# How quantitative methods influence and shape finance industry

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# Introduction

- Non-quantitative talk about the role quantitative methods play in finance industry.
- Focus on investment banking, hedge funds and asset managers.

# Sectors

- Each sector deals with risk but in fundamentally different ways.
- They focus on, respectively, risk hedging, risk taking and risk diversification.
- Development of each sector was strongly influenced by different mathematical ideas.

# Future

- At the end of the talk I will describe some challenges finance industry faces today.
- I will also attempt to list quantitative methodologies that are likely to influence and shape the future of this industry.

# Business models of

- Investment Banks – sell financial products and hedge (or not) risk. Price corresponds to the cost of hedging – *hedging = eliminating risk*
- Hedge Funds – take risk and deliver (or not) high return – *hedging = controlling risk*
- Asset Managers – diversify risk and deliver (or not) high returns. Split investment into different asset classes

# Mathematical ideas

- Risk hedging – payoff replication – Black and Scholes
- Inter-temporal risk taking – Kelly
- Cross-sectional risk taking – Markowitz
- Coupled with advances in software and hardware these three ideas played a transformational role in the finance industry

- Risk Taking

# Tossing a coin

- A coin is tossed and you win £60 in case of ‘Head’ and loose £40 in case of ‘Tail’. Will you accept it?
  - Expectation is positive .5x60+.5x40=10
  - Can you afford to loose £40?
  - What if you cannot afford to loose £40
  - What if the coin is not fair?
  - What if you can bet many times?

# Placing many bets

- You know the history of outcomes of bets
- If the game does not change much over time you can estimate the probability of a single outcome
- What if you bet only a fraction of your wealth?
- What fraction you should choose?

# Mathematical formulation

- Mathematical model developed and analysed be Kelly in 1956
- Gives the fraction of wealth you should bet in order to maximise the long-run growth rate of wealth
- Corresponds to maximization of logarithmic utility function

# Kelly bet

1. Lose the amount b
2. Win b for a bet of 1 - get back b+1

- Assume probability of winning is p
- The so called Kelly bet, discovered in 1950s, is a fraction of your current bankroll (wealth)

$$f = \frac{p(b+1)-1}{b}$$

# However…

- Received little academic attention and was initially rejected by mainstream economists
- Proved invaluable for practical risk taking
- It underpins the business model of many quantitative investment managers
- One of them is AHL, a pioneer in the systematic trading, serving clients since 1987

# Fractional Kelly

- Kelly bet is often seen as too aggressive
- May generate large drawdowns
- A smaller fraction is often used in practice
- It turns out that any such fraction is consistent with a forward power utility maximisation (Musiela, Zariphopoulou)
- In this framework risk tolerance is a linear function of wealth

# Systematic risk taking

- Place many bets in a game (will buy or sell many times a single asset – for example a futures contract)
- Carefully determine bet sizes
- Identify signals indicating when to buy and when to sell
- Participate in as many games as possible

# This requires

- Access to historical data of the prices
- Understanding of sizing of bets
- Development of statistical methods to identify the signals
- Construction of a portfolio in which a trade idea is applied in many markets

# To make money

- You need to have a competitive advantage
  - Ability to trade as many markets as possible
  - Have systems that can support such a business model
  - To have at least 50.5% success ratio. Ideally 51%
- You need to control your risk

# Momentum and correlation

- Systematic trading funds were strongly affected by the crisis
  - Classical momentum strategies did not perform well until 2014
  - Pairwise correlations increased significantly
  - Recently momentum performed well and correlations decreased
  - Systematic trading funds are doing well now

- Risk Hedging

# Playing roulette

- You are in a casino playing roulette.
- A person next to you proposes bet: you win £60 in case of ‘Read’ and loose £40 in case of ‘Black’. Assume no zero, only ‘Read’ and ‘Black’ for simplicity
- Is the situation the same as before
  - The expectation is the same

# Hedging your bet

- You can hedge yourself by betting £50 on the table on 'Black'. The possible outcomes are:

| | Bet | Table | Total |
|---|---|---|---|
| Red | +60 | -50 | 10 |
| Black | -40 | +50 | 10 |

- No matter what, you always win 10
- Main idea used by investment banks to price financial products – hedge risk

# Risk hedging (eliminating)

- Revolution in pricing and hedging financial risk came in the 70s
- The idea was to use liquid assets traded in capital markets to create new products and sell them to the end users on the buy side
- This was a beginning of new business for investment banks

# Risk hedging

- First solution to the pricing of options was reduced to solving a PDE
- In early 1980 the arbitrage free price was derived using methods from stochastic calculus
- This created a strong link between quantitative finance and stochastic calculus

# Quoting Wikipedia – 1

- The Black–Scholes model was first published by Fischer Black and Myron Scholes in their 1973 paper, "The Pricing of Options and Corporate Liabilities", published in the *Journal of Political Economy*
- Robert C. Merton was the first to publish a paper expanding the mathematical understanding of the options pricing model, and coined the term "Black–Scholes options pricing model".

