### 📚 **Black-Scholes Model and “Greeks” Learning Guide**

#### Combining Theory and Interactive Experimentation

### **1. Introduction to the Black-Scholes Model**

#### **1.1 What is the Black-Scholes Model?**

The Black-Scholes model is a mathematical framework developed in 1973 to calculate the **theoretical price of European options** (options that can only be exercised at expiration). It revolutionized financial markets by providing a systematic way to value derivatives.

#### **1.2 Key Assumptions**

The model relies on these assumptions:

1. **Efficient markets**: No arbitrage opportunities.
2. **Constant volatility (σ) and risk-free rate (r)**.
3. **No dividends**: The underlying asset pays no dividends.
4. **Lognormal distribution**: Asset prices follow a geometric Brownian motion (no jumps).

#### **1.3 The Formula**

For a **call option**:

For a **put option**:

Where:

* : Cumulative distribution function (CDF) of the standard normal distribution.

#### **1.4 The Greeks**

The Greeks measure how sensitive an option’s price is to changes in key variables:

* **Delta (Δ)**: Sensitivity to the underlying asset’s price.
* **Gamma (Γ)**: Sensitivity of Delta to the asset’s price.
* **Theta (Θ)**: Sensitivity to time decay.
* **Vega (ν)**: Sensitivity to volatility.
* **Rho (ρ)**: Sensitivity to interest rates.

### **2. Hands-On Learning with the Interactive Tool**

#### **2.1 Setup Instructions**

(This will work, but for more information on **how to properly install** the tool, namely using a virtual environment, using VS Code, **please see the README file.**)

1. **Install Python Libraries**:

* pip install streamlit numpy scipy matplotlib

1. **Save the Code**: Copy the [English version of the code](https://chat.openai.com/c/1863e566-8d8c-4f3f-9b8a-0f9b4d1b9e9d) into a file named black\_scholes\_greeks\_en.py.
2. **Run the App**:

* streamlit run black\_scholes\_greeks\_en.py

#### **2.2 Interface Overview**

* **Sidebar**: Adjust parameters using sliders.
* **Main Panel**:
  + **Option Price**: Dynamically calculated.
  + **Greeks Table**: Shows Delta, Gamma, Theta, Vega, and Rho.
  + **Interactive Plot**: Visualizes how a selected Greek varies with the asset price.

### **3. Step-by-Step Tutorial**

#### **3.1 Basic Experimentation**

1. **Adjust the Asset Price (S)**:
   * Move the slider from €50 to €150.
   * **Observe**:
     + The option price increases for calls (and decreases for puts) as rises.
     + **Delta** approaches 1 for deep ITM calls and -1 for deep ITM puts.
2. **Change Volatility (σ)**:
   * Increase volatility from 0.2 to 0.8.
   * **Observe**:
     + Both call and put prices rise (higher uncertainty = higher option value).
     + **Vega** is positive for all options.
3. **Time Decay (Theta)**:
   * Reduce time to expiry () from 2 years to 0.1 years.
   * **Observe**:
     + **Theta** becomes more negative as expiry approaches (accelerated time decay).

#### **3.2 Exploring the Greeks**

1. **Delta (Δ)**:
   * Select "Delta" in the dropdown.
   * **Key Insight**:
     + Delta measures the slope of the option price curve.
     + For calls, Delta ranges from 0 (OTM) to 1 (ITM).
2. **Gamma (Γ)**:
   * Select "Gamma" and set .
   * **Key Insight**:
     + Gamma peaks near the strike price, indicating maximum sensitivity of Delta to .
3. **Vega (ν)**:
   * Select "Vega" and increase .
   * **Key Insight**:
     + Vega is highest for at-the-money (ATM) options.

### **4. Exercises for Mastery**

#### **Exercise 1: Impact of Strike Price (K)**

1. Set , (ATM).
2. Gradually increase to 120 (OTM call).
3. **Observe**:
   * Call price decreases, and Delta approaches 0.
   * Put price increases, and Delta approaches -1.

#### **Exercise 2: Interest Rates (Rho)**

1. Set , then increase to 10%.
2. **Observe**:
   * **Rho** is positive for calls (higher rates boost call prices).
   * **Rho** is negative for puts (higher rates reduce put prices).

#### **Exercise 3: Extreme Volatility**

1. Set (100% volatility).
2. **Observe**:
   * Even OTM options have significant value due to high uncertainty.

### **5. Real-World Scenarios**

#### **Scenario 1: Earnings Announcement**

* **Setup**: High volatility (), short time ().
* **Observation**:
  + **Theta** is highly negative (rapid time decay).
  + **Vega** dominates the option’s value.

#### **Scenario 2: Low-Rate Environment**

* **Setup**: , , (OTM put).
* **Observation**:
  + **Rho** is small but negative (low rates have minimal impact on puts).

### **6. Limitations and Practical Notes**

1. **Assumption Violations**:
   * Real-world volatility is not constant (use implied volatility).
   * Markets experience jumps (Black-Scholes underestimates tail risk).
2. **American Options**:
   * The model does not account for early exercise (use the Binomial model instead).

### **7. Conclusion**

By experimenting with the interactive tool, you will:

1. **Intuitively grasp** how parameters like volatility and time affect option prices.
2. **Visualize abstract concepts** like Delta and Gamma.
3. **Build confidence** in applying the model to real-world problems.

**Pro Tip**: Try "breaking" the model with extreme values (e.g., , ) to see its limitations!