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# Cboe Global Markets

## Options Deep Dive: Mastering Volatility and Trading Strategies

## Unlocking Opportunities and Managing Risks with the Option Greeks


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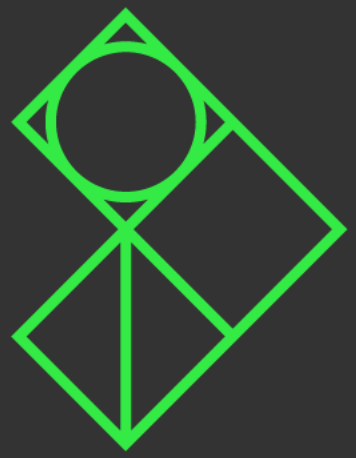
**Capital you invest is at risk**



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# Jose Mosquera

*CIO, Rho Investments*

**Jose Mosquera** is Chief Investment Officer at RHO Investments, an innovative multi-strategy hedge fund based in Madrid and part of the asset management firm Quadriga Asset Managers. Jose has over 28 years of experience in fund management, proprietary trading, and market-making across equities, interest rates, and credit markets—both in cash instruments and derivatives.

Prior to returning to Spain to join Quadriga, Jose held several director-level position in London leading trading teams at prominent financial institutions such as Barclays Capital, UBS, and HSBC.

Jose holds a Master's degree in Finance (MSc in International Securities, Investment and Banking) awarded in 1997 by the ICMA Centre at Henley Business School (UK).

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Options Deep Dive: Mastering Volatility and Trading Strategies

# Unlocking Opportunities and Managing Risks with the Option Greeks

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# Learning Objectives

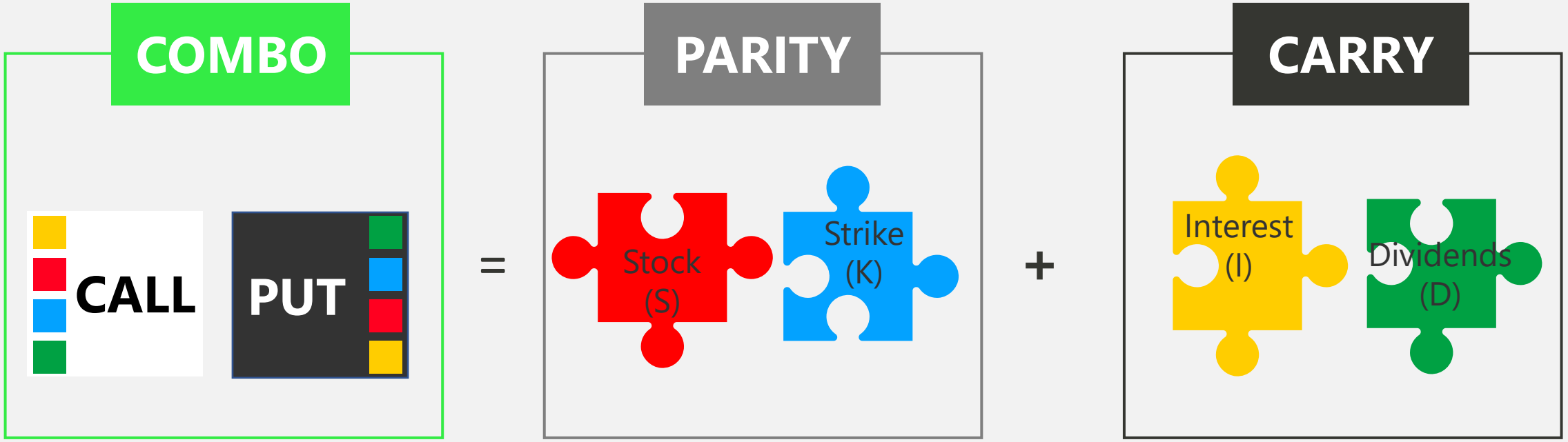
- Explore options trading in Europe and what index and single-stock options are traded in Europe.
- Underscore the key benefits and risks of using options in a portfolio
- Define and explain common risk sensitivity measures (the Greeks)
- Demonstrate utility of the Greeks to manage exposure and risk using a real-life case study

# Why use options?

1. **Income Generation**
2. **Capital Protection**
3. **Risk Management** (hedging)
4. **Efficient Exposure**
5. **Managing Cashflows**

# Put-Call Parity

**(Call – Put) = (Stock – Strike) + (Interest – Dividend)**



# SKILLS DRILL: Put-Call Parity

**Assume a simple interest rate calculation and solve for the values.**

Spot (S) = $102

Strike (K) = $100

Call (C) = $18.50

Put (P) = $13.50

Time to Expiry = 1 year

Interest Rate (int) = 5%

Dividend (dvd) = $2

**What are the values of the following variables?**

1) Parity =

2) Interest =

3) Carry =

4) Parity + Carry =

5) Combo =

**Hint**

(Call – Put) = (S – K) + (I – D)

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**What are the values of the following variables?**

1) Parity = $102 - $100 = **$2**

2) Interest = $100 x 5% = **$5**

3) Carry =

4) Parity + Carry =

5) Combo =

**Hint**

(Call – Put) = (S – K) + (I – D)

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**What are the values of the following variables?**

1) Parity = $102 - $100 = **$2**
2) Interest = $100 x 5% = **$5**
3) Carry = $5 - $2 = **$3**
4) Parity + Carry =
5) Combo =

**Hint**

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4) Parity + Carry = $2 + $3 = **$5**
5) Combo = $18.50 - $13.50 = **$5**

**Hint**

(Call – Put) = (S – K) + (I – D)

