

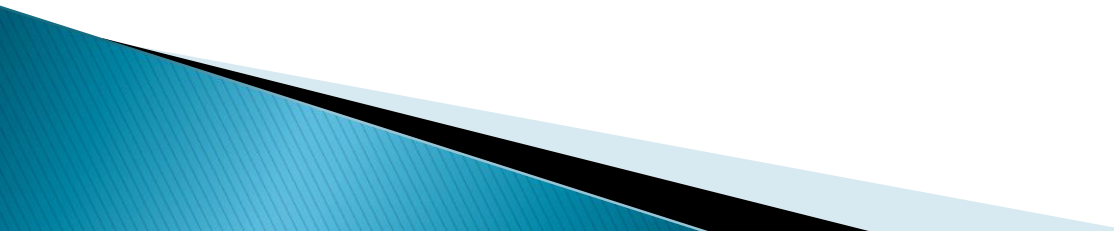
How quantitative methods influence and shape finance industry

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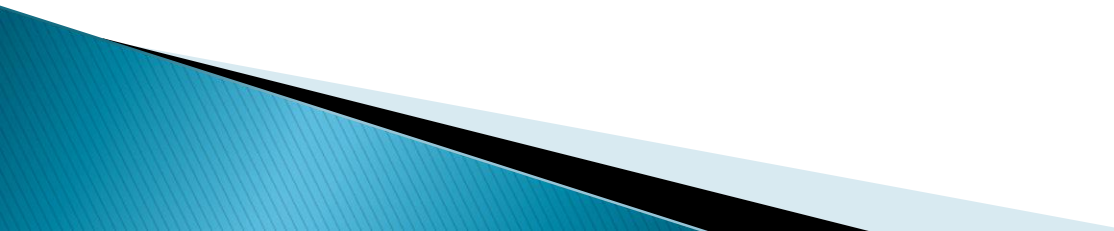
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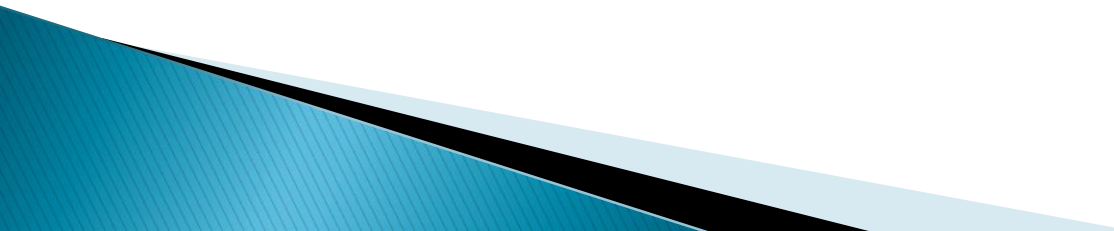
Introduction

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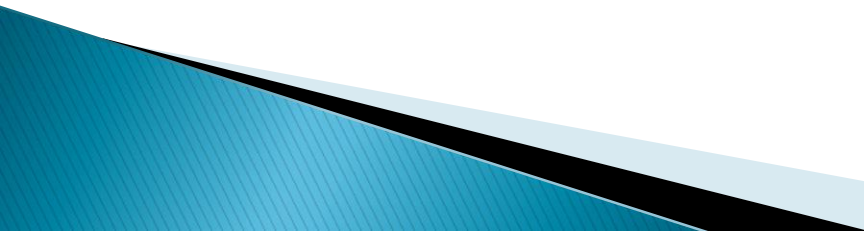
Future

- 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.
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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

