Understanding risk and uncertainty: A brief history

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Understanding Risk and Uncertainty
A Brief History

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Terms

Animal spirits
A phrase coined by John Maynard Keynes’ to describe the non-rational and non-economic decision-making propensity of people, firms and institutions. In Keynes’ view, animal spirits are the main cause why the economy fluctuates the way it does. An understanding of animal spirits and bounded rationality helps project managers make better decisions in conditions of uncertainty.

Bayes’ theorem
A theory of conditional probability, the principle that subjective degrees of belief can be treated as mathematical probability. For example, patients with measles may or may not exhibit spots and patients may exhibit spots without having measles. The probability that a patient has spots given that they have measles is a conditional probability.

Behavioural economics
The study of economic behaviour and its consequences. It departs from the *homo economicus* view that all economic decisions are rational, calculating and selfish and never makes systematic mistakes (Cartwright 2011) and borrows from psychology, and the social sciences to provide insights and a better understanding of decision-making in conditions of risk and uncertainty.

Bell curve
A graphic representation of the distribution of data.

Beta
A measure of volatility to the mean. In stock markets, it measures the relationship between a stock, a class of stocks, or an index and the market as a whole. It is a measure of volatility and a proxy for risk.

Black swans
Large-scale, unpredictable and irregular events of massive and harmful consequence.

Blue noise
In markets, generally is a medium or long-term trend in which a stock prices have momentum in a particular direction for a sustained period.

Bounded rationality
The constraints to rational decision-making which include (1) lack of information, (b) time constraints and (c) the cognitive abilities of the decision-maker. Other factors that may impair rational decision-making include poor advice, cultural and peer group influences, limited understanding of the issues through poor education or training, cultural and organisational value systems and emotional states.

Chartism
The practice of attempting to forecast the future from large volumes of past data.

Chaos theory
The mathematical study of complex systems whose development is highly sensitive to slight changes in conditions – small events can lead to great consequences.

Complexity
Man-made systems are increasingly complex and inadvertently have the potential to develop runaway chains of reactions that decrease, even eliminate predictability and contribute to black swan events and downside impacts.
**Correlation**
The relationship between two sets of data on a scale -1 to +1 with 1 being certainty or a perfect match, and 0 being non-existent.

**Delphi Method**
A method for identifying and measuring risk that uses a panel of experts and either a formal or informal process to arrive at a best-case recommendation. Panel selection and the design of the process to identify and test the views of the group are critical to the success of the Delphi method.

**Efficient markets hypothesis**
The theory that markets are perfectly efficient adjusting prices instantaneously as new information becomes available.

**Empiricism**
Knowledge derived from sense-experience.

**Equilibrium**
A state of balance. In markets, it is the belief that demand and supply are in equilibrium at all times through the price mechanism.

**Expected utility hypothesis**
A theory of individual choice under conditions of risk or uncertainty. From a given number of choices, decision-makers will select the expected highest utility-probability outcome.

**Financial economics**
A branch of economics that examines monetary matters generally at the macroeconomic level.

**Fractal geometry**
The geometric shape of many parts each of which bears close resemblance to the whole. Fractal geometry was discovered by Benoit Mandelbrot who used math-based geometric representations of the uncontrolled elements of data (or roughness) to identify symmetry and order. In analysing small elements of disorder, he found a similar geometric pattern to the whole.

**Fragility, anti-fragility**
Fragility refers to the vulnerability of natural and man-made systems to uncertainty whereby the downside of uncertainty exceeds any possible upside. Antifragile refers to natural and complex systems that survive and experience greater upside than downside in conditions of volatility, randomness and shock.

**Game theory**
The mathematical study of opposing dynamics in an unpredictable environment.

**Heuristics**
Rules of thumb or traditional explanations that individuals rely on when they lack sufficient information, time or the tools to rigorously analyse a decision.

**Hindsight bias**
The justification of unexpected outcomes using suppositions that tell us the outcomes was likely. Also termed misremembering.

**Homo economicus**
The rationalisation that all economic decisions are rational, calculating and objective and never subject to systematic error.

**Information**
When dealing with risk and uncertainty, information is essential to making an informed decision. Information available only to one party in a transaction is said to be asymmetrical and when the same
information is available to all parties, it is described as information symmetry.

