Winter School of Quantitative Finance

Session 1

Brief profile

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- Director, SkillX (IAQS)

- 7 years of consulting experience with banks, insurance companies and NBFCs across India, Middle East and ASEAN

- Qualified Actuary, IFOA and IAI

- Financial Risk Manager (GARP, USA)

- SCR, GARP

- Extensive training experience with corporates as well as students

- Worked with banks, insurance companies, financial institutions and corporates on a range of risk and financial advisory services including credit risk, ERM, ICAAP, model development and validation, hedging strategies, program management, automation, structuring, strategy and derivative valuations

Agenda for the day

1   What is quantitative finance?

2   Type of quant roles

3   Where engineering fits in
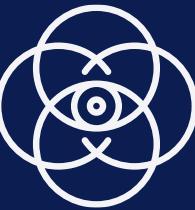
4   Case studies: LTCM and Renaissance Technologies

5   Time value of money basics

What is quant finance?

Quantitative finance is the use and application of **mathematics, statistics and computational models** to design **investment strategies, value financial assets and manage risk** effectively.

A brief timeline

1800s: Concept of **random walk** used by Jules Regnault to explore stock price changes.

1900s: **Efficient market hypothesis** (EMH) published by Eugene Fama, leading to the development of quantitative models for stock analysis and portfolio optimization. Development of pricing models including the **Black-Scholes model** for pricing options.

Today: **Significant advancement in technology**, advancement and evolution of financial products and markets, increase in trading volumes has led to the use of quant models in all markets from equities to commodities.
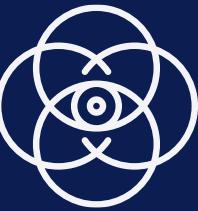
| Mathematics | Statistics | Computer Science | Finance |

What is quant finance?
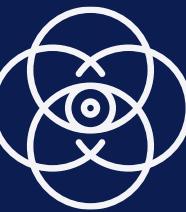
Quantitative investing relies on **data without considering qualitative factors** like management quality. Quants—who frequently have a scientific background and a degree in statistics or math—use their knowledge of computers and programming languages to build **customized trading systems** that automate the trading process.

To pursue "risk-adjusted returns", quants compare **risk measures** like alpha and beta to find the best investment returns for the risk level. The idea is that investors should take no more risk than is necessary to achieve their targeted level of return.

Advances in computing have revolutionized quantitative trading by allowing rapid data analysis and automated trade execution.

Areas of work

Some fields and areas in which quants typically work are detailed below:

Trading
- Work with traders, **developing and implementing complex models** for pricing securities, creating **trading algor**ithms, and finding profitable opportunities, directly impacting firm revenue

Risk management
- Develop **risk model frameworks** across various markets and assets
- Use techniques including value at risk ("VaR"), **Monte Carlo** simulation and linear regression-based statistical models, to measure the **potential of loss** on an investment profile

Quant research and analysis
- Use **statistical and quantitative methods** to analyze and predict the markets and apply programming tools to **design investment strategies**

Portfolio management
- Design **optimum portfolios** considering client circumstances, risk appetite, taxation, returns, capital and diversification requirements

Data science and analytics
- Data mining, gathering data sets, and **deriving insights** from these data sets
- Risk management and **predictive analytics** using machine learning, clustering algorithms, and artificial intelligence to identify **unusual data patterns**

Investment banks

Hedge funds

Consulting firms

Asset management companies

Family offices

Fintech companies

Research firms

Insurance companies

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Type of roles

The typical job roles offered to quants are as below:

Role	Description
Desk quant	Work directly on a **trading floor**, implementing and maintaining pricing models, algorithms, and tools for traders to use in real-time for pricing
Risk quant	Build **risk models**; stress testing; scenario modelling; VaR frameworks
Quant developer	Convert **quant ideas into production systems**; build trading/risk engines
Research quant	Build **mathematical/statistical models** to predict returns; research trading strategies
Fintech quant	**Build pricing engines**, OMS/EMS components, analytics libraries

Role	Description
Treasury quant	**Model interest rates**, yield curves, treasury products
Portfolio quant	Uses **optimization techniques** to manage a firm's portfolios and optimize the trading costs
Capital quant	Works on modeling a **bank's credit exposures and capital requirements**
Quant trading	Responsible for **executing algorithmic strategies** in live markets and making real-time trading decisions
Pricing quant	Develop and maintain **pricing models** for options, swaps, structured products

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How engineering skills complement quant finance