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# Black-Scholes Model

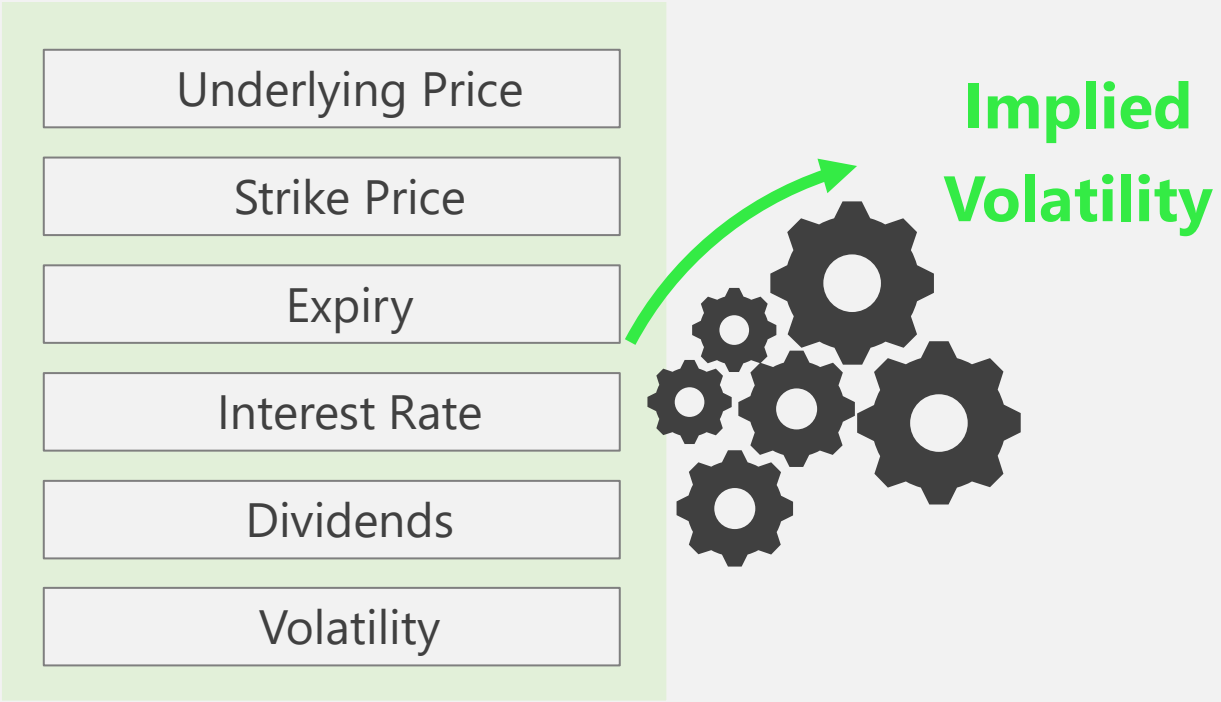
$$C = N(d_1)S_t - N(d_2)Ke^{-rt}$$

$$\text{where } d_1 = \frac{\ln\frac{S_t}{K} + (r + \frac{\sigma^2}{2})t}{\sigma\sqrt{t}}$$

$$\text{and } d_2 = d_1 - \sigma\sqrt{t}$$

**Assumptions**

- Underlying price has a lognormal distribution
  - All moves measured as a % of spot
  - Stock price cannot go below 0
- Volatility is constant
- Continuous hedging
- No arbitrage opportunities
- No transaction costs



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A translation tool between **price** and **implied volatility**.

**Underlying Price**

**Strike Price**

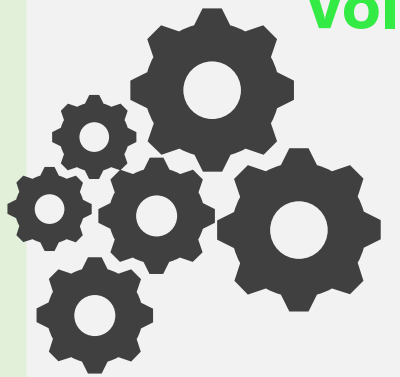
**Expiry**

**Interest Rate**

**Dividends**

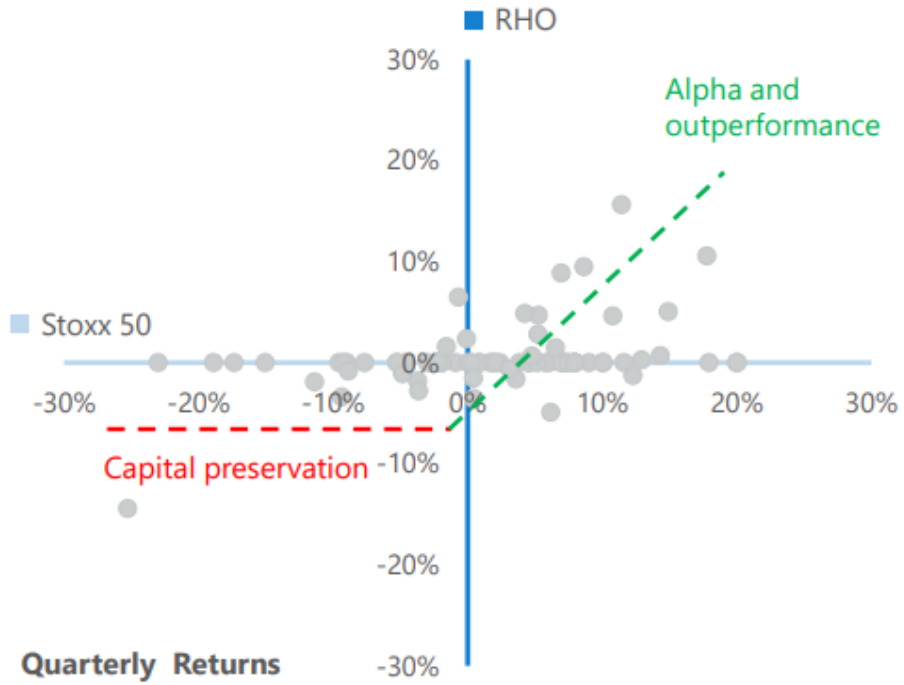
**OPTION PRICE**

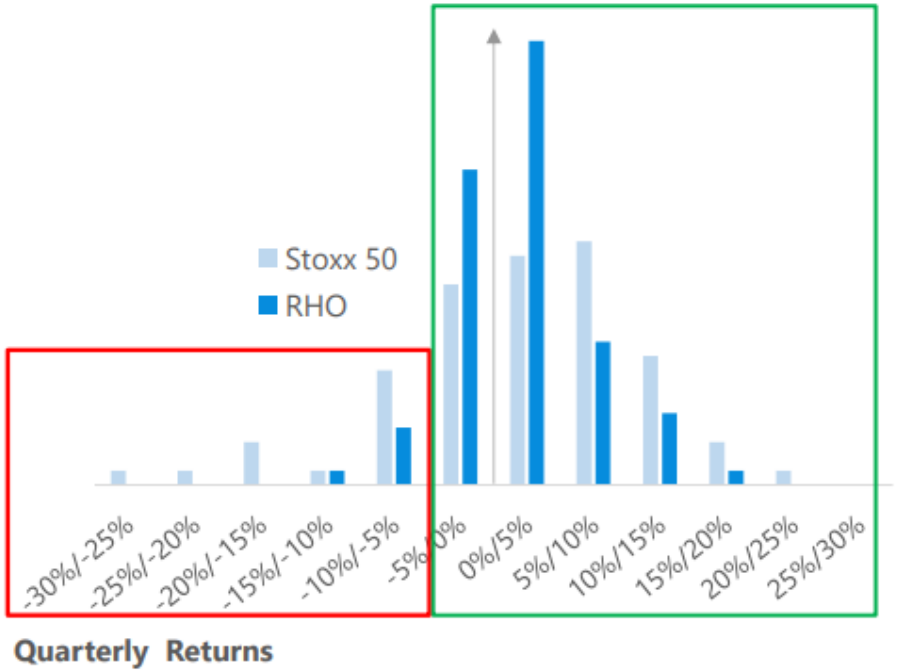
**Implied Volatility**



# Black-Scholes Model: Challenges

- Capital preservation is of essence to best meet long-term investment goals.
- In real life, financial asset returns are not normally distributed: "fat tails". Avoiding negative tails and participating of the positive ones.




