Lesson 2: Reading and plotting stock data

Stock Header explaination

- **Open**: opening price of the stock
- **High**: HIghest price of the stock during the day
- **Low**: Lowest price of the stock during the day
- **Close**: Closing price of the stock at the end of the day
- **Volume**: Total number of stocks traded during the day
- **Adj Close**: Adjusted close is the adjusted value of close for dividend splits etc

Pandas Dataframe

- **NaN** is not a number or does not exist
- Pandas can also handle df's in a 3D-way
- `pd.read_csv()` reads the csv file
- `pd.head(n)` returns the first n rows of df (default = 5)
- Similarly, `pd.tail(n)` returns the last n rows
- To get data from rows n1 to n2, use `df[n1,n2+1]`
- Mean. Max, Min are callable functions like `df['Volume'].max()`

Lesson 3: Working with multiple stocks

Problems to solve

- Date Ranges
- Multiple stocks
- Align dates
- Proper Date order

Building DataFrame

- `join` you join the columns with intersection of indexes
- `parse_dates=True` will parse trhe dates into date objects
- `usecols` param can be used to define what colums to keep in the dataset
- `index_col` param can be used for defining the index column in df
- `Pandas.DataFrame.dropna()` will drop all the rows with `NaN` value
- `Pandas.DataFrame.rename()` to rename a specific column in the dataframe
- `Pandas.DataFrame.dropna(subset=[])` : subset can be used to direct which be checked for na and then to be dropped

Slicing DataFrame

- `df.loc` , `df.iloc` can be used for row splicing;loc for label based splicing, iloc is based splicing
- column splicing can be done by passing a list of columns inside `df[[x,y]]`

Lesson 4: The power of Numpy

Intro

- `np.empty(shape)` to generate empty array;But the array retains the memory val
- `np.ones(shape)` to create ones' array
- `np.random.random(shape)` to create uniformly random values in $[0, 1)$
- `np.random.normal(mean=0, std=1, shape)` for normal distribution
- `np.random.randint(min, max, shape)` to generate random integer array

Array attributes

- `array.shape` = shape tuple
- `array.size` = number of elems
- `array.dtype`

Operations on ndarrays

- `axis=0` for operations on that axis; `a.sum(axis=0)` would give sum of all the r maintaining the columns
- `a.min(axis)`, `a.max(axis)`
- `a.mean()`
- `np.argmax()`
- `a[i,j]`
- `a[i,m:n:step]`
- You can pass array of indices to sample as `a[idxs]` where `idx` is the array of in want to sample
- boolean masks can be put on 2D arrrays and extract the elements under the mask b `a[condition]`
- $*$ operator does element by element not matrix multiplication and similarly / does el

Lesson 5: Statistical analysis of time series

Rolling Statistics

- rolling statistics important argument of TA
- **Bollinger bands** are drawn $2 * rolling\_std$ to identify buy and sell signals

- **Daily Returns** is $curr\_day\_price/prev\_day\_price - 1$

Lesson 6: Incomplete Data

Reality of stock data

- Data is an amalgamation from multiple sources
- Not all stocks trade at all time
- Gaps in data are common

Why data goes missing

- Companies who trade once in a while generate gaps
- Also companies when acquired by a new company etc also begin or end abruptly

What to do?

- Fill forward from the latest data in the entire gap
- At the beginning of stock, you can fill backward in time
- `fillna(method=)` can be used to fill; `method=ffill` for forward, `method=bf` backward
- in the `fillna` function, argument `inplace` can be set to true to modify inplace

Lesson 7: Histograms and Scatter plots

Histogram of daily retuns looks like a bell curve i.e., gaussian distribution

- Mean, Std can be measured from the histogram
- Kurtosis can be measured
  - Fat tails means positive kurtosis
  - Skinny tails means negative kurtosis
- Mean less => Lower return
- Std less => Lower Volatility

α & β definitions

- α, β are the intercept, slope of the line fit between market and stock
- can be used to check relative performance of the stock compared to market

Correlation $not = \beta$

- can be computed by `df.corr(method='pearson')`
- correlation is how tightly the data fits the line

Lesson 8: Sharpe ratio & other portfolio stat

Daily portfolio calue estimation

- normalize prices
- multiply with allocations of each stock (which sum to 1 altogether
- mutliply by initial investment
- `df.sum(axis=1)` will give value fo portfolio each day

