Queens College, CUNY, Department of Computer Science

Computational Finance

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1 Lecture 1

1.1 Finance & 'Money'

- The fundamental assumption is that everything (all goods, services) have a cash value.
- Hence the question: ***What is money?***

1.1.1 'Money' is a functional definition

- ***Money is anything which can perform the functions that money does.***
- It must be possible to express the value of all goods and services in terms of money.
- It must be acceptable as a means of payment for goods and services.
- It must be durable (keeps its value over time).
- It must be difficult to forge or counterfeit (security).

1.1.2 Money $\neq$ cash

- The vast majority of financial transactions are electronic.
- Financial transactions involve electronic debiting and crediting of accounts.
- The volume of 'electronic money' far exceeds the value of paper money in circulation.

1.1.3 Legal tender

- US currency is 'legal tender' *in the United States*.
- That means vendors **must** accept US currency in payment for goods and services.
- Checks and credit cards can also be used for payment, but they are not legal tender.
- A vendor can legally refuse to accept checks and/or credit cards.
- Legal tender is enforced by law, to give validity to the currency.
- Example: US dollars are legal tender in USA, but not in UK.

1.2 Stocks & Bonds & FX

1.2.1 Derivatives and basic building blocks

- The word 'derivative' means an object which is derived from more basic building blocks.
- The value of a derivative instrument originates from the value of those building blocks.
- In this course, the basic building blocks of all financial securities are stocks and bonds.
- For international transactions, there is also FX (exchange rates).

1.2.2 Commodities

Question: ***What about commodities? (wheat, corn, oil and gas, etc.)***

- These also exist (and are important).
- In this course we shall focus on stocks and bonds.
- ***Problem:*** crops are eaten as food, oil and gas are burned as fuel → complication.

1.2.3 Bonds & cash

- Why 'bonds' and not 'cash' (or money)?
- Key concept: ***interest rates.***
- Bonds are intimately connected with interest rates.
- Money stored in a bank (for example), accrues interest and increases in value.
- The use of bonds captures the feature of interest rate compounding.

1.3 Time value of money

1.3.1 Cashflows at different times

- ****** Very important concept ******
- Because of interest rates, \$1 today is ***not*** worth the same as \$1 one year from now.
- Suppose the (continuously compounded) interest rate is r. Then

$$\$1_{\text{future}} = e^{r(t-t_0)}\,\$1_{\text{today}}\,. \tag{1.3.1.1}$$

- To compare cashflows, we must express them all at a common point in time.

1.3.2 Discount factor

- Let today $= t_0$.
- Suppose we have a cashflow F at a time $t > t_0$ in the future.
- The value of the cashflow today is called the **present value (PV)** of F.
- The present value is given by a ***discount factor***, say d:

$$\text{PV}(F) = F \times d\,. \tag{1.3.2.1}$$

- **In response to much confusion by students in homework, let me state clearly that**

$$\text{discount factor} = \frac{\text{value of cashflow today}}{\text{value of cashflow at future date}} = \frac{F_{\text{today}}}{F_{\text{future}}}\,. \tag{1.3.2.2}$$

- The relation between the discount factor and the (continuously compounded) interest rate is

$$d = e^{-r(t-t_0)}\,. \tag{1.3.2.3}$$

- Note: the discount factor depends on both the future time t and the present time t_0.
- We can define a discount factor $d(t_1, t_2)$ between any two times t_1 and t_2.
- The most common example is discounting to today.

1.4 Bonds and coupons

1.4.1 Bonds

- Bonds encapsulate the concept of borrowing money (and repaying with interest).
- The US govt borrows money by issuing US Teeasury bonds.
- People buy the bonds (= give money to US govt).
- The US govt pays back the money at a later time, with interest.
- Local govts do the same (municipal bonds) also companies (corporate bonds).

1.4.2 Coupons

- Bonds are issued with a maturity date (5 years, 10 years, 30 years, etc).
- On the maturity date, a bond repays its face value (usually $10,000 in the USA).
- In addition, a bond pays cashflows called **coupons**.
- In the USA, bonds typically pay coupons semi-annually (twice a year).

1.5 What does "coupon" mean?

A student asked an important question: ***why are the payments called "coupons"?***

The word "coupon" suggests a piece of paper that one presents to get a discount in sales at a shop.

- **Originally, bonds were paper certificates with actual paper coupons attached.**
- The owner of a bond would tear off a coupon and redeem it for money.
- *So yes! "Coupons" were pieces of paper with redemption dates on them.*
- Today we use the word "coupon" to denote a cashflow from a bond.

***** I encourage such astute questions from students *****

1.6 Bonds, yields & interest rates

1.6.1 Yield

- Suppose we have a bond, whose market price is B.
- To keep the calculations simple, suppose it is a newly issued bond (today).
- Let the bond have a face value F and it pays coupons c semi-annually.
- Suppose there are totally n cashflows.
- The intermediate cashflows pay $c/2$ each and the final cashflow is $F + (c/2)$.
- The (annualized) **yield** of the bond is defined via the formula

$$B = \frac{\frac{1}{2}c}{1+\frac{1}{2}y} + \frac{\frac{1}{2}c}{(1+\frac{1}{2}y)^2} + \cdots + \frac{\frac{1}{2}c}{(1+\frac{1}{2}y)^{n-1}} + \frac{F+\frac{1}{2}c}{(1+\frac{1}{2}y)^n}\,. \tag{1.6.1.1}$$

1.6.2 Yield and discount factors

- Why do all the discount factors have the form $1/(1+\frac{1}{2}y)$, $1/(1+\frac{1}{2}y)^2$, $1/(1+\frac{1}{2}y)^3$, etc.?
- ****** This is an important question, an item for future lectures ******

1.6.3 How do we know the value of the yield of a bond?

- In practice it is the other way around.
- We observe the market price of the bond B (from trading in the financial markets).
- We **invert** the above formula to calculate the yield.

1.6.4 Yield curve

- There are many bonds in the financial markets, with different yields and maturities.
- From these we obtain a **"yield curve"** (for example the US Treasury yield curve).
- From the yield curve, *we back out the interest rates and discount factors.*
- ****** This is a very important procedure in finance ******
- ****** It is an item for future lectures ******