*Source: Bloomberg y Quadriga Rho Investments*

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# Black-Scholes Model: Challenges

**XYZ US EQUITY - Implied Volatility Surface [OVML]** — Moneyness View | 28-Apr-2026

| MONEYNESS | 1W | 2W | 1M | 2M | 3M | 6M | 9M | 1Y | 18M | 2Y |
|---|---|---|---|---|---|---|---|---|---|---|
| | 38.2% | 36.8% | 35.1% | 33.6% | 32.0% | 31.2% | 30.8% | 30.5% | 30.2% | 29.8% |
| | 36.5% | 35.0% | 33.4% | 32.0% | 30.5% | 29.8% | 29.4% | 29.1% | 28.9% | 28.5% |
| | 34.1% | 32.8% | 31.3% | 30.0% | 28.6% | 28.0% | 27.7% | 27.4% | 27.2% | 26.9% |
| | 31.8% | 30.6% | 29.2% | 28.0% | 26.8% | 26.2% | 26.0% | 25.8% | 25.6% | 25.4% |
| | 29.8% | 28.7% | 27.4% | 26.4% | 25.2% | 24.8% | 24.6% | 24.5% | 24.3% | 24.2% |
| | 28.2% | 27.2% | 26.0% | 25.2% | 24.1% | 23.8% | 23.6% | 23.5% | 23.4% | 23.2% |
| | 27.0% | 26.1% | 25.0% | 24.3% | 23.3% | 23.0% | 22.9% | 22.8% | 22.7% | 22.6% |
| | 26.1% | 25.3% | 24.3% | 23.7% | 22.8% | 22.6% | 22.4% | 22.3% | 22.2% | 22.1% |
| | 25.5% | 24.8% | 23.9% | 23.4% | 22.5% | 22.3% | 22.2% | 22.1% | 22.0% | 21.9% |

SPOT REF: 148.72 | ATM IV (1M): 25.2% | SKEW (25d): +2.1 | TERM: CONTANGO | IV RANK: 71 | HV30: 28.4%

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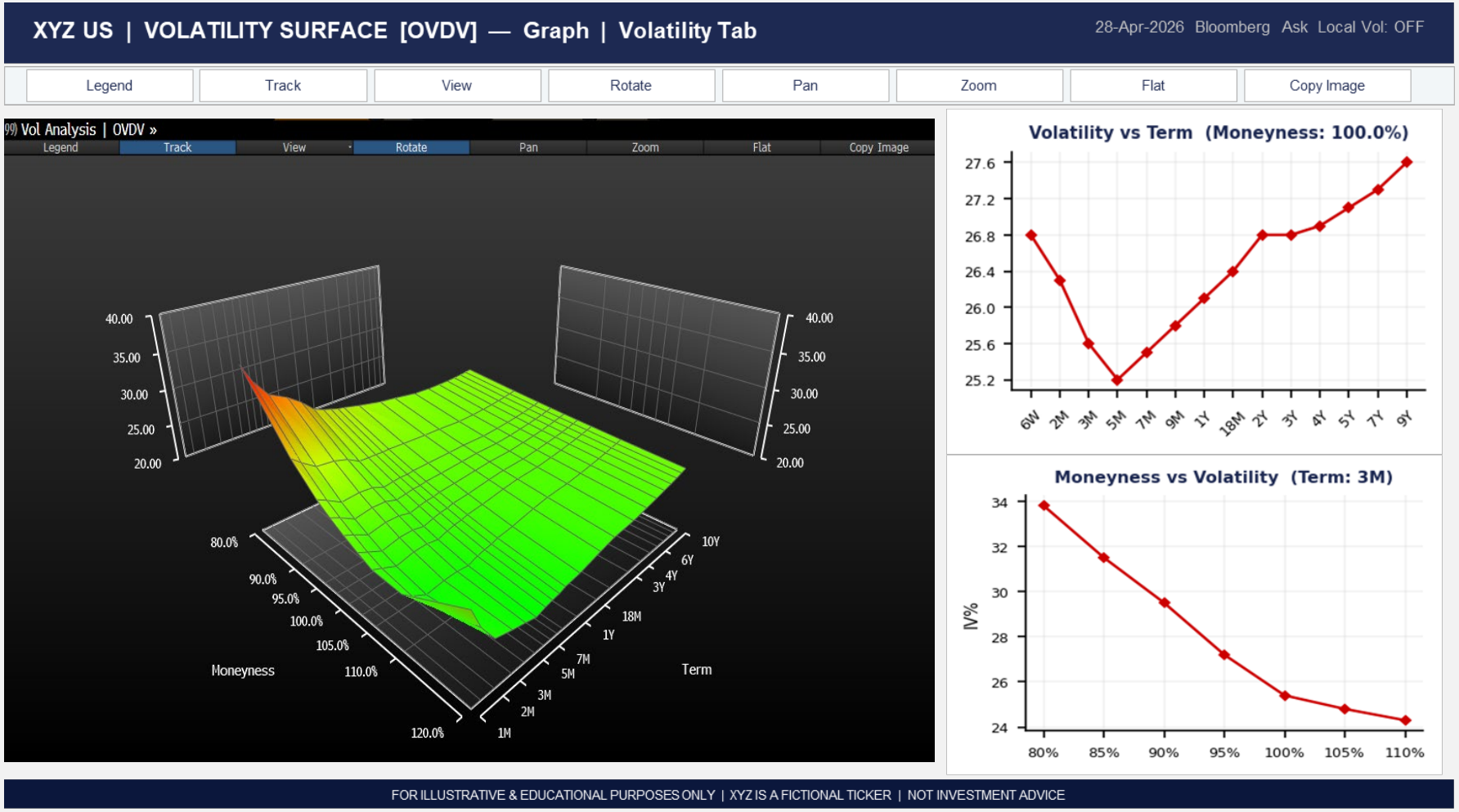
# Black-Scholes Model: Challenges

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# Black-Scholes Model: Challenges

**XYZ US EQUITY - Options Chain [OPCH]** 28-Apr-2026 15:43:22 ET LIVE

| LAST | CHG | BID | ASK | VOL | IV RANK | HV30 | 52W H | 52W L |
|---|---|---|---|---|---|---|---|---|
| 148.72 | v -2.34 (-1.55%) | 148.70 | 148.74 | 4,821,300 | 71 | 28.4% | 187.45 | 121.08 |

