Project A Due • Project B Distributed	Class 5
Thursday	March 13	Part 1: Life-Cycle Investing and Asset Allocation Part 2: Introduction to Stochastic Dynamic Programming • Review BKM Chapter 26 • Read Bodie (1995)	Class 6
Thursday	March 20	No Class (Spring Break)	
Thursday	March 27	No Class (Spring Break)	

* Bodie, Kane, and Marcus, 4th Edition, (1999).
† Campbell, Lo, and MacKinlay (1997).

Thursday	April 3	Mid-Term Examination (closed-book) • Project B Due • Project C Distributed	
Thursday	April 10	Part 1: Asset Allocation and Dynamic Optimization Part 2: Empirical Issues In Asset Allocation • Read Ibbotson and Kaplan (2000) • Read Sharpe (2002)	Class 7
Thursday	April 17	Part 1: Introduction to Derivative Pricing Models Part 2: Continuous-Time Stochastic Processes • Review BKM Chapters 19 and 20 • Read CLM Chapter 9	Class 8
Thursday	April 24	Parts 1 and 2: The Itô Calculus	Class 9
Thursday	May 1	Parts 1 and 2: Derivation of the Black-Scholes Formula • Read Boyle, Broadie, and Glasserman (1997)	Class 10
Thursday	May 8	Part 1: Introduction to Fixed-Income Analytics Part 2: Models of the Term Structure • Review BKM Chapters 14 and 15 • Read CLM Chapter 10 • Read Kao (2000) • Project C Due	Class 11
Thursday	May 15	Part 1: Introduction to Hedge Funds and Proprietary Trading Part 2: Risk Management for Hedge Funds • Read CLM Chapter 3 • Read Lo and MacKinlay (1990) • Read Lo (2001) • Read Lo (2002)	Class 12

15.450 Readings

1. Black, F., 1993, "Beta and Return", *Journal of Portfolio Management* 20, 8–18.

2. Bodie, Z., 1995, "On the Risk of Stocks in the Long Run", *Financial Analysts Journal* 52, 18–22.

3. Boyle, P., Broadie, M. and P. Glasserman, 1997, "Monte Carlo Methods for Security Pricing", *Journal of Economic Dynamics and Control* 21, 1267–1321.

4. Ibbotson, R. and P. Kaplan, 2000, "Does Asset Allocation Explain 40, 90, or 100 Percent of Performance?", *Financial Analysts Journal* 56, 26–33.

5. Jagannathan, R. and E. McGrattan, 1995, "The CAPM Debate", *Federal Reserve Bank of Minneapolis Quarterly Review* 19, 2–17.

6. Kao, D., 2000, "Estimating and Pricing Credit Risk: An Overview", *Financial Analysts Journal* 56, 50–66.

7. Lo, A., 1994, "Data-Snooping Biases in Financial Analysis", in H. Russell Fogler, ed.: *Blending Quantitative and Traditional Equity Analysis*. Charlottesville, VA: Association for Investment Management and Research.

8. Lo, A., 2001, "Risk Management for Hedge Funds: Introduction and Overview", *Financial Analysts Journal* 57, 16–33.

9. Lo, A., 2002, "The Statistics of Sharpe Ratios", *Financial Analysts Journal* 58, 36–52.

10. Lo, A. and C. MacKinlay, 1990, "When Are Contrarian Profits Due to Stock Market Overreaction?", *Review of Financial Studies* 3, 175–205.

11. Merton, R., 1994, "Influence of Mathematical Models in Finance on Practice: Past, Present, and Future", *Philosophical Transactions of the Royal Society of London* A 347, 451–463.

12. Sharpe, W., 2002, "Budgeting and Monitoring Pension Fund Risk", *Financial Analysts Journal* 58, 74–86.

13. Treynor, J. and F. Black, 1973, "How to Use Security Analysis to Improve Portfolio Selection", *Journal of Business* 46, 66-86.

