History of Quantitative finance

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ACM India Winter School 2025: AI and Finance

History of …

Money, deals, transactions

Interest rates

Derivatives

Trading of derivatives

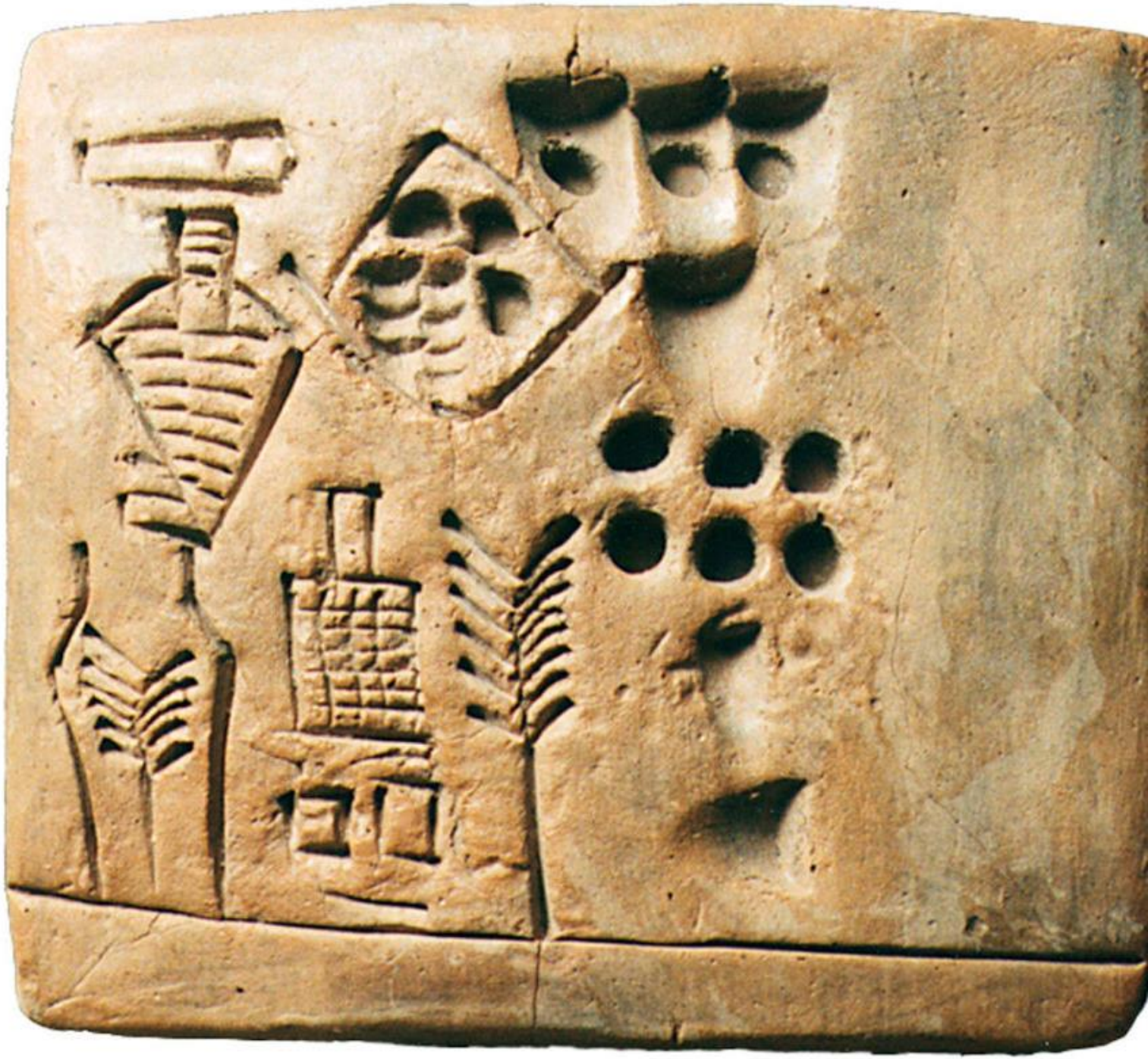
Options

Financial crisis

Mathematics in finance

What is the role of finance

