IEOR E4602 Quantitative Risk Management: Spring 2016
Columbia University

Syllabus and Logistics

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Course Website: All course material will be posted on CourseWorks.

Class Time: Mondays and Wednesdays 11.40pm to 12.55pm.

Pre-requisites / Corequisites
Students should have a good background in financial engineering. In particular they should know:

1. What forwards and futures are and the differences between them.
2. Basic options theory including the Black-Scholes formula and the "Greeks".
3. The main ideas behind risk-neutral or martingale pricing and complete / incomplete markets.
4. The basic mechanics and pricing of credit-default-swaps (CDS).
5. Basic mean-variance analysis and the CAPM.

The material in *IEOR E4706: Foundations of Financial Engineering* provides more than a sufficient background for this course. If you have not taken this course then you should make sure you are very familiar with the topics listed above. Before the semester begins I will post some of the relevant lecture notes from *IEOR E4706*.

Students should also have had some prior exposure to stochastic processes and simulation, optimization (in particular linear programming) and statistics. The following courses or their equivalents are more than sufficient to meet these requirements:

1. IEOR E4701: Stochastic Processes for Financial Engineering
2. IEOR E4007: Optimization Models and Methods for Financial Engineering
3. IEOR E4709: Data Analysis for Financial Engineering
4. IEOR E4703: Monte Carlo Simulation

Monte-Carlo techniques will arise in several parts of the course and it will be assumed that students know how to simulate random variables, stochastic processes etc. If you have not had prior exposure to simulation then it is still possible to take this course if you are also taking a simulation in parallel this semester.

With regards to statistics, it is important to be familiar with *maximum likelihood estimation* (MLE). Other statistical methods and models will be introduced as necessary during the course.

If a student does not satisfy these requirements they will **not** be admitted to the course. In addition, this is a course for **graduate students only**. Undergraduates are not permitted to take this course. Finally, there tends to be a lot of demand for this course and only MSFE students and suitably qualified MSOR students are guaranteed a place.

Textbooks There are no required textbooks for the class and there is no text that covers everything we will study in this course. There are two texts worth mentioning, however:

1. *Statistics and Data Analysis for Financial Engineering* (2nd ed., 2015) by David Ruppert and David S. Matteson, and published by Springer. While the focus of this text is on statistics and data analysis, it is an excellent text, provides a good introduction to `R` and also overlaps with several topics in the course. If students are going to purchase a text then I recommend this one. It may be downloaded for **free**, however, from the Columbia network or purchased from Springer's website. Errata and a link to the Springer site are available at
`http://people.orie.cornell.edu/davidr/SDAFE2/index.html`.

2. *Quantitative Risk Management* (2nd ed., 2015) by McNeil, Frey and Embrechts and published by Princeton University Press. This is the standard reference for quantitative risk management and some of the earlier topics in the course will draw heavily from this book. It is a PhD level / reference text, however, and you are not expected to have access to this text. The official web-page for the book is at
`http://press.princeton.edu/titles/8056.html`.

Course Materials: Lecture notes, slides, assignments and solutions to the assignments will be posted on CourseWorks. Students will also be directed to papers / primers that they will be asked to read before some of the lectures. These papers / primers are an integral part of the course.

Assignments
There will be approximately 8 assignments that must be submitted by the due date. Late assignments will **NOT** be accepted. Students are welcome to work together on the assignments but each student MUST write up his or her own solution. Most of the assignments will require programming using some combination of `Matlab`, `R` and `Excel / VBA`. No prior knowledge of `VBA` is assumed but students should be prepared to learn some `VBA` during the course. Students are expected to have prior knowledge of at least one of `Matlab` and `R`.

Exams
There will be a midterm and a final examination. The exams will be **closed-book** where individual "cheat-sheets" will **not** be allowed. A common "cheat-sheet" will be provided to students taking each exam. Any student who is unable to take an exam must have a very good reason, e.g. a medical emergency, for doing so. They will also require permission from the Dean's Office if they therefore need to take a makeup exam. Any such makeup exam will be at least as difficult as the regular exam taken by the rest of the class.

Exam regrades may be requested by:

1. Explaining in a written statement why you think you should obtain more points.
2. Submitting this statement and the exam to either the TA or course instructor no later than one week after the exam was returned to the class. (This means that if you failed to collect your exam within a week of it being returned to the class, then you cannot request a regrade!)

It should be kept in mind that when a regrade is requested the entire exam will be regraded and it is possible that your overall score could go down as well as up. We will also **photocopy a subset of the exams before returning them** to the class. This is intended to deter the very few people (hopefully there are no such people in this class!) who might be tempted to rewrite parts of their exams before requesting a regrade.

Grading
The grading scheme will be *approximately*: Assignments 20%, Midterm 35%, Final 45%. I do, however, reserve the right to deviate from this scheme.

Tentative Syllabus: The course will cover the following topics.

1. Basic concepts and techniques of risk management including risk factors, loss distributions, historical and Monte-Carlo simulation, variance-covariance approximations and stress testing.
2. Multivariate distributions: review of basic facts, introduction to multivariate normal, spherical and elliptical distributions.
3. Dimension reduction techniques including factor models and principal components analysis.
4. Copulas including the estimation and simulation of copulas.
5. Measures of risk including VaR, CVaR / Expected Shortfall and coherent / incoherent risk measures. Possibly also a brief introduction to risk aggregation and capital allocation via the Euler principle.
6. Model risk and transparency including applications to equity and credit derivatives.
7. Portfolio optimization including (the problems with) mean-variance analysis, Black-Litterman, mean-CVaR etc.

8. Monte-Carlo methods and variance reduction techniques with applications to insurance, credit risk and pricing equity derivatives.

If time permits we will also delve into

9. Time-series methods and in particular, using ARCH / GARCH models to construct dynamic estimates of VaR and CVaR.

10. Extreme value theory (EVT) with applications to estimating VaR and CVaR.

There is clearly substantial overlap between these topics and some of the topics covered in the core FE courses in the Fall semester as well as FE electives in the spring semester. This is to be expected given the interdisciplinary nature of risk management but this should be viewed as a strength rather than a weakness of the course: studying topics for a second time and in a different context should help reinforce and improve your understanding of this material.

Several important topics that are not listed above include credit risk, liquidity risk and insurance risk. They will be discussed by way of examples during the lectures and course assignments. Credit risk is a particularly important topic that we will not discuss formally. We will, however, introduce various credit models and examples (including the infamous Gaussian copula model) during the course that will provide some exposure to this important topic. Liquidity risk and the concept of a "crowded trade" are also enormously important in practice and these are topics that we will also discuss on occasion. Another important topic that we will not cover is systemic risk which has become a very hot research topic in recent years (for obvious reasons). We will have little to say about this as it not yet well understood.