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Vanilla Options vs Barrier Options

Vanilla options are kind of like a contract made by the buyer or seller to buy or sell an underlying asset like stocks, commodities...etc. At a given timeframe called maturity of the option. Now when this contract is made this gives the right to buy or sell the underlying asset but not the obligation. Which means the buyer or seller can buy or sell the underlying only when it profits them.

Vanilla options are used by individuals, companies, and institutional investors to hedge their exposure in a particular asset or to speculate on the price movement of an underlying asset.

In a similar way barrier options behave the same except with one extra condition or a limit for the underlying asset. We can say that if the price of the underlying asset reaches above this limit only then there is value for the option, if not the option is worthless. The barrier options act the same way vanilla options do but with the one extra condition mentioned above.

Barrier options are very popular amongst retail investors as the barrier feature provides the investor with additional protection or leverage.

Valuation:

Valuing a vanilla option is simple, each option has a strike price. If the strike price is greater than the price of the underlying asset then we exercise the option.

Barrier option valuing is a little tricky because it is time dependent and has to be considered at every path. Because of the price limit condition imposed on the option.

The payoff of a barrier option option with maturity T; strike K and barrier B is given as follows:

$$C = (S_T - K)^+ \mathbb{I}_{\{\max_{0 \le t \le T} S_t \le B\}}$$

barrier options have more complex features and are generally traded over the counter.

Out-of-The-Money(OTM) vs At-The-Money(ATM)

Out-of-The-Money(OTM) and At-The-Money(ATM) both are expressions used to describe an option contract. When we say an option is OTM that means the strike price is higher than the market price of the underlying asset. When we say an option is ATM that means the strike price is equal to or very near to the market price of the underlying asset.

A volatility smile is a graph from plotting the strike price to the implied volatility. The fig 1.1 gives a visualization of the relation between OTM and ATM and the smile graph. A call option is said to be OTM if the implied volatility is rising and the same call option is ATM if the implied volatility is lowest.

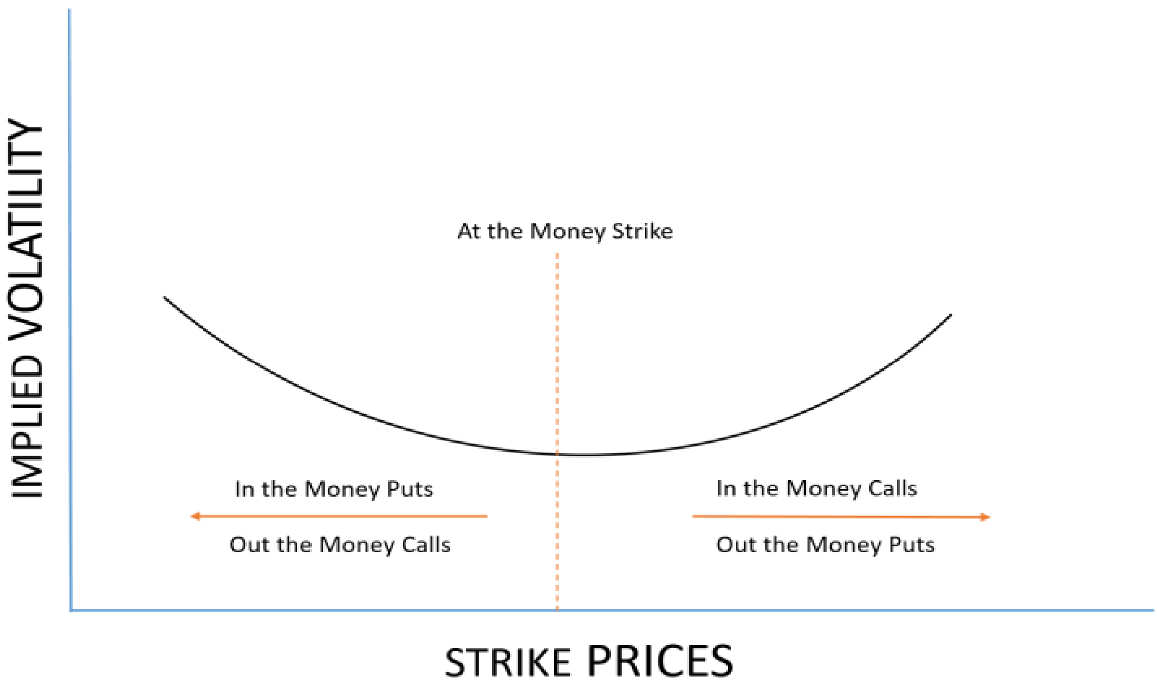

fig 1.1

Default-free option pricing vs Credit Value Adjustment(CVA) option pricing.

Default-free option pricing is used to anticipate the returns of the option under a default-free risk measure. We derive various formulas to validate the option using various methods under different parameters. Out of many different models the most widely used is the Black-Scholes model. The Black-Scholes model assumes that the option is default free.

