NYU Tandon School of Engineering – Financial Engineering

Course title: Quantitative Risk and Portfolio Management, FRE-GY 7841 - I2 (21574)

Meets: Thursdays September 5, 12, 19, 26; October 3, 10, 17, 2019. 6PM-8:41PM, Rogers Hall, Room 214, Brooklyn Campus

Instructor: Ken Winston, kjw241@nyu.edu

Prerequisites: Multivariate calculus, linear algebra, calculus-based probability, and Python.

Course motivation and aim: This is a condensed 7-week version of the full-semester course MATH-GA.2751

Learning outcome: At the end of this course, students will know the major quantitative techniques of risk and portfolio management in equities and fixed income as they are used in the financial industry today. Students will understand and be able to use standard models for risk estimation and management, perform portfolio optimization, and communicate model output and outcomes to business leaders.

Format and evaluation: The lectures of this half-semester class will be based on assigned readings, online material and class notes. Students will be given homework to solidify and deepen their understanding as well as to get exposed to the practical aspects of the materials taught.

Each student will be graded based on their performance in (1) individual homework assignments (25%), (2) quizzes and midterm (35%), and (3) a final exam (40%).

Course description: Risk management is arguably one of the most important tools for managing investment portfolios and trading books and quantifying the effects of leverage and diversification (or lack thereof).

This course is an introduction to portfolio and risk management techniques for portfolios of (i) equities, delta-1 securities, and futures and (ii) basic fixed income securities.

A systematic approach to the subject is adopted, based on selection of risk factors, econometric analysis, extreme-value theory for tail estimation, correlation analysis, and copulas to estimate joint factor distributions. We will cover the construction of risk measures (e.g. VaR and Expected Shortfall) and portfolios (e.g. portfolio optimization and risk). As part of the course, we review current risk models and practices used by large financial institutions.

It is important that students taking this course have good working knowledge of multivariate calculus, linear algebra, calculus-based probability, and Python.

Readings

Quantitative Risk and Portfolio Management, by Ken Winston ("QRPM")

Software

- Jupyter / iPython notebook
    - Python Libraries: Pyplot, Scipy, Pandas, Numpy

Schedule (subject to change)

Week 1 (September 5, 2019)
What is risk?
- Risk vs. Knightian uncertainty
- Making decisions under uncertainty

Utility theory
- Von Neumann-Morgenstern (VNM) utility theory
- VNM axioms and theorems
- Risk aversion
- Drawbacks of utility theory

Reading: Economics, Capital markets, Probability, and Stochastic process terminology in QRPM 1.5, 1.6, 1.7 and 3.7
Homework: Probability and stochastic process problems; Utility theory – finding indifference points

Week 2 (September 12, 2019)
Risk metrics
- Coherent risk measures
- Volatility, VaR, ES/CVaR (and spectral risk measures)
- Risk-averse prices
- No-arbitrage
- State prices and risk-neutral probabilities
- Stochastic Discount Factors
- The Ross Recovery Theorem

Reading: QRPM Chapter 2
Homework: Computing risk metrics of theoretical distributions

Week 3 (September 19, 2019)
Fixed income risk & bond mathematics
- The time value of money & discounting
    - The risk in the risk-free rate
- Real, inflation and nominal rates
- Basic bond mathematics
    - Generic pricing equation
    - Duration & convexity
    - Approximations and basis risk
- Yield curves

    - Features of yield curves
    - Zero curves and par curves
    - Types of yield curves
    - Yield curves and economic conditions
    - Rolldown and key rate durations
    - Bootstrapping the yield curve, interpolation and smoothing techniques
    - Implied forward curves
- Term Structure Models – Short Rate Models

Reading: QRPM Chapter 3
Homework: Getting interest rate data from FRED; curve calculations

<u>Week 4 (September 26, 2019)</u>
Convex optimization

- Basic terminology: Constrained vs. unconstrained optimization, feasible point, global vs. local solutions
- Karush-Kuhn-Tucker first-order conditions
- Linear and quadratic programming (QP)
- Convex programming (CP)

Reading: Handouts
Homework: Optimizing maximum likelihood functions using CRSP data

<u>Week 5 (October 3, 2019)</u>
Equity risk

- Modern portfolio theory and mean-variance optimization
    - Equality-constrained frontier
    - Equality-constrained frontier: example
    - Inequality constraints
    - Efficient frontier and utility functions
    - The capital market line
    - Benchmark-relative
    - Efficient frontiers: theory and practice
- Bayes' Rule and shrinkage estimators
    - Shrinkage estimators
    - Statistical tests
    - Resampled efficient frontier

Reading: QRPM 4-4.2
Homework: Finding efficient portfolios using CRSP data

<u>Week 6 (October 10, 2019)</u>
Equity risk, cont'd

- Introduction to Black-Litterman
    - Market equilibrium
    - Investor views

Factor models

- The Capital Asset Pricing Model (CAPM) and the three-, four-, and five-factor models

- Arbitrage pricing theory (APT)
- Factor models in practice
- Principal components analysis (PCA)

Reading: QRPM 4.2-4.3, Chapter 5
Homework: Resampled efficient frontier, Black-Litterman using CRSP and FRED data

Week 7 (October 17, 2019)
Distributions

- The normal distribution
- Central limit theorem
    - Checking normality – q-q plots, p-p plots
    - Jarque-Bera test
    - Causes of non-normality
- Student's t distribution
- Mixtures of normals
- Stable distributions
- Extreme value distributions
- Tail distributions

Reading: QRPM Chapter 6
Homework: Fit tail distributions to FRED data