Quantitative Investment Handbook

Xinhe Liu

2018-5-28

Contents

Part I

Financial Market and Investment Tools

Chapter 1

Economics and Econometrics

1.1 Macroeconomics

GDP, Inflation and Unemployment:

- GDP = C + I + G + X
- CPI, RPI, PPI, Core CPI, Nonfarm Payroll, HICP (Europe)
- Philips Curve(Inflation and Unemployment)
- Unemployment Rate(labor force), Participation Rate(total population), Quit Rate
- Unemployment: Frictional, Cyclical, Structural, Seasonal, Voluntary

Economic Indicators:
Leading Indicators:

- PMI, Tanken Survey(Japan)
- Capacity Utilisation
- Retail Sales
- Consumer Sentiment/Confidence

Market Data Release Time Schedule:

Time	Market Data
Week 1	Employment Situation (First Friday), ISM
Week 2	Retail Sales, Consumer Sentiment
Week 3	CPI, IP
Week 4	Durable Goods, GDP, Consumer Sentiment(UoM final & Conference Board)

- PMI
- Capacity Utilisation
- Retail Sales
- Consumer Sentiment/Confidence

Fiscal Policy and Monetary Policy:

- General Economic Goals: Full Employment, Economic Growth, Low Inflation
- Fiscal Policy: Government Spending and Tax Policy
- Monetary Policy: Open Market Operations, Discount Rate, Reserve Requirement, Federal Fund Rate(Upper Limit for Repo Rate) (In other countries: Overnight discount rate, Refi Rate, Deposit Rate, Main Lending Rate)
- Interaction: Crowding Out: Higher Interest Rates may cause investment and consumption
- Central bank, Taylor rule

1.1.1 Business Cycle and Debt Cycle

According to Ray Dailo's Opinion, business cycles are created by credit (borrowing). Growth = Productivity Growth + Debt Cycle Effect.

- Total output = Price × Quantity, while Price = Money + Credit
- Long term debt cycle: 75 to 100 years. Short term debt cycle" 5-7 years
- Key indicators Inflation, deflation, tax, government spending, unemployment (Government Action)
- "Beautify Deleveraging": The phase total debt decreases. Needs: Spending cut, Debt Restructuring, Wealth transfer, Print Money (Government Debt increases, total debt decreases, if not carefully, lead to hyper-inflation
- 2-3 years depression/deleveraging and 7-10 yeas "reflation"

Keysian Theory

stagflation and non zero inflation

1.2 Financial Economics

- Rationality. Utility Theroy, Indifference Curve, Risk Aversion. Participants are perfect optimizers with perfect Bayesian Information
- Efficient Market Hypothesis : 3 Forms
- Market Anomalies: Fundamental Anomalies (Factor), Technical Anomalies, Calendar Anomalies, Limits to Arbitrage

1.3 Behavioral Finance

- Behavioral Finance micro: Assumes limited information, bounded rationality

  Prospect Theory

  Neuroeconomics

- Behavioral Finance macro

  Challenge Efficient Market Hypothesis(EMH): Anomalies

  Fundamental Anomalies: (eg. Value Factor, Factor Models)

  Technical Anomalies (Moving Average, Support and Resistance)

  Calendar Anomalies

  Due to other reasons such as Limits to Arbitrage

  Asset Pricing: Behavioral Stochastic Discount, Sentiment Risk Premium

  Behavioral Based Portfolio Theory

  Adaptive Market Hypothesis

- Behavioral Biases in investing

  Cognitive Errors-Belief Perseverance Bias

  - Conservatism (Systematically review and update new information)
  - Confirmation Bias(Review screening criteria, promote diversification),
  - Representativeness Bias(Review Base-rate Neglect and Sample-size Neglect, check if forecast based solely on new data, check if treat complex and simple information equally),
  - Illusion of Control(excessive trading, lack of diversification, need to keep records and manage info)
  - Hindsight Bias(overestimate the degree of prediction, rightness of selection (manager or investment)

  Cognitive Errors-Information Processing Bias

  - Anchoring and Adjustment (stick to original information)
  - Mental Accounting(under-diversify, distinction of income and capital appreciation) Framing Bias(affects risk appetite)
  - Availability Bias: weight according to experience, relevance, under-diversify, affected by Ad

  Emotional Bias

- Loss-Aversion: Disposition Effect: work together with Framing bias, Myopic loss aversion
- Overconfidence: Under-diversify, Trade Excessively
- Self-Control Bias: Not save for long-term, taking too much/little risk, asset allocation imbalance - prefer income generating assets
- Status Quo Bias: unknowingly maintain, work with Regret-Aversion and Endowment
- Endowment: hold familiar, refuse to sell certain assets
- Regret-Aversion: Herding, conservatism

Chapter 2

Basic Financial Concepts

This chapter summarizes some basic financial concepts you should know about.

2.1 Asset Management

Asset Owners(Real Money): From conservative to active: Banks, Insurance Company, Defined Contribution Plan, Pension, Endowment/Foundations

Hedge Funds(Fast Money)

Investment Purpose Statement(IPS): Consider Return, Risk, Time Horizon, Tax, Liquidity, Legal and Unique.

2.2 Accounting, Corporate Finance and Fundamental Analysis

Accounting:

- Balance Sheet, Income Statement, Cash flow Statement Basics

- EBIT = operating profit + non recurring expense - non-recurring income, EBITDA, Operating profit, normalized net income = NI + non recurring items
- Gross Profit, Operating profit, profit before tax, net income
- Gross Margin, EBIT Margin, EBIT Margin, Net Operating Margin, Net Profit Margin
- Cash flow from Operations = NI + DA +- change in inventory/accounts payable, receivable, operating items
- CF from investing = Capital Expenditure -+ Disposal/Purchase of Assets
- CF from financing = -Dividend - Share buybacks + issuance of stock/bond
- Equity: Preferred shares, authorized shares (maximum shares the board can issue), Treasury stock, buy back book value, Free float Market capitalization = share price * (shares outstanding - shares not traded), Small free float: little share holder control, volatile share price, high premium in M&A

Capital Structure:

- Operating items vs financing items (cash, financial asset/liability, equity)
- Working Capital = Current Assets - Current Liabilities, Operating Working Capital = Operating Assets - Operating Liabilities(exclude cash)
- Inventory COGS LIFO FIFO inventory turnover
- Payable days, receivable days, working capital cycle (payable days - inventory days + receivable days)
- Leverage ratios: Debt/Equity, Total Debt/EBITDA, EBITDA/inst expense

Credit Scoring/Credit Analysis

- Credit Risk = Business Risk(Country, Economic Cycle, Industry Cycle, Currencies, Commodities, trends) + Financial Risk(Cash Risk)
- Creditor Cashflow Statement Net Income + D/A/non-cash items = FFO(Funds from Operations), FFO +- Decrease/Increase in OWC = Operating Cash Flow, Operating Cash Flow - Capex = Free Operating Cash Flow(FOCF)
  FOCF + Dividends = Discretionary Cash Flow, DCF +- Acquisition, Asset Disposals, Net other sources/uses of cash = pre-financing cashflow +- Increase(Decrease) in Debt, +- Net Sale/Repurchase of Shares = Inc/(Dec) in Cash/Securities
- Profitability & Efficiency Ratios: EBIT/EBITDA margin, Return on Assets, Return on Invested Capital
- Coverage Ratios: EBITDA/interest(net interest), EBITDA/(interest + Principal Amortization), EBIT/interest or net interest
- Leverage Ratios: Debt/Equity, Debt/Capital, Debt/EBITDA
- Cash flow adequacy Ratios: FFO/Debt, FOCF/Debt, Free Cash flow/Debt, Retained Cash Flow/Debt
- Liquidity Ratios: maturing debt principal this year/FFO or discretionary cash flow, Quick Ratio = (Cash + Marketable Securities + Committed un-used bank credit lines)/maturing debt principal this year.