(The) “invisible hand”
A creation of the political economist Adam Smith who argued that people consistently act in a way that improves their wellbeing. Smith was referring to the rational self-interest that drives the majority of decision-making by economic actors. This view does not recognise irrational, benevolent or altruistic decision-making that also drives the conduct of economic actors. See animal spirits.

Irrational exuberance
Non-rational behaviours in markets. Actors are influenced by short-term market trends and a herd mentality.

Joint probability problems
Circumstances where two or more causes may singularly or jointly contribute to the probability of a risk event. For example, it may be necessary for dams on two river tributaries experiencing high rainfall to release water downstream. A risk manager needs to estimate the likelihood and timing of water releases from one or both dams to ascertain the potential for downstream flooding of the river.

Just noticeable difference
Perception is everything.

Logic
The use of valid reasoning to solve a problem.

Long-run, short-run
In markets, long run generally refers to periods of seven years or greater, medium term indicates terms of five to seven years, and short-term means five years or less.

Long-tailed, short-tailed, fat tailed distribution
In a probability distribution, a long-tailed distribution refers to a wide dispersion to the mean suggesting a lower likelihood of an expected outcome. A short-tailed distribution indicates a low dispersion to the mean and a greater probability of an expected outcome.

Marginal utility
The principle that utility diminishes with increased consumption of a particular good or service.

Markets
A forum for exchange between buyers and sellers with demand and supply determined by equilibrium pricing.

Modern portfolio theory
The change in overall risk profile of a portfolio of securities with the addition of an additional security. It is not the risk profile of the new asset that is important but the change the acquisition makes to the overall risk profile of the portfolio.

Money illusion
The illusion that money retains value over time.

Probability theory
The likelihood of an event calculated by the actual number of actual occurrences divided by the number of possible occurrences.

Prospect theory
An approach to decision making under uncertainty that states that the value of an alternative or option is the sum of the product is calculated by multiplying the utility from x by the weight attached to the objective probability of obtaining x.

Prospect
An economic option or course of action.
Random walk
The view that independent stock prices follow a random path and are incapable of prediction based on past performance. Random walk implies there are no patterns in the movement of prices.

Rationality
Decision making based on facts or reason. Plato held that the most important truths must be attained through reason alone. Aristotle believed that observation or empiricism was more important with the human mind processing the meaning and rationalising outcomes. The systematic investigation of natural phenomena.

Rational expectations
The hypothesis that individuals have all the relevant information available to them when making decisions under conditions of risk and uncertainty. Errors in analysis are attributed to random forces.

Regression
The tendency for data to regress or converge to the mean. It is used to identify causation in discrete data.

Risk
The probability of a (positive or negative) outcome at variance to expectation. The probability of risks may be estimated using historical data and evidence of past performance.

Risk aversion, risk appetite
The willingness of a party to accept a given level of risk. A risk-averse actor selects investments with low risk of capital loss or an uncertain return. An actor with a strong risk appetite will take longer odds or a greater level of risk on a high return.

Symmetry of information
When information reaches two parties dealing with a common matter at the same time. In markets, it refers to both sides to a transaction receiving the same information simultaneously. Asymmetrical information influences prices to the detriment of one of the parties.

Theory of large numbers
The larger the sample, the greater the number of experiments, the smaller the error and more accurate the average.

Uncertainty
Events that cannot be predicted. For example, seismic activity in the form of volcanic eruptions and earthquakes. Uncertain events of catastrophic dimension are termed black swans.

Utility theory
Utility is the benefit or enjoyment economic actors receive from consumption of a good or service.

White noise
Short-term events and movement in indicators in markets.

