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:

<table>
<thead>
<tr>
<th>Quantitative Method</th>
<th>Derivatives</th>
<th>Portfolio Management</th>
<th>Risk Management</th>
<th>Proprietary Trading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimization</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Monte Carlo Simulation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Stochastic (Itô) Calculus</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Statistical Inference</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Financial Econometrics</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

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):


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:

<table>
<thead>
<tr>
<th>Project</th>
<th>Topic</th>
<th>Distributed</th>
<th>Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Portfolio Management</td>
<td>February 13</td>
<td>March 6</td>
</tr>
<tr>
<td>B</td>
<td>Monte Carlo Methods and Risk Management</td>
<td>March 6</td>
<td>April 3</td>
</tr>
<tr>
<td>C</td>
<td>Derivatives, Fixed-Income, and Trading</td>
<td>April 3</td>
<td>May 8</td>
</tr>
</tbody>
</table>

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   Class 1
Part 2: Means, Variances, and Basic Statistical Inference
   • Review 15.060 Classes 4–7
   • Read BKM* Appendix A
   • Read Merton (1994)

Thursday February 13  Part 1: Modern Portfolio Theory   Class 2
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

Thursday February 20  Part 1: Basic Properties of Financial Data   Class 3
Part 2: Cross-Sectional and Time-Series Models of Returns
   • Read CLM† Chapter 1
   • Read Lo (1994)

Thursday February 27  Part 1: The CAPM/APT and Linear Factor Models   Class 4
Part 2: Performance Attribution
   • Review BKM Chapters 9–11
   • Read BKM Chapter 24
   • Read Black (1993)
   • Read Jagannathan and McGrattan (1995)

Thursday March 6     Part 1: Stochastic Processes and Financial Time Series   Class 5
Part 2: Monte Carlo Simulation and Statistical Inference
   • Read CLM Chapter 2
   • Project A Due
   • Project B Distributed

Thursday March 13    Part 1: Life-Cycle Investing and Asset Allocation   Class 6
Part 2: Introduction to Stochastic Dynamic Programming
   • Review BKM Chapter 26
   • Read Bodie (1995)

Thursday March 20    No Class (Spring Break)

Thursday March 27    No Class (Spring Break)

†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)

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

Thursday April 24 
Parts 1 and 2: The Itô Calculus

Thursday May 1 
Parts 1 and 2: Derivation of the Black-Scholes Formula  
- Read Boyle, Broadie, and Glasserman (1997)

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

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)