Portfolio Stats

- Daily returns
  - exclude the initial zero of day 1
  - `daily_ret = daily_ret[1:]`

- cumulative return
  - `(port_val[-1]/port_val[0])-1`
- average return
  - `daily_ret.mean()`
- standard dev of daily returns
  - `daily_ret.std()`
- **sharpe_ratio**

Sharpe Ratio

- by william sharpe
- measures risk adjusted return
  - lower risk (σ_p) is better
  - higher return (R_p) is better
- volatility is considered as risk
- SR also considers risk free rate of return(R_f) (like interest rate of banks)
- Sharpe Ratio $= \frac{E[R_p - R_f]}{std[R_p - R_f]}$
- if R_f is constant, which it usually is, it vanishes from the denominator

More on sharpe ratio

- SR varies based on how we sample
- SR is an snnualized measure
- $SR_{annualized} = \sqrt{Samples\ per\ year} * SR$
- If we are sampling daily, $SR_{annualized} = \sqrt{252} * SR$

Lesson 9: Optimizers: Building a parametriz model

Convex function is a real-valued function f(x) defined on an interval is called convex if t segment between any two points on the graph of the function lies above the graph

Lesson 10: Optimizers: How to optimize a portfolio

Framing the problem

- Optimize the allocations of the portfolio in order to maximize sharpe ratio
- loss function = $-1 * SR$

Ranges and Allocations

- Limit the search range
  - Ex: put in zero to 1
- Constraints
  - Sum of the allocations to be 1

Lesson 11: So you want to be a hedge fund manager

Types of funds

- **Exchange Traded Funds**
  - Has 3/4 letters
  - Buy/Sell like stocks
  - Baskets of stocks
  - Transparent and are very liquid (easy to trade)
- **Mutual Funds**
  - Usually has 5 letters
  - Buy/Sell at EOD
  - Quaterly disclosure
  - Less Transparent
- **Hedge Funds**
  - Buy/Sell by agreement (secret)
  - Hard to exit a hedge fund
  - No disclosure about what they are holding
  - Not transparent

AUM: *Assets Under Management* is the total amount of money being managed by the fu

How are these fund managers compensated?

- ETFs
  - Expense ratio 0.01% to 1.00% (fraction of AUM)
- Mutual Funds
  - Expense ratio 0.5% to 3%
- Hedge Funds
  - Two and Twenty
    - 2% of AUM and 20% of profit
  - Now-a-days they charge a little less
  - A very few charge even more

How hedge funds attract investors?

- Who?
  - Individuals
    - Wealthy folks
  - Institutions
    - Large retirement foundations
    - University foundations
  - Funds of funds
    - grouping of money
- Why?
  - Track record
  - Simulation/Back test our strategy
  - Good portfolio fit for the investors

Hedge fund goals and metrics

- **Goals**

    - Beat a benchmark
        - Ex: Beat the SP500 index
    - Absolute return
        - Positive return no matter what
            - **Long** Positive bets in funds going up
            - **Short** Negative bets in funds going down
- **Metrics**
    - Cumulative return
    - Volatility
        - Standard deviation
    - Risk/Reward
        - Sharpe Ratio

Lesson 12: Market Mechanics

What's an order?

- Buy or Sell?
- Symbol of the stock
- #shares
- Limit Order or Market Order
    - Limit is playing safe
    - Market order no price spec required
- Examples
    - BUY, IBM, 100, LIMIT, 99.95
    - SELl, GOOG, 150, MARKET

The order book

- Keeps track of sell, buy orders
- Allots the buyers to sellers of their price req match
- If no match, appends into the book

Example of order book in operation

BID/ASK	PRICE	SIZE
ASK	100.10	100
ASK	100.05	500
ASK	100.00	1000
BID	99.95	100
BID	99.90	50
BID	99.85	50

[Book at the beginning]

1. Order Buy,100, Market
    - 100 shares from 1000 shares cut & **Price = 100$**

BID/ASK	PRICE	SIZE
ASK	100.10	100
ASK	100.05	500

BID/ASK	PRICE	SIZE
ASK	100.00	**900**
BID	99.95	100
BID	99.90	50
BID	99.85	50

[Book after order 1]

2. Order Buy, 100, Limit, 100.02
    - 100 shares from 900 are deducted & **Price = 100 $**

BID/ASK	PRICE	SIZE
ASK	100.10	100
ASK	100.05	500
ASK	100.00	**800**
BID	99.95	100
BID	99.90	50
BID	99.85	50

[Book after order 2]