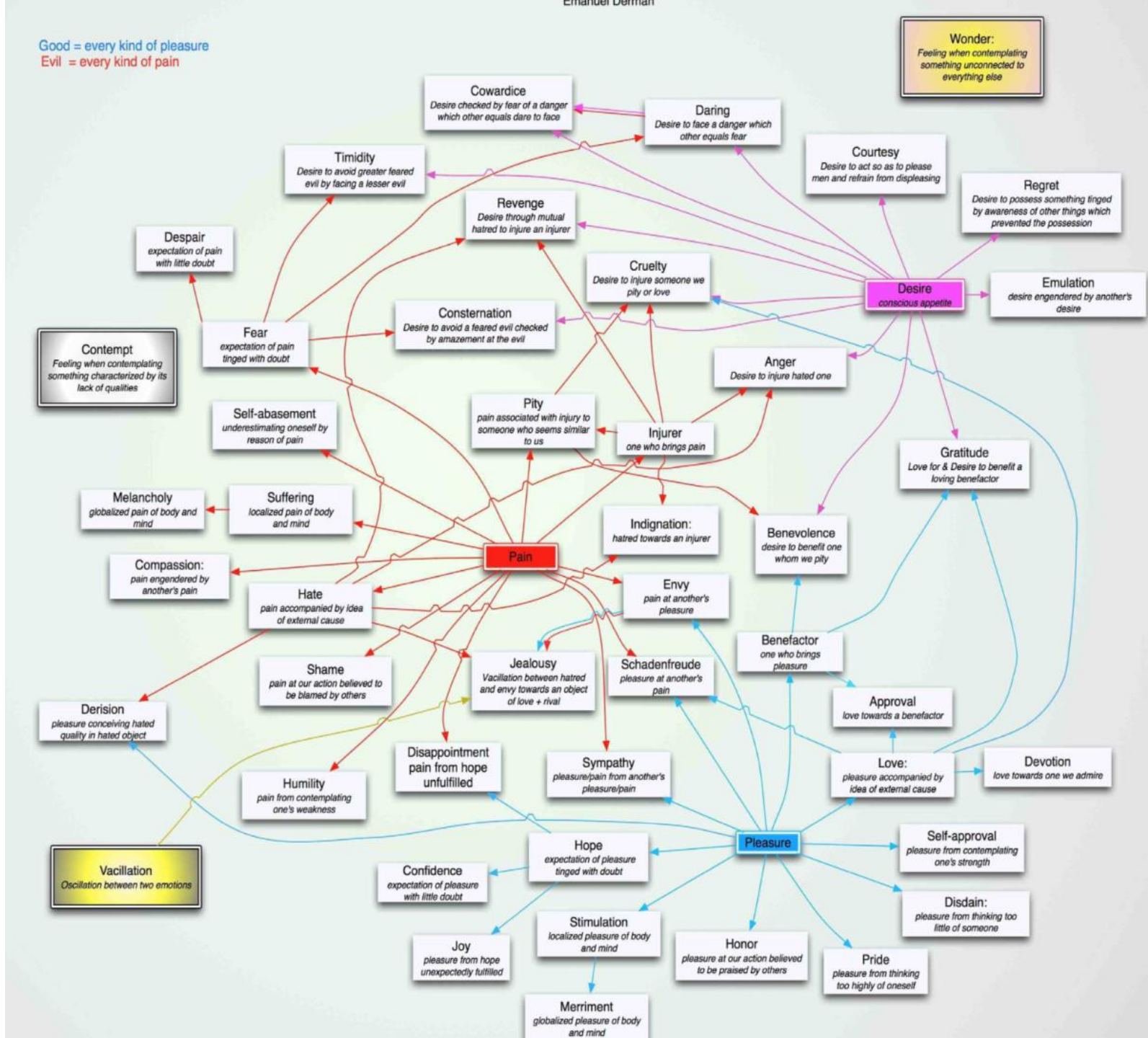
- 33 centuries before Christ to a 5,000-year-old clay tablet found in Mesopotamia (modern Iraq).
- It states: *A total of 29,086 measures of barley were received over the course of 37 months. Signed, Kushim.*
- The first recorded name is not that of king, or a celebrity, but that of an accountant!