Winner’s curse
Values at variance to peer group suggest overconfidence. Bidders for projects that submit the highest price have probably made a mistake in their assessment.
A HISTORY OF RISK AND UNCERTAINTY

1. Introduction

Risk is an explanation for human activity that doesn’t go to plan, i.e. the undertaking achieves an outcome at variance to expectation. The risks that we encounter today are similar in form and substance to those that faced our ancestors over the past 5,500 years. What has changed over that time is the greater complexity of systems today, which amplify the likelihood, and the magnitude of unexpected outcomes in all forms of human activity. For example, we load our economic and social infrastructure, our services, our supply chains and our commercial networks to breaking point. London’s public infrastructure, including its energy and water resources, performs at 98% of capacity at peak times with greater vulnerability to breakdown than systems operating at lower stress levels. On the other hand, there are greater opportunities today for risk-takers to speculate and disperse the adverse consequences of risk over a growing number of stakeholders and internationally networked institutions through sophisticated financial instruments, insurance, derivative securities, guarantees and indemnities. Capital markets play a key role in the monetisation of risk, its dissemination over a number of different asset classes and the provision of risk management services that support global trade and commerce. A market also provides a good proxy for identifying, measuring and valuing risk over time and at every minute of every day that the market is trading.

Securities, risk, and actors are the essential elements of a capital market. Market dynamics are affected by one further element – externalities in the form of man-made and natural events. Externalities impact markets positively and negatively which quickly translates to investor confidence, which in aggregate becomes the prevailing market sentiment. Market sentiment is the key determinant of the pricing of risk, and securities. Externalities also impact risk through insurance premiums, and indirectly through credit risk spreads, institutional and firm level risk appetite and transaction costs. So markets are important for us because they provide a microscope through which we can examine risk as a dynamic force in our economy and better understand the role it plays in our day-to-day decision-making. Events such as the recent global financial crises remind us that risk dispersion increases the likelihood that risk liabilities of a global dimension can bring down the largest of corporations, and all but the largest of nations. Events such as these also remind us that risk transfer through capital markets creates a new and more dangerous level of risk that is only as effective as the financial strength of the counterparty bearing it.
2. Progress Through History

This essay traces the evolution of risk as a discipline and a science from 3,500 BCE to the present day and identifies many of the contributions to the science of risk and risk management. These contributions have come from many fields beginning with early metaphysics, philosophy, mathematics, physics and the social sciences. The line of evolution has followed an erratic but progressive path that most likely became a formal science with Galton’s actuarial assessment of social indicators leading to the use of large quantities of historical data and probability theory to predict the likelihood of future events, leading the rapid growth in the insurance industry.

Early explanations of risk drew on the metaphysical in the context of a society steeped in determinism and the inevitability of calamity. Early civilisation was based on theocratic institutions with the merger of constitutional leadership in the form of a god-king and religious beliefs. It was in ancient Sumeria, the first of the modern civilisations that predated classical Greece by 3,000 years that theocratic rulers enacted secular laws for the regulation of trade and property rights including a comprehensive code of law to deal with trade by sea, loans to shipowners and limited legal liability with the non-enforceability of loans involving merchant losses at sea. These were the first recorded laws regulating liability for losses under commercial contracts, a form of insurance against inadvertent loss. The Sumerians also invented mathematics for use in astronomy and engineering although the development of mathematics as a science was taken up by later civilisations in Egypt, China and Byzantium, principally for applications in engineering, astronomy and geography.

In classical Greece, the early philosophers especially Socrates, Plato and Aristotle introduced the explanatory power of logic, which required scientific advance to be supported by evidence. Later, Greek philosophy embraced the study of human nature and the role of institutions in society, all of which were to later contribute to the scientific, commercial and constitutional foundations of western civilisation. The Greeks and later the Romans did not make significant advances in commercial law until the time of Augustus largely because the commercial classes were not viewed as equals by the landed aristocracy or the political class. Although the Romans also based their scientific thought on logic, which required proof, scientific progress was relatively slow and the metaphysical continued to explain the unprovable. In the Roman Empire at the time of Claudius (10BC-54AD) state-owned insurance was available for shipowners transporting grain and suffering loss at sea.
The entrepreneurial trading ports of Phoenicia were among the first to develop institutions to spread the risks and rewards of maritime trade over a wider stakeholder base. The institutions included trade finance (letters of credit drawn on wealthy merchants), profit-share and, the syndication of equity, insurance and trade indemnities.

Around 100BC, Mediterranean trade a long period of trade expansion with the establishment of colonies on the North African coast, the eastern Aegean and Black Sea and Spain. Mediterranean traders exchanged commodities and goods with traders in northern Europe, China, the subcontinent and peoples living in what is modern day France, Germany and the Lowlands. Growth in trade led to greater innovation in shipbuilding, better navigation, chronometry, and later, further development of financial securities to facilitate trade such as letters of credit, debt and insurance.