3. Order Sell, 175, Market
    - 100, 50, 25 will be deducted from the three bids respectively
    - Executed price is average of these 175, **99.66$**

BID/ASK	PRICE	SIZE
ASK	100.10	100
ASK	100.05	500
ASK	100.00	800
BID	99.95	**0**
BID	99.90	**0**
BID	99.85	**25**

[Book after order 3]

4. Because of the selling pressure being higher than buying pressure, the prices will lik

How Hedge funds explot market mechanics

- HF will buy and sell you the stock by the time the order you placed reached stock ex because of the delay in 10-20 ms
- **Geographic arbitrage** HF have multiple locations like NY, London. If the same stoc different prices in these places, HF will buy in the lower price city and sell in higher p They made profits ez

Additional order types

- Exchanges
    - Buy and Sell
    - Market and Limit
- Broker
    - Stop Loss
    - Stop Gain

- Trailing Stop
- **Sell Short**

Mechanics of short selling

- Sell without owning the stock yet
- Sell at higher price, buy&exit at lower price
- Hence you make profit

What can go wrong in short selling?

- If prices go after short selling, you make loss when you exit the position

Lesson 13: What is a company's worth?

- True value of company
- Stock price goes above true value, sell
- Stock price goes below true value, buy

Ways to estimate worth

Intrinsic Value
Value of the company estimated by dividends

Book value
Value of the assets the company owns
Ex: Factories etc

Market Cap
Value of the stock and number of outstanding stocks

The value of a future dollar

$$\text{Present Value} = \frac{Future\ Value}{(1+Interest\ Rate)^{Years}}$$

$$\textbf{Intrinsic Value} = \sum \frac{Future\ Value}{(1+Interest\ Rate)^{i}}$$

$$= \frac{Future\ Value*(1+Interest\ Rate)}{Interest\ Rate}$$

$$= \frac{Future\ Value}{Discount\ Rate}$$

Book Value = Total value of the assets minus intangible assets and liabilities

Market Capitalization = #shares * price

Lesson 14: Capital Assets Pricing Model (CAPM)

Portfolio

- r_s, w_s are returns, weights of each stock in portfolio
- Return of portfolio $r_p = \sum r_s * w_s$
- $\sum abs(w_s) = 1$

Market Portfolio

- Every country has index of stocks
- Weight of each stock in the index is $w_i = Market\ Cap_i / \sum Market\ Cap_j$
- SP500 is a market portfolio of 500 stocks

CAPM Equation

$r_i(t) = \beta_i * r_m(t) + \alpha_i(t)$

- Return of markets: $r_m(t)$
- Return of stock i: $r_i(t)$
- Significant portion of return of the stock is from the growth of market
- Most stocks have β as 1
- CAPM says $E[\alpha_i(t)] = 0$; Its essentially a random variable
- β, α are **slope, intercept** of line fitted between stock, market daily returns' scatter

CAPM vs Active management

- passive: buy index portfolio and hold
- active: pick stocks with different weights compared to index
  - Some have underweight
  - Some have overweight
- CAPM says $E[\alpha_i(t)] = 0$; $\alpha_i(t)$ is fully random
- Active managers believe we can predict alpha and its not fully random

CAPM for portfolios

- Return of portfolio $r_p = \sum w_i * (\beta_i * r_m(t) + \alpha_i(t))$
- Beta of the portfolio is $\beta_p = \sum w_i * \beta_i$
- $r_p(t) = \beta_p * r_m(t) + \sum w_i * \alpha_i(t)$
  - CAPM would say alpha term is simply a random number with mean zero $\alpha_p(t)$
  - Active managers would use the summation formulation

Arbitrage Pricing Theory

- Beta of market can be broken down into betas of different fields like fincance, tech, manufacturing etc

Lesson 15: How Hedge funds use the CAPM

Two stock CAPM math

- $r_p = (w_a\beta_a + w_b\beta_b) * r_m + w_a\alpha_a + w_b\alpha_b$
- If we make net beta as zero, we equate to zero market risk in case of long short inve

Summary

- Assuming
  - We forecasted alpha
  - We got beta pf the stock
- CAPM enables
  - minimize market risk by making beta of portfolio to be zero
  - allocate weighst to stocks ion the portfolio such that above happens

