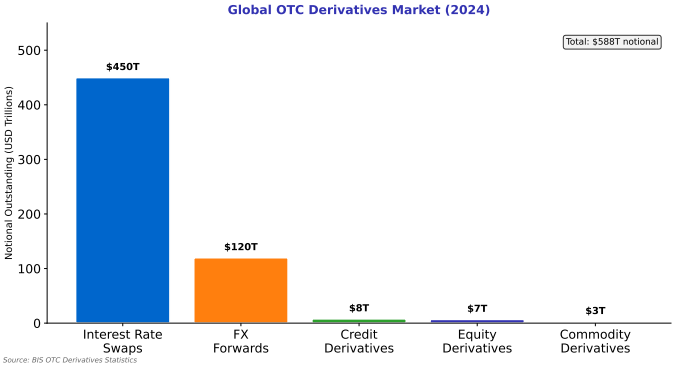
Lesson 45: Derivatives Technology

Mini-Lecture Version (30 min)

Digital Finance

Learning Objectives: Understand derivatives pricing and risk systems architecture — Analyze futures and options trading platforms — Examine OTC derivatives lifecycle and central clearing (CCPs) — Evaluate EMIR and Dodd-Frank technology requirements

Derivatives Notional Outstanding



This concept is fundamental to understanding Derivatives Technology.

Derivatives Market Landscape

Market Size (BIS, June 2024):

- Interest rate derivatives: $530T notional
- FX derivatives: $120T notional
- Equity derivatives: $9T notional
- Credit derivatives: $8T notional
- Exchange-Traded: 45B contracts (2023)

Trading Venues:
Exchange-Traded:

- **CME Group:** Rates, equity indices, commodities, FX
- **Eurex:** European equity and rates derivatives
- **ICE:** Energy, agriculture, financial futures
- **Cboe:** Equity options, VIX futures

OTC:

- Bilateral negotiation (historically)
- SEFs (Swap Execution Facilities) - US
- MTFs (Multilateral Trading Facilities) - EU
- Electronic platforms: Bloomberg SEF, Tradeweb, MarketAxess

Post-2008 trend: 75%+ of interest rate swaps now cleared via CCPs (vs 20% pre-crisis)

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Derivatives Product Types

Futures:

- Standardized exchange-traded contracts
- Daily mark-to-market and margin
- **Financial:** Equity indices (E-Mini S&P), rates (Eurodollar), FX
- **Commodities:** Oil (WTI, Brent), metals (gold), agriculture (corn, wheat)

Options:

- **Call:** Right to buy at strike price
- **Put:** Right to sell at strike price
- **American:** Exercise any time before expiry
- **European:** Exercise only at expiry
- **Exotic:** Barriers, Asians, lookbacks, digitals

Swaps:

- **Interest Rate Swaps (IRS):** Fixed-for-floating (LIBOR/SOFR)
- **Cross-Currency Swaps:** Principal and interest in different currencies
- **Equity Swaps:** Index return vs floating rate
- **Commodity Swaps:** Fixed price vs floating (spot)

Credit Derivatives:

- **CDS (Credit Default Swaps):** Insurance against default
- **Index CDS:** CDX (US), iTraxx (Europe)
- **Tranches:** First-loss, mezzanine, senior

IRS: Most liquid OTC derivative (80%+ of notional outstanding)

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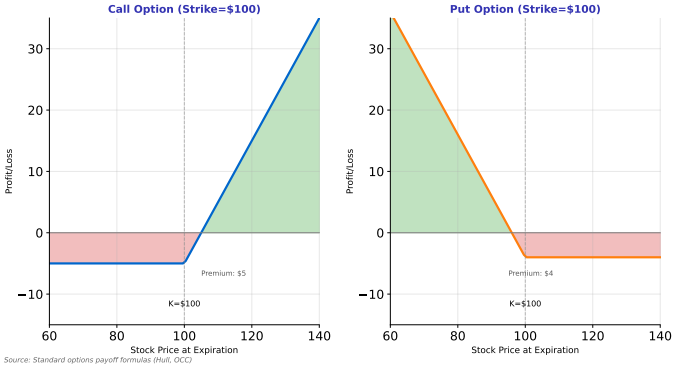
Option Payoff Profiles



Source: Standard options payoff formulas (Hull, OCC)

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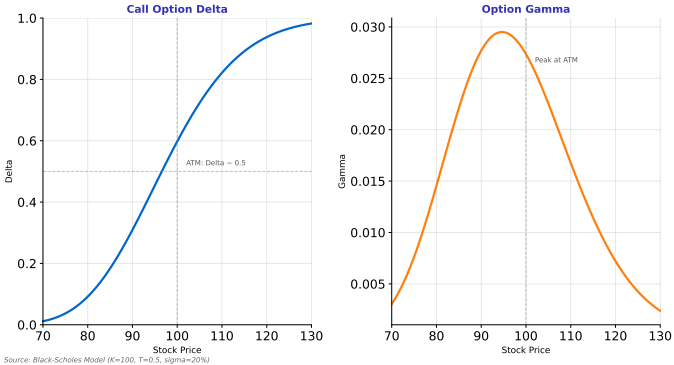
Option Greeks Sensitivity



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Derivatives Pricing Models

Equity Options (Black-Scholes):

$$C = S_0 N(d_1) - K e^{-rT} N(d_2)$$

$$P = K e^{-rT} N(-d_2) - S_0 N(-d_1)$$

where

$$d_1 = \frac{\ln(S_0/K) + (r + \sigma^2/2)T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

