A share on algorithm trading strategy design and testing

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About me

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Agenda

- Understand algorithm trading
- Testing of an algorithm trading strategy
- Approach to algorithm trading strategy design
- Share of useful web resources and reads
- Q&A

Understand Algorithm Trading

Understand Algorithm Trading

- Algorithm trading could mean different things in different context:
  - It can refer specifically to execution algo like VWAP, TWAP etc.
  - These are usually used and provided by the broker to allow for more efficient execution
  - More extensively researched by the **sell-side**
- In this presentation, we refer algorithm trading to:

  Automated trading that follows that aims at generating profit

Understand Algorithm Trading

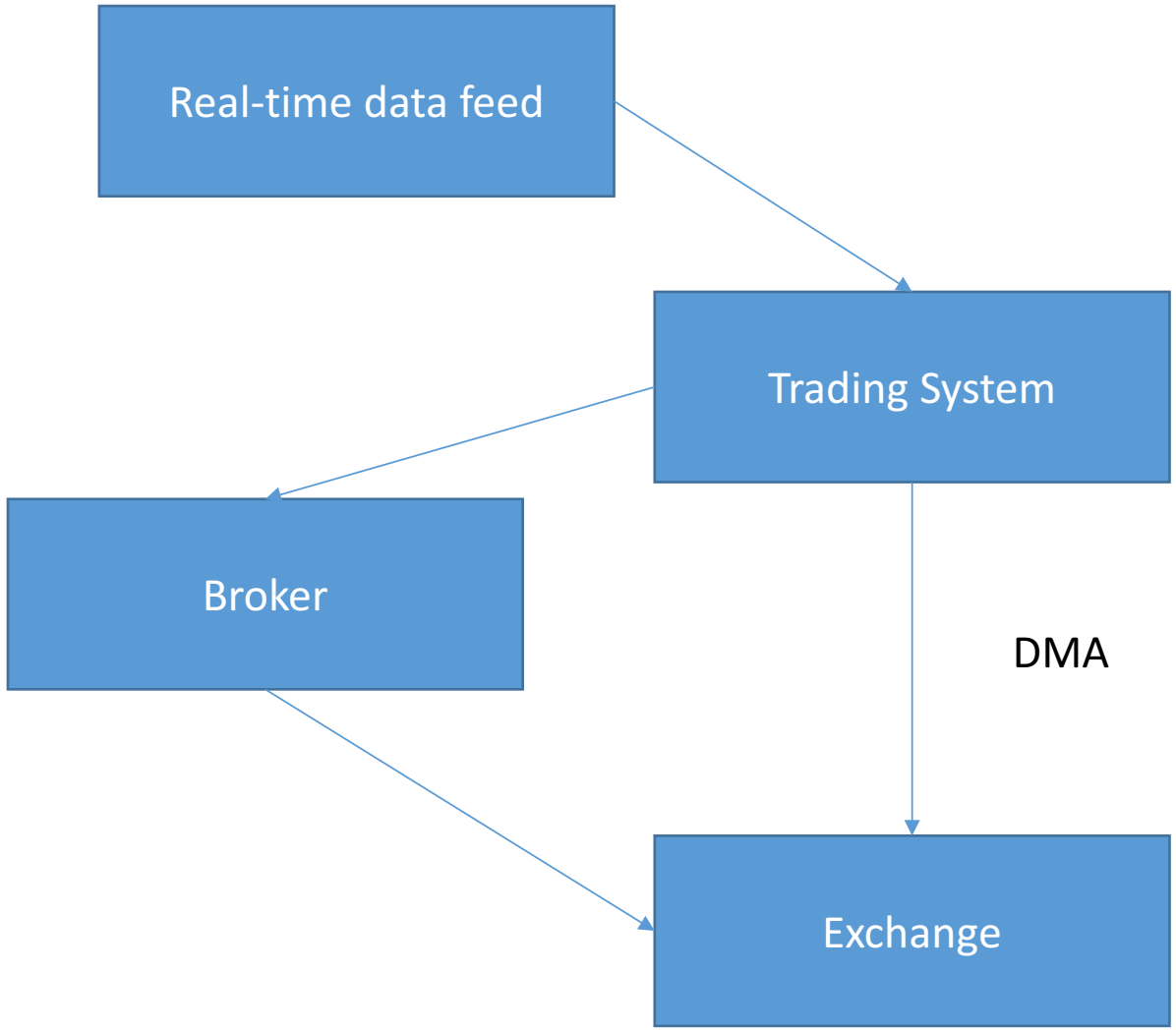
- Algorithm trading is a form a systematic trading
- Only 10% of the actively managed global assets is fully systematically traded (Carver, 2015), most of the active asset management are done using a hybrid method of discretionary trading and systematic trading
- **In this presentation, we use "systematic trading" and "algorithm trading" interchangeably**