Early progress in understanding risk took place in the mathematical sciences. In particular, predicting future events and conditions using celestial mapping of phenomena such as a full moon and tides. Around 500AD, Diophantus (200-299AD) adopted the Hindu numbering system (the Roman numeral system was too unwieldy) and invented symbolic algebra (pie, infinity and beta). In 825AD al Khowarizmi (800-850AD) invented the first algorithm (plus, minus, multiplication and subtraction). Metaphysical explanations of risk and uncertainty were yielding to science and logic in all matters other than those dealing with spiritual, ethical or moral nature. The recognition of secularity by Pope Gregory VII (1073-1085) and the demarcation of religious life from that of government and trade led to the introduction of all the legal and institutional foundations of the market economy and led to the liberalisation of trade and commerce free of the strictures of canon law (Collins 2009; Lall 2006, pp. 154-156). The growth of commerce now took a different path in Europe to that which occurred in Eurasia.

The Renaissance in Italy in the 14th Century was the catalyst for remarkable advances in science, and the formal recognition of risk in the pricing of assets and returns from trade during a rapid expansion of the market economy and capitalism. This led to advances in bookkeeping and attempts at forecasting. Fibonacci (1170-1250) created the basis of modern accounting and mathematics with protocols for the preparation of accounts and methods for calculating profit margins, fractions, percentages, weights and measures. He also created the interest calculator and discovered the rule of 67 (that 67% of observations lay within one standard deviation of the mean).
Strong growth occurred in capitalism, trade and mathematics in Europe during the 12th and 13th Centuries, and scientists sought to discover methods for predicting risk events. However, it is thought that the Chinese were first to discover algebra around 1303. In 1310, bills of exchange were in wide use to syndicate equity and debt investment for the high-risk trade by land and sea. In the 15th Century, maritime trade increased dramatically with sailing ships growing in size to accommodate larger holds, which were divided into parts or carats, which were owned by investors who claimed a share of trading profits generated by traders who hired the space. Port magistrates who relied on the log and accounts of the ship’s captain resolved civil disputes over profit sharing and other matters. High-interest loans were provided by merchants to finance the trip, which were then insured by another group of investors who carried the risk of the loan not being repaid with interest, and loss of profits from the voyage (Braudel 1992, p. 365). The new forms of trade finance provide an early model of risk unitisation; dispersion and mitigation through risk sharing, finance, and insurance. Merchant banks sprung up in the major European ports to provide financial and insurance services to facilitate growing maritime and trade in commodities.

Paccioli (1445-1490) a mathematician and gambler explored games of chance and discovered probability, the first systematic analysis of probability or the confidence that a particular event will take place. By now, quantitative analysis had replaced metaphysical explanations of natural events (Bernstein 1998, p. 51). Other gamblers took an interest in probability reckoning that games of chance had a lot in common with picking winners in foreign trade. Cardano (1501-1576) established the principle that the probability of an outcome is the ratio of favourable outcomes to unfavourable outcomes so where the odds were equal, say with the toss of a coin, frequent throws would fall equally between heads and tails. The importance of this step was that it identified the importance of n, the frequency of the throws. The more throws, the greater the accuracy of the result. Subsequent work by Cardano and his colleagues developed this theory for application to single and multiple dice, cards and other games of chance. Galileo (1564-1642) adapted similar methods for use in astronomy and chronology, space and time.

Blaise Pascal (1623-1662) was one of a family of mathematicians who invented the first calculator and established the basis of present day decision theory, i.e. techniques for decision-making in conditions of uncertainty. Pascal also identified statistical inference or the practice of developing hypothesis from a limited set of facts (or sampling). Pierre de Fermat (1601-1665) was a lawyer, mathematician
and analytical geometrician and a friend of Pascal. Their correspondence marks the foundation of probability theory. De Fermat also contributed the first differential calculus, which led to a series of new discoveries in mathematics including practical algebra and the principle that it is possible to predict the likelihood of events if past events are capable of being measured by numbers. At this time, the theory of utility developed in mathematics and was quickly adapted to economics as an explanation for decision-making (Bernstein 1998, p. 71).

