



0-overview

## QTM 385 Quantitative Finance

### Lecture 0: Course Logistics and Overview

Instructor: Ruoxuan Xiong



#### An introduction about myself

- Assistant professor at QTM
- PhD in Management Science and Engineering from Stanford
- My research, broadly speaking, is at the intersection of econometrics and operations research
  - Topics of interest: causal inference, experimental design, and factor modeling
  - Applications of interest: finance and healthcare



#### Lecture plan

- Course structure
  - What is this class about?
  - Expectations
  - Course logistics
  - Evaluation
- Course outline



## Making financial decisions

- You have saved 2000 dollars from your summer internship. Should you put it under your mattress, buy a Certificate of Deposit, Apple stock or an S&P 500 index fund?
- You are the manager of a mutual fund specializing in technology stocks. How should you allocate the funds' assets among the stocks recommended by your analysts?
- You work for a venture capital firm that wants to sell off a venture through an IPO. What is the fair value the venture?



## Investment for retirement

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"A sensible retirement portfolio should include mutual funds, stocks, bonds, lottery tickets, magazine sweepstakes, returnable cans and bottles, money under the sofa cushions, loose change in your junk drawer, anything you find in the coin return of a vending machine, pennies left in old loafers...."



## Quantitative Finance

- In each situation, you need to
  - Commit resources (money, effort, time etc.)
  - In the face of uncertainty about the future
- *Quantitative finance* uses mathematical models and large datasets to analyze financial markets and securities
- A fascinating interdisciplinary subject that uses methods from probability and statistics, finance and economics, operations research and computer science

Risk comes from market interest rate  
Interest rate surged several times in the past year. Affected equity and bonds markets.  
When interest rate is higher, effective return is lower



## What is this course about?

- Preliminary material on financial markets, financial institutions, and various types of securities
- *Modern portfolio theory*: Risk, return, portfolio optimization, and capital asset pricing model
- *Security valuation*: how bonds and derivatives are priced



## What is quantitative finance relevant?

- In an *uncertain* world, we have to make decisions about alternatives whose outcomes cannot be predicted with certainty
- Suppose we can evaluate alternatives in terms of *money*
- Quantitative finance provides a quantitative framework to *analyze* these *decisions* and their *consequences*
- Quantitative finance has a *profound* impact how *securities* are *priced* and how *risk* is *measured* and *managed*



## Expectations

- Require basic knowledge on
  - *Probability*: model uncertainty and characterize risk
  - *Optimization*: construct optimal strategies under constraints
  - *Statistics*: estimate the model parameters from observable data
- Do not require knowledge of advanced material from these areas
- Homework
  - Conceptual and computational questions
  - Computational questions can be finished in any programming language (e.g., R, Python, or excel)



## Course logistics

- Instructor: Ruoxuan Xiong
- Time: Mondays and Wednesdays, 2:30 PM-3:45 PM in Anthropology Building 105
- Office hours: Mondays, 4:00 PM-5:00 PM in my office, 581 PAIS building
- Lectures will be recorded
- Details in syllabus on Canvas



## Evaluation

- Homework 30%
- Take-home midterm: 30%
- Take home final: 35%
- Participation: 5%



## Homework

- 4 homework assignments in total
  - Group homework
  - Groups of 1-3 students. Target group size is 2. Students arrange their own group
  - Same group for all homework assignments
- You have a total of three free late days for all homework assignments as a group. You can use at most two late days for one homework assignment



## Important dates

- Homework
  - Problem set 1: out 1/22, due 2/12
  - Problem set 2: out 2/12, due 3/5
  - Problem set 3: out 3/5, due 4/2
  - Problem set 4: out 4/2, due 4/23
- Take-home midterm
  - Out Friday 3/17 00:00 am, due Monday 3/20 11:59 pm (no class on 3/20)
  - You can choose any 24 hours in between to complete
- Take-home final
  - Out Sunday 4/30 00:00 am, due Wednesday 5/3 11:59 pm
  - You can choose any 24 hours in between to complete