Derivatives

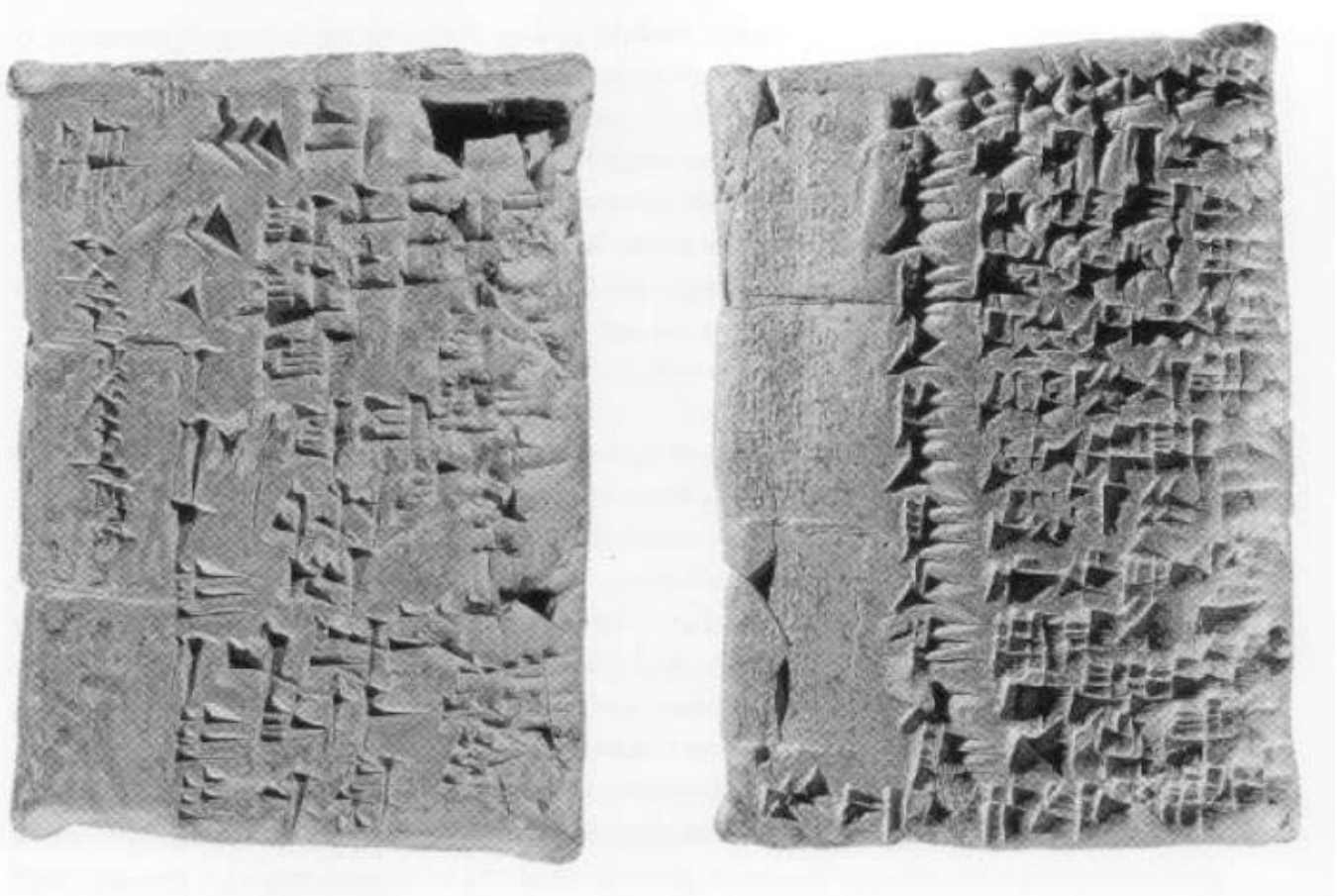
- Spinoza (17th century) every passion expressed in terms of their relation to three more primitive feelings:
  - Pain,
  - Pleasure,
  - and Desire.
- Every passion or emotion, in his view, is a **derivative** of these three sensations
- Thus **Hate**, for example, is the **Pain** associated with an external object or person
- Some passions have two under-liers. **Envy** is **Pain** at someone else's **Pleasure**, analogous to a convertible bond that depends on both equity and interest rates.
- Similarly, Cruelty as the **Desire** to inflict **Pain** on Someone You **Love**, a triple derivatives analogous to a convertible bond that is additionally exposed to credit risk.

Ref: A stylized history of quantitative finance. Emanuel Derman



Earliest recorded financial contract

1. Invention of promises.
2. Invention of writing.
3. Invention of control and intervention.



Thirty wooden [planks?], ten of 3.5 meters each, twenty of 4 meters each, in the month Magrattum Akshak-shemi will give to Damqanum. Before six witnesses (their names are listed).
The year that the golden throne of Sin of Warhum was made.

1900 BC.
(van de Mieroop 2005, p. 23)

Example of forward commodity swap

Six shekels silver as a šu-lá loan, Abuwaqar, the son of Ibqu-Erra, received from Balnumamhe. In the sixth month he will repay it with sesame according to the going rate. Before seven witnesses (their names are listed). These are the witnesses to the seal. In month eleven of the year when king Rim-Sin defeated the armies of Uruk, Isin, Babylon, Rapiqum and Sutium, and Irdanene, king of Uruk.

1800 BC

Early Mesopotamian Forward Contract (ca. 1750 BC)

204 2/3 qu of oil in the measure of Shamash, to the value of 1/3 mina 2/3 shekels of silver, as the price for healthy slaves from Gutium, Warad-Marduk son of Ibni-Marduk has received from Utul-Ishtar the troop-commander on the authority of Lu-Ishurra son of Ili-usati. Within one month he shall bring healthy slaves from Gutium. If he does not bring them within one month, Lu-Ish(k)urra son of Ili-usati will repay 1/3 mina 2/3 shekels of silver to the bearer of this tablet. Before (four witnesses whose names are listed). Month Ab, sixth day, year in which King Ammisaduqa, etc.