**16-May-2026** | 20-Jun-2026 | 18-Jul-2026 | 19-Sep-2026 | 19-Dec-2026 | Jan-2027 LEAP

| OI | VOL | DELTA | BID | ASK | IV% | LAST | STRIKE | LAST | IV% | BID | ASK | DELTA | OI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3,241 | 812 | 0.91 | 23.40 | 23.60 | 31.2% | 23.50 | 120 | 0.08 | 33.1% | 0.07 | 0.09 | -0.09 | 892 |
| 4,108 | 943 | 0.86 | 18.90 | 19.10 | 30.8% | 19.00 | 125 | 0.14 | 32.7% | 0.13 | 0.15 | -0.13 | 1,204 |
| 5,872 | 1,341 | 0.80 | 14.60 | 14.80 | 30.1% | 14.70 | 130 | 0.28 | 31.9% | 0.27 | 0.30 | -0.20 | 2,341 |
| 6,210 | 2,104 | 0.72 | 10.70 | 10.90 | 29.6% | 10.80 | 135 | 0.55 | 31.2% | 0.53 | 0.57 | -0.29 | 3,108 |
| 8,341 | 3,822 | 0.63 | 7.40 | 7.60 | 29.1% | 7.50 | 140 | 1.05 | 30.8% | 1.03 | 1.08 | -0.38 | 4,210 |
| 11,204 | 5,931 | 0.53 | 4.70 | 4.90 | 28.7% | 4.80 | 145 | 2.10 | 30.1% | 2.08 | 2.13 | -0.48 | 6,341 |
| 14,872 | 8,204 | 0.44 | 2.75 | 2.85 | 28.4% | 2.80 | 150 | < ATM 3.90 | 29.8% | 3.85 | 3.95 | -0.57 | 9,104 |
| 9,341 | 4,108 | 0.34 | 1.45 | 1.55 | 28.9% | 1.50 | 155 | 6.20 | 30.2% | 6.15 | 6.30 | -0.66 | 7,832 |
| 7,204 | 2,341 | 0.25 | 0.68 | 0.74 | 29.4% | 0.71 | 160 | 9.30 | 30.9% | 9.25 | 9.40 | -0.75 | 5,210 |
| 4,108 | 1,204 | 0.17 | 0.28 | 0.34 | 30.1% | 0.31 | 165 | 13.10 | 31.6% | 13.05 | 13.20 | -0.83 | 3,108 |
| 2,341 | 841 | 0.10 | 0.10 | 0.14 | 30.9% | 0.12 | 170 | 17.40 | 32.4% | 17.30 | 17.50 | -0.89 | 1,841 |
| 1,204 | 412 | 0.05 | 0.03 | 0.06 | 31.8% | 0.04 | 175 | 22.10 | 33.2% | 22.00 | 22.20 | -0.94 | 1,024 |

DTE: 18 | IV RANK: 71 | HV30: 28.4% | P/C RATIO: 0.87 | TOTAL OI: 112,340 | PUT SKEW: +2.1 | TERM STRUCT: CONTANGO

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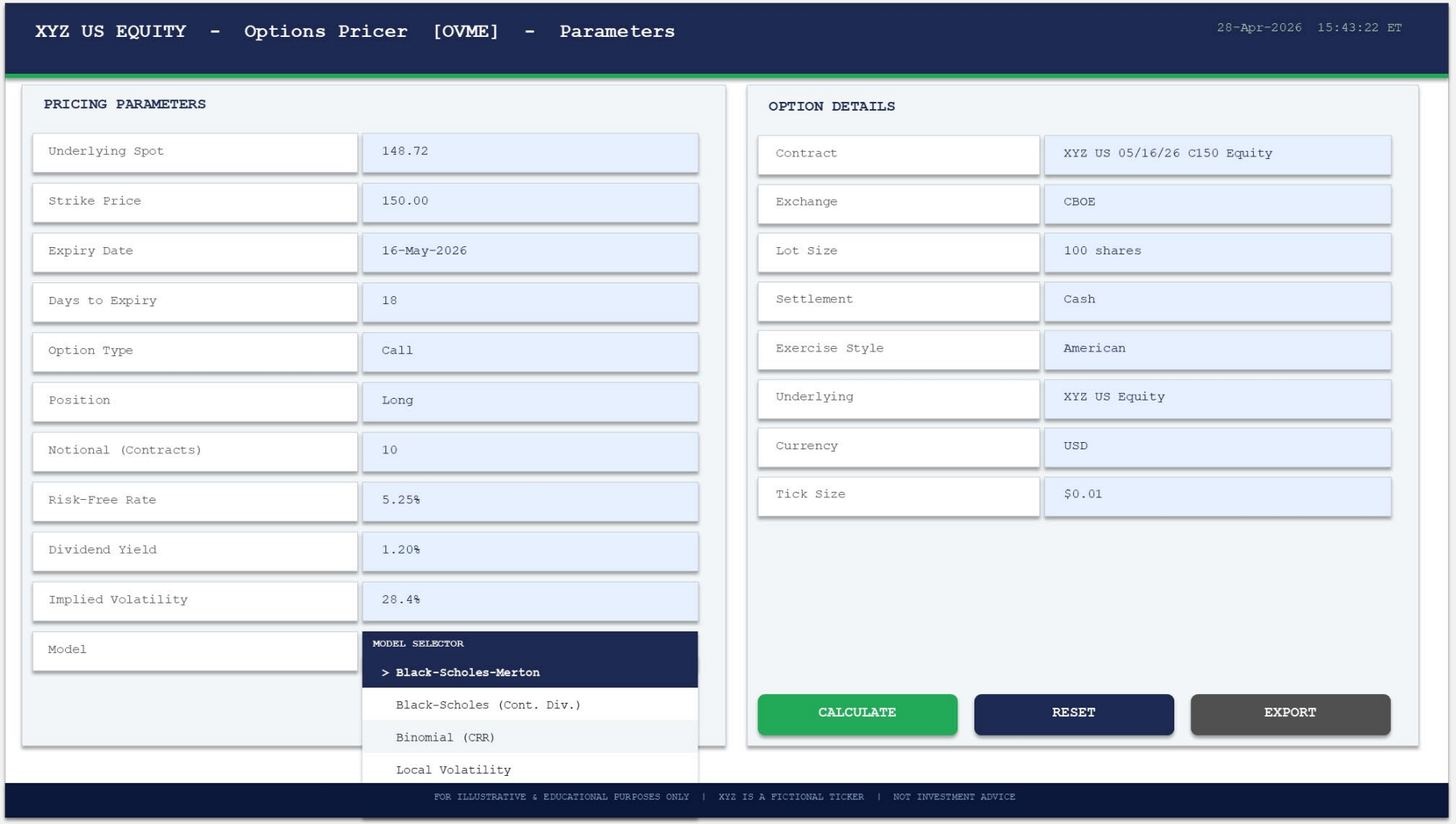


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# Black-Scholes Model: Challenges