## Participation

- You can fulfill your class participation through
  1. Attend the class, ask and answer questions
  2. Submit questions for lecture material or feedback for this course through the [Google form](#)
    - Questions will be answered at the beginning of each lecture



## Lecture notes and textbooks

- Lecture notes will be uploaded to Canvas before lecture
- Main reference
  - Bodie, Zvi, Kane, Alex, & Marcus, Alan. *Investments*. 2020 (12th edition)
- Supplementary reference
  - Luenberger, David G. *Investment science*. OUP Catalogue. 2013 (2nd edition)



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## Securities

### Fixed-income or debt securities

- Pay a stream of income over time
- For example, a corporate bond promises the bondholder a fixed amount of interest each year



Long term maturity  
(e.g. 3 years to 30 years)

Usually the risk of the bond is positively correlated with the time to maturity

State govt and firms (corporate) can also issue securities - they are riskier than federal govt etc.



## Securities

### Common stock or equity

- Equity holder are not promised any particular payments
- They may receive dividends from the firm
- Riskier than fixed fixed-income securities



# Securities

## Derivatives

- Payoffs determined by the prices of other assets, such as bond or stock prices
- For example, call option (right to buy a share of stock at a given price on or before expiration date)

Determined by price of other assets like bonds and stocks. Options are here. Option holders have the right to buy or sell a stock at a certain price before the expiration date. They can exercise or not exercise this option. And they pay a price for this option. In this course we will talk about how to price these options.



Calls for January 15, 2023

Contract Name	Last Trade Date	Strike	Last Price	Bid	Ask	% Change	Volume	Open Interest	Implied Volatility
IBMD11C13010000	2023-01-10 10:54AM EST	130.00	13.28	0.00	0.00	-	9	0	0.00%
IBMD11C13510000	2023-01-06 3:17PM EST	135.00	12.27	0.00	0.00	-	1	0	0.00%
IBMD11C14010000	2023-01-09 10:43AM EST	140.00	12.55	0.00	0.00	-	1	0	0.00%
IBMD11C14510000	2023-01-05 1:40PM EST	145.00	7.81	0.00	0.00	-	1	0	0.00%
IBMD11C15010000	2023-01-10 11:34AM EST	150.00	8.55	0.00	0.00	-	1	0	0.00%
IBMD11C15510000	2023-01-09 2:54PM EST	155.00	8.85	0.00	0.00	-	3	0	0.00%
IBMD11C16010000	2023-01-10 11:34AM EST	160.00	9.55	0.00	0.00	-	3	0	0.00%
IBMD11C16510000	2023-01-10 11:34AM EST	165.00	9.48	0.00	0.00	-	17	0	0.00%
IBMD11C17010000	2023-01-09 2:53PM EST	170.00	5.30	0.00	0.00	-	24	0	0.00%
IBMD11C17510000	2023-01-10 2:40PM EST	175.00	4.35	0.00	0.00	-	42	0	0.00%
IBMD11C18010000	2023-01-10 2:40PM EST	180.00	3.57	0.00	0.00	-	19	0	0.00%
IBMD11C18510000	2023-01-10 11:43AM EST	185.00	2.46	0.00	0.00	-	21	0	0.00%
IBMD11C19010000	2023-01-10 3:40PM EST	190.00	2.52	0.00	0.00	-	76	0	0.00%
IBMD11C19510000	2023-01-10 3:40PM EST	195.00	1.55	0.00	0.00	-	270	0	0.00%
IBMD11C20010000	2023-01-10 3:40PM EST	200.00	1.27	0.00	0.00	-	307	0	0.00%



## Financial institutions

- Connect between the security issuer (e.g., firm) and owner of the security (e.g., individual investor)
- For example,
  - *Financial intermediaries*: Banks, investment companies, insurance companies, credit unions
  - *Investment bankers*: Issue securities to raise capital for firms
  - *Venture capital and private equity*: Invest in smaller and younger firms

Investment banks has diff divisions: can act as financial intermediaries or owners of securities



## Risk and return

- Risk-return tradeoff: High risk high return, low risk low return
- Estimate expected returns and risk from historical data



We will look at risk metrics  
We can estimate risk metrics from historical data  
Financial market this year is def different from market 10 years ago  
How can we deal with this changing environment while estimating return and risk when the data/parameters varies substantially over time?