Canopius in 1637 set up one of the first coffee houses in the business district of London and this immediately proved popular with merchants, financiers and shipowners as a venue for the exchange of information, the listing of shipping schedules, notification of losses and forthcoming trips. The coffee house rapidly became a forum for shippers, merchants and trade financiers similar to the modern industry association or club, and a place of commerce.

Jacob Bernoulli (1655-1705) created the law of large numbers, which established that the error between observed and true average could be reduced with a larger sample or number of observations. He was also the first to recognise moral certainty as the key to ascertaining levels of confidence in probability and regression analysis, improving data quality, and greater accuracy in causation and forecasting. Jacob Bernoulli also created a formula for risk-weighting data which is still in use today: Risk weighted cost (RWC) = original value + cost of a risk event x probability of occurrence. Probability for these purposes is the outcome of the cost of a risk event multiplied by its relative likelihood. The work of Jacob and later, his cousin Daniel Bernoulli and their colleagues led to other insights into probability theory including the St Petersburg paradox and the role of subjective belief in addressing uncertainty. This line of research known as the expected utility hypothesis continues to the present day with applications to economics, social sciences (bounded rationality), psychology and pure mathematics. The hypothesis was developed further with the von Neumann-Morgenstern utility theorem, which provides an explanation of risk appetite and how this may differ between individuals for a number of subjective reasons.

Bernstein argues that the legacy of Jacob Bernoulli was to focus future research into the management of risk in three directions: full information, independent trials and quantitative valuation (p 121).

Abraham De Moivre (1667-1754) took an interest in historical data, examined frequency distribution in data sets, and came up with the standard deviation (and its representation, the bell curve) and the rule of 68 which holds that in all data
sets, 68.3% of observations lie within 1 standard deviation from the mean, and 95.5% of observations lie within 2 standard deviations of the mean. He was the first to explicitly define risk as chance of loss (Bernstein 1998, p 126).

Daniel Bernoulli (1700-1782) was a mathematician and scientist who examined risk and two distinct yet inseparable elements: objective facts and subjective analysis to determine the utility of what is to be lost or gained by the decision. This led to a greater understanding of risk appetite through recognition of diminishing marginal utility, i.e. as a general rule, risk appetite diminishes with greater wealth (fear of loss outweighs the satisfaction from gain). This important development led to a new class of investor, the risk-taker and resulted in a line of research that included the von Neumann-Morgenstern expected utility theory (1944).

Bayes (1702-1761) was the first to draw a distinction between risk and uncertainty, the latter concerned with exogenous occurrences or the environment, which is dynamic and unpredictable. Bayes established that uncertainty refers to unknown probabilities and was incapable of prediction. Bayes' work was taken up by Francis Galton (1822-1911) who discovered correlation and regression in probability analysis. These methods were now problem-solving tools for use in risk estimation and pricing. This work also led to the development of theories about the role of information in markets, its random and “cascade” characteristics, which were immediately absorbed into market prices. The importance of information flows in markets led to a number of more recent developments about market pricing, the random walk hypothesis, game theory, and complexity economics.

Carl Frederick Gauss (1777-1855) was a mathematician and economist interested in the symmetry of frequency distributions. Gauss' work had a significant impact on 19th Century classical economics and particularly, equilibrium in markets. He confirmed that for accurate probability calculations, a large sample of independent observations was required (Bernstein pp. 142-3).

Fifty odd years after Canopius set up his coffee shop in London, Edward Lloyd (1664-1730) opened another in the mercantile centre of London, then undergoing rapid growth as a centre of international trade. Lloyds provided a forum for merchants, shipowners, captains and financial intermediaries and space for notices about shipping schedules, weather, foreign news and conditions, and cargo space availability on departing vessels. This led to a newsletter then a shipping newspaper. Later, Lloyds “list” was famous for its insurance syndication
work, ship auctions and for its brokerage and insurance services. Risk investors, underwriters, fire and life insurers all became part of the business, which incorporated in 1720. Canopius and Lloyds’ provided a market for the trading of risk, finance and insurance and provided the missing link that recognised risk as a branch of probability theory and a discipline. They were precedents for the early trade associations and led to two innovations: (a) the aggregation of trade data by land and sea, and detailed information about risk events and their consequences, and (b) they became a forum for the exchange of information, contracts, insurance, capital raisings, and underwritings which were then documented on the premises. This led to the first archive of transactional data including trade aggregates, shipping information and price data that enabled the estimation of trade outcomes (or probabilities) with greater accuracy.