1750 BC

Transaction Structure

- **Underlying asset:** *Healthy slaves from Gutium*
- **Payment-in-kind collateral:** *204 ⅔ qu of oil (Shamash measure)*
- **Valuation:** Equivalent to **⅓ mina + ⅔ shekel of silver**
- **Parties:**
  - **Buyer/Receiver:** Warad-Marduk (son of Ibni-Marduk)
  - **Seller/Deliverer:** Utul-Ishtar, troop commander
  - **Guarantor:** Lu-Ishurra (son of Ili-usati)

Witnesses: Four listed individuals

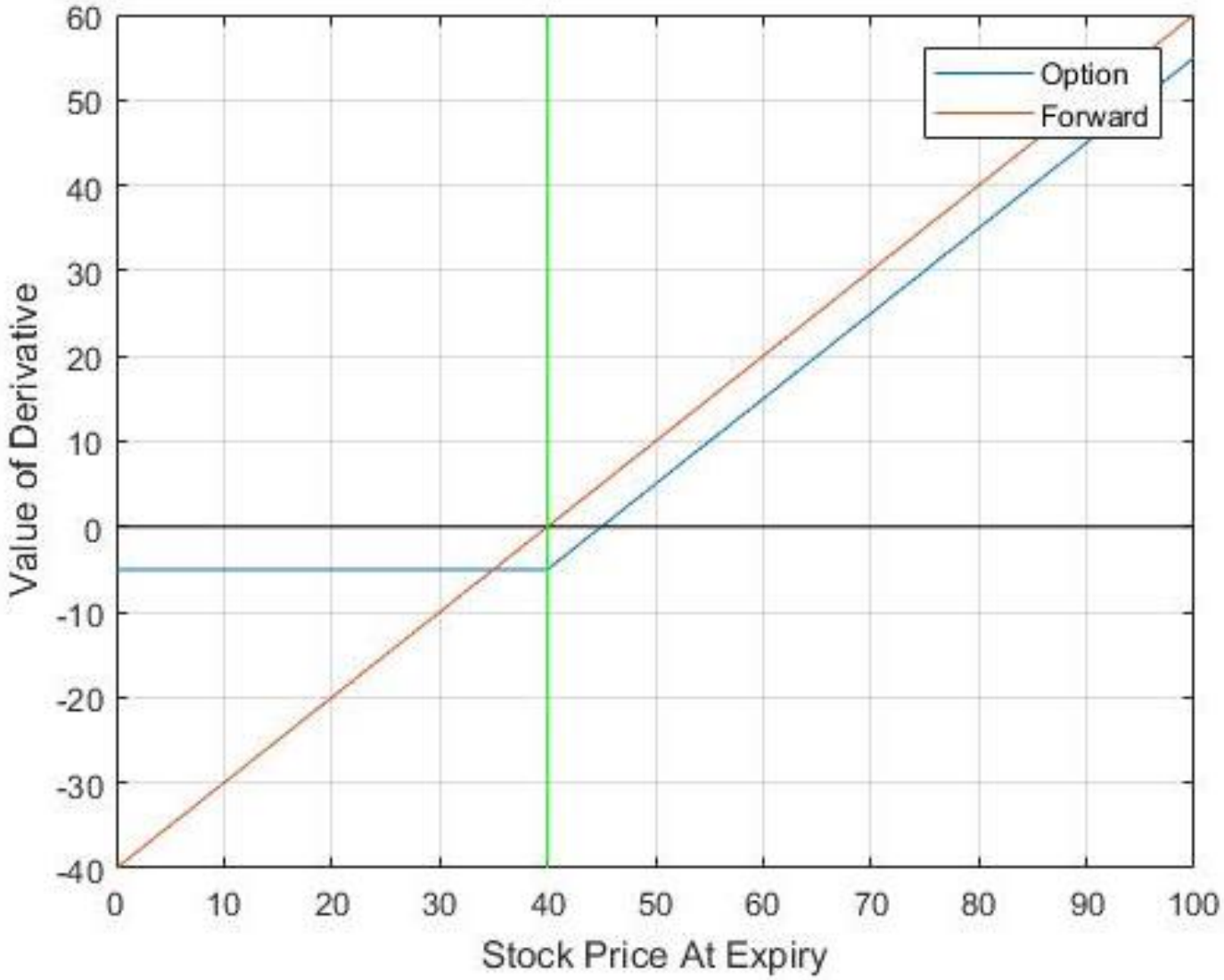
Date: Month Ab, 6th day, **Year-name of King Ammisaduqa** (ca. **1750 BC**)

Key Contract Terms (Derivative-Like Features)

- **Forward delivery obligation:**
  Utul-Ishtar must deliver **healthy Gutian slaves within one month**.
- **Settlement / default clause:**
  If delivery fails, **Lu-Ishurra must repay the silver value** to the bearer of the tablet.