Systematic Trading	Discretionary Trading
• Follow pre-defined trading rules that usually will not be changed during trading • Little or no human-intervention during trading • Usually automated by computer programs, but can also be done manually	• Follow subjective decision made by the trader or portfolio manager • Usually cannot be automated

Examples of systematic trading rules

- Trading using technical indicator:
  - E.g. Buy when 5-days simple moving average of price > 20-day simple moving average of price, sell when it reverses
- Holding portfolio that is constructed in a pre-defined way:
  - Buy and hold SPY (SPDR S&P 500 ETF Trust), which tracks the performance of S&P500 index by tracking its performance
- ...and anything that can be clearly defined and automated.

Trading an algorithm trading strategy



- Most of the automated trades are sent and executed through broker
- DMA (Direct Market Access) allows the trader to have more control of how a order is executed, and order execution is usually faster, which is required by high-frequency trading strategies

Testing of an Algorithm Trading Strategy

Testing of an Algorithm Trading Strategy

Backtest

Simulation

Paper trading

Pilot testing

Production

Backtesting Trading Strategy

- Thanks to using pre-defined rules and the availability of data nowadays, most of the algorithm trading strategies can be backtested
- Backtest is a simulation done on historical data to examine whether the strategy has worked historically or not
- A reliable backtest is a key to identify truly profitable trading strategies