Access to data was the next big challenge and the Englishman Francis Galton (1822-1911) provided this with his actuarial work collecting qualitative and quantitative demographic data to identify social trends including causes of death, longevity, and heredity genius. This led to the development of comprehensive data sets and actuarial tables to which probability theory and statistical inference could be employed in forecasting with greater accuracy.

In 1921 a major breakthroughs occurred with John Maynard Keynes’ work, *A Treatise on Probability* in which he drew a distinction between risk, which could be ascertained with some accuracy using historical data and probability theory, and uncertainty, which could not (Keynes 1921). This same distinction was drawn by US economist Frank Knight also in 1921 (Knight 2006, pp. 19-20) although neither knew of the others work at the time. The work of Keynes and Knight formalised the discipline of risk and uncertainty, which is used so widely today in capital markets and across the banking, actuarial, and insurance industries.

3. Capital Markets Research

Capital markets in the form of stock, bond and commodity prices provide an excellent laboratory for testing theories about risk and uncertainty. Some of the early work by Knight (1921) and Keynes (1921) was followed by a large number of US researchers commencing in the 1890s. The human instinct to achieve a high return at least risk accounts for around 75% of investors in the stock market today with the remainder adopting a long-term investment strategy in stable
stocks and bonds with a view to steady interest and dividend returns over time.\(^1\) Warren Buffet and John Maynard Keynes adopted this latter strategy and the secret of their success was in their astute selection of growth stocks with strong future prospects. In the 1970s, the study of risk shifted focus to stock and bond markets and explanations were sought for why, in the presence of so much information, movement in stock prices were so difficult to predict.\(^2\)

An excellent study by Justin Fox provides a detailed analysis of the work of leading US capital market theorists include Irving Fisher, Fred Macaulay, Holbrook Working, Harry Markowitz, Paul Samuelson, Modigliani and Miller, Gene Fama, Fisher Black, Michael Jensen, Dick Thaler, Bob Shiller, Alan Greenspan, Andrei Shleifer, and Mike Jensen (Fox 2009). This book traces the development of rational market theory, the efficient market hypothesis and the belief that all information is spontaneously absorbed into security prices. The following outlines the major theoretical constructs that emerged from this work.

The prevailing assumption throughout the late 20\(^{th}\) Century was the efficient market hypotheses and that the market know best because it moves capital to those that need it, it can disperse risk, gather and spread information, and regulate economic affairs with a swiftness and decisiveness that government policy decisions can never match (Fox 2009, p. xii). A further assumption and a fault line for this theory is that buyers and sellers receive the same information at the same time (i.e. symmetrically). Recent evidence suggests that this is a fallacy and a major driver of arbitrage opportunities for homogenous stocks or bonds in different markets.

The challenge with direct investment in capital markets is identifying a strategy to outperform the market.\(^3\) However, if we accept that return is correlated with risk, then to outperform the market as a whole (the market beta) an investor will need to absorb a greater level of risk. There are four main approaches and a number of derived theories and methods have been tried over the years for identifying, measuring and managing risk in capital markets.

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\(^1\) The percentage varies between markets depending on the investment preferences of institutional investors particularly pension fund managers of accumulation and defined benefit funds, which is subject to continuous change.

\(^2\) Capital markets are not limited stock, bond and commodity markets and may also trade in derivatives (such as futures and options), corporate debt and equity instruments. Derivatives have provided most market risk research over the past 20 years.

\(^3\) A second objective of this research was to identify and test risk management methods particularly options, swaps, futures and forward rate agreements. These methods were designed to reduce the risk of adverse movement in asset values, currency exchange and interest rates, and commodity prices.
**The Chartists**

Chartists map the future from past historical data using combinations of various economic, social and financial indicators. Computers made the task much easier than it was but the chances of anticipating future events, stock or bond movements from the past is extremely difficult given changes in context for a given level of indicators such as laws, market actors and size, externalities, political economy, and the institutions that shape the incentives of actors in the economy from time to time. Despite the odds, chartists using high-speed computers can identify trends not readily visible to other investors at a given point in time.

