Algorithmic Trading
Session 1
Introduction

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Outline

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An Introduction to Algorithmic Trading

Definition, Research Areas and Relevance

- **Definition:** Algorithmic trading is a discipline at the intersection of finance, computer science and mathematics. It describes the process of using algorithms to generate and execute orders in financial markets. Such algorithms generate long/short/neutral signals, adapt market quotes and/or execute trading decisions with minimal market impact and/or improved transaction prices

- **Research areas** are mainly in two different disciplines:
  - Computer Science: Build more reliable and faster execution platforms
  - Mathematics: Build more comprehensive and accurate prediction models

- **Relevance:** Algorithmic trading strategies account for approximately:
  - 60% of all US equity volume
  - 40% of all European equity volume
  - 25% of all Forex transactions
  - 20% of all US option trades

Source: Interactive Brokers

An Introduction to Algorithmic Trading

Applications

- **Algorithmic Execution:** Use algorithms to search/discover fragmented liquidity pools to optimize execution via complex / high frequency order routing strategies. Profit comes from improved prices and reduced market impact
  - Example: Order routing to dark pools to improve execution price, iceberg orders to reduce market impact

- **Market Making:** Supply the market with bid – ask quotes for financial securities. Ensure the book respects certain constraints such as delta profile or net position. Profit comes mainly from client's trading activity, hence the bid-ask spread. Also known as flow trading or sell side. Main risk comes from market moves against position if net position/Greeks are not perfectly hedged
  - Example: A broker offers to sell a financial security at the ask and to buy at the bid to earn the spread

- **Trade Signal Generation:** Design proprietary strategies to generate profits by betting on market directions. Profit comes from winning trades. Also known as propietary trading or buy side. Main risk is that market does not move as expected/back tested and strategy becomes unprofitable
  - Example: Buy/sell security when moving averages cross each other

General Trading Overview

Goals of Trading

- **Profit Generation**

1. **Entry:** Based on a trade signal, generate order to go short or long a certain financial instrument in a certain quantity. Trade results in a certain position in this security
2. **Mark-to-Market:** As the price of the security changes, so does your unrealized PnL.

$$PnL = Side * Quantity * (P_{bid} - P_{ask})$$

3. **Exit:** Generate order to exit the position and create a realized PnL. Orders to exit are usually one of the three categories: take profit order, a trailing stop or stop loss order.

$$PnL = Side * Quantity * (P_{exit} - P_{entry})$$

- **Hedging**

- Hedging describes the process of placing a trade to reduce/eliminate a certain kind of exposure
- Example: Reduce exposure of an option position to a move of the underlying by entering a delta-neutral position
- Hedging costs money, but reduces uncertainty. Continuous hedging as assumed by much of the academic literature is neither feasible nor cost effective

General Trading Overview

Types of Trading

- **Fundamental:**
  - Stock Picking
  - Ratio Analysis
  - Sector Analysis
  - Executive Management Signals
- **Quantitative:**
  - Rule based
  - Econometric Forecasting
  - Statistical Arbitrage
- **Technical:**
  - Charting
  - Trend Analysis
- **Time Frames:**
  - Long Term: Months to Years
  - Short Term: Days, Weeks, Months
  - Intraday: Seconds to Hours
  - High frequency: Fractions of Seconds

General Trading Overview

Instruments and Order Types

- **Instruments:**
  - Equities
  - Bonds
  - Commodities
  - Foreign Exchange
  - Credit Default Swaps
  - Asset Backed Securities
  - Swaps
  - Rates
  - Futures and Options on the above
- **Order Types:**
  - Market
  - Limit
  - Stop Loss
  - Trailing Stop
  - Attached Orders
  - Conditional Orders

Algorithmic Trading Framework

Prop Trading Strategy Steps

- Proprietary algorithmic trading strategies can be broken down into three subsequent steps: Signal Generation, Trade Implementation and Performance Analysis
- The first step, **Signal Generation**, defines when and how to trade. For example, in a moving average strategy, the crossing of the shorter running moving average over the longer running moving average triggers when to trade. Next to long and short, the signal can also be neutral (do nothing). Using moving averages to generate long/short trading signals is an example choice of how to trade
- **Trade Implementation** happens after the Signal Generation step has triggered a buy or sell signal. It determines how the order is structured, e.g. position size and limit levels. In advanced strategies, it can also take into account cross correlation with other portfolio holdings and potential portfolio constraints
- **Performance Analysis** is conducted after the trade has been closed and used in a backtesting context to judge whether the strategy is successful or not. In general, we can judge the performance according to five different metrics: return, risk, efficiency, trade frequency and leverage