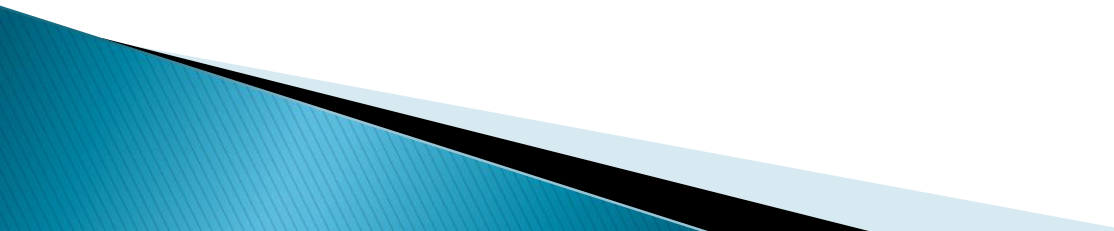
- Risk hedging – payoff replication – Black and Scholes
 - Inter-temporal risk taking – Kelly
 - Cross-sectional risk taking – Markowitz
 - Coupled with advances in software and hardware these three ideas played a transformational role in the finance industry
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▶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

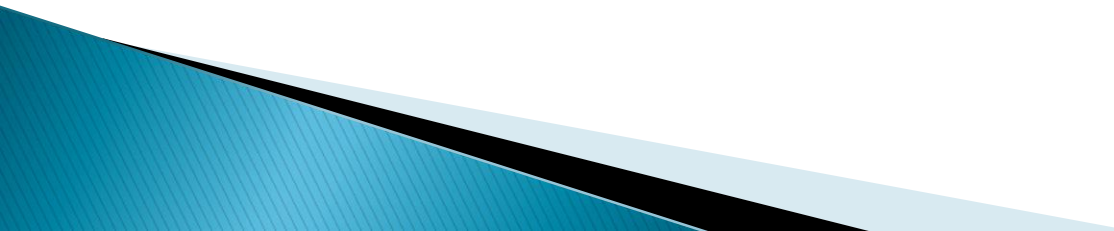
Tossing a coin

- 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 $.5 \times 60 + .5 \times 40 = 10$
 - 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?
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Mathematical formulation

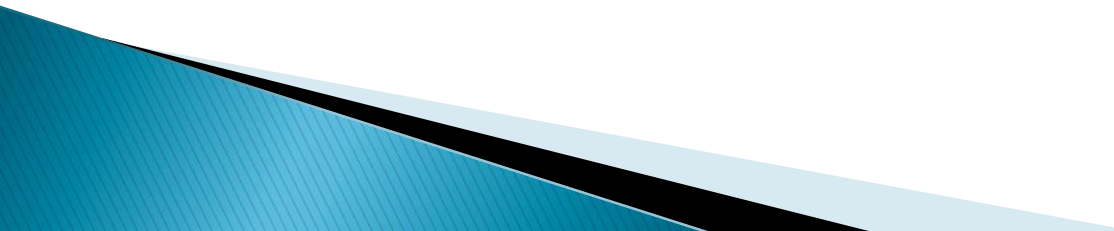
- Mathematical model developed and analysed by Kelly in 1956
 - Gives the fraction of wealth you should bet in order to maximise the long-run growth rate of wealth
 - Corresponds to maximization of logarithmic utility function
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Kelly bet

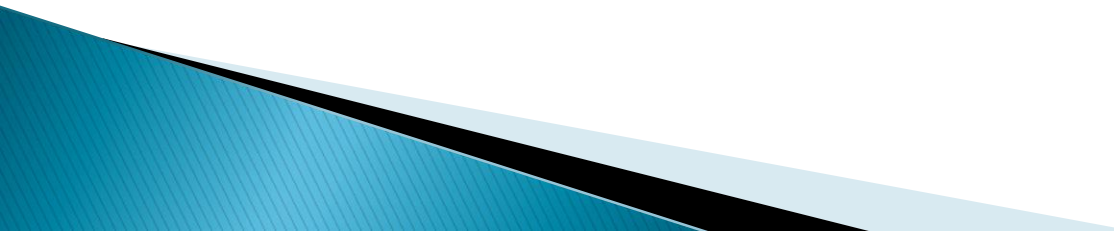
1. Lose the amount b
 2. Win b for a bet of 1 – get back $b+1$
- Assume probability of winning is p
 - The so called Kelly bet, discovered in 1950s, is a fraction of your current bankroll (wealth)