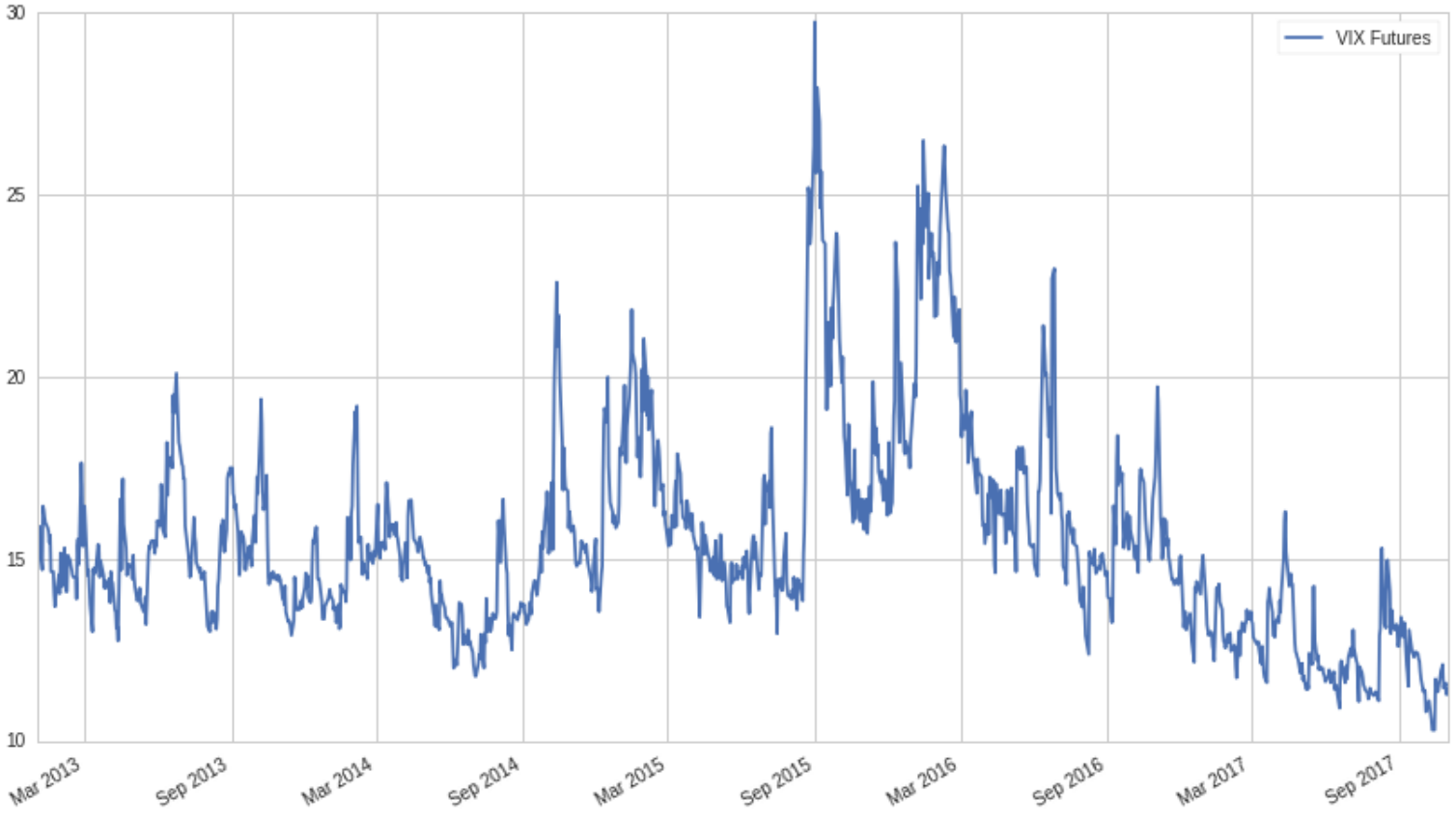
Common backtest issues

- Incorrect way of handling data
- Unrealistic assumption of trading cost
- Survivorship bias
- Look-forward bias
- Data-snooping

Incorrect way of handling data

- Many historical data has to be processed before used for backtesting
  - Split and dividends for equity
  - Futures contract rolling
- The data vendor usually provides both unadjusted and adjusted price series. Both are important as in a real-time environment, only unadjusted price will be available.

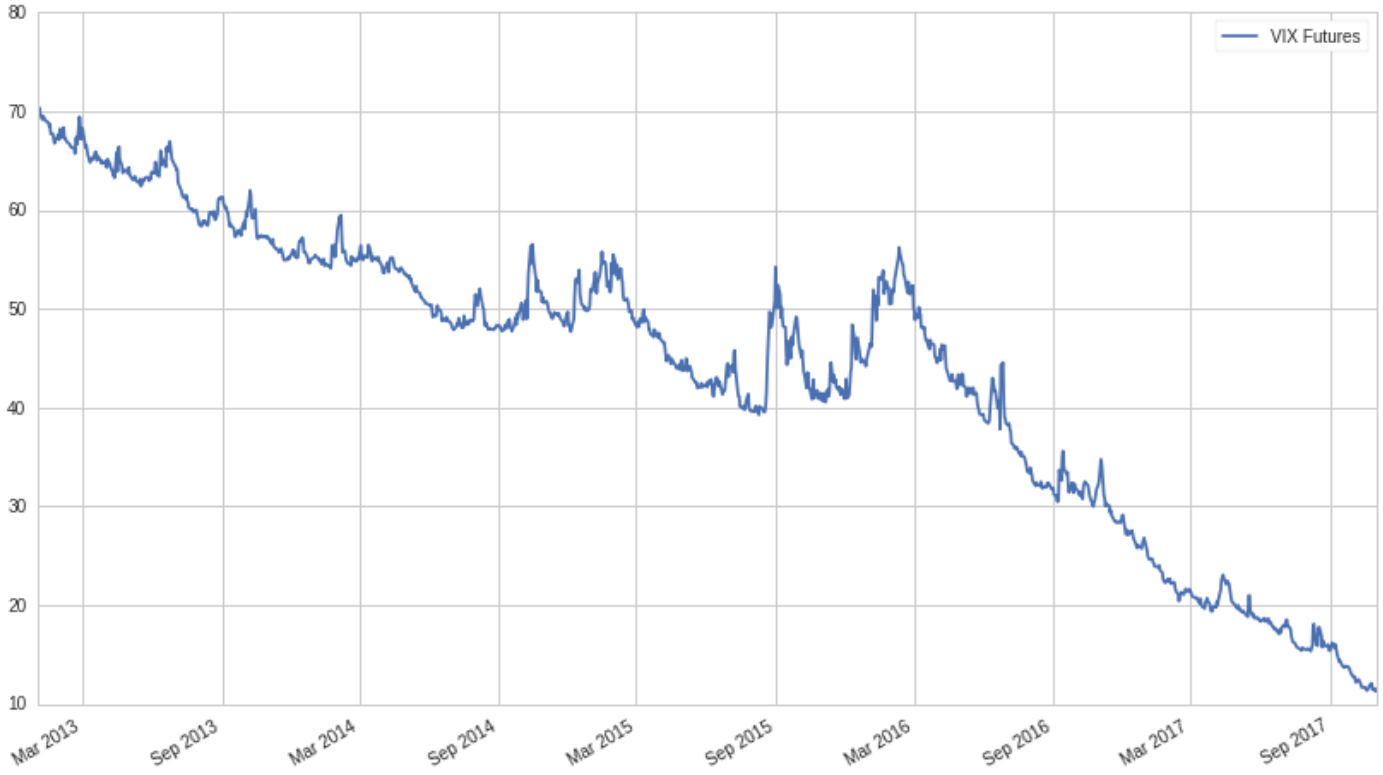
Importance of processing the data, an example:



- VIX futures are available in CBOE, and it is commonly known that the VIX is mean-reverting
- If we do not adjust the VIX futures data, a similar pattern will be observed
- It seems that a mean-reverting strategy on VIX-futures would then be highly profitable

Data from Quantopian

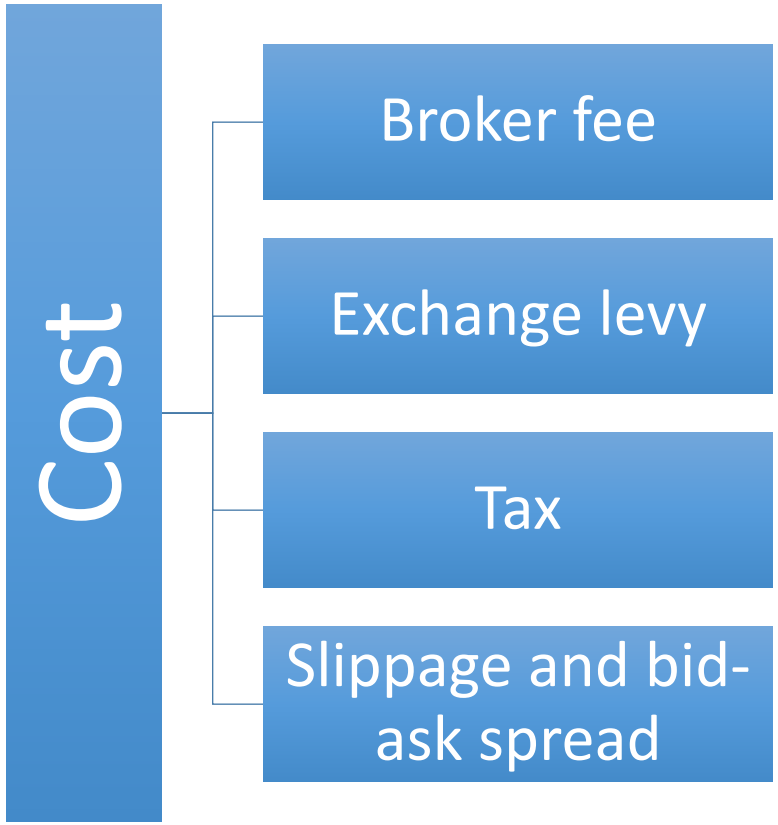
Importance of processing the data, an example:



- However, this is not true since that we have to roll the futures contract on or before it expires
- The profit from the jump between two futures contracts are thus not realizable.
- After adjustment, it can be seen clearly that a mean-reversion strategy would perform horribly on VIX futures

Data from Quantopian

Trading cost



- Unrealistic estimation of trading cost would give you superficial results
- Broker fees, exchange levy and tax (such as stamp duty) are usually pre-defined and easy to calculate
- Slippage and bid-ask spread has to be estimated from the real-time or historical data
- Slippage and bid-ask spread is usually higher for products that are less liquid; and slippage grows non-linearly with the size of your order
- Slippage and bid-ask spread is extremely important when developing high-frequency trading strategy, as these usually have very small profit per trade

Survivorship Bias

- Survivorship bias is commonly seen in stock-trading.
- As stocks can be delisted, if a database without delisted stocks are used, the performance of the backtest is subjected to survivorship bias
- The impact could be significant as it rules out the possibility to invest in the delisted stocks during backtest, however in real-trading, this can not be avoided

Look-forward bias

- Look forward bias occurs when you introduces future information in strategy design, and would usually lead to superficial results
- The mistake looks easy to avoid but can sometimes be hard to identify, and even some publicly published materials do have look-forward bias
- One common look-forward bias example:
  - When using historical OHLC (Open, high, low, close), assuming that trade signal at close can be executed at the same time would introduce look-forward bias
  - Some strategies' result can be severely effect by this assumption (Chan, 2017)

Data snooping bias

- Systematic strategies usually have parameters, and thus can be optimized using historical data
- Nevertheless, this optimization would inevitably introduce data snooping bias, and is impossible to avoid
- Machine learning strategies are most vulnerable to this kind of bias (Prado, 2017), as these strategies are majorly data-driven. Sadly, the financial market's in-sample and out-sample behavior are not consistent
- One possible way is to conduct **sensitivity test** on the parameters. Strategy which is too sensitive to parameter is usually not a good strategy.

Evaluation of a strategy

- Return is usually not the sole concern in a trading rule, usually there are other criteria to look at
  - Risk adjusted return (Sharpe ratio)
  - Maximum Drawdown
  - Performance recently
  - Sensitivity to parameters

Summary for this chapter

- Backtest on tradable products only
- Simulate data to make sure that your rule works when the traded assets behave like you expect
- Make sure the data is correctly adjusted and survivorship bias free
- Consider reasonable transaction cost in the backtest
- Avoid look-forward bias
- Conduct sensitivity analysis for parametric strategies

Approach to algorithm trading strategy design

Two types of idea generation (Carver, 2015)

- Generally speaking there are two types of idea generation. Some others (like market making models) are hard to be backtested, therefore would not be discussed here.
- The two ideas can be merged together to form one strategy

Idea First

- Design a system that captures a source of return, and hope the source would persist in the future
  - E.g. Inter-market arbitrage of gold futures in Shanghai and CME

Data First

- Find a system that is profitable in the past given the patterns in the market, but the reason is not necessarily understood.
  - E.g. First develop a trading rule that profits from trading mean-reverting assets, then try and find an asset or a synthetic asset which you could trade on

Why trading strategies fail?

- It never really worked
  - You have made unrealistic assumptions or even incorrect backtest
  - The strategy only worked within very limited time historically
- The world changes
  - The trade can become over-crowded and the room left for profit becomes extremely small or even none. This is more often seen in strategies like arbitrage and market-making

Why trading strategies work and how to find them?

- Market inefficiency
  - Arbitrage or statistical arbitrage opportunity exists
- The strategy is harvesting certain type of risk premium
  - A perhaps most well-known example is equity risk premium, such that the historical annual excess return of U.S. stock over long-term government bonds average 3% to 5% over long data window.
  - A more detailed discussion on risk premium could be found in “Expected Return” (Ilmanen, 2011)
- Market Constrains
  - Some strategy works because the barrier to enter the trade is high or you have an edge in getting lower transaction cost
    - E.g. Designated market makers are usually awarded with a rebate, which lower their trading cost and lead them to making money where others cannot

Why trading strategies work and how to find them?