Tax: Effective Tax Rate, Loss Harvesting and Tax-Aware investment

Valutaion fundamentals:

- Intrinsic Value and two approaches - absolute valuation and relative valuation
- Enterprise Value = Debt + Equity Value - Cash/Cash Equivalent = Net Debt Value + Equity Value
- Equity Value (affected by performance (operating), investing and financing (leverage)) = Price x Shares Outstanding

- Asset = Enterprise Value + Non-core assets(not valued by Multiples/DCF models, like cash)
- Free Cash Flow Calculation: EBIT - tax on EBIT (LT tax rate x EBIT) = NOPAT (net operating profit after tax)/EBIAT, Free Cash flow = NOPAT + D&A - capex - increase in OWC + decrease in OWC - Increase in Other net operating assets + Decrease in other net operating assets -+ change in Long term tax liabilities
- FCFF, FCFE
- Discount Rate- Weighted Average Cost of Capital (WACC) - CAPM / required rate of return, WACC = D/(D+E) cost of net debt x (1-t) + $(rf + (r_m - r_f) \times beta) \times E/(D+E)$, D is net debt
- Gordon Growth Model
- EV multipliers : EV/Sales, EV/EBITEV/EBITDA

Fundamental Analysis, Company Analysis and Value Investing

Management/Strategic Analysis(SWOT, Five forces etc), Industry/Region/ Sector Analysis + competitor Analysis

2.3 Real-life trading

- Shorting a Stock: achieved by a stock-loan process of broker/dealer: broker need to borrow and put colleteral, during borrow agreement, any dividend is passed (synthetically) from the borrower to the beneficial owner. Corporate actions: borrower vote as in lender's proxy.
- SHOrt squeeze: Stock with high short interest trended upwards, short side cover their shorts.
- Naked short: short (t+2) before borrow, can borrow/buy later.
- Short interest thredhold: 8% of market cap or free float.
- Prime-brokerage: Agency only brokerage does not own books

Chapter 3

Major Asset Classes and Asset Valuation Theories

3.1 Money Market

- Overnight (O/N) reference ratesL SONIA(Sterling Overnight Index Average), EONIA, SOFR - ALl has different day count convention
- LIBOR Rate, STIR Futures (Cash Settlement by 100 - expected interest) , IMM Dates(Exchange for interest rate and currency futures)
- T-bill(1,3,6,12 Month) , T-note, T-bond
- Commercial Paper(Issued by best quality companies)
- Day Count Conventions
- Repo Market: Repo(seller, needs cash), Reverse Repo(buyer, owns collateral for a while)
- Fed Funds Rate:
  - The Upper Bound: Interest on Excess Reserves: interest rate paid by the Fed on Excess reserves held by banks at the Fed. (many money market participants are not reserve account holders so they do not have access to the IOER).

- Lower Bound: Overnight RRP: Non-reserve account holder can earn interest by entering into an overnight reserve repo(overnight RRP)- offer each day.

3.2 Asset Management Overview

factor investors

market - CAPM + APT

value - HML FX carry trade commodity - roll returns Fixed Income - riding the yield curve

momentum UMD - up minus down WML - winner minus losers

size -SML

volatility risk premium (a negative risk premium) illiquidity risk premium

alpha and active investing

Fundamental Theorem of Active Management

backtesting

surviorship bias sample selection bias infrequent trading (report same price/ missing price)

hedge fund strategies

merger/risk arbitrage

fixed income arbitrage swap spread arbitrage yield-curve spread arbitrage mortgage spread arbitrage (on prepayment rates) capital structure/credit arbitrage volatility trading interest cap vol) arbitrage

3.3 FX

Basic Concepts:

- FX Market is Extremely liquid (smaller bid ask spread on equity)
- Market Size High to Low: USD, EUR, Cheap Currencies: JPY(safe currency), CHF, GBP, Rich(high rate) currencies: ZAR, MXN, AUD
- Uncovered Interest Rate Parity and Covered IRP
- Interest Rate Forward/Futures, Non-deliverable forwards(NDF)
- FX Drivers: Interest rate differential, inflation rate differential, Global M&A/Capital Flows, Technical Drivers(Indicators), Central Bank Policies, Risk Appetite
- Purchasing Power Parity

3.4 Equity

Sell Side Services

- Traditionally, Sales and Trading Service build around research (content stream)
- New Model -automation: Algo-trading, Dark pools, MiFID
- ETF Market: Market Maker/Specialist who issue ETF Shares to investors, buy underlying stocks with ETF or money from fund and stock exchange.

  Physical ETF: generate return from holding all, or samples of underlying shares like index funds. Kept safe by a custodian.

  Synthetic ETF: Entering into total return swaps with counterparty issuer.

  ETFs fo pay dividends monthly, quarterly, half-yearly or annual. Based on funds income net of expense and distribute to share holders on the register on record date. Paid via brokerage account.

Tracking error: Annual fees are deducted Reflecting daily NAVs.

3.5 Currency/Foreign Exchange

3.6 Fixed-Income

Basic Concepts:

- Day Count Convention, Dirty Price
- Macaulay Duration, Modified Duration, DV01, Dollar Duration, Effective Duration
- Maturity Effect, Coupon Effect, Yield Effect, Coupon Frequency Effect on Duration
- Term Structure of Yield Curve, Expectation Theory, Liquidity Preference Hypothesis, Segmented Markets/Preferred Habitat Theory. Bond Markets: ¡ 1 y (money market) 1-3, 3-10 (bellwehter of market movements, the major contributor for beta in the fixed-income portfolio) 10(long end, relatively illiquid and sensitive)
- long end risks: liquidity, credit(sovereign credit), inflation, growth
- Carry(difference between coupon-like cash-flow and funding cost) and Roll Down: Both assumes no yield curve shift
- yield curve trading/fly trading, steepner, flatener, positive/negative butterfly, Barbell and Bullet
- Inflation Linked bonds(Linkers) UK Index-Linked Gilts, French OATi, US TIPS, JGBi. Breakeven Inflation: The difference in linker yields and nominal bond yields (linker coupon is always lower under positive inflation)
- Treasury Strips, UK Gilt Strips

Calculations

- Spot yield, par yield, forward rate, Bootstrapping

3.7 Commodities

- Much more volatile than other major asset classes.(volatility from both supply/demand side)
- Low correlation with traditional asset classes
- Market drivers
  - Fear: Reduced risk appetite/ fight to real assets. Geopolitics shuts down supply chains
  - Currencies; Gold-USD, Oil-USD
  - OPEC, Freak weather, earthquake
- Commodity Currencies: IMF found 22 commodity currencies (CHF-copper, AUD-Iron Ore,uranium)
- Stocks-to-Use Ratio, Reverse-to-Production Ratio
- Oil: Brent
- Physical Trade vs Derivatives(liquidity and leverage, low cost, less exotic)
- BSCOM, GSCI
- Commodity Futures, Convenience Yield, Contango(normal), Backwardation(Reversed)