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

where:

$$d_1 = \frac{ln\frac{S_t}{K} + (r + \frac{\sigma_v^2}{2})\, t}{\sigma_s \sqrt{t}}$$

and

$$d_2 = d_1 - \sigma_s \sqrt{t}$$

where:

C = Call option price

S = Current stock (or other underlying) pric

K = Strike price

r = Risk-free interest rate

t = Time to maturity

N = A normal distribution

Credit Value Adjustment(CVA) is a lot different from the regular option pricing CVA prices the credit risk of a counterparty. So in mathematical terms it is the difference between the value of a portfolio which is assumed to be risk free and the value of a portfolio where we account for credit risk.

$$\mathbf{CVA(T)} = E^Q[L^*] = (1 - R)\int_0^T E^Q\left[\frac{B_0}{B_t}E(t) | t = \tau\right] d\mathrm{PD}(0, t)$$

Default free option pricing gives the estimates of the stock price under a risk free state. Whereas the CVA calculates the credit risk of the counterparty.


Counter Party Credit Risk
Fair Value of Derivative
Cost to Hedge Against Credit RIsk
Eliminated Risk
Market Value of Derivative

fig 2.1

Analytical-pricing methods vs Monte Carlo simulation methods

Option pricing is a crucial part of financial research. The goal of our research is to simulate the option price as close as possible to the actual price. Basically Analytic pricing is pricing our option using Black Scholes formula. And Monte Carlo simulation is mostly stochastic modeling.

Analytical pricing method or Black Scholes model is the most popular model for pricing financial instruments. It depends on a fixed input like Stock price, Strike price, Maturity, Volatility, risk free rate. The best thing about this model is it assumes there is no default risk and the math is very simple, and can be calculated on a simple calculator. The Analytical pricing model is good enough for regular options. The downside is the model is not flexible enough to model non-standard features of an option.

Black Scholes is a model, whereas Monte Carlo is not a model, it is a numerical implementation algorithm. Because when it comes to derivatives there are no closed form solutions for few derivatives. We need to implement numerical algorithms. One of the many techniques to solve numerical integration is Monte Carlo simulation. The main idea behind Monte Carlo is to express an integral we want to solve as an expectation. And it relies on the average of all its results of the option.

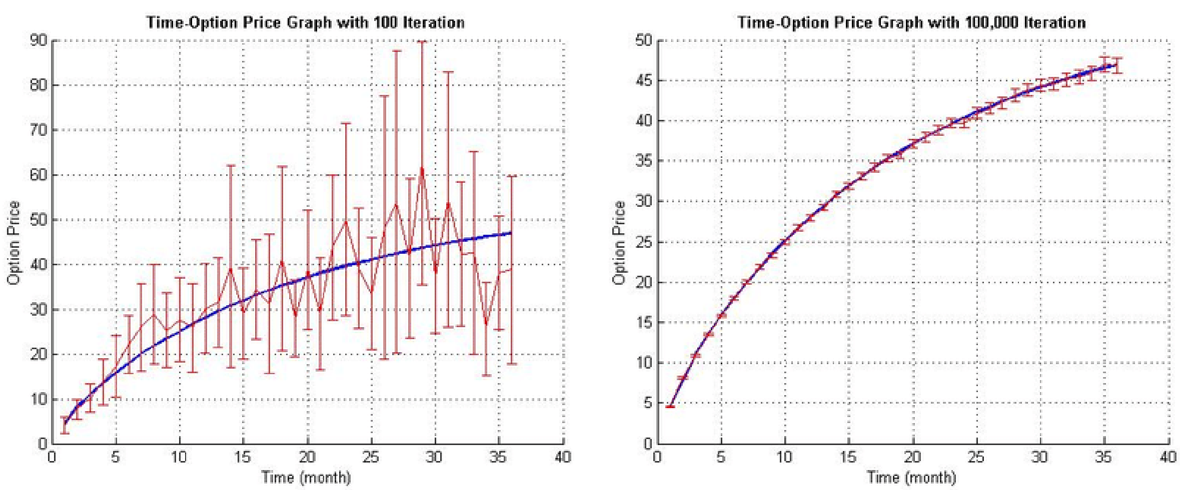

fig 3.1

The graphs in the fig 3.1 represent the application of Monte Carlo simulations in a Black Scholes equation. The blue line is the Analytical pricing or Analytical results, the red line is the Monte Carlo results. The vertical red line is the standard error of the Monte Carlo simulation.

From fig 3.1 we can see the blue line i.e., Analytical pricing has a simple curve and the red line i.e., Monte Carlo is more volatile and gives more information about the option.

among Black-Scholes volatility, Heston volatility, and local volatility.

Black Scholes volatility is the estimate of the future variability of the underlying asset of the option. It is called implied volatility since it is the expectation of the volatilities implied by the option.

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