Intuitive Explanation of the Black-Scholes Model (Part 1)

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Why Do We Need a Model?

When I first started studying quantitative finance, I came across a really interesting analogy. Think of a model like a map, a map will never be a perfect replica of the world, because of limitations, such as distortion and the fact it cannot capture every detail. It is a simplified version that highlights the most important features while leaving out the rest. In the same way that sailors once relied on two dimensional charts to navigate the globe, traders can use an option pricing model to charter a course through the turbulent waters of financial markets.

But sailors never depended on the map alone. They paired it with experience, intuition, and constant awareness of the conditions around them. A map could show coastlines and bearings, but it could not predict storms, shifting currents, or the temperament of the sea. Likewise, a model provides a structured starting point but it cannot anticipate every fluctuation in market behaviour. As new information arrives and volatility changes, the trader must adjust, interpret, and sometimes deviate from the model's guidance. The model sets the direction, but judgement and adaptability will keep you on course.

Options can be incredibly overwhelming, in the sense that prices can change quickly, and a single stock can have hundreds of associated options contracts, each with different strikes, maturities, and sensitivities. Comparing raw option prices across stocks, or even across strikes on the same stock, becomes almost meaningless because so many variables are changing at once. A model helps cut through that noise by transforming fast moving prices into slower, more interpretable quantities such as implied volatility (which represents the market's forecast of a probable movement in an underlying asset's price, S) and the Greeks, which is fundamental to the Black–Scholes model.

If we tried to compare options purely through their quoted prices, the result would be confusing and uninformative. Differences in time to expiration, underlying price, and option premium would obscure any real insight. A model allows us to express a stock in a common language through implied volatility.

Intuition of the Black-Scholes Model

If stock prices evolve randomly in a lognormal way but consistent with constant interest rates and volatility, we can ask the question: what must an option be worth at any time t for a perfectly hedged position to just break even? In the previous article, I explained that the Black-Scholes model is derived under the assumption of Delta hedging, using the hedge ratio (number of shares) Δ, which is one of the Greeks. In a perfectly hedged position, the change in the option's value and the change in the value of the hedge cancel out, so the combined position has zero instantaneous PnL (where PnL stands for Profit and Loss), it doesn't make nor loses money. In other words, $\text{Option}_{PnL} + \text{Shares}_{PnL} = 0$, which ensures that the hedged portfolio earns the risk-free rate, and this no-arbitrage requirement uniquely determines the option's fair price.

I previously derived the Black-Scholes equation (1):

$$\frac{\partial C}{\partial t} + \frac{1}{2}\sigma^2 S^2 \frac{\partial^2 C}{\partial S^2} + rS\frac{\partial C}{\partial S} - rC = 0 \tag{1}$$

This is the relationship between how two key variables, the underlying asset price, S, and time, t, will affect the value of the call option, C. The Black-Scholes model is a perfect introduction to the Greeks:

$$\Delta = \frac{\partial C}{\partial S}, \qquad \Gamma = \frac{\partial^2 C}{\partial S^2} = \frac{\partial \Delta}{\partial S}, \qquad \Theta = \frac{\partial C}{\partial t} \tag{2}$$

Clearly, Delta (Δ) is how the call price will change with a change in the stock price, Gamma (Γ) is the rate of change of Delta and Theta (Θ) is how the call price will change as time passes. Thus, we obtain:

$$\Theta + \frac{1}{2}\sigma^2 S^2 \Gamma + rS\Delta - rC = 0 \tag{3}$$

There are other terms here, such as rS which represents the forward price of the stock (i.e. the value of the stock at expiration if only the interest affects the price) and rC which represents the call option's value back to present (i.e. removes the effect of interest from the option's value at expiration). Finally, σ which is the volatility, and it is the standard deviation of the assumed lognormal standard normal distribution, showing how the stock price movements affect the rate of Delta changes.

Conclusion

The Black-Scholes model relies on the assumption of constant volatility, Although this does not reflect real market behaviour, it certainly makes the maths required easier whilst still introducing an incredibly useful framework.

In Article No.4, I will continue with the intuitive explanation of the Black-Scholes model, diving deeper in understanding what the fair price of a European-style call option is given by and why this is the case.

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