**The Theorists**

There are three typical theoretical constructs attempting to interpret and explain markets. These mathematical methods have been around for 50 years or so and were developed by academic financial economists mainly based in the United States.

First, the capital asset pricing model (CAPM) is a mechanism for pricing equity and is based on work by Markowitz, Sharpe and Lintner. It values risk in a stock market as premium x over the return offered by a risk-free asset such as government bond. The premium can be calculated using historical market returns (the average market risk premium for all listed stocks over a term of years) or stock betas. The CAPM model also is associated with the recognition of systematic risk (that which is beyond the manager’s control) and unsystematic risk (that which is within the investor’s control). Unsystematic risk may be managed with diversification of a portfolio of stocks.

Second, modern portfolio theory (MPT) (Markovitz 1952) is based on the proposition that portfolio investors select assets on the basis of each asset’s contribution to the overall mean and variance of the portfolio. Markowitz views risk not in terms of the variation of a single investment but in terms of its interaction with other assets in the portfolio. Diversification by stock, sector and location enables investors to dilute individual stock risk at no cost. Investment management is all about maximising return without increasing portfolio risk.
Third, option pricing builds on the work of Black, Scholes and Merton who developed a model for pricing financial options when the stock price is constantly changing. Options are a discrete instrument for managing future price risk.

**The Random Walkers**

The random walk hypothesis is based on the principle that markets are chaos in a limited space and incapable of predictive interpretation (Bachelier 1900; Fama 1965; Malkiel 1973; Roberts 1959; Mandelbrot 2004, Malkiel 2012). It assumes that information about stocks is not absorbed into stock prices instantaneously because it arrives in an asymmetrical manner, few actors are rational at all times, externalities governing markets are random and data influenced by automated high-frequency trading. Malkiel first published in 1973, A Random Walk Down Wall Street captures the theory in the book.

The test is always about predictive powers with the theoreticians coming under intense scrutiny following events such as the 1929 stock market crash, the oil price hikes of the 1970s and 1980s, global recessions in 1976 and 1983, the stock market correction of 1989, the 1990 recession in Australia, and the 2008 GFC.

**The Pragmatists**

Silver and Strogatz are neither chartists nor theorists and offer simple explanations about the application of probability theory and demonstrate how easily it is used to produce the wrong result.

4. New Conceptual Models

Today, in the light of the global financial crises, the efficient market hypothesis is discredited but not yet deceased. Research has switched to new approaches such as systems fragility, bounded rationality, chaos theory, and chaos theory. The work of contemporary theorists such as Schiller, Kahneman, Silver, Malkiel, Ariely, Mandelbrot and Taleb are bringing new perspectives to understanding the roles of risk and uncertainty. Schiller attributes market volatility to the irrational exuberance of actors in the market, which Keynes described as “animal spirits” (Akerlof and Shiller 2009; Shiller 2005). This line of reasoning was taken in another direction by Ariely (2009) and Kahneman (2011), a Nobel laureate who viewed risk through the lense of behavioural economics. Kahneman believes that we are prone to think that the world is more regular and predictable than it really
is, a form of optimism bias. He believes that people automatically and continuously maintain a story about what is going on, finding simplistic explanations for the unexpected and suppress alternatives. Conspiracy theories demonstrate the phenomena. Bounded rationality then influences decision-making and we become vulnerable to individual preferences, loyalties, prejudices, risk appetite and other subjective states of mind when acting in an environment of risk, unpredictability and decision-making in conditions of uncertainty.

Mendelbrot and others were critics of conventional risk management practice particularly the efficient market hypothesis and modern portfolio theory (MPT). Benoit Mendelbrot was a radical thinker, mathematician and physicist who studied risk using stock and bond market data. He accepted that markets were unpredictable but developed a theory that there is a parallel between capital market prices and the natural order of things. For example, the size of waves on a beach, the colour and shape of leaves on a tree and wind gusts in a storm display irregularity or “roughness” but at the same time exhibit similarities and repetition if we can unlock the code. Mandelbrot presented a theory of fractal geometry which identifies underlying patterns of order amongst the disordered, represented by the geometry of price changes, a form of trend analysis. He observed that markets were unpredictable, prices were determined by externalities, and price movements had their origins in long past events. However, Mandelbrot held out hope that the random walk hypothesis provides us with information in the form of fractal geometry with which to measure and anticipate patterns of performance.