Calculations

- Yield = Collateral Yield + Roll Yield/Cost + Spot Return

1. NPV and IRR
2. Discounted Cash Flow Model
   - Free Cashflow

- Required Rate of Return = Cost of Capital = Risk-adjusted discount rate : Usually from the CAPM

3. Valuation using Multiples - P/E, P/B

3.8 Derivatives

Swap

- Interest Rate Swap - fixed bond + floating bond (received swap position: long fixed bond, short floating/FRA, duration/DV01 is the difference of these two)
- Asset swap: Asset manager pay fixed, receive float, subject to credit risk

Futures

- long futures/ long cash = "funded beta"
- Used in asset-management: Tactical Asset Allocation, Beta management, Volatility Management
- Mark-to-market : "A martingale", variation margin changes everyday, fixed on EDSP -Exchange Delivery Settlement Price at the last day, cash settlement
- Open interest(# of net short contracts) vs volume(activity)
- Basis and Basis Risk: divergence of futures and underlying

CDS(Derivative)

- Reference entity(borrower or obligor), reference obligation, obligations(trigger to credit event), deliverable obligations(usually pari-passu or senior in priority of payment to the reference entity), portfolio(deliverable obligations the protection buyer elects to deliver, execute accrued interest), conditions to payment(Entity party must have deliveredL Credit Event Notice, Notice to Public Info, Physical Settlement, etc)

- Fixed Coupon CDS: standardized (not "par spred") CDS: 100, 500bp(High Yield): To payment moves
- CDS pricing: probability of default x exposure of default x Loss Given Default - driven by time, rates, spread

Credit Value Adjustment(CVA)

- pricing according to credit worthness of the counter-party
- Volatility   market volatility, probability of counterparty default
- Funding Value Adjustement(FVA): uncollatteralised position hedge with collateralised

3.8.1 Option

Credit Value Adjustment(CVA)

- Black-Scholes Model, Black's Model, Black-Scholes Equation (Heat Equation)
- Pricing factors and Greeks $\Delta, \Gamma, \theta, \nu$(vega), vanna, ρ, ϵ
- Pricing American Option

$$\frac{\partial V}{\partial t} + \frac{\sigma^2 S^2}{2}\frac{\partial^2 V}{\partial S^2} + rS\frac{\partial V}{\partial S} - rV < 0$$

- Option Trading Strategies

    put call parity c+pv(K) = p + S

    protective put, covered call, collar

    1x1 spread(bull/bear), 2x1 spread, calendar spread

    risk-reversal(short p, long c)

    straddle, strangle, butterfly, iron butterfly

    volatility carry, dispersion trade

Part II

Quantitative Investment Theories

Chapter 4

Quantitative Portfolio Mangement

1. Efficient Market Hypothesis (Weak, Semi-strong, Strong forms)
2. Markowitz Portfolio Optimization
   - Minimum Variance Portfolio / Tangency Portfolio
   - Jensen's alpha
3. Capital Asset Pricing Model(CAPM) Model

$$r = \beta(r_m - r_f) + r_f$$

$$\beta = \frac{cov(r, r_M)}{var(r_M)}$$

4. APT(Arbitrage-Free-Pricing) Model
5. No-arbitrage(weak, strong) and Law-of-one-price
6. Metrics
   - Sharpe Ratio
   - Jensen's alpha
   - Required Rate of Return = Cost of Capital = Risk-adjusted discount rate : Usually from the CAPM

7. Valuation using Multiples - P/E, P/B

Mainframe Portfolio Optimization Models Include

1. portfolio optimization - mean-variance short-comings and 1. Monte-Carlo simulation 2. reverse optimization and black-litterman(less sensitive to inputs) 3. resampled mean-variance optimization 4. add additional constriants (other than budget) - concentrated position 5. resampled mean-variance 6. non-normal optimization approach 7. allocating to less liquid asset class - (no investable benchmark) 8. risk budgeting vs factor based asset allocation(risk parity)

1. liability-relative 1. surplus optimization 2. hedging/risk-seeking portfolio 3. integrated asset-liability (non-linear correlation) 2. goal-based approach 1. describing goals, constructing sub-portfolios (selecting a module) One-fund theorem, two fund theorem

convex reformulation of maximizing Sharpe ratio problem(normalizing)

Multi-factor Risk Model

$$r = \mathbf{B}f + u \ V = \mathbf{B}cov(f)\mathbf{B}^T + cov(u)$$

Mixed Integer Optimization

Stochastic and Dynamic Optmization

Issue

Active Holding Optimization optimize alpha holdings and tracking error

Improvements on MVO estimation error Shrinkage estimators Jason-Stein Estimator Black-Litterman Model Robust Estimators

optimization issue add constraints resampled efficiency use other diversification approach risk-parity maximize diversification

Mixed Integer Optimization

Heuristic forward backward selection clustering

Stochastic Optimization scenario optmization approach Var cVar

Kellys Crirterion

Multi-period optmization room

Excel solver CVX matlab CVXOPT python optmization toolbox matlab Gorubi

4.1 Estimating Return and Co-variance Matrix

4.2 Transaction Cost

4.3 Tax

4.4 Dynamic Portfolio Choice

4.5 Covariance Matrix

Table 5.4
Covariance estimators

Equally weighted	Exponentially weighted
$\sigma_{12}^2 = \frac{1}{T}\sum_{t=1}^{T} (r_{1t} - \bar{r}_1)\ (r_{1t} - \bar{r}_2)$	$\sigma_{12}^2 = (1\text{-}\lambda)\sum_{j=1}^{T} \lambda^{j-1} (r_{1t} - \bar{r}_1)\ (r_{1t} - \bar{r}_2)$

4.6 Easy

1. Two coins, one is double tail, you see one

   - three pancakes: golden-golden, golden-brunt, brunt-brunt, see one golden, probability that the other side is golden two

-

2. Two coins - one toss n+1, one toss n, probability that n+1 gets more tail than n man?

4.7 Medium

1. Use coins to create probabilities : fair coin to create 1/3 probability - toss twice, one result is retoss unfair coin to create 1/3 probability - combine two toss as one

Chapter 5

Statistical Arbitrage

5.1 mean-reversion

intraday mean-reversion

Volatility Clustering and Leverage Effect

Chapter 6

Factor Investing

6.1 Factor Models

Factor Models plays a key role in all components of asset management

- Valuation and Market Expectation: CAPM, APT, alpha signals
- Risk Management: Risk attribution, stress test, risk modelling
- Portfolio Management: Smart beta, portfolio construction
- Performance: Performance attribution, style analysis

Major Types of Factor Models

- Regression Model: Observable factor returns

  $$\mathbf{X} = \mathbf{a} + \mathbf{B}\mathbf{Z} + \mathbf{U}$$

  ,where $\mathbf{Z}$ is observable, estimate $\mathbf{B}, \mathbf{a}(\beta, \alpha)$

  $$(\mathbf{a}, \mathbf{B}) = \arg\min \mathbb{E}(\|\mathbf{a} + \mathbf{B}\mathbf{Z} - \mathbf{X}\|^2)$$

  $$B = cov(\mathbf{X}, \mathbf{Z})var^{-1}(\mathbf{Z}), a = \mathbb{E}(\mathbf{X} - \mathbf{B}\,\mathbb{E}(\mathbf{Z}))$$