Algorithmic Trading Framework

Trading System Development Cycle

- The **development cycle** of a quantitative strategy is an iterative process that can be split into 8 steps:
  1) Generate or improve a trading strategy idea (based on intuition)
  2) Quantify the trading idea and build a model to replicate it
  3) Back test the strategy for multiple time frames, trade implementation rules and related financial instruments
  4) Calculate performance, risk and efficiency statistics, choose trade frequency and leverage
  5) If the statistics are not satisfactory, restart at step #1
  6) If the strategy does not add significant value to the existing strategies, restart at step #1
  7) Implement the strategy on an execution platform (e.g. Interactive Brokers, Oanda), initially as a paper trading account
  8) Trade the strategy with real money

Signal Generation

Mathematical Tools and Attributes of Scientific Trading Models

- **Mathematical Tools:**
  - Markov Models
  - Co - Integration
  - Stationarity vs. Non-Stationarity
  - Mean Reverting Processes
  - Bootstrapping
  - Signal Processing Tools
  - Return Distributions / Lévy Processes
  - Time Series Modelling
  - Ensemble Methods

- **Attributes of Scientific Trading Models:**
  - Scientific Trading Models are based on logical arguments
  - One can specify all assumptions
  - Models can be quantified from assumptions
  - Model properties can be deduced from assumptions
  - Model properties can be back tested in an objective, rule-based manner
  - Clear Model property specification allows for iterative strategy improvement

Signal Generation

Strategy Development and Back Testing

- **Strategy Development:**
  - Identify patterns in historical data or formulate trading idea
  - Quantify these patterns/trading idea in an initial trading model
  - Verify if the patterns are persistent/trading idea would have worked in the past
  - Create a more advanced trading model based on these signals

- **Back Testing:**
  - Back testing simulates the potential success of a strategy based on historical or simulated data
  - Gives an estimate how the strategy would have worked in the past, but not if it will work in the future
  - It is an objective method to conduct performance analysis and choose most promising strategy
  - Data from Performance Analysis step helps in further strategy improvement and trade implementation, e.g. determining exit order levels

Signal Generation

Calibration and Robustness

- **Calibration:**
  - Most strategies calibrate model parameters to optimize certain performance analysis factors, e.g. total return
  - Calibration is an inverse process: we know how to get from market data to model parameters when we have a model, but not how to get to the most realistic model from market data alone
  - Occam's razor: Fewer parameters are usually preferable and tend to increase model robustness

- **Robustness:**
  - How much does the success of a strategy change given a small variation in parameter values?
  - Avoid in-sample overfitted parameters – out of sample testing is crucial!!!
  - Plot of performance measure vs. delta of or absolute parameter(s) values visualizes parameter sensitivity
  - We look for plateaus where a broader range of parameters results in stable performance measures
  - Ensembles of different models can help to increase meta model robustness

Trade Implementation

Order Manipulation Process

- Portfolio Analysis: Cross correlation with other portfolio positions, position limits, portfolio constraints
- Exposure Analysis: Convex or linear payoff profile? Instrument constraints?
- Order Sizing: Determine number of contracts/instruments to be bought/sold
- Order Execution: Market or Limit Order? Time in Force? Potential Issues:
  - What if an order is already filled before a modify command arrives at the market?
  - What if an old order is partially filled and then deleted/reduced?
  - What if a confirmation arrives too late (or never arrives)?
  - What if the price moves again before the new limit order is placed?
  - What if the new order is rejected by the Market ?
  - What if the new order breaks position limits or portfolio constraints?
  - What if the gateway, market or broker is down?

Trade Implementation

Exit Orders

- Implement Take Profit orders or keep positions until signal direction changes?
- Stop Loss vs. Trailing Stop to limit downside? Optimal distance of Stop Level to Market?
- Time in Force for Orders, Maximum Holding Period for portfolio constituents?
- Triggers to change Exit Orders?