- Cognitive Bias
  - People dislikes huge losses, and like small chance of winning big
    - E.g. Selling deep out of money call could usually earn a premium because people who buys is essentially buying a lottery and would happily pay the premium
    - Another example: put writing of profitable when the market is calm, but sustain losses during turnoil

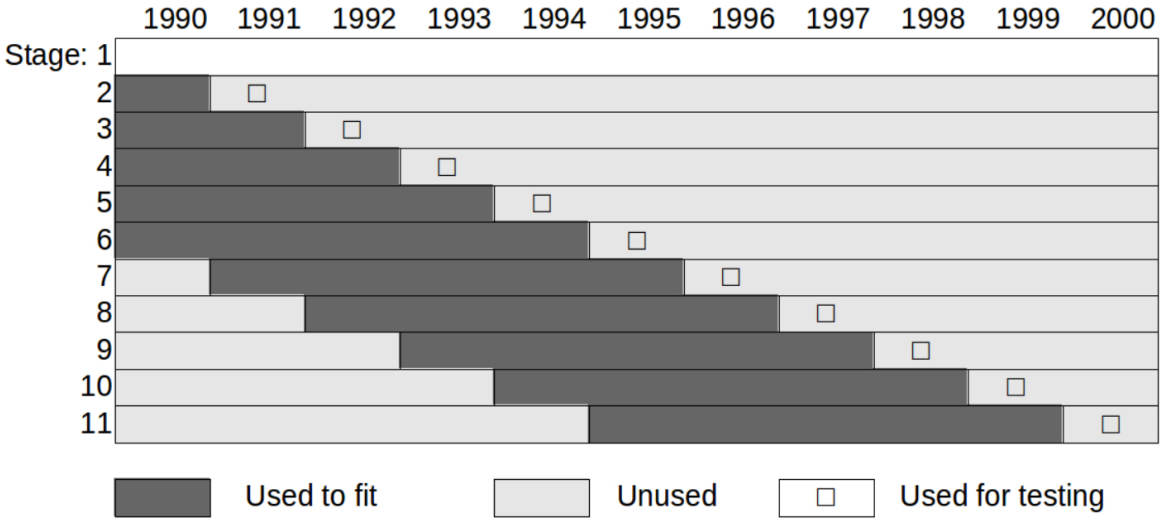
The above graph shows the CBOE's S&P500 PutWrite Index, which is designed to track the performance of selingl a sequence of one-month, at-the-money, S&P 500 Index puts and invest cash at one- and three-month Treasury Bill rates

Or maybe it doesn’t really work…

- It works just because of high correlation to certain assets
  - E.g. Buying Tencent would have remarkable return historically, if a strategy that has high correlation with its performance, then it is likely to perform remarkably as well.
- Or it can just because of pure luck

Optimization of Single Strategy

- Most strategies have parameters to be optimized, though this would introduce over-fitting issue, it is an essential step to make our strategies more profitable and stable
- Always only do optimization in sample and backtest out of sample



Above is a commonly used fitting method in strategy design called rolling out of sample

Optimization of Single Strategy

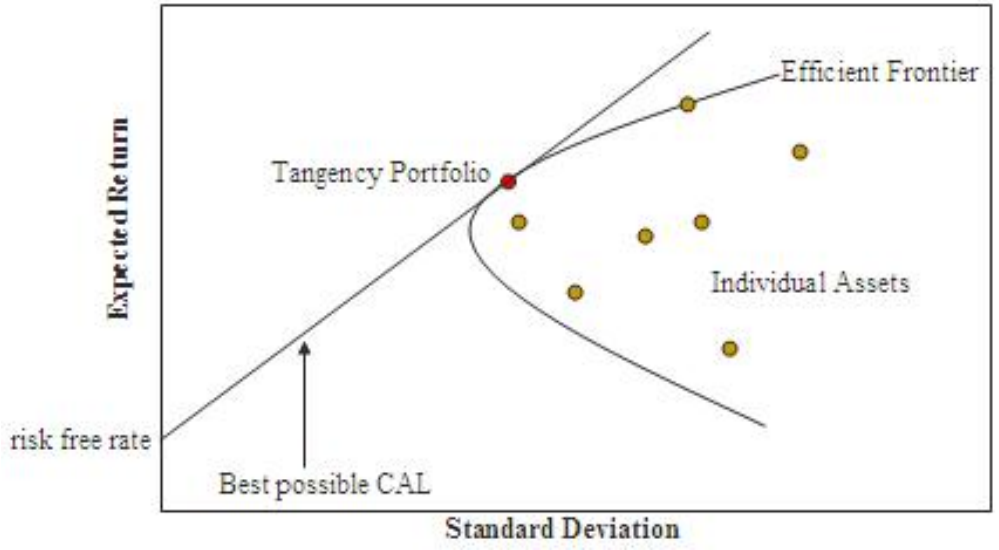
- Avoid extensively trying for variation of one single strategy
  - If it just earn 0 expected return like a random walk, it is possible that you can get few variation with a high sharpe like 2.0!
- Avoid using small sample to optimize strategy
  - Good performance in a small sample time is not unusual even when the strategy doesn't really work