  Example: CAPM (CAPM beta can be improved by shrinking towards 1

- Cross-sectional Model: $\mathbf{B}$ (factor loadings) is observed. Usually use weighted list squares
$$\mathbf{X} = \mathbf{a} + \mathbf{B}\mathbf{Z} + \mathbf{U}$$
Usually solved with Weighted Least Squares:
$$(\mathbf{a}, \mathbf{Z}) = \arg\min \mathbb{E}(\|\mathbf{a} + \mathbf{B}\mathbf{Z} - \mathbf{X}\|^2_{\Delta^{-1}})$$
$$Z = (\mathbf{B}^T \boldsymbol{\Delta}^{-1} \mathbf{B})^{-1} \mathbf{B}^T \boldsymbol{\Delta}^{-1} \mathbf{X}, a = \mathbb{E}(\mathbf{X} - \mathbf{B}\,\mathbb{E}(\mathbf{Z}))$$
$\boldsymbol{\Delta}$ is often diagonal - associated to preassumed residual sizes. Example: most common models, and risk models such as Aximoa and Barra $\mathbf{r} = \mathbf{Bf} + \mathbf{u}$, use time series data of r to compute time series data of f

- Principal Components Model
$$\mathbf{X} = \mathbf{a} + \mathbf{B}\mathbf{Z} + \mathbf{U}$$
$$\mathbf{Z} = [Z_1, Z_2, ..., Z_n]^T$$
$$Z_i = \mathbf{e}_i^T(\mathbf{X} - \mathbb{E}(\mathbf{X})$$
$$\mathbf{e}_i = \arg\max_{\mathbf{e}} var(\mathbf{e}^T\mathbf{X})$$
$$\|\mathbf{e}\|^2 = 1$$
$$\mathbf{e}_k^T \mathbf{e} = 0, k = 1, ..., i-1$$
then
$$\mathbf{V} = var(\mathbf{X}) = [\mathbf{e_1}, \mathbf{e_2}, ...\mathbf{e_n}] \begin{bmatrix} \lambda_1^2 & & \\ & \ddots & \\ & & \lambda_n^2 \end{bmatrix} [\mathbf{e_1}, \mathbf{e_2}, ...\mathbf{e_n}]$$
Principal Components
$$X_i^{PC} = \mathbf{e}_i z_i = \mathbf{e}_i \mathbf{e}_i^T (\mathbf{X} - \mathbb{E}(\mathbf{X})$$
$$\mathbf{B} = [\mathbf{e_1}, \mathbf{e_2}, ...\mathbf{e_n}], \mathbf{a} = \mathbb{E}(\mathbf{X})$$

- Hidden Model: Try to distinguish between systematic and idiosyncratic risk
$$\mathbf{X} = \mathbf{a} + \mathbf{B}\mathbf{Z} + \mathbf{U}$$
want $cov(\mathbf{Z}, \mathbf{U})$ to be 0 and $varU$ diagonal, want $\mathbf{V} = var(\mathbf{X}) = \mathbf{B}^T var(\mathbf{Z}) \mathbf{B}^T + \boldsymbol{\Delta}$ Example: the APT Model

From a factor portfolio

- Signal portfolio: from factor signals, From a fractile(divide the universe to fractile, form equal weighed portfolios for each fractile) or long-short(long equal weight portfolio with high score, short with low score)

- Factor Mimicking Portfolios: with only exposure to one of alpha singal/factor attributes **a**

$$min \mathbf{h}^T \mathbf{V} \mathbf{h}$$

,

$$\mathbf{a}^T \mathbf{h} = 1$$

$$\mathbf{h} = \frac{1}{\mathbf{a}^T \mathbf{V} \mathbf{a}} \mathbf{V}^{-1} a$$

in additional, be cash neutral or factor neutral

$$\mathbf{1} T \mathbf{h} = 0$$

or

$$\mathbf{B}^T \mathbf{h} = 0$$

6.2 Alpha

Grinold and Kahns rule of thumb

$$\alpha = IC \times score \times volatility$$

Fundamental law of active management

$$IR = IC\sqrt{BR}$$

6.3 Smart beta and Smart Alpha

long-short STS strategy short extension(120/20) Strategy alpha and beta separation portable alpha

long short equities (factor) convertible arbitrage

6.4 Risk Premia Factors

- Value

- Momentum

- Carry

  Credit: beta-neutral relative value trade

- Betting-against Beta: Long low beta equity

  Credit: Jump-to-Default

- Volatility Carry

  CVA Desk vs Real Trade

Momentum

6.4.1 Equity Multi-factor Investing

6.4.2 Cross-Asset Risk Premia Portfolio

6.4.3 Volatility Strategies

6.4.4 Credit Strategies

6.4.5 Dynamic Customization

6.4.6 Hedging Strategies

6.4.7

value, momementum, quality, volatility, betaRM-RF The return spread between the capitalization weighted stock market and cash.

QUality Minus Junk (quanlity)

SMB The return spread of small minus large stocks (i.e., the size effect).

HML The return spread of cheap minus expensive stocks (i.e., the value effect).

RMW The return spread of the most profitable firms minus the least profitable.

CMA The return spread of firms that invest conservatively minus aggressively.

UMD (momentum/trend) UMD is long winners and short losers and also from Ken Frenchs website)

Carry Vol Carry

Special: liquidity premia

Market Ineffciency Analysis: funding constraint of financial institutions, grand move of large funds constraints

6.5 Market Anomalies

6.5.1 Behavioral Finance

Behavioral Finance Theories Includes Prospect Theory(People suffice rather than optimize, the utility curve is concave at the gain part and convex at the loss part(loss aversion). Bounded Rationality and Behavioral Market Anomalies/bias

1. loss aversion(herding)
2. illusion of control(TAA)
3. Mental accounting(goal),
4. availability bias(familiarity, home-bias)
5. recency bias(tactical shifts)
6. framing(risk-return presented in a different way)

other: liquidity risk premia

1. Risk Management and Hedging
2. Leverage
3. Correlation
4. Strategy replacements, leverage rebalancing and rebalancing frequency, leverage reset

other: liquidity risk premia

1. Risk Management and Hedging

2. Leverage
3. Correlation
4. Strategy replacements, leverage rebalancing and rebalancing frequency, leverage reset

Chapter 7

Quantitative Trading Strategies

7.1 Strategy Toolbox List

- Signal

  Multi-signal mix: Multi-window

  Signal Smoothing

- Risk

  Correlation

  Leverage Control

  Volatility Target

  Idiosyncratic Risk

-

7.2 Equity

7.3 Volatility and Dispersion Trades

7.3.1 Volatility Models and Time-Series Models

7.4 fixed income + macro

7.5 fixed income derivatives

MBS Convexity Trade

1. real estate-direct vs indirect environment 2. benchmarks of real estate 3. other alternative, commodity to hedge

7.6 credit

7.7 commodities

7.8 Cross Asset

1. Cross-Asset Risk Premia
2. Cross-Asset Trend

Chapter 8

Quant Strategies and Long-short Strategies

Stat Arb (typically high volume), Merger Arb, Relative Value, IntraCap Pairs

Part III

Quantitative Modeling and Strategies Implementation

Chapter 9

Strategy Development Overview

Typically, need the sub functions/sub teams including:

1. Data Curator: Data collection, cleaning, indexing, storing, adjusting and delivering
2. Feature Engineering and Analytics: Data Mining, Signal Extraction and Processing using information theory, Data visualization, labeling, filtering, classifiers building - try to extract features
3. Strategies Research: Make sense of features, market observation, instrument knowledge and try to formulate general theory/intuition that explains market mechanics. Submit code to the backtesting team
4. Backtesting: Statistical, Stochastic, Econometric tests of strategies/portfolios
5. Deployment: Rely heavily on computing, process schedulers, automation servers, vectorization, multithreading, multiprocessing, Big Data, Machine Learning on Big Data and High-performance computing

Backoffice and Risk Management (See Risk Management chapter)

1. Portfolio Aggregation
2. Portfolio Evaluation
3. Performance/Risk Attribution

Also, teams should also maintain and select current strategies, typically, a strategy experiences Embargo, Paper Trading, Real-money trading, Re-allocation and Decommission.

