

MP6212: Computational Finance

Introduction

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Slides are prompts (for me). You are expected to make your own notes when material is explained using the white-board, and by referring to textbooks and papers.

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Logistics

- Teaching slots
 - Mondays 14:00-16:00 Laboratory
 - Thursdays 9:00-10:00 Lecture
- Philosophy: Learning by doing, **not** learning by observing.
- This is not a module on Finance as taught in business schools
 - i.e. not a lot of descriptive material on details of financial instruments and how they are traded.
- This is not a module on Mathematical Finance as taught in the School of Mathematics
 - We will not be too *formal* with fundamental theory
- Our focus will be on some tools that are *computational*; we will use real data, implement computational algorithms and understand the basics of some interesting problems.
- We will need some continuous mathematics for this.

If your expectations are different, please do not take this module.

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Rapid Review of Some Basics

Organization of Businesses

- Sole ownership 独资
- Limited liability company 有限责任公司
- Corporation
- Purpose: Maximize profit
 - Profit Margins
 - 毛利率 ● Gross Profit Margin = (Sales - Cost of Goods Sold) / Sales
 - 经营利率 ● Operating Profit Margin = EBIT / Sales
(earnings before interest and taxes)
 - 净利率 ● Net Profit Margins = Net Profits after Taxes / Sales
 - Minimize Cost
 - Maximize Market Share

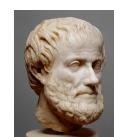
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Rapid Review of Some Basics

Money



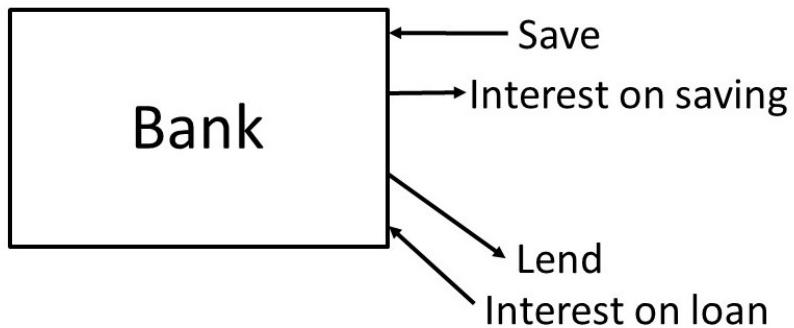
- "For the love of money is the root of all evil"
 - New Testament Timothy 6:10
- "every object has two uses, the first being the original purpose for which the object was designed, and the second possibility is to conceive of the object as an item to sell or barter"



Aristotle (384-322 BC)

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Basic Institutions



Rapid Review of Some Basics Financial Institutions

- Commercial Banks
- Investment Banks
- Insurance Companies
- Brokerages 手续费
- Investment Companies
- Investment Trust 投资信托公司
- Building Society 建房协会（英国、澳大利亚），提供银行和相关金融服务，特别是存款和抵押贷款

Rapid Review of Some Basics

Financial Markets

- Capital Markets
 - governments / companies sell securities to raise capital
- Stock Markets
 - investors buy and sell shares in publicly traded companies
- Bond Markets
 - debt instrument in which an investor loans money; borrower (company, government) promises to pay a regular fixed rate for a fixed period
- Money Market
 - short term borrowing and lending (days to one year)
- Spot or Cash Market 现货市场
 - goods are sold for cash and are delivered immediately
- Derivatives Markets 衍生品市场
 - trading contracts on the future price of an asset

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Rapid Review of Some Basics

Macroeconomic Policy

干预
Government interventions:

- Monetary Policy 货币体系
 - Control of money supply
 - Interest rates 量化宽松
 - Print / devalue / “quantitative easing”
- Fiscal Policy 财政政策
 - Taxation and government spending 政府收支

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Financial Equilibrium

Caution: A peculiar and rather personal view



Financial Markets



www.investors411.com

jamesnichollsillustration.blogspot.co.uk

- Generate products and services
 - In need of
 - stability against fluctuations (e.g. demand, exchange rate)
 - capital investment (e.g. to modernise, grow)
 - Process wealth & capital
 - Driven by gambling instinct and greed 赌博本能 贪婪
- 稳定性与波动性

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The Setting

- Finance gets bad publicity; bankers and fund managers are sometimes disliked
- The system can fail badly
- When the system fails, large amounts of tax-payer money is used to bail them out. I don't like this! 保释
- Yet the system is useful
 - Investors interested in future returns
 - Greed?
 - Pay for retirement
 - Firms / Governments looking to raise capital for investment
 - Companies looking for stability; e.g. insure against exchange rate fluctuation
- What are the sources of computational problems?
 - Time - present value of money.
 - Uncertainty - of the future.

Overview of the Module

Topics:

- Portfolio Optimization
- Derivatives Pricing
- Time Series Analysis

Keywords:

Mean-Variance optimization, Linear and quadratic programming, Multivariate Gaussian distribution, Constrained optimization, Value at risk and Conditional value at risk, Sharpe ratio, Present value, Stochastic differential equations, Ito's Lemma, Black-Scholes model, Options pricing, Stochastic Simulations, Monte Carlo methods, Autoregressive Moving Average, Autoregression with Conditional Heteroskedasticity, Kalman filtering, Particle filtering, Importance sampling, Stochastic volatility.