Difference between option and forwards

- A futures/forward contract gives the holder the obligation to buy or sell at a certain price
- An option gives the holder the right to buy or sell at a certain price



Example of option from bible

The Story (Genesis 29)

Jacob agreed to work seven years to marry Rachel, but her father Laban deceived him and gave him Leah instead. Jacob then worked another seven years to finally marry Rachel. A biblical tale that—humorously—resembles an early "option contract" with counterparty default.

Jacob's Option to Marry Rachel – A Humorous Finance Interpretation

- **Underlying Asset:** Rachel
- **Option Premium:** 7 years of labour
- **Contract Type:** *European-style marriage option* (exercise only after 7 years!)
- **Counterparty Risk:** High — Laban defaults and delivers **Leah** instead
- **Settlement:** *Physical delivery* (unexpected underlying!)
- **Recovery:** Jacob negotiates a **second option**, costing another 7 years

Outcome:

- Two wives
- Twelve sons → founders of the Twelve Tribes of Israel
- Substantial **domestic volatility**

Finance Moral:

Even in ancient times, options had premiums, exercise conditions, and default risk — and poor contract enforcement could lead to significant family-level systemic risk.

Yet another option

- *Aristotle (in Politics) recounts how the philosopher Thales demonstrated that thinkers could get rich if they wished.*
- *Anticipating a bumper olive harvest, Thales paid small deposits to secure exclusive rights to all olive presses in Miletus.*
- *When the abundant harvest arrived, demand for presses soared.*
- *Thales sublet the presses at high prices and made a substantial profit.*
- *His strategy effectively created an option:*
  - *Maximum loss = the deposits*
  - *Upside = profit from increased demand*
- *If an exchange existed then, he might have shorted olive futures—but this would have exposed him to unlimited losses if the crop failed.*
- *In essence, Thales engineered an option on a future for a non-storable commodity, 2,500 years before modern derivatives.*

First futures exchange

Japan is credited with creating the first futures exchanges in the modern era. Japan's futures markets can be traced back to 1700s at the Dojima Rice Exchange in Osaka.

Was legalized by Tokugawa Yoshimune

First instance of standardization of forward contracts.

**The Dojima Rice Market and the Origins of Futures Trading*

Harvard Business School

Amsterdam Bourse — The First Organized Securities Market (1602)

The Amsterdam Bourse, established in 1602, is considered the world's first formal stock exchange.

Created by the Dutch East India Company (VOC) to trade its shares and bonds.

Enabled continuous, public trading—a major leap from private merchant agreements.

Developed early financial innovations:

- Forward contracts
- Options
- Short selling

Set the foundation for modern equity markets and global capital flows.

A key milestone in the evolution from commodity trading to organized securities exchanges.

The tulip and the bulb crash, 1634-1637

- Tulips were brought from Turkey to the Netherlands in 1593.
- After some time tulips contracted a nonfatal virus called ‘mosaic’, which did not kill the population but causing ‘flames of colors’.
- This made the flower unique. Thus, tulips began to rise in price. Everyone began to deal in bulbs, essentially speculating on the tulip market.
- The true bulb buyers filled up their inventories, so increasing scarcity and demand.
- Soon prices were rising so fast and high that people were trading their land, life savings to get more tulip bulbs.
- The originally overpriced tulips enjoyed a twenty-fold increase in value - in one month.

One of the first derivative linked crash

- The prices were not an accurate reflection of the value of a tulip bulb.
- This is called a speculative bubble, and typically some people decided to sell and crystallize their profits.
- A domino effect of progressively lower prices took place, as everyone tried to sell while not many were buying.
- Dealers refused to honor contracts and people began to realize that they traded their homes for some bulbs.
- The government attempted to step in and halt the panic and the crash, but that did not work out well.
- Even the people who locked in their profit early suffered under the following depression

A very brief history of mathematics in finance

Jacob Bernoulli (1713): The Expected Value Framework

•**Pioneering Work:** In *Ars Conjectandi*, Jacob Bernoulli introduced rigorous mathematical probability and the concept of **Expected Monetary Value (EV)**.

•**The EV Calculation:** A simple weighted average of all possible outcomes of a gamble or investment:

$$EV = \sum P_i \times O_i$$

The Shortcoming: The St. Petersburg Paradox. When applied to certain risky scenarios, EV theory suggested irrational behavior (e.g., paying an infinite amount to play a simple game). EV failed to explain why people exhibit **risk aversion**.

•**Core Idea:** The framework was mathematically sound but didn't account for how human psychology values money relative to existing wealth.