Role	Requirement	Skills required	How engineering fits
Quant research	Build statistical models, signals, systematic strategies	Probability, statistics, regression, time-series, optimization, Python and other programming languages	Engineers are generally good with math, signals, data analysis, pattern recognition
Quant trading	Build/monitor trading strategies, optimize execution speed, reduce latency	Market microstructure, signal processing, optimization, fast coding, C++, Python and other programming languages	Engineering covers performance optimization, controlling latency and modelling noisy signals
Quant developer	Convert models into production trading & risk systems; build infrastructure	OOP, data structures, software architecture, APIs, C++, Python and other programming languages	Engineers are already trained in coding discipline, system building, testing, version control
Risk quant	VaR, stress testing, scenario models, exposure modelling	Probability, portfolio theory, scenario analysis, programming languages	Engineers are familiar with risk, reliability, failure analysis, which maps well to quant. risk modelling
Derivatives pricing quant	Build mathematical models for options, swaps, structured products	Stochastic calculus, SDEs/PDEs, Monte Carlo simulation, numerical methods, programming languages	Engineers have a strong calculus & numerical methods background

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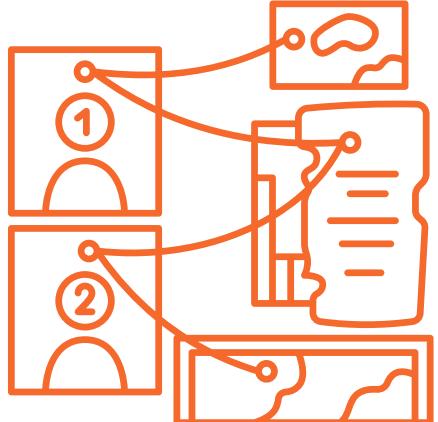
Case study – Long Term Capital Management (LTCM)

Background
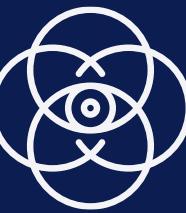
Hedge fund set up to profit by designing strategies using a combination of **quantitative models** and traders' market judgment. Founders included well-known names like **John Meriwether, Myron Scholes and Robert Merton**.

Some strategies pursued by the fund

Convergence trading: Find securities that are mispriced relative to one another, take **long positions in the cheap ones** and **short positions in the expensive ones**. Eg: Going short on recent issues of government securities and long on older issues of a similar tenor in the expectation the valuations of the two bonds would converge and the positions then unwound at a profit.
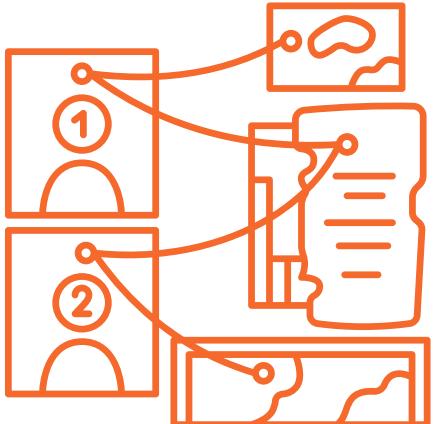
Merger arbitrage: Strategy designed to make money from corporate mergers and acquisitions. Involves buying the stock of a takeover target while accounting for the risk that the deal might not go through. Eg: Going short on acquiring company shares and long on target company shares and profiting once the spread narrows as the chances of the deal going through increase.

Case study – Long Term Capital Management (LTCM)

What went wrong?

Russian default on its sovereign bonds in 1998 led to a **flight to liquidity** across all asset classes across geographies. Simply put, investors dumped any kind of risky assets in favour of highly liquid and safe investments such as government securities. This significantly impacted the convergence trades of LTCM as the liquid securities it was short in became more expensive and the cheaper but illiquid securities it was long in became cheaper. The total losses made by the fund were an eye-watering **$4.6 billion** and it had to be bailed out.
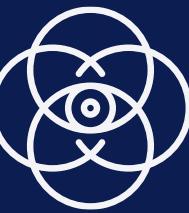
A brief timeline

1994: Founded by John Meriwether and accepts investments from 80 investors who put up a minimum of $10 million each. The initial equity of the firm is $1.3 billion.