**XYZ US EQUITY - Options Pricer [OVME] - Results** 28-Apr-2026 15:43:22 ET

**PRICING PARAMETERS**

| | |
|---|---|
| Underlying Spot | 148.72 |
| Strike | 150.00 |
| Expiry | 16-May-2026 |
| DTE | 18 |
| Type | Call - Long |
| Contracts | 10 |
| Risk-Free Rate | 5.25% |
| Div Yield | 1.20% |
| Impl. Vol | 28.4% |
| Model | Black-Scholes-Merton |

**PRICING RESULTS**

| | |
|---|---|
| Price (Per Contract) | $2.80 |
| Price (Per Share) | $0.0280 |
| Price (%) | 1.88% |
| Position Cost (10 cts) | $2,800.00 |
| Intrinsic Value | $0.00 |
| Time Value | $2.80 |
| Max Profit | Unlimited |
| Max Loss | -$2,800.00 |

**GREEKS SNAPSHOT (ATM CALL - 150 Strike)**

| | | |
|---|---|---|
| **Delta** | **0.44** | *Directional exposure* |
| Gamma | 0.048 | *Rate of delta change* |
| Theta | -0.089 | *Daily time decay ($/day)* |
| Vega | 0.312 | *IV sensitivity (per 1% move)* |
| Rho | 0.041 | *Rate sensitivity* |

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# The “Greeks”

- Risk management tools for measuring the overall impact of specific variables on an option’s price.
- Describe the risk and potential reward of an option position or portfolio of positions.

# The Greeks

## XYZ US EQUITY - Greeks Reference Panel [GREC]

28-Apr-2026 | Strike 150 ATM Call

### FIRST-ORDER GREEKS

| GREEK | SYMBOL | VALUE | DESCRIPTION |
|---|---|---|---|
| Delta | Δ | 0.44 | Sensitivity to underlying price change |
| Gamma | Γ | 0.048 | Rate of change of delta |
| Theta | Θ | -0.089 | Time decay - daily P&L erosion |
| Vega | ν | 0.312 | Sensitivity to 1% change in implied vol |
| Rho | ρ | 0.041 | Sensitivity to 1% change in risk-free rate |
| Lambda | λ | 3.21 | Percentage leverage / elasticity |

### ADVANCED GREEKS

| GREEK | SYMBOL | VALUE | DESCRIPTION |
|---|---|---|---|
| Charm | dΔ/dt | -0.0032 | Delta decay per calendar day |
| Vanna | dΔ/dσ | 0.0215 | Delta change per 1% IV change |
| Volga | dν/dσ | 0.0184 | Vega sensitivity to IV change |
| Speed | dΓ/dS | -0.0008 | Gamma change per $1 underlying move |
| Color | dΓ/dt | 0.0019 | Gamma decay per calendar day |
| Zomma | dΓ/dσ | 0.0041 | Gamma sensitivity to IV change |
| Ultima | dv3/dσ3 | -0.0012 | 3rd derivative of value w.r.t. vol |
| DvegaDtime | dV/dt | -0.0028 | Vega decay per calendar day |
| Phi / Rho2 | Φ | -0.038 | Sensitivity to dividend yield |
| Epsilon | ε | 0.0041 | Sensitivity to foreign interest rate |

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*The options chain, ticker, price data, and all market scenarios depicted here are entirely fictional and hypothetical. XYZ is a made-up stock ticker and does not represent any real company, security, or financial instrument. All prices, Greeks, implied volatility figures, open interest, and volume data are simulated for educational illustration only. Past performance and hypothetical scenarios are NOT indicative of future results. The illustrative returns, Greeks, and volatility metrics are constructed for instructional purposes only and may not reflect real-world conditions. Always consult a qualified financial professional before making any investment decisions.*

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# The Greeks

**STOCK**

**XYZ**
**$125.46**

**Delta** Δ

**Gamma** Γ

**Theta** Θ

**Vega** ν

**Rho** ρ

**PnL** $

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# The Greeks

| STOCK |
| --- |
| XYZ<br>$125.46 |

## Delta Δ

RISK: Underlying asset price

DEFINITION: The change in the price of an option for a $1 change in the price of the underlying asset.

CHARACTERISTICS:

- Represents % exposure to the underlying
- Long asset = 100 Δ, Short asset = (100) Δ
- Call Δ = positive, Put Δ = negative
- ATM options are 50 Δ
- Slope of the payout diagram = DELTA
- Delta is not constant

**Combo Δ =**
Call Δ – Put Δ = 100 Δ

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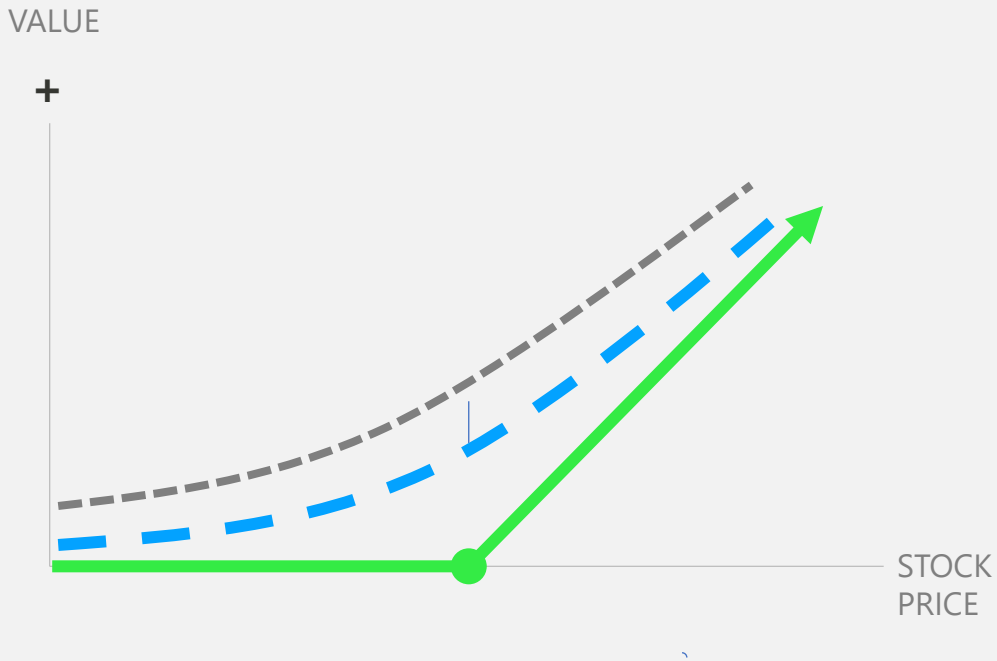
# Delta: Call Option




**T = 3 months**

**T = 1 month**

**T = 0**

**NOTE**

At expiration DELTA converges to either 1 or 0.

