NYU Tandon School of Engineering – Financial Engineering

Course title: Risk Preference and Portfolio Selection, FRE-GY 7841 - I2 (21574)

Meets: Virtually on Thursdays September 3, 10, 17, 24; October 1, 8, 15, 2020. 6PM-8:41PM

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 have been introduced to 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) Class participation (18%); (2) individual homework assignments (32%), and (3) a final exam (50%).

Course description: 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. Some work will be done in passing with options, futures and other derivatives but this is not mainly a derivatives class.

Risk preference – the fact that people do not enter into risky ventures linearly - plays a major role in the financial markets. Risk management thus becomes one of the most important tools for managing investment portfolios and trading books and quantifying the effects of leverage and diversification (or lack thereof). The combination of risk management with portfolio selection is a powerful technique to form long-term efficient investment programs.

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 and calculus-based probability. Students will be required to have (or to quickly acquire) facility with Python.

Readings

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

Software

- Jupyter / iPython notebook
    - Book is hosted on mybinder but your own instance is recommended, preferably Anaconda
    - Python Libraries: Pyplot, Scipy, Pandas, Numpy

Schedule (subject to change)

Week 1 (September 3, 2020):

What is risk? Venture vs. Peril. Frank Knight's framework
Class polls – what would you do in risky situations?
Economic terminology
Capital markets terminology
Probability terminology
Utility Theory
St. Petersburg paradox, early forms of utility functions
von-Neumann Morgenstern axioms – lotteries and prizes, big-U and small-u utility equivalence
Risk tolerance: Aversion; Neutrality; Seeking. Coefficients of risk aversion. Characterizations of utility functions with respect to risk tolerance.
Problems with utility theory

QRPM Chapter 1

Week 2 (September 10, 2020):

"*Caveat Laws" – Rules about lack of rules*
Risk metrics:
  Standard Deviation, MAD, Semi-Standard Deviation, Inter-p-tile range
  VaR, ES, cVaR
  Coherent Risk
Risk-adjusted reward metrics
Risk-averse prices
No-arbitrage
State Prices and Risk-Neutral Probabilities
Stochastic Discount Factors (SDF's)
The Ross Recovery Theorem

QRPM Chapter 2

Week 3 (September 17, 2020):

How can there be risk in the risk-free rate?
Pricing discounted cash flows
Sensitivity to changes in rates; Macaulay duration; convexity
Portfolio duration
Yield curves: Par curves; bootstrapping a zero curve.
Litterman-Scheinkman: Level, slope, twist
Continuous yield curves: Nelson-Siegel
Forward curves
Stochastic Processes; The short rate
Vasicek's short rate model; example; solution
Other short rate models

QRPM Chapter 3

Week 4 (September 24, 2020):

Equity modeling
Markowitz efficient frontier
- *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
- *Shrinkage estimators*
- *Statistical tests*
- *Resampled efficient frontier*

Black-Litterman
- *Market equilibrium*
- *Investor views*

QRPM Chapter 4

Week 5 (October 1, 2020):

Factor Models
- *Capital Asset Pricing Model (CAPM)*
- *Four-Factor Model (Fama-French-Carhart)*
- *Arbitrage Pricing Theory (APT)*
  - *Exact*
  - *Specific*

Factor models in practice
Principal Components Analysis

QRPM Chapter 5

Week 6 (October 8, 2020):

Distributions
Central Limit Theorem
Testing for Normal – QQ Plots and Jarque-Bera
Student's T distribution
Mixture of Normals distributions
Stable distributions; Generalized Central Limit theorem
The Generalized Extreme Value family
Extreme Value Theorem
Maximum Domains of Attraction
Generalized Pareto distributions
Pickands Theorem

QRPM Chapter 6

Week 7 (October 15, 2020):

The time-varying nature of volatility
Historical volatility
Volatility as a tradable asset
Implied volatility
Skews and smiles
Recovering the risk-neutral probability density from options prices
Recovering the real-world probability density
Stochastic and Local Volatility Models; SABR
Review of time series
ARCH – AutoRegressive Conditional Heteroskedasticity volatility modeling
GARCH – Generalized ARCH
The Merton model (en passant)
Variants of ARCH – EGARCH, TARCH

QRPM Chapter 8