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

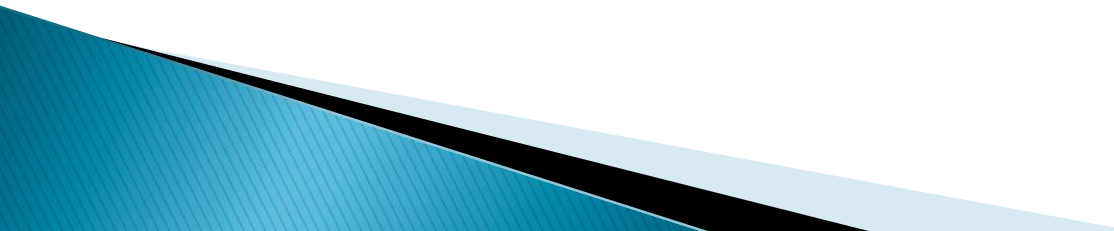
However...

- 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
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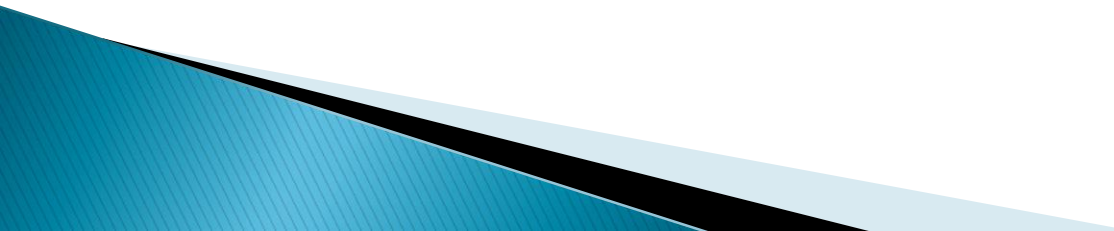
Fractional Kelly

- 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 (Musielá, Zariphopoulou)
 - In this framework risk tolerance is a linear function of wealth
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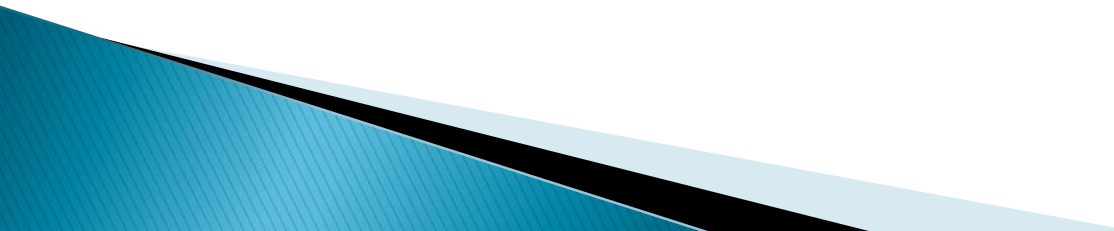
Systematic risk taking

- 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
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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
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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
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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 'Red' and loose £40 in case of 'Black'. Assume no zero, only 'Red' and 'Black' for simplicity
- Is the situation the same as before
 - The expectation is the same