A number of researchers including Taleb and Mandelbrot have identified new models for explaining uncertainty in markets as well as natural phenomena such as winds, storm and earthquakes. There is little consensus between these researchers with Mandelbrot drawing a parallel between capital market pricing and natural events such as the direction and rate of flow of wind. He studied long and short wave natural cycles in nature (waves on a beach, the shape of leaves on a tree) and found a pattern of repetition (which he described as fractal geometry). Mandelbrot believed that there is predictability in natural and market phenomena.

Taleb is the author of the best sellers Fooled by Randomness, The Bed of Procrustes, and The Black Swan although his later work Antifragile advances his

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4 This suggests that the interpretation placed on information is designed to preclude explanations that do not meet with an actor’s values or beliefs or an unwillingness to accept explanations that challenge limits of understanding.
thinking about risk and uncertainty. Taleb argues that we create problems when managing for uncertainty by attempting to over-engineer systems in an attempt to beat uncertainty. However, in doing so, we introduce complexity and the combination is fatal – systems collapse under stress. Taleb argues that we should replicate many of the principles of nature (for example, trees bend before strong wind and don’t resist it), which he calls antifragility and stop wasting energy building heavyweight and complex systems for the 1% of occasions they may be necessary.

5. Risks at the Project Level

In early 2003, Flyvbjerg, Berzelius and Rothengatter examined risk at the project level in their book, *Megaprojects and Risk*, which examined the relationship of risk and failure in large infrastructure projects. Research by Mott McDonald (2004) coined the term “optimism bias” to describe poor planning and management practices for the delivery of construction and civil works projects, and Bain researched the incidence and characteristics of forecasting error in land transport projects (Bain and Wilkins 2002; Bain 2002a, 2003b; Bain and Plantagie 2004).

**Optimism Bias**

Optimism bias demonstrates bounded rationality, that is, humans are optimistic when setting schedules, budgets and forecasts for new projects. The result is drawn from 30 years of empirical evidence that 70% of projects are, on average, underestimating delivery to schedule and within budget (Mott McDonald 2004; Flyvbjerg, Berzelius and Rothengatter 2003). The problem is much greater for government projects when cost estimate is set by politicians and their advisers (Queensland Audit Office 2015; Flyvbjerg, Berzelius and Rothengatter 2003).

**Forecasting Error**

Transport projects also have a high incidence of optimism bias or forecasting error in setting patronage levels which invariably overestimates users for around 70% of projects by an average 30% (Flyvbjerg, Skamris Holm and Buhl 2006; Bain and Wilkins 2002; Bain 2002a, 2003b; Bain and Plantagie 2004). It is a systemic problem with toll roads and a major impediment to wider use of light and heavy rail systems because many expectations are set by politicians and their advisers, the high cost of construction and operation, and the fact that most systems are delivered and managed by government agencies (Flyvbjerg, Bruzelius and Rothengatter 2003; Queensland Audit Office 2015). For civil works
and buildings, complexity is a major cause of cost overruns (Mott McDonald 2002). Optimism bias has been a problem for over 30 years but the rate of error has remained unchanged over that period of time). Recent work by Love et al (2015) argues that optimism bias is a result of context and it varies over time in response to contemporary financing and procurement methods, contract law, types of project management and the role of institutions in delivering projects.
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released, however, the 2003 edition is best for coverage of risk, uncertainty, change management and decision-making in conditions of uncertainty (pp. 276-299). Of particular interest is the Vroom-Jago decision tree approach to qualitative risk measurement (p. 294) and the case study in Chapter 4 Managerial Decision Analysis, pp. 121-128 (distributed in class).


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Taxpayers’ Alliance 2007, *Beyond the Dome*, London. This paper can be viewed on the Serco Institute website. The paper examines 305 recent projects in Britain and identifies cost overrun of A$50 billion or 34% between estimation and completion price. Standard and Poor’s also published data on optimism bias between 2003 and 2005 which can be accessed on the Standard and Poor’s website and the Serco Institute website

www.serco.com/instituteresource/subjects/procurement/optimismbias/index.asp