End of 1997: After two years of returns running close to 40%, the fund has some $7 billion under management and is achieving only a 27% return — comparable with the return on US equities that year.
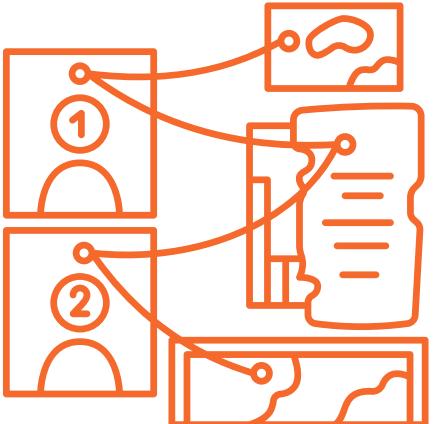
1998: Russian default on sovereigns triggers a massive flight to liquidity, dealing a severe blow to LTCM's portfolio. Ultimately, the fund is taken over by a consortium of banks.
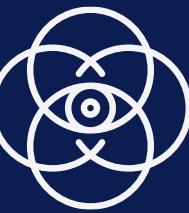
Case study – Long Term Capital Management (LTCM)

Key learnings

❖ *Models must be stress-tested and combined with judgement:* According to the complex mathematical models used by LTCM, the positions were low risk. Judgement tells us that the key assumption that the models depended on was the high correlation between the long and short positions. A simple stress testing of this correlation parameter could have led to LTCM taking on a lower leverage.

❖ *Importance of liquidity risk as a factor*: LTCM fell victim to a flight to liquidity. This phenomenon is common enough in capital markets crises that it should be built into risk models, either by introducing a new risk factor — liquidity — or by including a flight to liquidity in the stress testing.

❖ *Market value vs fair value*: The strategies employed by LTCM may have been sound but the fund ended up in liquidation due to short-term phenomena impacting market values drastically. In crises, it is the market value that matters more than the fair value derived from quantitative models.
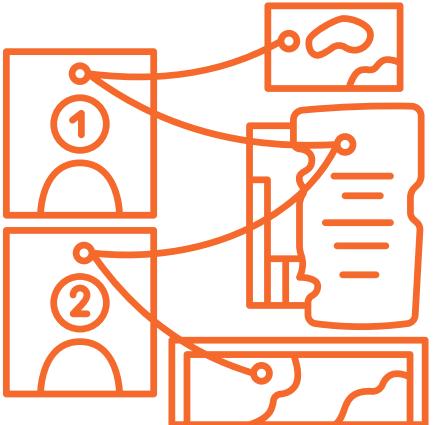
Case study – Renaissance Technologies

Background

Hedge fund set up by James Simons in 1982 that undertakes **systematic trading using quantitative models** built using statistical models and analysis. Its star performer is the **Medallion fund**, which does not accept outside money and consists of money invested by current and former employees. The fund has generated a **66%** annual gross return from **1988 to 2018**!

Key features of its trading model

❖ <u>Huge data store</u>: Petabyte-scale data warehouse capturing all data from weather, news articles, prices, movements, etc. used to assess statistical probabilities for the direction of securities prices in any given market.

❖ <u>Systematic trading approach</u>: Use of computer-based models to predict price changes by analyzing as much data as possible and looking for non-random patterns and movements to make predictions.

❖ <u>Effective risk management</u>: Advanced risk management techniques are employed to mitigate potential losses, ensuring the preservation of capital during volatile periods.

❖ <u>Extreme diversification</u>: The fund trades a vast array of securities across multiple asset classes and geographies, reducing exposure to any single market or sector.
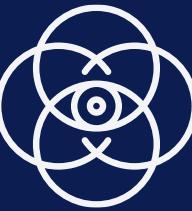
Case study – Renaissance Technologies

Background

The table below displays the returns generated by the **Medallion Fund** over the last 40 years. Even in 2008, the fund generated returns of **152%!**

Medallion Fund Gross Returns

Year	Gross Returns	Fund Size ($M)	Year	Gross Returns	Fund Size ($M)
1988	16%	$20	2004	50%	$5,200
1989	1%	$20	2005	58%	$5,200
1990	79%	$30	2006	84%	$5,200
1991	54%	$42	2007	137%	$5,200
1992	47%	$74	2008	152%	$5,200
1993	54%	$122	2009	75%	$5,200
1994	93%	$276	2010	58%	$10,000
1995	53%	$462	2011	71%	$10,000
1996	44%	$637	2012	57%	$10,000
1997	32%	$829	2013	89%	$10,000
1998	57%	$1,100	2014	75%	$9,500
1999	36%	$1,540	2015	69%	$9,500
2000	128%	$1,900	2016	69%	$9,500
2001	57%	$3,800	2017	85%	$10,000
2002	51%	$5,240	2018	76%	$10,000
2003	44%	$5,100			
			AVERAGE (1998-2018)	66%	$4,545

From Gregory Zuckerman's "The Man Who Solved The Market"

Time value of money

Would you prefer to receive INR 1 lakh today or a year from today?