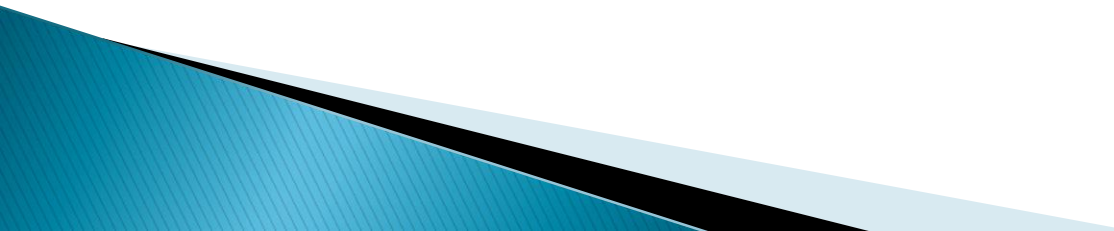
Hedging your bet

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

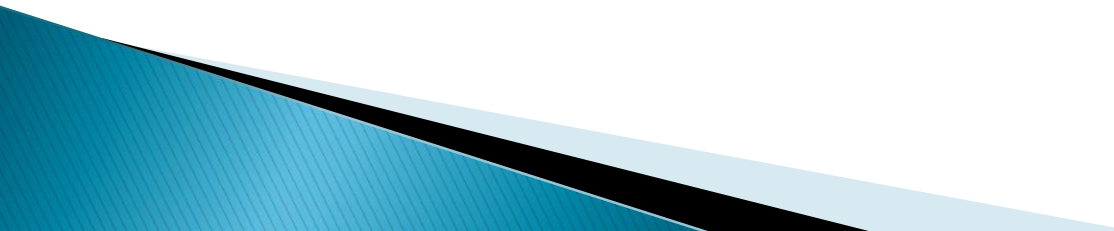
	Bet	Table	Total
Red	+60	-50	10
Black	-40	+50	10

- 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
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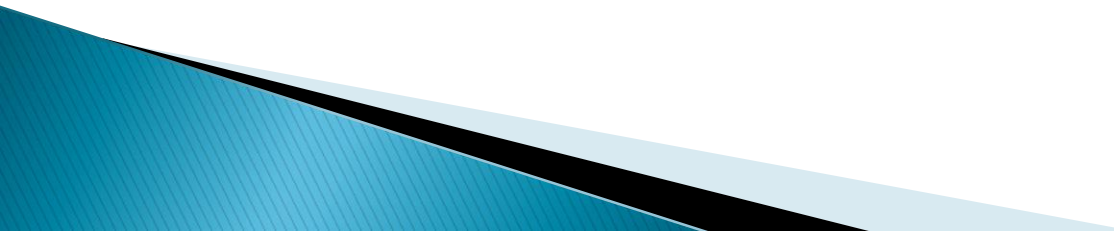
Risk hedging

- 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
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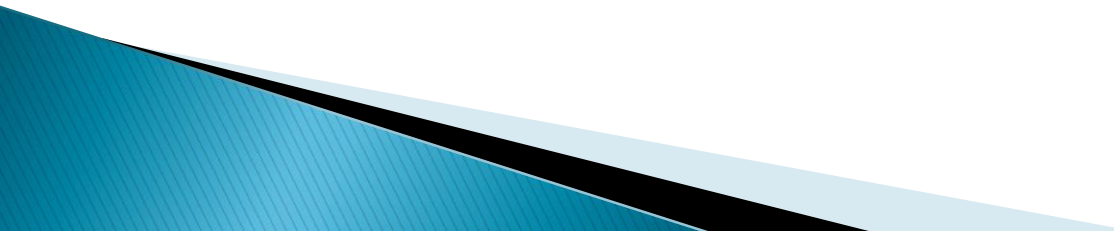
Quoting Wikipedia – 1

- 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
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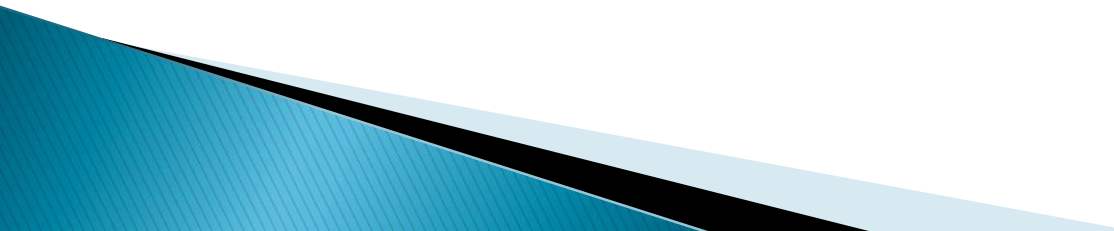
The 1990s

