UNIVERSITY of VIRGINIA
DEPARTMENT OF SYSTEMS AND INFORMATION ENGINEERING

SYS 4581/6581: FINANCIAL ENGINEERING
FALL 2023

INSTRUCTORS:

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COURSE LOGISTICS

Lecture:	Friday	1:00-3:30pm	Thornton Hall D115
Office Hours:	Thompson: Friday Neha: TBD	3:30pm-	TBD (by Appointment)

Prerequisites: Multivariate Calculus, Linear Algebra, Probability & Statistics, some programming exposure

Required Textbook: Luenberger, David. *Investment Science.* 2nd ed. New York, NY: Oxford University Press, 2013. ISBN: 0199740089

Software: Actual, hands-on experience with financial data is a key part of the course. Many problems can be solved using Microsoft Excel, but others will likely require (or more conveniently solved) using a statistical programming package or general development environment. Two encouraged options are the statistical package *R* and the programming language *Python* using the *Pandas* data package.

R:

R is not the only statistical package suitable for quantitative financial analysis, but it does have a couple key advantages; namely it is free, and it remains the package of choice for many research statisticians, so new methods frequently released first in R. R can be downloaded from http://www.r-project.org/ . There are many manuals, tutorials, and YouTube videos covering R freely available online.

RStudio is a recommended interface for the R software. It is also free, and it runs on Windows, Mac, and Linux operating systems. http://www.rstudio.org

Python:

Python is a full programming language offering vast capabilities, so it can be used for full scale software development with your quantitative analytics neatly embedded. The advantage is that you do not have to "switch" languages when switching from data processing and other general computing tasks to do perform data analysis and build specialized analytics. The sacrifice is that Python lacks some of the convenience features of a specialized statistical package. That, however, has changed dramatically with the emergence of the Pandas package. It performs many basic data analysis tasks as easily (if not more so) than R. It was initially developed at the hedge fund AQR, but is now open source and being adopted across the financial industry. Like R, Python is free and extensive documentation and tutorials exist online. You can download Python directly at https://www.python.org/. I recommend using the latest stable version of Python 3 (rather than version 2.7).

Anaconda

If you are new to Python, instead of installing Python directly from the link above, I would encourage you to instead install Continuum Analytics, Anaconda distribution of Python (https://store.continuum.io/cshop/anaconda/) as it comes pre-configured with Pandas as well as many other useful packages for scientific computing. It also contains a nice IDE called Spyder, which is convenient if you do not have an IDE/ enhanced text editor of choice (e.g. Emacs). Kevin Shepard has a nice set of notes titled "*Introduction to Python for Econometrics, Statistics and Data Analysis*" that offers a great introduction to Python for financial data analysis, including installing Anaconda (http://www.kevinsheppard.com/images/0/09/Python_introduction.pdf).

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COURSE DESCRIPTION & OBJECTIVES

The course will provide an introduction to the field of financial engineering focusing on three primary coverage areas:

1) Asset Pricing – including the risk-neutral pricing framework, standard models for security price evolution, derivative pricing, and associated numerical techniques
2) Portfolio Construction – including well-known factor model approaches (e.g., CAPM and APT), portfolio optimization techniques, and the computational methods for model estimation and optimization
3) Risk Management – including common metrics for sensitivity analysis of single securities and derivatives, portfolio risk aggregation and hedging, and model selection and robustness

Treatment of the course topics will focus both on developing the underlying quantitative financial theory and building skills in practical application and problem solving. Accordingly, students will be required to complete problem sets, work in groups for case studies & projects, and engage in class discussions. Upon successful completion of the course, students should be able to:

- When encountering a new security:
  - Evaluate its characteristics, including any available historical data to determine the suitability of standard security price models for modeling this security
  - Derive expressions for pricing and risk metrics, evaluate these expressions analytically or numerically, and identify potential limitations or inherent risks in their modeling approach
- If given a portfolio of common assets (i.e., equity & fixed income securities and derivatives):
  - Estimate exposures to common market factors (e.g., equity Beta) and identify key drivers within the portfolio for these exposures
  - Conduct a risk assessment of the portfolio, including calculation of aggregate risk metrics (VaR and Expected Shortfall) as well as risk concentrations, such as jump-to-default/zero and sector
  - Formulate an optimization problem to calculate the optimal portfolio for a given utility function and portfolio constraints
  - Identify any areas of particular model fragility in their approach to any of the above

EVALUATION & GRADING

Assignments	
35%	Problem Sets
25%	Projects
±5%	Class Participation

Exams	
15%	Midterm
25%	Final

NOTE: Assignments for both sections will be the same, but the graduate students will have to complete additional exercises/problems in most assignments.

TENTATIVE SCHEDULE

Week	Dates	Lecture Topics	Reading
		Asset Pricing	
1	Aug-25	Introduction, Time Value of Money Chapters 2, 3 & 4 - Bonds, Annuities, and the Term Structure of Interest Rates	2.*; 3.1-3.4; 4.1-4.7
2	Sep-01	Chapters 5 & 11: Utility Theory, Dynamic Programming, State Models & Risk Neutral Pricing	5.3-5.4; 11.1-11.12
3	Sep-08	Chapter 12: Forwards, Futures, & Swaps	12.1-12.8
4	Sep-15	Chapter 13: Models for Asset Dynamics	13.*
5	Sep-22	Chapters 14 & 15: Options Theory	14.1-14.7; 14.9
6	Sep-29	Chapters 14 & 15: Options Theory (Cont'd)	
7	Oct-06	Midterm (Take-Home) Chapter 16: Interest Rate Derivatives Chapter 17: Credit Risk	16.1-16.8; 16.9 17.1-17.5; 17.10-17.12
		Portfolio Construction	
8	Oct-13	Chapter 6: Portfolio Optimization (Mean-Variance, etc.)	
9	Oct-20	Chapter 7: Capital Asset Pricing Model	
10	Oct-21	Chapter 8: Other Factor Models	
		Risk Management	
11	Nov-03	Single-Security Risk Metrics (Fixed Income)	
12	Nov-10	Single-Security Risk Metrics (Equities)	
13	Nov-17	Portfolio Risk Metrics	
	Nov-24	Thanksgiving Recess	
		Projects	
14	Dec-01	TBD – (Project Presentations)	