Some Major Challenges:

1. Traditional Portfolio Mangers work in silos and make decisions alone. While quant investing need to cut-down the decision making process to small research projects and run as a strategy factor
2. Combine "black-box" PM views/market intuition with quant research results from data/math.
3. Combine machine learning algorithm with existing traditional strategies.
4. "Backtest overfitting": Without limitation on number of trials, Sharpe ratio in back test could be very high.

Chapter 10

Financial Data Modeling

10.1 Financial Data Structure

Basic Assumptions: Most time should check implicit assumptions

- Equities $log(\frac{V_{t+1}}{V_t}$ i.i.d
- Fixed Income $Y_t(\tau) = -\frac{1}{\tau}log(V_t(t+\tau))$ i.i.d shock on interest rate (bond yield)
- Risk drivers/factors $\mathbf{X}_t = [X_{1,t}...X_{\bar{d},t}]$ homogeneous in time, and determines the joint PnL of instruments

Data Problems

- return measured less than a year includes implicit extrapolation
- illiquid and infrequent priced assets may be priced with

  Matrix pricing (common in bond market)

  Consensus/Expert Data
- Bonds: Recall, Termination (Aging), Exchanged
- Stock: Corporate Actions (Splits, Reverse Splits, Voting Rights, etc)

- Futures and Options: Termination and Rolling
- Currencies: Not Traded in centralized order book

Signals

- Quote Offers canceling/replacing with sell orders o potnetial sell off information
- Limit Orders vs Market Orders