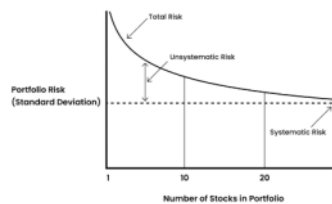
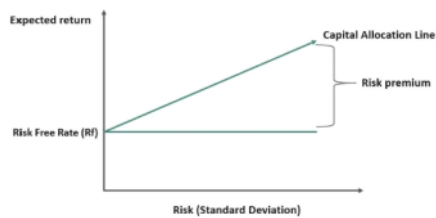
## Capital allocation

- Capital allocation between risk-free (e.g., Treasury bills) and risky assets (e.g., stocks)
- Efficient risk diversification

When we invest in more stocks in portfolio, risk will actually be lower because of diversification. Risk will be lower even with the same return.

Expected return ↑

- Efficient risk diversification



When we invest in more stocks in portfolio, risk will actually be lower because of diversification. Risk will be lower even with the same return.

E.g. don't put all eggs in one basket

#### Systematic and idiosyncratic risk

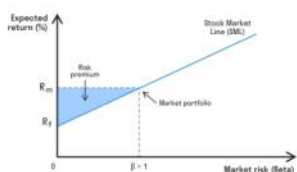
Systematic - the market is systematic and drives all stocks up and down  
Idiosyncratic risk - elon musk sends a crazy tweet

"When we invest in tons of stocks, we can reduce idiosyncratic risk  
But we cannot reduce systematic risk"

## Asset pricing models

- A prediction of the relationship between risk and return
- Capital asset pricing model
- Arbitrage pricing theory and multifactor models of risk and return

UP TO ASSET PRICING MODELS (INCLUDED) FOR THE MIDTERM\*\*\*\*\*



## Fixed-income security valuation

- Bond characteristics: time to maturity, coupon payments and par value
- How to calculate **bond price**?
- How to calculate **bond yield** (rate of return)?
- How does **yield curve** (yield vs time to maturity) inform expectation on future interest rates?

Table 14.2

Bond prices at different interest rates (8% coupon bond, coupons paid semiannually)

Time to Maturity	Bond Price at Given Market Interest Rate				
	2%	4%	6%	8%	10%
1 year	1,059.11	1,038.83	1,019.13	1,000.00	981.41
10 years	1,541.37	1,327.03	1,148.77	1,000.00	875.35
20 years	1,985.04	1,547.11	1,231.15	1,000.00	828.41
30 years	2,348.65	1,695.22	1,276.76	1,000.00	810.71

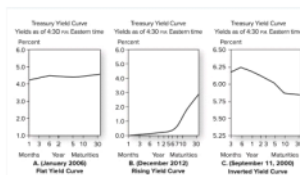


Figure 15.1 Treasury yield curves

Source: Various editions of The Wall Street Journal.

Curves on the right have very important implications on people's expectations of future market interest rate.



# Derivative pricing

## Option pricing

- Binomial option pricing
- Black-Scholes option valuation

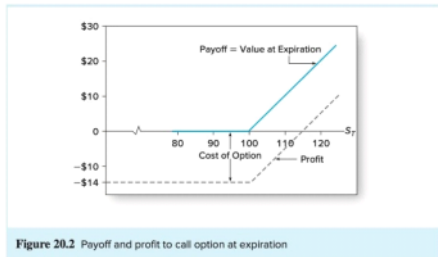


Figure 20.2 Payoff and profit to call option at expiration

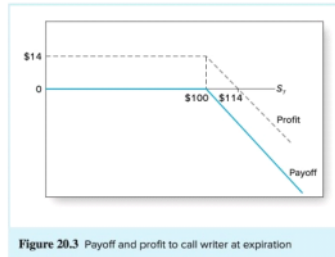


Figure 20.3 Payoff and profit to call writer at expiration

