Financial Analytics

AD 561/CS 561 Spring 2025

Leo Law, CFA
leolaw@bu.edu

Summary:

This course presents an overview of modern investment topics. We will start with a survey of the financial markets and the common quantitative technique to value a range of financial instruments. Once the basic blocks of valuation tools are established, the course will move on to the discussion of portfolio construction process, risk management with derivative and time series analysis. The course will rely on using Python's Jupyter Notebook to illustrate the concept and build visualization for effective communication. By completing the course, students will be able to conduct exploratory data analysis independently and leverage their programming skillset with real-world financial case studies.

Text:

No required textbook. We will draw on slides, class notes, and supplemental readings that I will be posting on Blackboard.

Suggested Reference Book:

1. Bodie, Kane, Marcus, *Investments,* McGraw-Hill, 12th ed., 2021
2. Hull, *Options, Futures, And Other Derivatives*, Pearson, 8th ed., 2012
3. Python for Finance (Yan), 2nd ed., 2017

Technology:

We will use the Jupyter Notebook extensively in class and homework assignment. I recommend choosing the Anaconda distribution due to the ease of use of its package management system and cross-platform compatibility.

Grading:

60% Lab HW/Assignments
10% Midterm
15% Final
15% Project

Assignments are due at the beginning of class, no exceptions. This allows me to review the assignment with the class immediately. If assignment requires the use of spreadsheet, it may be submitted via email. Other assignments may be submitted using email or paper at the beginning of class.

Exams are a mixture of multiple choice/true-false and short answer/worked math problem. They will be drawn on worked example and topics discussed in class.

The class will conclude with an individual project prestation to the class on topic and data analytics research related to the class lectures throughout the course. A minimal viable WebApp showcasing your work or a Jupyter Notebook documenting your analytics journey is required for the project. Accompanying code must also be submitted for the project. Suggested topics will be discussed later in the course.

Lecture Topics (Tentative schedule)

1. Introduction to Financial Markets
   Review of Syllabus
   Introduction to Asset Classes, Trading Instruments, and Investment Statistics
   Notebook: Setting up Jupyter Notebook (in Anaconda), Downloading Market and Economics Data in Python, EDA

2. Time Value of Money
   Concepts such as present value of future cash flow/perpetuity
   Net Present Value, Internal Rate of Return
   Notebook: Building a financial calculator using related financial function in the numpy-financial module

3. Fixed Income and Equity Valuation
   Sector overview, Interest Rate Term Structure, Bond Pricing with YTM
   Interest Rate Compounding (EAR/APR/Continuous), Interest Rate Structure, Credit Spread, Dividend Discount Valuation (single and multi-period), Free cash flow discount model, Discount Rate and Weighted Average Cost of Capital
   Notebook: EAR/APR/Continuous Compounding Calculation and Conversion, Pricing Corporate Bond using the Discount Method, Stock Valuation (DDM/Free Cash Flow (WACC))

4. Capital Asset Pricing/ Multifactor Model, Performance Measures
   CAPM introduction and one-factor estimation. Fama-French Three-(and Five) Factor model. Performance Analytics: Sharpe, Treynor, Sortino Ratio. Jensen's Alpha
   Notebook: Using statsmodels module to run OLS Regression Analysis and perform statistical inference. Performance Analytics (Sharpe and Treynor Ratio) for a stock/strategy/portfolio.

5. Portfolio Theory
   Introduction to portfolio theory. Formation of 2-stock portfolio with zero-risk. Using Utility Function to determine risk preference. Formation of n-stock portfolio and building the optimal portfolio
   Notebook: Introduction to using SciPy's optimize module to solve objective functions (ie. Minimization of portfolio variance). Utility function and performance analysis using Pyfolio.

Mid-Term (February 27th, 2025)

6. Building Event-Based Backtesting Class and Brief Intro of Kernel Density Estimation and Multivariate Simulation
   Survey of Object-Oriented Programming in Python, building a back-testing system to test momentum and mean-reversion strategy, Using Kernel Density Estimation (KDE) for sampling using historical return (non-parametric method). Using Cholesky decomposition technique to conduct simulation with predefined correlation structure
   Notebook: Using the sklearn package to build a kernel density and sample market data based on historical return for simulation. Survey of OOP will be introduced, and structure of an event-based back-testing structure will be used as a case-study.

7. Derivatives (Risk Management)
   Motivation for using derivatives in investment management. Currency and index future pricing, option strategies, Black-Scholes-Merton option model, Option Greek
   Notebook: Using future to beta hedge the portfolio, Building Call/Put Option pay off graph using popular strategies, Implementing the BSM option model and its associated Greek (risk metrics), Building the implied volatility chart to show the skewness of the smile

8. Value at Risk
   Introduction to VaR, and review of the pdf for normal distribution. How to use VaR and modified VaR (including skewness and kurtosis) to calculate the percentage of loss. Using non-parametric, historical return approach to calculate VaR. Monte Carlo simulation and its link to VaR. Expected Shortfall calculation.

   Notebook: Graphing the normal distribution curve and identifying the VaR region. Using the Fama-French industry portfolios to calculate the VaR for each industry. Testing for Normality. Verifying that VaR is not additive, and portfolio VaR is lower than the sum of its parts

9. Monte Carlo Simulation
   Generating random number from normal, uniform, Poisson distribution, and illustration of how MC can be used in different application.

   Notebook: Simulation of stock price movement with lognormal distribution, Replicating BSM option model by simulation and pricing, simulation of two-assets with correlation. Capital budgeting w/ MC simulation

10. Volatility Estimation
    Quick review of volatility as a measurement of asset's risk.
    Is volatility constant over time in the market?
    Introduction to ARCH and GARCH.
    Notebook: Using Breusch-Pagan test to detect Heteroskedasticity. Identifying volatility clustering using S&P 500 daily return. Integrating ARCH/GARCH for return simulation.

Final (April 24th, 2025)

Presentation (May 1st, 2025)