# SKILLS DRILL: Delta

**If the spot increases from $106 to $108, what is the estimated value of the call option?**

Spot (S) = $106

Strike (K) = $105

Call (C) = $4.20

Put (P) = $2.15

Time to Expiry = 1 year

Interest Rate (int) = 1%

Dividend (dvd) = $0

Δ = .55

*Assume gamma = 0*

**Hint:** Change in stock price x Delta

# SKILLS DRILL: Delta

**If the spot increases from $106 to $108, what is the estimated value of the call option?**

Spot (S) = $106

Strike (K) = $105

Call (C) = $4.20

Put (P) = $2.15

Time to Expiry = 1 year

Interest Rate (int) = 1%

Dividend (dvd) = $0

Δ = .55

*Assume gamma = 0*

**Change in stock price** = ($108 - $106) = $2

**Delta** = .55

.55 x 2 = $1.10

**New estimated call price = $5.30**

# SKILLS DRILL: Delta

**If the spot increases from $106 to $108, what is the estimated value of the call option?**

Spot (S) = $106

Strike (K) = $105

Call (C) = $4.20

Put (P) = $2.15

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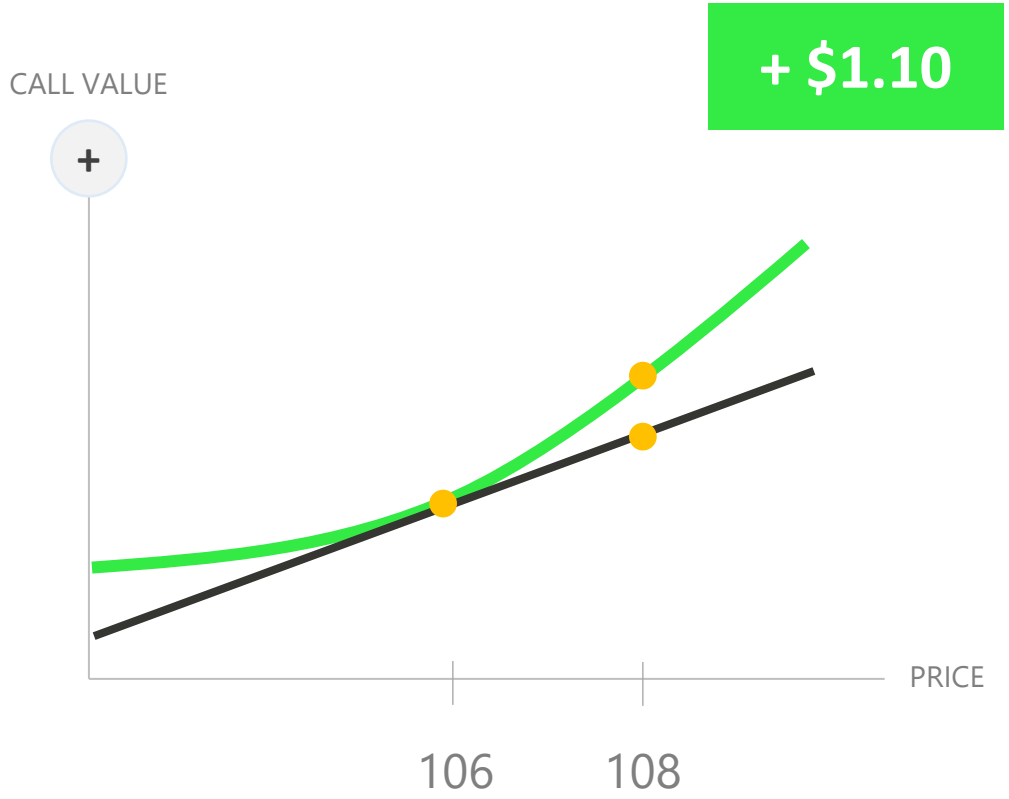
*Assume gamma = 0*




**+ $1.10**

# DELTA

- **Measures the change in the price of an option caused by a $1 change in the price of the underlying.**
- **Delta is NOT constant.**
  - Delta of a call option is always positive.
  - Delta of a call varies between 0 (OTM) and 100 (ITM).
  - Delta of a put option is always negative.
  - Delta of a put varies between -100 (ITM) to 0 (OTM).
  - ATM options are 50 Δ.
  - Call Δ – Put Δ = 100 Δ