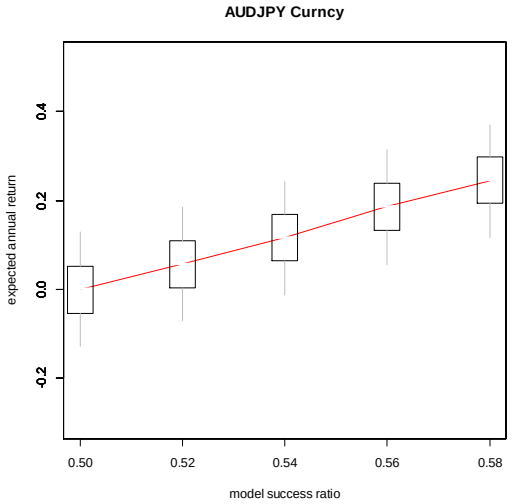
Performance Analysis

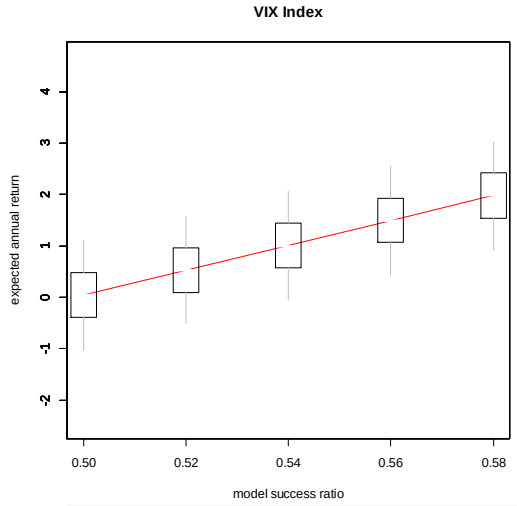
Return, Risk and Efficiency Metrics

- **Return Metrics:**
  - Total Return, Annualized Return, Winning %, Avg. Winning Size, Biggest Winner, Distribution of Winning Trades, Loosing %, Avg. Loosing Size, Biggest Looser, Distribution of Losing Trades
- **Risk Measures:**
  - Annualized Standard Deviation, Downside Deviation, Max Drawdown, Peak to Through
- **Efficiency Measures:**
  - Sharpe, Information and Sortino Ratio
- **Trade Frequency:**
  - Fractions of seconds to Months/Years. Hurdle rate for transaction costs?
- **Leverage:**
  - Unleveraged ($\leq$ 100% of equity value) or leveraged positions ($\geq$ 100% of equity value)? Costs of leverage?

Performance Analysis

Success Factors of Quantitative Trading Strategies





- Quantitative Investment Strategies are driven by **four success factors**: trade frequency, success ratio, return distributions when right/wrong and leverage ratio
- The two graphs show 95% confidence levels of annualized expected returns of two underlyings exhibiting different volatilities (7.8% annualized for AUDJPY vs. 64.6% for VIX) and daily trade frequency. The higher the success ratio, the more likely it is to achieve a positive return over a one year period. Higher volatility of the underlying – assuming constant success ratio – will lead to higher expected returns
- The distribution of returns when being right / wrong is especially important for strategies with heavy long or short bias. Strategies with balanced long/short positions on any underlying are less impacted by these distributional patterns. Downside risk can further be limited through active risk management, e.g. stop loss orders
- Leverage plays an important role to scale returns and can be seen as an "artificial" way to increase the volatility of the traded underlying. For example, a 10 times leveraged position on an asset with 1% daily moves is similar to a non-leveraged position on an asset with 10% daily moves
- Assuming daily trade frequency, a success ratio of 54%, even long/short return distributions and a leverage ratio of 100% implies a probability of less than 5% of non-positive annual returns

Performance Analysis

Trading System Efficiency

- Van Tharp introduced the concept of R multiple. 1 R measures the initial risk of a position, which is equal to the distance between entry and stop loss level. Exit levels should be chosen so that the gains are higher than 1R. This is another way of saying cut losses short and let profits run. Example: Enter long position at 10 EUR with stop loss order at 9 EUR. 1R= initial risk = 10%

- In mathematical terms, the expected profit of a trading strategy is:

  Gain in %= frequency of trades * (winning % * avg. winning size – loosing % * avg. loosing size) * leverage ratio

  loosing % = 1 – winning % and avg. winning size = n * R, with n = average win to loss ratio

  Gain in % = frequency of trades * (winning % * n * R – (1 – winning %) * R) * leverage ratio * 1/100

- Example: A strategy trades daily, has a success ratio of 60%, equal average winning and losing size of 1 % and trades a leverage ratio of 200% of equity. In this case, the expected yearly gain is:

  Gain = 250 * (60% * 1 % – 40% * 1 %) * 2 = 100% p.a.

  Gain = 250 * (60% * 1/1 * 1 – (1 – 60%) * 1) * 2 * 1/100 = 100% p.a.

Summary and Questions

- Algorithmic trading is an emerging, intellectually challenging field in quantitative finance where computer science is as important as mathematics
- Successful firms are either faster (computer science) or have better forecasting accuracy (mathematics) than the competition, or both
- A scientific approach to algorithmic trading helps to differentiate signals from noise / chance from recurring patterns
- Proprietary algorithmic trading strategies can be broken down into three subsequent steps: Signal Generation, Trade Implementation and Performance Analysis

- Questions?