Number of rules tested in pool	Minimum Sharpe ratio		
	0.5	1.0	2.0
1	<1	<1	<1
5	1.4	<1	<1
10	3	1.5	<1
50	16	8	1.2
100	30	16	2.3

The table shows the that when testing more numbers of random rules, we can easily end up picking a rule that shines in backtest but never workout in real life

Diversification

- Diversification is the only “free lunch” in investment
- The advantage of diversification has been demonstrated by Markowitz (Markowitz, 1952) in the modern portfolio management theory
- In practice, practitioners have developed many mathematical techniques to practice this idea, the details of them are beyond the scope of this presentation and worth a in depth discussion

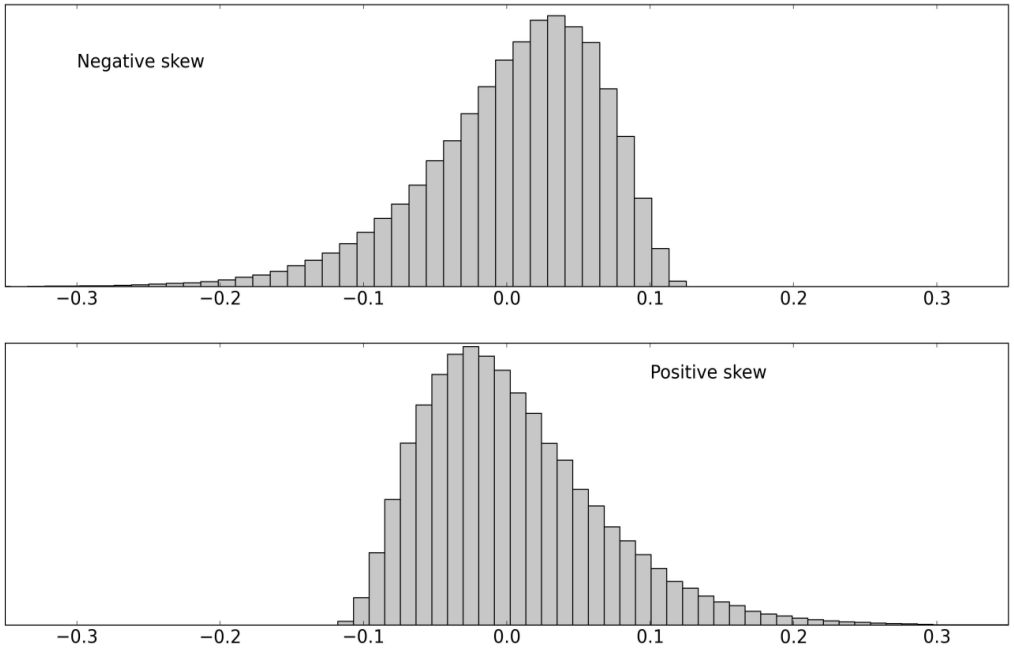


Important factors to consider in diversification

- Type of trading strategy
- Exposure to risk factors
- Asset classes
- Region/Country