Daniel Bernoulli (1738): The Utility Hypothesis & EUT

•**The Solution:** Daniel Bernoulli solved his cousin Jacob's paradox in his paper "Exposition of a New Theory on the Measurement of Risk." He argued that individuals value *utility* (satisfaction), not money itself.

•**Diminishing Marginal Utility:** The central insight: the added utility gained from an extra dollar decreases as a person's total wealth increases (e.g., $10,000 means more to a poor person than a rich one).

•**Expected Utility (EU):** Rational decisions maximize

$$EU = \sum P_i \times U(W_i)$$

This theory explains **risk aversion** and forms the bedrock of modern finance and insurance markets.

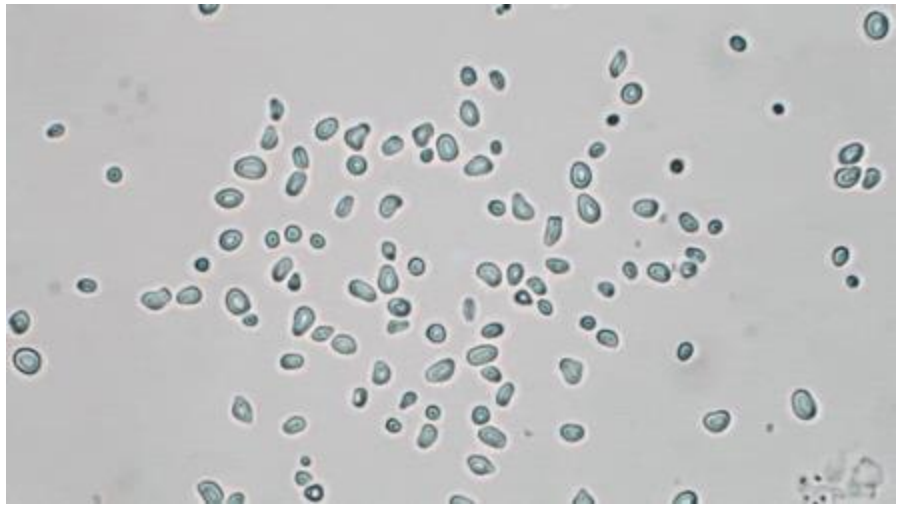
Brownian Motion

Brown (1827)

- Observed the random motion of small particles in a liquid, called it random walk
- Random walk : Now used universally to model unpredictable continuous-time processes.

Einstein (1905)

- Albert Einstein proposed a scientific foundation for Brownian motion in 1905.
- He did some other clever stuff as well.



Bachelier (1900)

- Louis Bachelier was the first to **quantify** the concept of Brownian motion.
- Student of Henry Poincare, he wrote his thesis titled “Theory of speculation”
- Developed a mathematical theory for random walks
- Proposed a model for equity prices, a simple normal distribution, built on it a model for pricing the almost unheard of options.
- His model contained many of the seeds for later work, but lay 'dormant' for many, many years.
- His work was not appreciated during his time.