Inputs: S_0 = spot price, K = strike, r = risk-free rate, σ = volatility, T = time to expiry

Limitations:

- Constant volatility assumption (implied vol smile/skew observed)
- No early exercise (American options need binomial/FDM)
- No dividends in simple version

Interest Rate Swaps:
Fixed Leg PV:

$$PV_{fixed} = N \times c \times \sum_{i=1}^{n} \tau_i \times DF(t_i)$$

Floating Leg PV:

$$PV_{float} = N \times \sum_{i=1}^{n} F(t_{i-1}, t_i) \times \tau_i \times DF(t_i)$$

where N = notional, c = fixed coupon, τ_i = accrual fraction, $DF(t_i)$ = discount factor, F = forward rate

Par Swap Rate:

$$c = \frac{1 - DF(T_n)}{\sum_{i=1}^{n} \tau_i \times DF(t_i)}$$

Curve Construction:

- Bootstrap discount curve from market instruments (deposits, FRAs, swaps)
- Multi-curve framework post-2008 (OIS discounting vs LIBOR/SOFR projection)

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Greeks and Risk Management

First-Order Greeks:
Delta (Δ): Sensitivity to underlying price

$$\Delta = \frac{\partial V}{\partial S}$$

Call delta: 0 to 1, Put delta: -1 to 0
Vega ($\mathcal{V}$): Sensitivity to volatility

$$\mathcal{V} = \frac{\partial V}{\partial \sigma}$$

Long options: positive vega (benefit from vol increase)
Theta (Θ): Time decay

$$\Theta = \frac{\partial V}{\partial t}$$

Typically negative (options lose value over time)
Rho (ρ): Interest rate sensitivity

$$\rho = \frac{\partial V}{\partial r}$$

Second-Order Greeks:
Gamma (Γ): Curvature of delta

$$\Gamma = \frac{\partial^2 V}{\partial S^2} = \frac{\partial \Delta}{\partial S}$$

Maximum at-the-money, near expiry (high gamma risk)
Vanna: Delta sensitivity to volatility

$$\text{Vanna} = \frac{\partial^2 V}{\partial S \partial \sigma}$$

Volga (Vomma): Vega sensitivity to volatility

$$\text{Volga} = \frac{\partial^2 V}{\partial \sigma^2}$$

Portfolio Greeks Aggregation:

- Sum across positions for linear Greeks (Delta, Vega)
- Gamma concentration risk (short gamma in crash)
- Hedge Greeks dynamically (delta-neutral, vega-neutral)

Addressing these challenges is critical for Derivatives Technology success.

Derivatives Valuation Systems

System Architecture:
Core Components:

- **Trade Capture:** Front-office booking (Murex, Calypso, Summit)
- **Market Data:** Live and historical prices, curves, vols
- **Pricing Library:** Quantitative models (C++/Python)
- **Risk Engine:** Calculate sensitivities and VaR
- **P&L Attribution:** Explain daily P&L by risk factor
- **Valuation Adjustments:** XVA (CVA, FVA, MVA)

Calculation Methods:

- **Closed-Form:** Black-Scholes, bond formulas
- **Lattice:** Binomial/trinomial trees for American options
- **Finite Difference:** PDE solvers for complex derivatives
- **Monte Carlo:** Path-dependent, multi-asset options

Leading Platforms:

- **Murex (Global):** Front-to-risk for derivatives
- **Calypso:** Multi-asset capital markets
- **SunGard (FIS) Adaptiv:** Counterparty risk and CVA
- **Numerix:** Pricing analytics and XVA
- **Bloomberg DLIB:** Derivatives pricing library
- **QuantLib:** Open-source quantitative finance (C++)

Performance Optimization:

- **Grid Computing:** Distribute Monte Carlo simulations
- **GPU Acceleration:** 10-100x speedup for pricing
- **AAD (Adjoint Algorithmic Differentiation):** Fast Greeks
- **Approximations:** Least-squares Monte Carlo, proxy models

Large bank derivatives book: 100k-1M positions, EOD risk calc in 2-4 hours

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Key Takeaways

1. Understand derivatives pricing and risk systems architecture
2. Analyze futures and options trading platforms
3. Examine OTC derivatives lifecycle and central clearing (CCPs)
4. Evaluate EMIR and Dodd-Frank technology requirements

Bottom Line: Derivatives Technology is transforming how financial services operate and compete.

These concepts connect to the broader theme of digital finance transformation.

Derivatives Technology in Visual Perspective

Technology view

Application view

Future view

Visual representations help reinforce key concepts of derivatives technology.

Concrete Examples: Making It Real

Technical Examples

- Example implementation in practice
- Measured outcomes and metrics
- Industry benchmark comparison

Case Study

- Real-world deployment scenario
- Quantifiable results achieved

Industry Leaders

- Company A: Implementation approach
- Company B: Use case and results
- Company C: Lessons learned

Market Data

- Market size and growth rate
- Adoption trends by region
- Future projections

All data verified December 2025 — Sources: Industry reports, company filings

Quiz Questions (1–5)

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A) Increase efficiency B) Reduce costs C) Improve access D) All of the above

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Q10. What is a key takeaway about derivatives technology?
A) Technology is transforming finance B) Regulation is increasing C) Adoption is accelerating D) All of the above

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Q10. What is a key takeaway about derivatives technology?
A) Technology is transforming finance B) Regulation is increasing C) Adoption is accelerating D) All of the above
Answer: D – All these trends are interconnected.