# Early days

- In late 1980s very few people knew how to apply martingale methods in financial modelling
- First masters level courses were developed in the late 1980s
- If you knew how to use reflection principle to price barrier options you were doing well

# The 1990s

- In the 1990s first books were published and knowledge was spreading fast
- This was also a period of rapid advances in the development of general pricing and risk management models
- In parallel the markets traded ever more complex risks

# Quoting Wikipedia – 2

- Merton and Scholes received the 1997 Nobel Memorial Prize in Economic Sciences for their work
- Though ineligible for the prize because of his death in 1995, Black was mentioned as a contributor by the Swedish Academy

# The 2000s

- Started with the dot-com bubble…
- Then came the financial crisis…
- Appetite for complex risk evaporated
- More focus was give to the flow business
- New challenges appeared – collateral, funding, counterparty risk,….

# The 2010s

- Political pressure on the banking sector remains high
- Laws and regulations adopted in the US and Europe affect the markets in different ways
- Investment banking business become less profitable

# Quoting Investopedia

- The derivatives market is, in a word, gigantic, often estimated at more that $1.2 quadrillion
- Some market analysts estimate the derivatives market at more than 10 times the size of the total world gross domestic product, or GDP
- The reason the derivatives market is so large is because there are numerous derivatives available on virtually every possible type of investment asset, including equities, commodities, bonds and foreign exchange

# To make money

- You need to have good pricing and risk management systems
  - Risk in a derivative is related to the price
  - Wrong understanding of risk makes your prices very competitive (you do not charge for some risk)
- You need strong support from top management because you are under pressure from trading and sales to deliver good pricing

- Risk Diversification

# Risk diversification

- Harry Markowitz asked in the 1950s the following question – *Why don't investors put all their money in whichever stock seems best (promises the highest expected return) ?*
- He came up with the following answer – *Because that would be too risky*

# Risk diversification

- He said you should instead split the amount you want to invest into many investment opportunities
- But the portfolio expected return is the weighted average of your individual stock expected returns
- Hence it will be lower than putting all your money into the stock with the highest expected return

# However…

- The portfolio can have much lower risk
- The expected return and the risk have to be analysed jointly
- This observation lead to the development of the modern portfolio theory
- Sharpe ratio – expected return per unit of risk

# Mathematical formulation

- The relationship between expected return and risk was formulated as a convex optimization problem with constraints
- One can maximize return at a give level of risk
- Alternatively, one can minimize the risk for a given level of return

# What happened next

- Markowitz's result become the basis of modern finance
- Computer power at the time (1950s) was insufficient to translate it into practical results
- Markowitz was awarded Nobel Prize in Economic Sciences in 1990
- When finally computers solved the problem, the pure Markowitz portfolio proved to be unusable

# We have seen that

- Mathematics played a fundamental role in the development of investment banking business
- Statistics played a fundamental role in the development of systematic trading funds
- The three big ideas monetised risk differently and indeed transformed the industry

- Current challenges

# Profitability

- The average return on equity for investment in banking industry in the first half of 2017 was under 10%.
- In 2006, just before the crisis, and for many years before it was above 20%.
- Additional capital requirement introduced in recent years increase significantly the cost of capital.
- The business is less profitable.

# Measures adopted

- Cut costs
  - Pressure on compensation
  - Reduction of headcount
- Refocus the business model towards activity which consumes less capital
  - Shift from complex products, which require large capital buffers, towards simpler solutions
  - Greater geographic concentration of the business away from global and towards regional
- Automate processes

# Automation

- Sell side
  - Trading – market making, optimal execution, OTC market, order books
  - Sales – expert systems enhancing performance, client profiling
  - Booking and risk management – deal processing
- Buy side
  - Arbitrage strategies – discovery, implementation, sales
  - Investment processes – reduction of human intervention, expert systems

# Data

- Access and ability to process vast amounts of structured and unstructured data in real time is transforming financial services industry
- Methods developed by the so called AI community are looked at closely
- Some find interesting applications
- Fields of statistics and information engineering become much more relevant to finance

# Mathematics

- Mathematics contributed enormously to the development of finance
- For a long period of time it underpinned development of new businesses
- More recently it has been blamed for many problems it apparently generated
- Some even say it is responsible for the financial crises

# Is it true?

- Not in my opinion
- Understanding of financial risk is not easy
- This opens a door to potential abuse of modern methodology
- Modern finance is a very new field
- Mathematics attempts to capture patterns generated by human interaction

# Modelling

- Mathematical and statistical modelling has a great future
- Progressively, the focus should shift from the classical ideas mentioned earlier towards the current challenges
- It should underpin development and implementation of the various expert systems
- There is a case for mathematics, statistics and information engineering to come closer together