- 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
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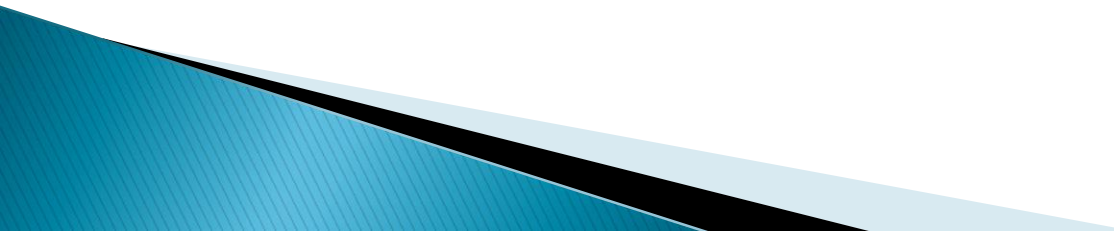
Quoting Wikipedia – 2

- 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,....
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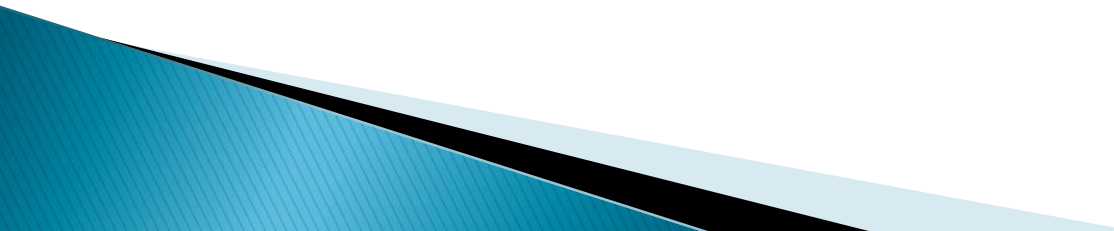
The 2010s

- 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
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Quoting Investopedia

- The derivatives market is, in a word, gigantic, often estimated at more than \$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
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To make money

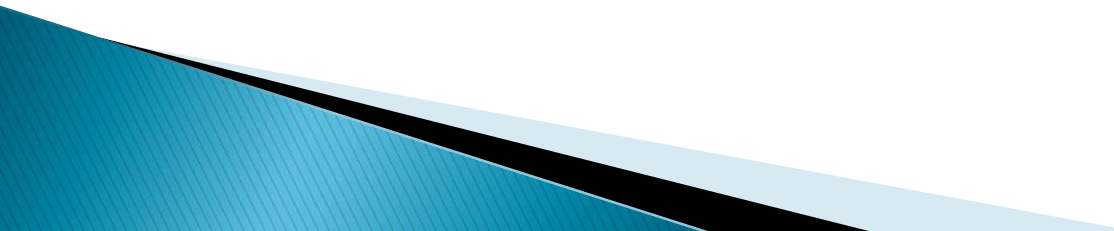
- You need to have good pricing and risk management systems
 - Risk in a derivative is related to the price
 - Wrong understanding of risk makes your prices very competitive (you do not charge for some risk)
 - You need strong support from top management because you are under pressure from trading and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