In both instances, one gets the same amount of money. However, most rational people would choose the option to receive the **money today**. This is because money received today has more value than in a year's time.
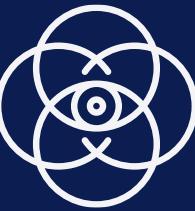
This concept is called the **time value of money (TVM)**. It's an important concept central to pricing models and portfolio management strategies used by quants.

There are primarily 3 reasons for this phenomenon:

❖ <u>Opportunity cost</u>: Money can be invested and earn interest, increasing its value.

❖ <u>Inflation</u>: A general increase in prices means the same amount of money can buy less tomorrow than today.

❖ <u>Uncertainty</u>: Invested money or promised money may not be paid back in the future due to numerous reasons.

Money today > Money tomorrow

Simple and compound interest

What is interest?

Interest may be regarded as a reward paid by one person or organization to another, for the use of an asset.

Interest represents compensation for **expected inflation, risk of the borrower defaulting, embedded illiquidity and the opportunity cost** of money. For example, a bank will charge a higher rate of interest to a construction company as compared to a public sector entity owned by the government.

Simple interest vs compound interest

Simple interest does not compound, meaning that an investor will only gain the principal and the interest on the principal, and not interest on interest. This contrasts with compound interest whereby interest itself earns interest.

The accumulated value (AV) of an amount C deposited at a rate of i% after n years is:

$C(1 + ni)$ under simple interest
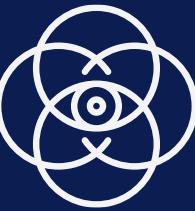
$C(1 + i)^n$ under compound interest

An amount of 10,000 invested for a period of 3 years at a rate of 8% would accumulate to:

$10,000 (1 + 3 * 8\%) = 12,400$ under simple interest

$10,000 (1 + 8\%)^3 = 12,597$ under compound interest

Effective and nominal rates

Nominal rate of interest

A nominal rate of interest per period, payable pthly, i(p), is defined to be a rate of interest of i(p)/p applied for each pth of a period. For example, a nominal rate of interest of 6% pa convertible quarterly means an interest rate of 6/4 = 1.5% per quarter. The **higher the frequency of compounding**, the **higher is the accumulated value** and hence the interest earned.
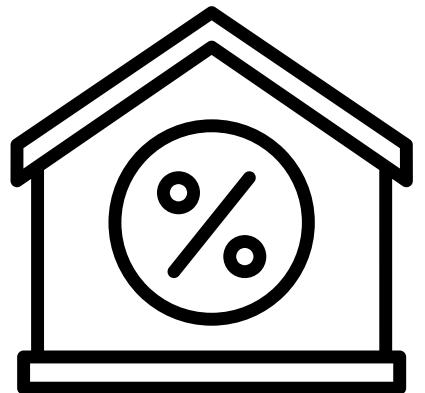
For example, an amount of 10,000 invested for a period of 1 year at a rate of 8% would accumulate to:

$10,000 (1 + 8\%)^1$ = 10,800 under annual compounding

$10,000 (1 + 8\%/4)^{1*4}$ = 10,824 under quarterly compounding

$10,000 (1 + 8\%/12)^{1*12}$ = 10,830 under monthly compounding
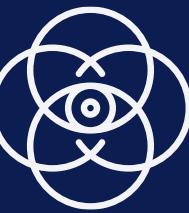
$10,000 (1 + 8\%/365)^{1*365}$ = 10,833 under daily compounding

The effective annual rate i is simply:

$I = (1 + i(p) / p)^p - 1$

In the above example, the effective annual rate for quarterly compounding is $i = (1 + 8\%/4)^4 - 1$ = **8.24%**

Applications in quant finance

Some applications and use cases are as below:

❖ Pricing of derivatives

❖ Pricing of fixed income securities

❖ NPV and DCF based project evaluation

❖ Interest rate modelling

❖ Assessment of risk premiums embedded in interest rates and understand potential capital losses

❖ Construction of interest rate and swap curves

❖ Calculating implied returns for investments given present/future values and cash flows

❖ Detection of arbitrage opportunities

❖ Discounting future cash flows (dividends, earnings) to find the fair price (PV) of stocks or bonds

Some questions

1. A bank account pays an effective annual interest rate of 10% over 5 years. Calculate the equivalent i) simple annual interest rate, ii) effective monthly interest rate, iii) effective two-yearly interest rate.

2. A woman who has won a prize is offered either: a lump sum of 100,000 to invest now or 55,000 to invest in one year's time and another 55,000 to invest in two years' time. If the investments earn interest at 7% pa effective, which option should she choose if she intends to withdraw the money after 4 years?

Thank you!

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