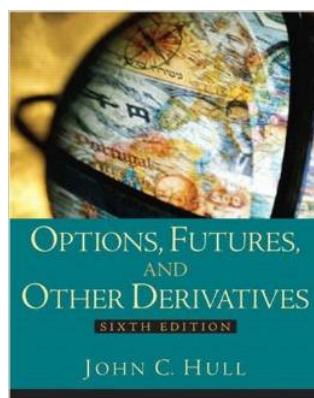
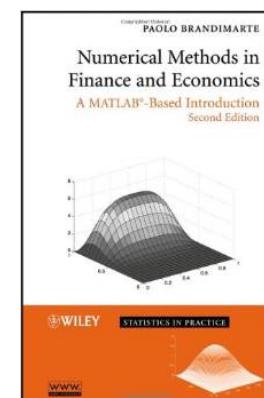
Assessment:

- Four large pieces of coursework
MATLAB exercises using real data
- Each might include a short in-class/take-home test
- You will be expected to work **independently**

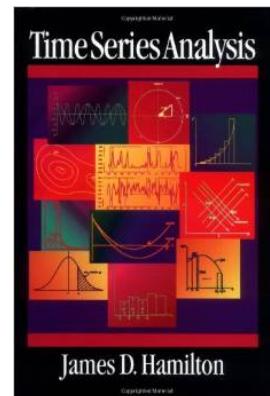
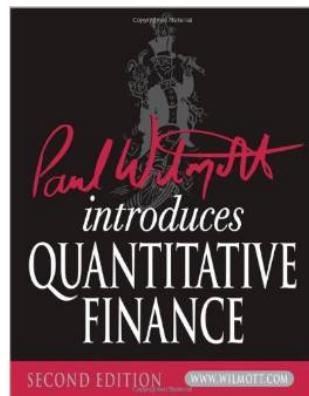
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Resources



o-book



P-hold

- plus several academic papers.

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Financial Instruments (broad classes)

- Bonds
 - Debt instrument to raise capital; delivers periodic payment (*coupon*); has a *face value* on *maturity*. No ownership associated.
 面值 到期
- Stocks
 - Own a small *share* of a company; the ownership may be traded in the market; owning the share might earn *dividends*.
 股息
- Derivatives
 - Contracts written on the basis of a future value of a stock, currency etc. Usually there is a time of *maturity* and a promised *payoff* in the contract. Variations in style of *exercising* the contract.
 合同履行方式的变化

Time: Present Value

- Wealth W_0 deposit in bank and get W_1 after one year
- $W_1 = (1 + r) W_0$, r interest rate
- 复利 ● Compound interest over n years: $W_n = (1 + r)^n W_0$
- Define interest rate as r per year; allow compounding at m intervals within the year
 间隔

$$W_1 = \left(1 + \frac{r}{m}\right)^m W_0$$

- 连续复利 ● Continuous compounding $m \rightarrow \infty$

$$W_1 = \exp(r) W_0 \quad e^r W_0$$

- Present value of your promise to give me cash C in time t is

现值

$$\exp(-rt) C \quad e^{-rt} C$$

Various Topics We Will Learn

Part I: Portfolio Optimization

Portfolios:

- Notion of expected return and risk in investing - balancing it out
- Investing in a portfolio of assets, than in a single asset - “not all eggs in one basket”
- Optimization techniques we will learn and use
 - Linear programming
 - Quadratic programming
 - (Second order cone programming)
 - Inducing sparsity – l_1 or *lasso* regularization
 - Convex optimization using CVX toolbox

诱导稀疏

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Various Topics We Will Learn (cont'd)

Part II: Derivatives Pricing

Derivatives Pricing (contract in the future, in an uncertain world):

- Brownian motion, Geometric Brownian motion
布朗运动 几何布朗运动
- Stochastic differential equations

$$\frac{dS}{S} = \mu dt + \sigma dZ$$
$$dZ = \phi \sqrt{dt}, \quad \phi \sim (0, 1)$$

- Ito's Lemma: Function of a Geometric Brownian Motion
伊藤定理

$$dG = \left(\mu S \frac{\partial G}{\partial S} + \frac{\sigma^2 S^2}{2} \frac{\partial^2 G}{\partial S^2} + \frac{\partial G}{\partial t} \right) dt + \sigma S \frac{\partial G}{\partial S} dZ$$

- Black-Scholes: options pricing under specific assumptions
布莱克-舒尔兹模型 期权的价格在某一特定指以下
- Monte Carlo / Stochastic simulations: general cases
蒙特卡洛

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Various Topics We Will Learn (cont'd)

Part III: Time Series Modelling/Analysis/Prediction

Time Series Analysis:

- Models:

- Linear time series models: MA, AR, ARMA

$$y(t) = \sum_{j=1}^p a_j y(t-j) + \sum_{i=1}^q b_i \epsilon(t-i) + \eta$$

条件异方差性自动回归 • Autoregression with conditional heteroskedasticity (ARCH)

随机波动率模型 • Stochastic volatility models

- Algorithms:

- Maximum likelihood and Bayesian methods
- Recursive estimation – Kalman filter, Particle filter
 回归的 卡尔曼滤波 粒子滤波

$$\left\{ \begin{array}{l} \theta(n-1|n-1) \\ P(n-1|n-1) \end{array} \right\} \rightarrow \left\{ \begin{array}{l} \theta(n|n-1) \\ P(n|n-1) \end{array} \right\} \rightarrow \left\{ \begin{array}{l} \theta(n|n) \\ P(n|n) \end{array} \right\}$$