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# The Greeks

| STOCK |
| --- |
| XYZ<br>$125.46 |

## Gamma Γ

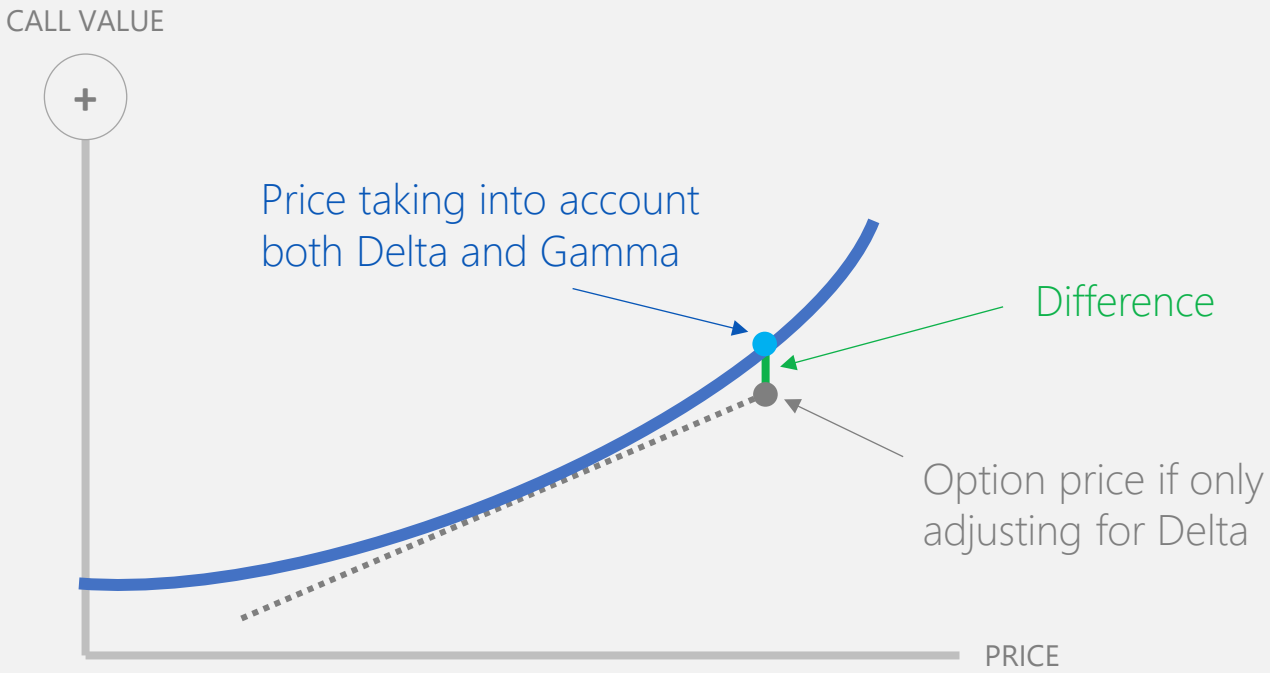
RISK: Underlying asset price

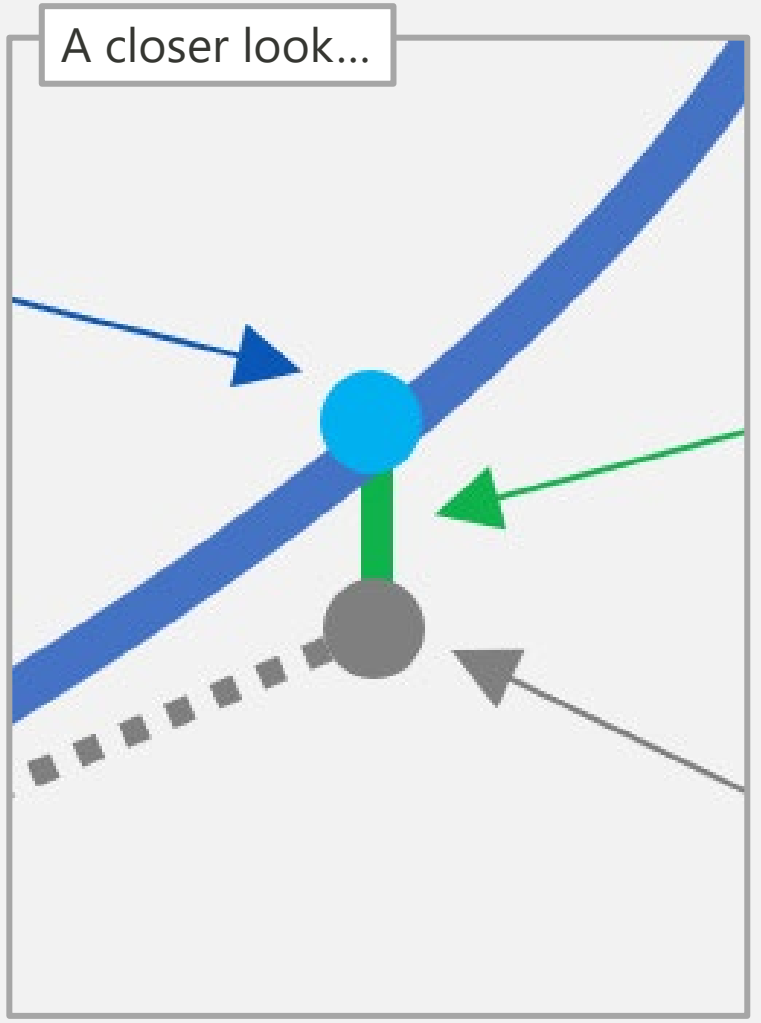
DEFINITION: The **change in DELTA for a $1 change in the price of the underlying** asset.

CHARACTERISTICS:

- Gamma is the same for calls and puts.
- Options buyers are “long” gamma
- Options sellers are “short” gamma
- Gamma is greatest for ATM options

# Gamma: Call Option



# SKILLS DRILL: Gamma

## If the spot increases from $106 to $108, what is delta of the call option?

Spot (S) = $106

Strike (K) = $105

Call (C) = $4.20

Put (P) = $2.15

Time to Expiry = 1 year

Interest Rate (int) = 1%

Dividend (dvd) = $0

Δ = .55

Γ = .04

**Hint:** Change in Delta = Change in Price x Gamma

# SKILLS DRILL: Gamma

## If the spot increases from $106 to $108, what is delta of the call option?

Spot (S) = $106

Strike (K) = $105

Call (C) = $4.20

Put (P) = $2.15

Time to Expiry = 1 year

Interest Rate (int) = 1%

Dividend (dvd) = $0

Δ = .55

Γ = .04

**Gamma** = .04
**Change in price** = ($108 - $106) = $2

**Starting delta** = .55

**Change in delta** = change in price x gamma
= 2 x .04
= .08

**New delta** = .55 + .08 = 0.63 or **63 Δ**

**Hint:** Change in Delta = Change in Price x Gamma

# GAMMA

- **Measures the change in DELTA caused by a $1 change in the price of the underlying.**
  - Gamma is positive for option buyers.
  - Gamma is negative for option sellers.
  - Gamma value for calls and puts (same strike, same expiry) is identical.
  - Gamma is greatest for at-the-money options.

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# The Greeks

| STOCK |
| --- |
| XYZ<br>$125.46 |

## Theta Θ

RISK: Time

DEFINITION: The change in the price of an option given a **decrease in time to expiration**.

CHARACTERISTICS:

- Daily decay of option premium.
- Theta is always negative, there is a continuous loss of value.
- As time passes, the likelihood an option expires ITM decreases.
- OTM and ITM options have similar decay profiles.
- **Think of theta as the gamma rent you pay or collect for your position.**

# THETA

Think of theta as the **gamma rent** you pay or collect for your position.

**Θ = 40.9**

**Thursday 7am**

**Option price = $12.66**


**Thursday end of day**

**Option price = ?**

**Hint:** Theta = Option price – Decay

# THETA

**Θ = 40.9**

**Thursday 7am**

**Option price = $12.66**


**Thursday end of day**

**Option price = ?**

**$12.66 – (1 day of decay) = end of day price**

**$12.66 – $0.409 = $12.251**

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# The Greeks

| STOCK |
| --- |
| XYZ<br>$125.46 |

## Rho ρ

RISK: Risk-free interest rate

DEFINITION: The change in the price of an option given a 1% change in the **risk-free interest rate**.

CHARACTERISTICS:

- Rising interest rates increase the value of carry.
- Rising combo values increase call values and decrease put values.

**C – P = (Stock - Strike) + (int – dvd)**

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# The Greeks

| STOCK |
| --- |
| XYZ<br>$125.46 |

## Rho ρ

The **risk-free interest rate** is the interest an investor could expect from a completely riskless investment over a specific period of time. It shows us an alternate, hypothetical return on our capital if we did not invest it in options.

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# The Greeks

| STOCK |
| --- |
| XYZ<br>$125.46 |

## Rho ρ

RISK: Risk-free interest rate

DEFINITION: The change in the price of an option given a 1% change in the **risk-free interest rate**.

CHARACTERISTICS:

- Rising interest rates increase the value of carry.
- Rising combo values increase call values and decrease put values.