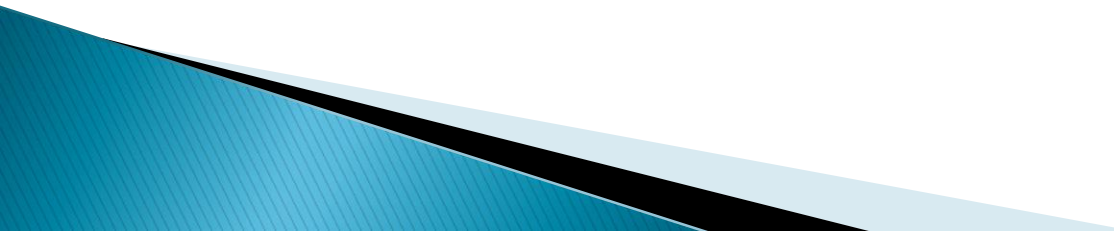
Risk diversification

- 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*

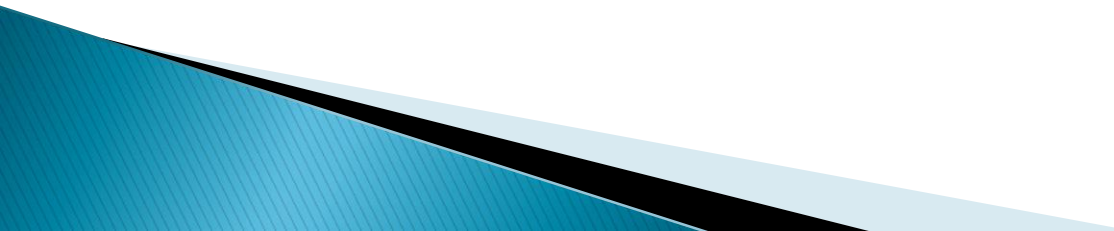
Risk diversification

- 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
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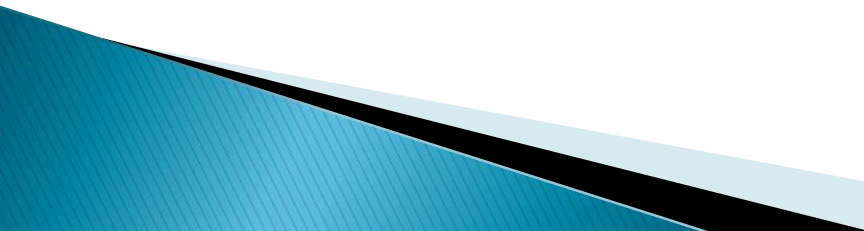
However...

- 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
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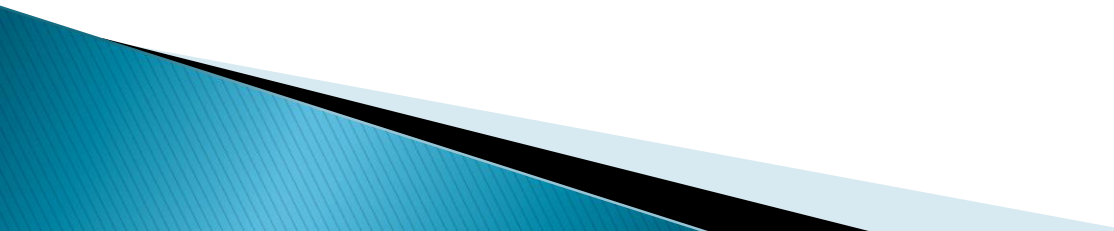
Mathematical formulation

- 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
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What happened next

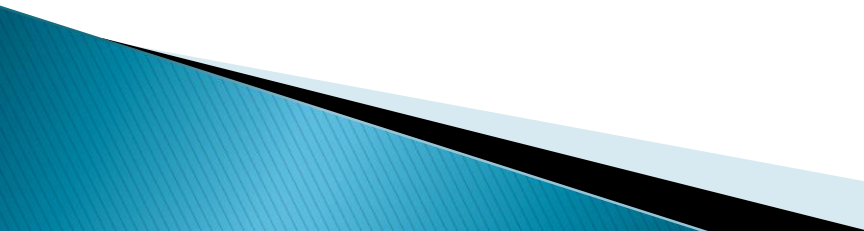
- Markowitz's result become the basis of modern finance
 - Computer power at the time (1950s) was insufficient to translate it into practical results
 - Markowitz was awarded Nobel Prize in Economic Sciences in 1990
 - When finally computers solved the problem, the pure Markowitz portfolio proved to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