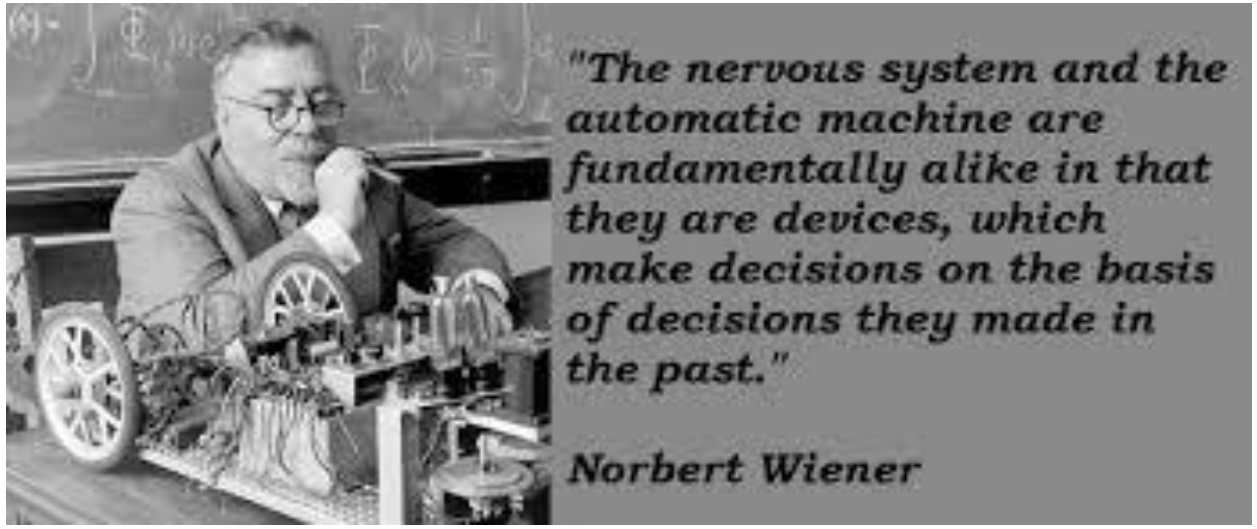
Buried in history

- *But it was not until 1956 that Bachelier's name reappeared in economics, this time, as an acknowledged forerunner, in a thesis on options pricing by a student of MIT economist Paul A. Samuelson.*
- *Bachelier's idea of a "fair game" caught on; and economists recognized the practical virtues of describing markets by the laws of chance and Brownian motion.*
- *They were, in the 1960s and 1970s, put into a broader theoretical framework by Eugene F. Fama. As a student at the University of Chicago, Fama contacted me at IBM and Harvard; I became his thesis adviser, by telephone, mail, and repeated visits. His dissertation was on my views of market dynamics (of which more, later). But we often discussed Bachelier's ideas beyond the model of independent increments, and in subsequent years Fama elaborated them into what is now called the Efficient Markets Hypothesis. It is the intellectual bedrock on which orthodox financial theory today sits. [**Mandelbrot (The misbehavior of Markets)]***

Richardson (1911)

- Most option models result in diffusion-type equations.
- They can be solved either using Monte Carlo schemes, or using finite difference based methods for solving partial differential equations.
- The very first use of the finite-difference method, in which a differential equation is discretized into a difference equation, was by Lewis Fry Richardson in 1911, and used to solve the diffusion equation associated with weather forecasting.
- Richardson later worked on the mathematics for the causes of war. Working on relationship between probability of war and the length of common borders between countries he stumbled upon the concept of fractals
- The fractal nature of turbulence was summed up in his poem ''*Big whorls have little whorls that feed on their velocity, and little whorls have smaller whorls and so on to viscosity*.''

Norbert Wiener (1923)



- Norbert Wiener developed a rigorous theory for Brownian motion.
- The mathematics of which was to become a necessary modelling device for quantitative finance decades later.
- The starting point, the first equation written down in most technical papers, includes the Wiener process as the representation for randomness in asset prices.

- The 1970 Nobel Laureate in Economics, Paul Samuelson, was responsible for setting the tone for subsequent generations of economists.
- Samuelson 'mathematized' both macro and micro economics.
- He rediscovered Bachelier's thesis and laid the foundations for later option pricing theories.
- His approach to derivative pricing was via expectations, real as opposed to the much later risk-neutral ones

Samuelson (1950s)

Ito (1951)

- Kiyosi Ito showed the relationship between a stochastic differential equation for some independent variable and the stochastic differential equation for a function of that variable.
- Some people even think mathematical finance is only about Ito calculus.

Markowitz (1952)

- Harry Markowitz was the first to propose a modern quantitative methodology for portfolio selection (Modern Portfolio Theory)
- His work resulted in novel ideas such as ‘efficiency’ and ‘market portfolios.’
- Diversification: Markowitz showed that combinations of assets could have better properties than any individual assets.
- Diversification was not a new idea, but the mathematics of it was:

  Believe me, no. I thank my fortune for it—
  My ventures are not in one bottom trusted,
  Nor to one place, nor is my whole estate
  Upon the fortune of this present year.
  Therefore, my merchandise makes me not sad.

- The work later won Markowitz a Nobel Prize for Economics

Sharpe, Lintner and Mossin (1963)

- Independently developed a simple model for pricing risky assets.
- This Capital Asset Pricing Model (CAPM) also reduced the number of parameters needed for portfolio selection from those needed by Markowitz's Modern Portfolio Theory, making asset allocation theory more practical.
- *I didn't know how important it would be, but I figured it was probably more important than anything else I was likely to do. I had presented it at the University of Chicago in January 1962, and it had a good reaction there. They offered me a job. That was a good sign. I submitted the article to The Journal of Finance in 1962. It was rejected. Then I asked for another referee, and the journal changed editors. It was published in 1964. It came out and I figured OK, this is it. I'm waiting. I sat by the phone. The phone didn't ring. Weeks passed and months passed, and I thought, rats, this is almost certainly the best paper I'm ever going to write, and nobody cares. It was kind of disappointing. I just didn't realize how long it took people to read journals, so it was a while before reaction started coming in.*

  Sharpe's recollection on publishing CAPM

Eugene Fama (1966)

- Concluded that stock prices were unpredictable and coined the phrase “market efficiency.”
- In a nutshell the idea is that stock market prices reflect all publicly available information, that no person can gain an edge over another by fair means.