10.2 Financial Data Sampling

10.2.1 Data Sampling Methods

10.2.2 Data Sampling Weights

10.3 Time-series Data Modeling

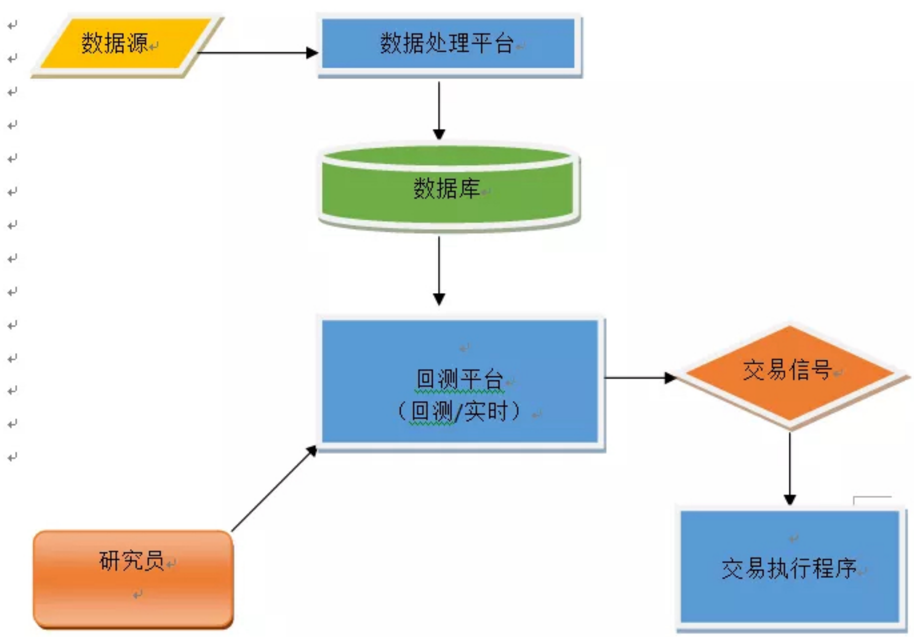
10.4 Data Labeling in Strategy Research

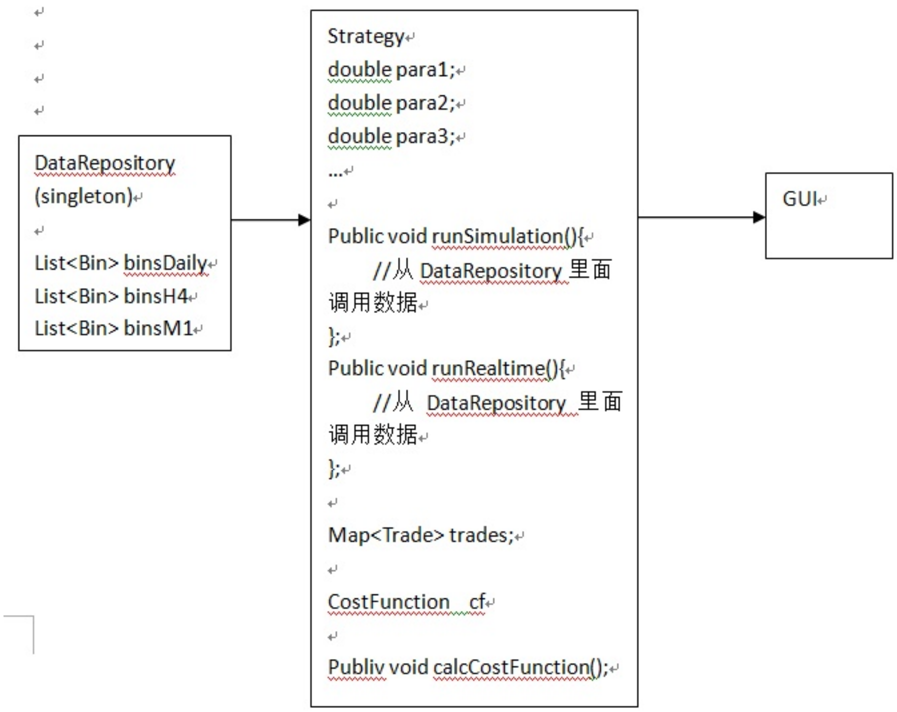
Chapter 11

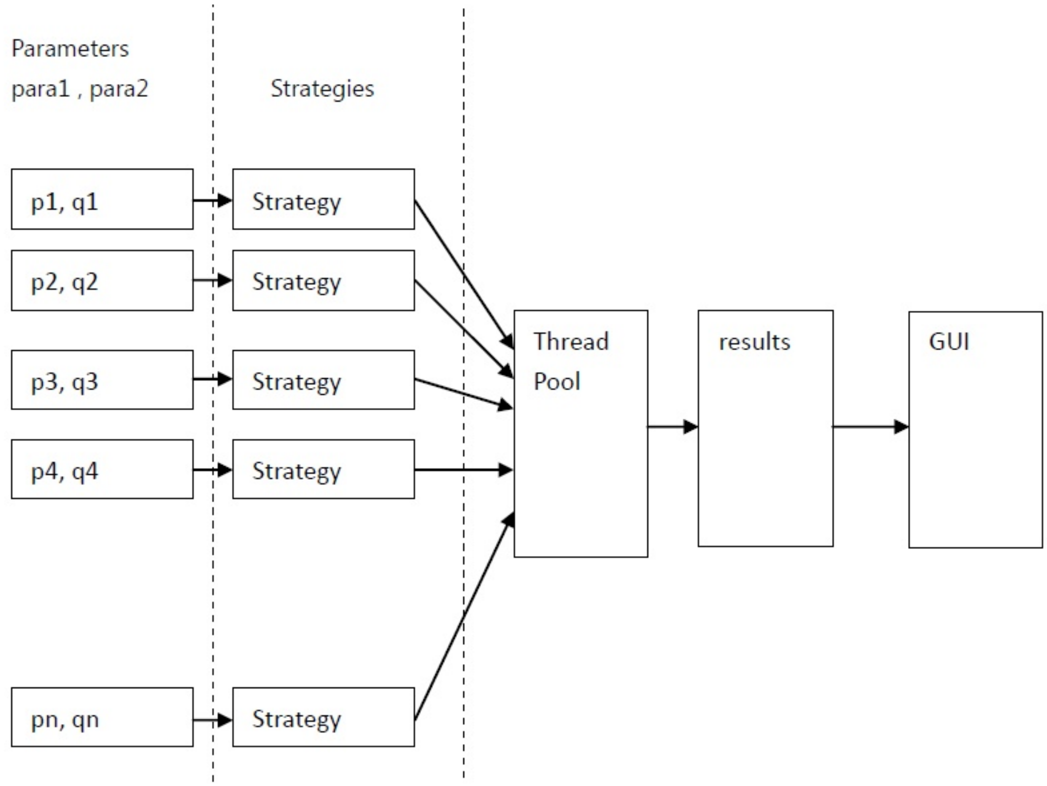
Trading System

11.1 Strategy Development Pipeline(Single/Linear Strategy)

11.1.1 Basic Architecture/System




DataRepository
(singleton)
List<Bin> binsDaily
List<Bin> binsH4
List<Bin> binsM1
Strategy
double para1;
double para2;
double para3;
...
Public void runSimulation(){
//从 DataRepository 里面调用数据
};
Public void runRealtime(){
//从 DataRepository 里面调用数据
};
Map<Trade> trades;
CostFunction cf
Publiv void calcCostFunction();
GUI




```java
public class Bin {

    public Calendar openTime;
    public Calendar closeTime;

    public double openBid;
    public double highBid;
    public double lowBid;
    public double closeBid;

    public double openAsk;
    public double highAsk;
    public double lowAsk;
    public double closeAsk;

    public double volume;

    public double pnl;

    public int length;
}
```

```java
import java.util.Calendar;
import java.util.UUID;

public class Trade {

    private UUID uuid;

    private String instrument;

    private double entryPrice;
    private double exitPrice;

    private double stoplossPrice;
    private double profitTargetPrice;

    private double commissionrate;
    private double commission;

    private double profit;

    private int quantity;

    private Calendar entryTime;
    private Calendar exitTime;

    private DirectionType direction;

}
```

```
for binsDaily {
    for (Bin bin:binsM1) {
        if(达到入场价){
            //入场一单
            Trade trade = new Trade()
            Trades.put(trade);
        }
        For (trades){
            If(打止赢/打止损){
                Trade.close()
            }
        }
    }
}
```

Historical Data is a singleton. All Market Data (eg. a candle stick) should be organized to feed the researcher to program strategies on the backtester (eg. like quantopian). All back-testing should be parallized (ideally on GPU) to display parameter-profit relationship. (heatmap, stock charts, etc) Ideally the optimization process could be visualized (like Tensorflow)

All like a research facility feedback cycle.

Key Details: API Design, Module Separation etc.

11.1.2 Data

Key is a real-time listener. Technical Considerations: KDB, Hadoop and HDFI(?), SQL Like, Mongo Db to store Archive Data. Market Data Providers consideration buying from Wind, BBG, Reuters, Etc.
teams: platform operation engineer, analytics builder, strategy control/management and risk management, data team, execution team, researcher team (3 x tech)
data licensing and data quality insurance
data base, text file archive, big data issue
cheap data: brokerage: interative brokers.

11.1.3 Backtester/Simulator

Key Components

*Send Singal to Quoting/Trading/Exection Tool(Real Time) *Market Data Objects (eg. loop for every time bins) *stop loss/risk control system integration *parameter-backtest profit/statistics result: optimization and loss function set function to tune the parameters *multi-thread: Java backter (Java thread pool*) *human selection of parameters: parameter table and visualization

11.1.4 Trade Record and Money Management

record every trade, summarize execution shortfall, statistical trends and information (shortcomings of strategy executions) and market information (learning material) build statistics and storage

More: order book and trade book level data handling

11.1.5 Analytics

Strategy Management

, Sharpe Anslysis, Holding Period, Slippage visualization to better assistant strategic allocation

Execution Analysis and Cost

quantitative trading/systematic trading strategies: * equity long/short

11.1.6 Research Team

Key problems: * Optimization and Combination of Sub-Strategies (Eg. factors) * Market Regime Change Detection(problem not solved): Distinguish between trend and oscillation market * market supply/demand imbalance analysis (risk-premia) * volatility trading, dispersion trading - 2nd and 3rd degree trading, (vol model, vol clustering effect, vol leverage effect) * hedging/overlay strategy research:

hedging cost and hedging risk management, how to adjust hedge according to market condition. * common ideas: market imbalance, mean-reversion, autocorrelation patterns etc (find patterns and trade) - based on statistics. Risk factors, implied arbitrage - based on math.

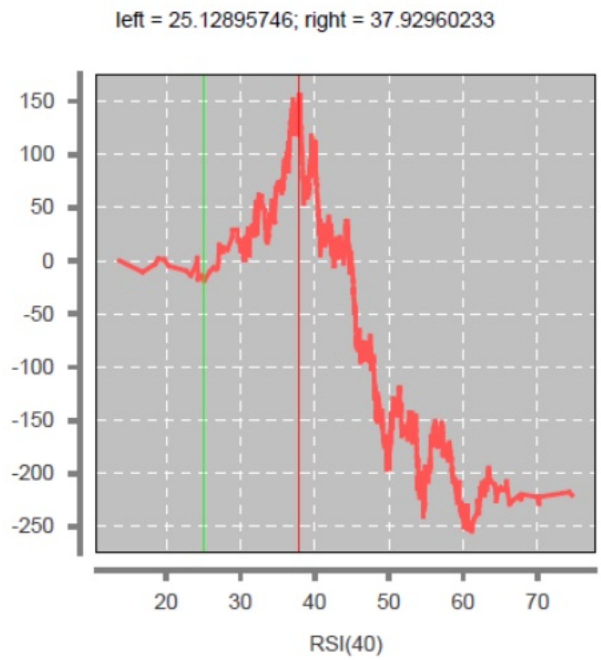
Parameter Optmization and Control

Rely on GUI - parameter distribution and selection optmization methdologies from machine learning (see optimization chapter) robustness anslysis and out-of sample test ** (random cut the universe of rolling window on selection period)