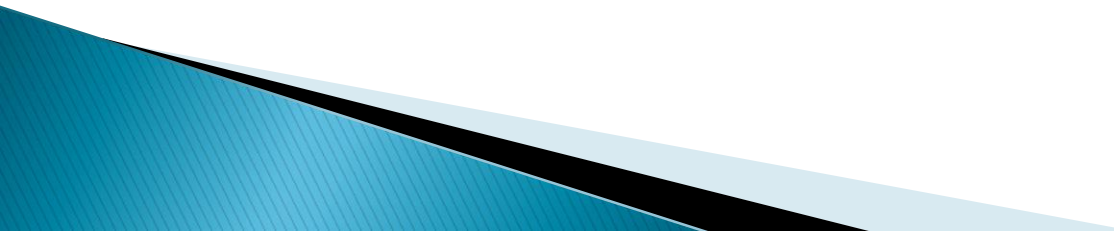
- Mathematics played a fundamental role in the development of investment banking business
 - Statistics played a fundamental role in the development of systematic trading funds
 - The three big ideas monetised risk differently and indeed transformed the industry
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▶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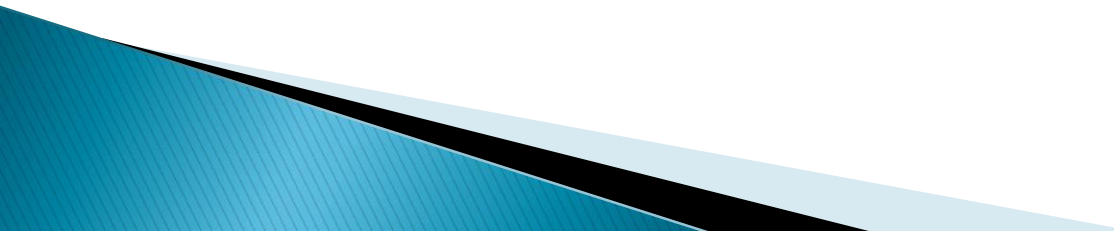
Measures adopted

- 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
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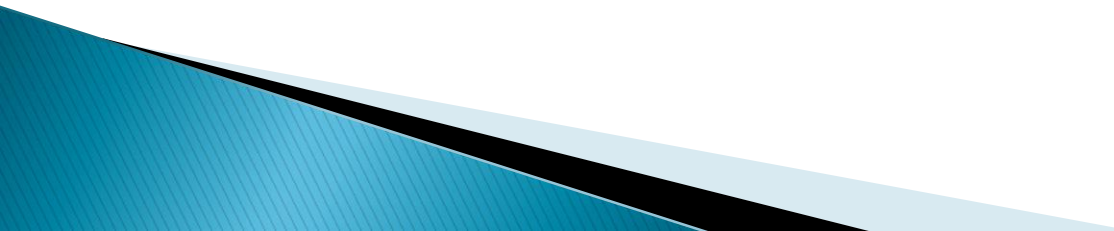
Automation

- 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

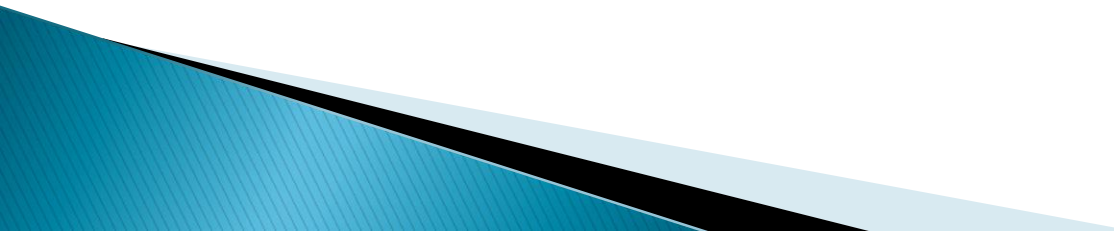
Data

- 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
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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
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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
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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
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