Lesson 16: Technical Analysis

Characteristics of TA

- Uses price and volume only
- Compute indicators by statistics on data
- There is information in price

When is TA effective

- Individual indicators are weak
- Combining multiple indicators makes predictions stronger
- Look for contrasts (Stock vs Market)
- Works better for shorter time periods than longer time periods
- Fundamental factors have higher value when horizon is longer

Momentum

- n-day momentum, $momentum_t = \frac{price_t}{price_{t-n}} - 1$
- -0.5 to +0.5

Simple moving average

- n-day SMA, IndicatorSMA$_t = \frac{price_t}{\frac{\sum price_t}{n}} - 1$
- -0.5 to +0.5
- Could be used as proxy for underlying value especially with window is large
  - If price above the average, it might indicate the stock is overpriced and bound t
  - If stock is below average, it might indicate the stock is undervalued and bound t
- The points where moving average curve and price curve intesects could be used as signals

Bollinger Bands

- have moving average and moving standrd deviation curves drawn
  - When price is going to fall inside the band at +2σ, it could be a sell signal
  - When price is goign to rise inside the band at -2σ, it could be a buy signal
- -1 to +1

Normalization

- Technical indicators ahve to normalized to allot equal importance to each indicators

Lesson 17: Dealing with Data

- data is sampled at lowest resolution called tick which indicates a successful transac when buy and sell match)
- **Stock Split** happens usually when the stock becomes very high price (n:1)
  - creates issue when we feed in data to our algorithm
  - adjusted close will adjust the prices by back tracking
    - At the latest day, actual price and adjusted close match
- **Dividends** comapny payouts
  - Adjusted close will reduce the price on the day previous to dividend pay by an a dividend
    - At the latest day, actual price and adjusted close match

Survivorship Bias

- Use survivor bias free data

Lesson 18: Efficient Market Hypothesis

Assumptions

- Large number of investors
- New info arrives randomly
- prices adjust quickly
- Proces reflect all available information

Three forms of EMH

- **Weak** Future prices cannot be predicted by historical prices
- **Semi-Strong** Prices adjust rapidly to new public info
- **Strong** Prices reflect all information public and private

Not considered to be true

Lesson 19: The Fundamental Law of active portfolio management

Information Ratio (IR)

- $return_p = \beta_p * market + \alpha_p$
- α_p is the skill of fund manager of portfolio
- IR = $\frac{mean(\alpha_p)}{std(\alpha_p)}$
- Sharpe ratio of excess return

Information Coefficient (IC)

- Correlation of forecasts to returns
- 0 to 1

Breadth (BR)

- Number of trading oppurtunities per year

Grinold's Fundamental Law

- $performance = skill * \sqrt{breadth}$
- $IR = IC * \sqrt{BR}$

Coin flipping casino example

- 1000 tables are tossing coins
- You have 1000 tokens to bet
- coins are biased with head's probability being 0.51

Option 1: Betting all tokens on a single table

- Expected return = $1000 * 0.51 - 1000 * 0.49 = 20$
- But the risk is too high
  - standard deviation = $\sqrt{1000^2 - 20^2} = 1000$
- risk discounted reward = $\frac{20}{1000} = 0.02$

Option 2: Betting a token each on all tables

- Expected return = $(0.51 - 0.49) * 1000 = 20$
- Standard deviation = $\sqrt{1000 * (0.51 + 0.49)1^2 - 20^2} = \sqrt{1000 - 400} = 24.4$
- risk discounted reward = $\frac{20}{24.49} = 0.82$

Observations

- SR_2 = 0.82 >> SR_1 = 0.02
- SR_2 ~= SR_1* $\sqrt{1000}$
- Coincidence? I think not.

Lesson 20: Portfolio optimization and the eff frontier

∗ **Risk is** $\sigma_{dailyreturns}$

Why covariance matters?

- Combining anti-correlated stocks would reduce risk i.e., standard deviation
- Combining strongly correlated stocks wouldn't add much to return or risk of the portf actually might remain nearly the same

Mean Variance Optimization (MVO)

- Inputs:
  - Expected return
  - volatility
  - covariance of daily returns
  - target return of the portfolio
- Output
  - Asset weights for portfolio that minimizes risk

The Efficient Frontier

- Dont go on the curve to a point where you reward is less for the same amount of ris
- If you are inside the curve, we can do better
- Tangent to the curve gives max sharpe ratio