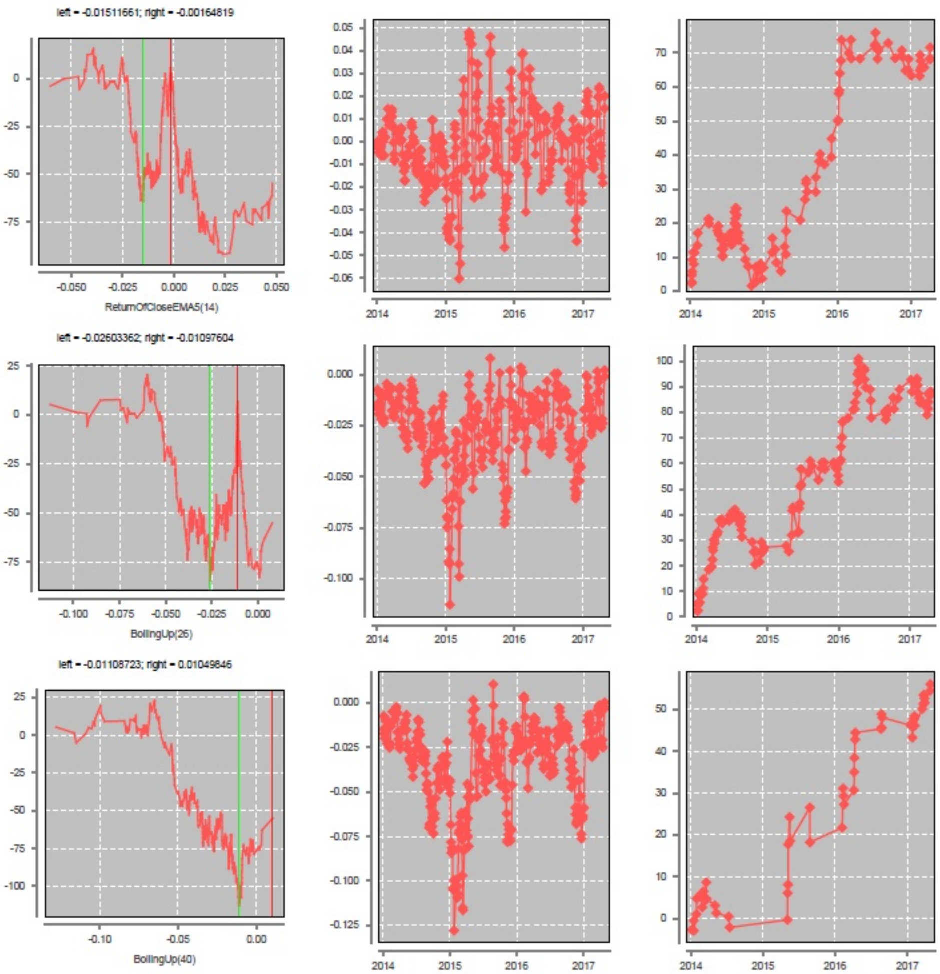
Signal Indicator Design

For example, based on fundemental ratio and technical indicators - design a formula. And check the level of prediction power (if any)

1.seeking stationarity: find a stationary time series use difference, integration, and normalize with volatility 2.find signal level, plot cumulative back-test return against different signal level (use own quotes, and use signal level to filter quotes)



3.Check stability of customized indicators



4. check overfitting and type-II error in all settings, apply noise filtering if possible 5. design a interface to input indicator(math formula parser to read string) and visualize information using GUI.(HTML/XML Render)

```xml
<?xml version="1.0"?>
<indicators>

<section name="priceDivEMA">
    <indicator>
        <f>OpenDivEMA(\i)</f>
        <i>2,3,4,5,7,10,14,20,24,26,30,36,40,42,46,48,50</i>
    </indicator>
    <indicator>
        <f>CloseDivEMA(\i)</f>
        <i>2,3,4,5,7,10,14,20,24,26,30,36,40,42,46,48,50</i>
    </indicator>
    <indicator>
        <f>HighDivEMA(\i)</f>
        <i>2,3,4,5,7,10,14,20,24,26,30,36,40,42,46,48,50</i>
    </indicator>
    <indicator>
        <f>LowDivEMA(\i)</f>
        <i>2,3,4,5,7,10,14,20,24,26,30,36,40,42,46,48,50</i>
    </indicator>
</section>

<section name="ReturnEMA">
    <indicator>
        <f>ReturnOfOpenEMA5(\i)</f>
        <i>2,3,4,5,7,10,14,20,24,26,30,36,40,42,46,48,50</i>
    </indicator>
    <indicator>
        <f>ReturnOfCloseEMA5(\i)</f>
        <i>2,3,4,5,7,10,14,20,24,26,30,36,40,42,46,48,50</i>
    </indicator>
    <indicator>
        <f>ReturnOfHighEMA5(\i)</f>
        <i>2,3,4,5,7,10,14,20,24,26,30,36,40,42,46,48,50</i>
    </indicator>
    <indicator>
        <f>ReturnOfLowEMA5(\i)</f>
        <i>2,3,4,5,7,10,14,20,24,26,30,36,40,42,46,48,50</i>
    </indicator>
</section>
```

```java
public static HashMap<String, List<String>> parseXML(File fXmlFile) {

    HashMap<String, List<String>> map = new HashMap<String, List<String>>();

    DocumentBuilderFactory dbFactory = DocumentBuilderFactory.newInstance();
    DocumentBuilder dBuilder = null;
    try {
        dBuilder = dbFactory.newDocumentBuilder();
    } catch (ParserConfigurationException e) {
        e.printStackTrace();
    }
    Document doc = null;
    try {
        doc = dBuilder.parse(fXmlFile);
    } catch (SAXException | IOException e) {
        e.printStackTrace();
    }

    doc.getDocumentElement().normalize();

    NodeList nList = doc.getElementsByTagName("section");

    for (int i = 0; i < nList.getLength(); i++) {
        Node nNode = nList.item(i);
        if (nNode.getNodeType() == Node.ELEMENT_NODE) {
            Element element = (Element) nNode;
            String sectionName = element.getAttribute("name");
            map.put(sectionName, new ArrayList<String>());
            NodeList childList = element.getElementsByTagName("indicator");

            for (int j = 0; j < childList.getLength(); j++) {
                Node childNode = childList.item(j);
                Element cElement = (Element) childNode;
                String indicatorNameOrigin = cElement.getElementsByTagName("f").item(0).getChildNodes().item(0)
                        .getNodeValue();
                if (cElement.getElementsByTagName("i").getLength() > 0) {
                    String indicatorParaList = cElement.getElementsByTagName("i").item(0).getChildNodes().item(0)
                            .getNodeValue();
                    String[] indicatorParas = indicatorParaList.split(",");
                    for (String indicatorPara : indicatorParas) {
                        String indicatorName = indicatorNameOrigin.replace("\\i", indicatorPara);
                        map.get(sectionName).add(indicatorName);
                    }

                } else {
                    map.get(sectionName).add(indicatorNameOrigin);
                }

            }

        }

    }
    return map;
}
```

6. aggregate all indicators(eg. macd, ead). Aggregate all strategies using optimization framework or selection framework to gain statistical alpha 7. indicator effectiveness test 1. test correlation - the correlation between indicator and profit vs. the correlation between correlation and white noise(hypothesis test) * use spearman correlation rather than pearson correlation* 2. Use Monte Carlo Simulation to do permutation test of effectiveness of indicator 3. Very very hard - detect sensentivity to market regime change(osicallation and trend) and identify market regime

change.

Integration of single indicators and portfolio theory

Form indicator as factors: standardization to mean-0, normal/t-distributed scores. Select powerful ones (ones that passed the permutation test). Optimize to maximize holdings exposure to factor with risk penalty. The key is still feature engineering.

$$h'f - ah'Vh$$

h:列向量，portfolio 里各个品种的持仓
f:列向量, expected return
a 常数: risk aversion
V： covariance matrix
‘ 意思是矩阵转秩

For Covariance, See section ”covariance matrix”.