Type of trading strategy

- Broadly speaking, trading strategies can be classified by their skewness:
  - Negative skew: strategy has higher chance of large down move than an equivalent up move
    - E.g. relative value strategies, statistical arbitrage etc.
  - Positive skew: strategy has higher chance of large up move than an equivalent up move
    - E.g. momentum strategies, investment in gold
- Negative skew strategies have more winning days but sustain heavy loss occasionally, it is generally not a good idea to rely on one kind of these strategies solely as they tend to show higher Sharpe ratio and sometimes hide the potential large drawdown
  - LTCM is a good example: the fund relies heavily on convergence trading (all negatively skewed strategies) and has a Sharpe ratio of 4.35 when imploded



Two assets with same sharpe ratio but different skew

Exposure to different risk factor

- As mentioned in previous slide, profitable trading strategy could be harvesting certain type of risk factor
- Usually, strategies that have exposure to similar factors would demonstrate strong correlation, thus not an ideal choice for effective diversification

Asset classes and region/country

- Investment across various asset classes and countries is a good way to diversify the risk
- Within an asset class, diversification does not always work (Sandoval, 2012)
  - During times of market crash, global equity markets demonstrate stronger correlation than usual
- Apart from Equity, Bond liked assets, assets such as volatility, commodity, currency, REITs can also be taken into consideration
  - E.g. The Yale endowment fund is known to have performed remarkably with annual return of 12.9% over a 30-year timeframe. The endowment invests a large amount of the capital in foreign equity, private equity fund and other non-traditional asset class
    - However, now they earn less since more fund managers are trying to copy this scheme, but this indicates a good source of diversification.
    - The development of certain ETF has made some of the alternative investment easily available even to retail traders (e.g. VXX & XIV for volatility, VNQ for REIT)

Share of useful web resources and reads

Useful resources

Name	Description
Quantopian	Backtest and paper trading platform for US equity and futures
Ricequant	Backtest and paper trading platform for Chinese equity and futures
VNPY	Open source quantitative trading project
Quantpedia	A source of quantitative trading ideas
SSRN	Social Science Research Network, where you may search for trading ideas and techniques
Udacity	Online programming and computer science courses

My recommended reads

Name	Reasons for recommendation
Ilmanen, A. (2011). *Expected returns: an investor's guide to harvesting market rewards*. John Wiley & Sons.	Good description and analysis of various risk premium, not mathematical but practical
Carver, R. (2015). *Systematic Trading: A unique new method for designing trading and investing systems*. Harriman House Limited.	Practical guide to building and managing profitable trading strategies
Chan, E. (2013). *Algorithmic trading: winning strategies and their rationale*. John Wiley & Sons.	An introductory read to algorithm trading and strategy designs
Hull, J., Treepongkaruna, S., Colwell, D., Heaney, R., & Pitt, D. (2013). *Fundamentals of futures and options markets*. Pearson Higher Education AU.	Great textbook on futures and options
Guo, X., Lai, T. L., Shek, H., & Wong, S. P. S. (2017). *Quantitative Trading: Algorithms, Analytics, Data, Models, Optimization*. CRC Press.	An encyclopedia-like, sound introduction of quantitative trading, covering topics of strategy design, trading system, portfolio management and order execution

Q&A

Reference

- Carver, R. (2015). *Systematic Trading: A unique new method for designing trading and investing systems*. Harriman House Limited.
- Chan, R. H. F., Ma, A. K. C., & Yeung, L. L. C. (2017). An uncertainty quantification framework for the achievability of backtesting results of trading strategies. *JOURNAL OF INVESTMENT STRATEGIES*, *6*(4), 21-46.
- Ilmanen, A. (2011). *Expected returns: an investor's guide to harvesting market rewards*. John Wiley & Sons.
- Lopez de Prado, Marcos, The 7 Reasons Most Machine Learning Funds Fail (Presentation Slides) (September 2, 2017). Available at SSRN: https://ssrn.com/abstract=3031282
- Markowitz, H. (1952). Portfolio selection. *The journal of finance*, *7*(1), 77-91.
- Sandoval, L., & Franca, I. D. P. (2012). Correlation of financial markets in times of crisis. *Physica A: Statistical Mechanics and its Applications*, *391*(1), 187-208.