Thorp (1968)

- Ed Thorp's first claim to fame was that he figured out how to win at casino Blackjack.
- Ideas that were put into practice by Thorp himself and written about in his best-selling **Beat the Dealer**, the ''book that made Las Vegas change its rules.''
- His second claim to fame is that he invented and built, with Claude Shannon, the information theorist, the world's first wearable computer.
- His third claim to fame is that he was the first to use the 'correct' formulæ for pricing options
- Thorp used these formulæ to make a fortune for himself and his clients in the first ever quantitative finance-based hedge.

Black, Scholes, and Merton (1973)

- Fischer Black, Myron Scholes and Robert Merton derived the Black–Scholes equation for pricing options
- The date corresponded almost exactly with the trading of call options on the Chicago Board Options Exchange.
- Scholes and Merton won the Nobel Prize for Economics in 1997. Black had died in 1995.

<u>Merton (1974)</u>

- Came up with the structural approach for pricing credit risk.
- Credit risk was huge in 1990s and later in 2007 (cause for recession)
- LTCM went bankrupt (had Black and Metron as principals!)

A brief history of Quantitative Finance

Boyle (1977)

- Was the first to demonstrate option price can be obtained using simulations.
- Role of Monte Carlo in finance is immense.

Vasicek (1977)

- So far quantitative finance hadn't had much to say about pricing interest rate products.
- Was first to model a short-term interest rate as a random walk and concluded that interest rate

Cox, Ross, Rubenstien (1979)

- Developed the binomial tree model for pricing options under the Black Scholes framework
- A simple algorithm requiring only addition, subtraction, multiplication and (twice) division. Even MBAs could now join in the fun.

A brief history of Quantitative Finance

Engle (1982)

- In econometrics, *autoregressive conditional heteroskedasticity* (*ARCH*) (Engle, 1982) is a model used for forecasting volatility which captures the conditional heteroscedasticity (serial correlation of volatility) of financial returns.
- Today's conditional variance is a weighted average of past squared unexpected returns. ARCH is an AR process for the variance.

Bollerslev (1986)

- A *generalized autoregressive conditional heteroskedasticity* (*GARCH*) model generalizes the ARCH model.
- Today's conditional variance is a function of past squared unexpected returns and its own past values.
- The model is an infinite weighted average of all past squared forecast errors, with weights that are constrained to be geometrically declining.
- GARCH is an ARMA(p,q) process in the variance.

A brief history of Quantitative Finance

The Appearance of the Smile (1987)

- Before the crash (1987) options on the same stock with the same expiration but with different strikes all had roughly the same implied volatility.
- Thus, even though the implied volatilities changed every day, at least they all moved up or down together for different strikes.
- After the 1987 crash, low-strike index options have higher implied volatilities than higher-strike options.
- When you fit the model to different option strikes, each one implies a different future volatility for the underlying stock.
- But in the model a stock can only have one volatility. Now something is really wrong – the BS model can NOT accommodate different volatilities for the same stock.

Heston (1990s)

- Introduced stochastic volatility to fit the smile and skews observed in the market.

Dupire, Rubinstien, Derman and Kani (1994)

- Came up with local volatility models which could consistently price exotics and vanilla instruments.

CVA and FVA (~2007)

- Outcome of the fall off of Lehman brothers etc during the credit crisis in 2007. Regulation of OTC markets.

References

1. *A stylized history of quantitative finance.* Emanuel Derman
2. *The (Mis)behaviour of Markets. A fractal view of risk, ruin and reward.* Mandelbrot and Hudson
3. *Frequently Asked Questions in Quantitative Finance*: Paul Wilmott
4. *Options, Futures, and Other Derivatives*: John Hull
5. *A brief history of derivatives and securities markets*. E. Weber

Different Shades of Quants

- Front Office Quant:

  A desk Quant works to implement models that are used directly for trading (traders).

- Model Validation Quant:

  Independently develops the pricing models to check the front office models

- Research Quant:

  Develops new pricing models.

- Quant Developer:

  Skilled programmers who develop production ready code, well integrated with other pricing libraries.

- Statistical Arbitrage Quant:

  Finds trends following statistical tools (now machine learning etc), usually engaged with Hedge funds.

- Capital Quant (XVA Quants):

  Works on models to manage the banks future exposure, and therefore capital requirements.

- Portfolio Theorist:

  Works on Markowitz Portfolio kind of problem, and is usually engaged on the ‘buy-side’

Different Shades of Employers

1. Commercial Banks: HSBC, CitiBank
2. Investment Banks: Goldman Sachs
3. Hedge Funds: BlackRock, D.E. Shaw, Alpha Grep
4. Accountancy Firms: EY, Deloitte
5. Software Companies: Thomson Reuters, Bloomberg

A Quant typically is

- Good at programming skills
- Ability to do maths
- Interest in finance

Questions ?