Strategy Risk Management and Money management

small stop loss, big stop gain level on reversion strategies.bigger stop loss, smaller stop gains on volatile markets - based on experience, market analysis.

Choose symmeteric/non-symmetric risk control based on market belief

Hedging and Market Exposture Management - Volatility Control and Automatic de-leveraging.

together with cost consdieration.

11.2 Backtesting

1. Surviorship-bias
2. Look ahead-bias
3. In-sample bias

Chapter 12

Portfolio Risk Management

12.1 Derivatives and Hedging Strategies

Sell Side Risk

Coherent Risk measure

monotonicity

subadditivity

positive homogeneity

translation invariance

liquidity risk

funding liduitdity market liquidity (brokerage fees, execution price compared to mid-point, impact of transaction in the market price, the speed of transaction execution)

evidence that liquidity good: stable quoted bid-ask spread, order book depth deep, falling realized bid-ask spread, evidence for bad liquidity: large trades have more market impact, average trade size fall, increased bifurcation in the corporate bond market(different liquidity preferring on-the-run) influncers

regulators(e.g. leverage, Volker Rule)

Central bank bank funding channel market functioning channel risk appetite channel

liquidity measures bid-ask spread effective spread Rolls price reversal Corwin and Schultz high-low spread price impact turnover Amihuds measure Markits liquidity score Dealer count Quote depth Imputed round-trip cost

tightness: cost of a round-trip transaction market depth: how much moved by a large order resiliency : length of time for which a lumpy order moves the market away from the equilibrium price adverse price impact slippage(the amount of deterioration in the market price induced by the amount of time it takes to get a trade done)

model validationquantitative)

validation of inputs and parameters(assumptions) model replication benchmarking and hypothetical portfolio testing (with another strategy) backtesting profit and loss distribution stress testing

2. risk management 1. Var - historical, analytical, MC good and bad 2. credit risk exposure (pv only swap has) 3. derivatives 1. futures, hedge, synthetic equity/cash, pre-investing 2. options 1. spread-bull bear, butterfly 2. straddle, collar, box spread(bull, bear spread- risk free rate) 3. interest rate swap - leveraged floating-rate notes, inverse floater; currency swap 4. swaption - payer, receiver - use receiver to add/remove callable bond features

1. fixed income 1. duration matching 1. requirements 2. vs cashflow matching(tenor offer), contingent immunization, horizon matching 2. index and challenges 1. index vs mutual fund,ETF, synthetic strategies(total return swap, less cash but counterparyt risk) 3. yield curve strategies 1. laddered, bullet, barbell vs level slope curvature 2. barbell vs bullet, condor and butterfly long short at level change, slope change, curvature change, yield volatility change performance and strategy (wing and body) 4. high yield and credit stprad 1. IGB HYB : credit risk, credit migration risk, interest rate risk, liquidity risk 2. access liquidity risk and tail risk 3. emerging market difference

12.2 FX risk management

1. currency management 1. forward price (long/short base currency) 2. options- risk reversal, put spread, seagull spread 2. index and benchmark 1. capitalization-weighted, price-weighted, equal-weighted index, fundamental-weighted indexes

Chapter 13

Monitoring and Performance Evaluation

13.1 Monitoring

1. rebalancing corridor width 2. CPPI/ swaption etc

13.2 Performance Analysis

1. Performance Measurement

   Measure returns: Time-weighted(TWRR) or money-weighted (MWRR)

2. Performance Attribution

   Key is benchmark

3. Performance Appraisal

   Different Performance Measures

13.2.1 Performance Attribution and Style Analysis

Key to do performance attribution and portfolio risk management is the selection of benchmarks (ideally liquid, investable, and reflects style). Common ones like indices, manager's universe, factor model or customized benchmark can be tested by

- Minimal systematic bias: (historical beta of portfolio of benchmark should be close to 1, correlation between P-B and B-M should be zero
- Tracking Error should be minimal
- Exposure to systematic risks should be similar to the portfolio
- Coverage (percent of market value of portfolio) should be maximal
- Turn over should not be excessive
- Active positions should be measurable and positive

Performance Attribution

- Macro Performance Attribution : From fund sponsor's perspective.

  Usually from asset class perspective: Policy Allocation + benchmark asset return + fund returns, variations, cash flows
- Micro Performance Attribution: To stock/asset level or to factor level (see: style analysis). e.g.

  $$r_v = \sum_j (w_{Pj} - w_{Bj})(r_{Bj} - r_B) + \sum_j (w_{Pj} - w_{Bj})(r_{Pj} - r_{Bj}) + \sum_j w_B(r_{Pj} - r_{Bj})$$
- Style Analysis

  $$r_p(t) = \sum w_i f_i(t) + u_p(t)$$

  Solve quadratic optimization

  $$\arg\min var(u_p(t))$$

  $$w_i \geq 0, \sum w_i = 1$$

  (notice, not minimize squared error, use $t - T$ period to estimate w_i, then get the selection return(specific risk)

- Variations include
  - weight change over time, the will cause the solution to be undetermined, need to discourage large movements by regularization.
  - factors usage:

    fundamental factor model

    sector factor: from return to get exposure

    style factor: from exposure (factor loading/factor scores) to get return. (See Factor Models)

    macroeconomic factor models(economic factors as GDP, rates)

    statistical factor models(PCA, Asymptotic PCAs and time varying factors)

- Then decompose the risk with factors: the risk of k-th exposure weighted factor:

$$\sqrt{\frac{1}{T}\sum_{l=1}^{T}(w_k f_k(l) - \overline{w_k f_k})^2}$$

- Bond portfolio performance Attribution: Same spirit but more complicated than equity portfolio: Need to separate

  External Interest Rate Enviroment

  returns on default free bonds with no forward rate change

  return due to the change of forward curves

  Management Process

  Interest Rate Management Effect: treat as if default free bonds

  Sector Quality Effect: sector and quality group

  Security Selection: within group selection

  Trading Activity: residual

13.2.2 Measure Performance

The key purpose is to collect data and do statistical tests on alpha.

Common Performance Measures

- Jensen's Alpha (expost $E(r_p) - E(r_b)$

  $$r_p(t) = \alpha_p + \beta_P r_B(t) + \epsilon_p(t)$$

  t-test on $\frac{\alpha_p}{SE_{\alpha_p}}$ usually use 2 as a thredhold
  Rule of Thumb:
  $$IR = \frac{t - stat}{\sqrt{T}}$$
  Can be used with a single benchmark, sector or style multi-factor models

- Ratio Measures

  Total Risk: Sharpe, M2 Measure

  Systematic Risk: Treynor Ratio

  Information Ratio:
  $$\frac{r_A - r_B}{\sigma_{A/B}}$$

Chapter 14

Alternative Data and General Machine Learning

Chapter 15

E-trading and Execution

Program Trading: Trading a group of instruments, typically cash equities, as single unit (Portfolio Trading or Basket Trading) Commissions from 3bps to 15 bps (2018). Used by active funds, arbitragers (derivatives to cash (eg. Treasury and Treasury Futures)etc)

Hedge Funds use it as part of Stat Arb (typically high volume), Merger Arb, Relative Value, IntraCap Pairs

Execution, Market Impact, VWAP

Bibliography

[1] Marcos Lopez De Pardo, *Advances in Financial Machine Learning*. Wiley, 1st Edition, 2018