**C – P = (Stock - Strike) + (int – dvd)**

ρ

# RHO

ρ = 5.7

**Interest rate = 1.5%**

**Call Option price = $12.66**

**Interest rate = 3.5%**

**Call Option price = ?**

**Hint:** Option price + (Change in Interest Rate x Rho)

ρ

# RHO

**Interest rate = 1.5%**

**Call Option price = $12.66**

**Interest rate = 3.5%**

**Call Option price = ?**

**$12.66 + (change in int rate x ρ) = ?**

ρ

# RHO

ρ = 5.7

Interest rate = 1.5%

**Call Option price = $12.66**

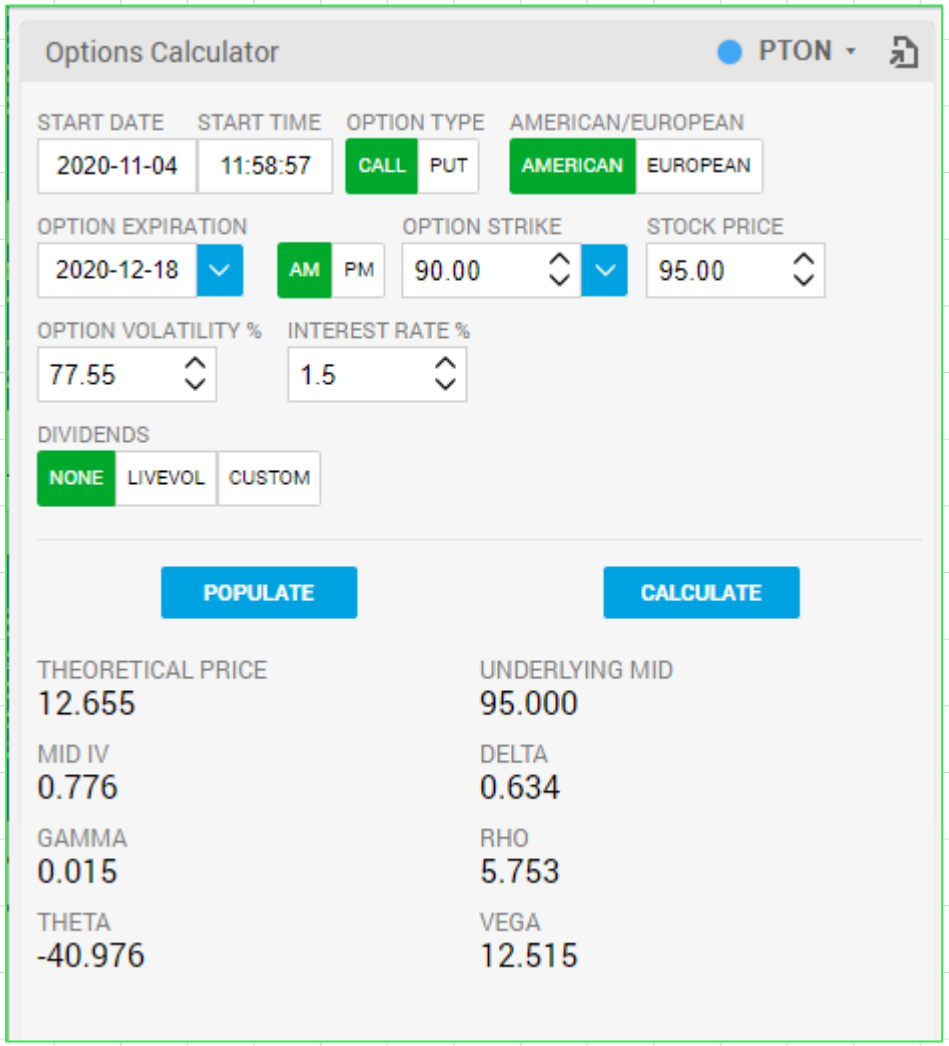
Interest rate = 3.5%

**Call Option price = ?**

$12.66 + (change in int rate x ρ) = ?

$12.66 + (2 x $0.057) = $12.774

# SKILLS DRILL: Options Calculator




1. What is the price of XYZ Dec 90 call?
2. What volatility level was used to calculate the theoretical price of the call?
3. What is the delta of the XYZ Dec 90 call option?
4. What is the delta of the XYZ Dec 90 put option?
5. If XYZ stock moves from $95 to $94, what is the delta of the option?
6. How much value does the option lose each day due to decay?

**Cboe.com/OI-LiveVolTrial**

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# The Greeks

| STOCK |
| --- |
| XYZ<br>$125.46 |

## Vega ν

RISK: Volatility

DEFINITION: The change in the price of an option given a 1% change in the **implied volatility of the underlying asset**.

CHARACTERISTICS:

- Higher daily moves in underlying = higher volatility
  - Higher implied vol increases option value.
  - Higher implied vol increases value of long gamma.
  - Long-term options have greater sensitivity to implied vol (they have more vega).

# VEGA

$\nu = 12.5$

**Implied Vol = 77**

**Option price = $12.66**

**Implied Vol = 76**

**Option price = ?**

**Hint:** Option price - (Change in Volatility x Vega)

ν

# VEGA

ν = 12.5

Implied Vol = 77

Option price = $12.66

Implied Vol = 76

Option price = ?

$12.66 – (change in vol x ν ) = ?

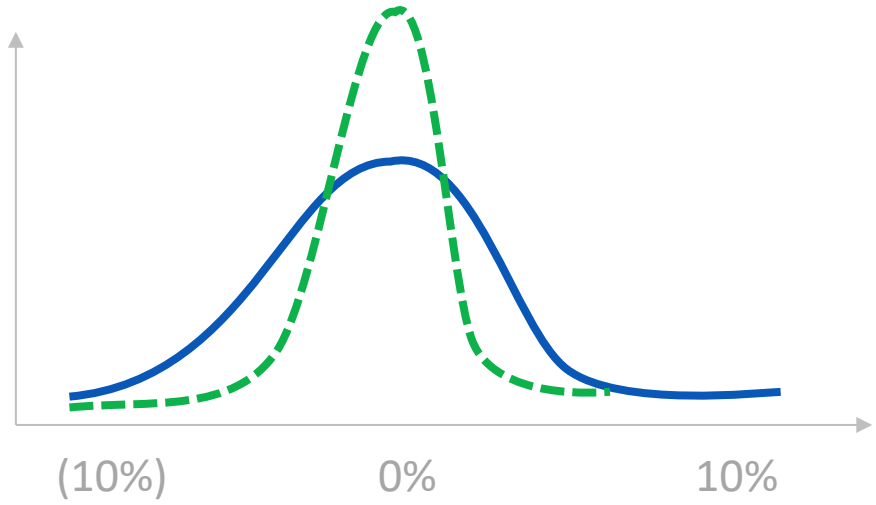
$12.66 – (1 x $0.125) = $12.535

# VEGA

- **The change in the price of an option price due to a 1% change in the implied volatility of the underlying**

**Volatility** is the measure of possible values of the underlying. It is the standard deviation of the stock returns, assuming a normal distribution.

$$\sqrt{Variance} = \sigma$$



# Q&A

# Thank you!

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