

VaR on option portfolio

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- Put: $P_T = \max\{K - S_T, 0\}$

Black-Scholes model

Price of european call option:

- $V_t = S_t \Phi(d_1) - Ke^{-R(T-t)} \Phi(d_2)$
 - K ... strike price
 - R ... risk-free interest rate
 - S_t ... the underlying asset's value at time t
- $d_1 = \frac{\ln(\frac{S_t}{K} e^{RT}) + \frac{\sigma^2}{2} T}{\sigma \sqrt{T}}$
- $d_2 = d_1 - \sigma \sqrt{T}$

VaR

VaR definiton

Let X be a random variable on a probability space $(\Omega, \mathcal{F}, \mathbb{P})$ and $\alpha \in (0, 1)$. $\text{VaR}_\alpha(X)$ is defined as the $(1 - \alpha)$ quantile of $-X$. Then

$$\text{VaR}_\alpha(X) := -\inf\{x \in \mathbb{R} \mid F_X(x) > \alpha\} = F_{-X}^{-1}(1 - \alpha).$$

Non-linear VaR

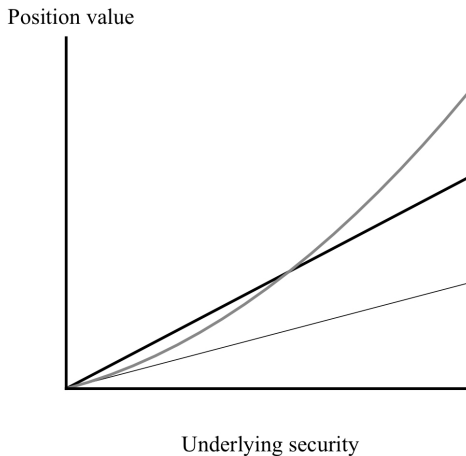


Figure: Linear and non-linear function of payoff.

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- European call option: $\Phi(d_1)$

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In general, the gamma is at its maximum point when the stock is near the strike of the option.

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Long positions generally have a negative theta and short positions a positive one.

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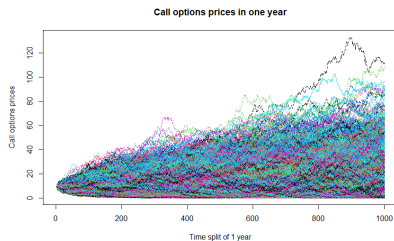
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Delta-Gamma-Theta Approach

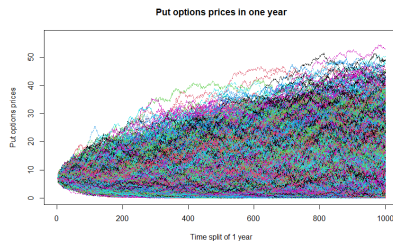
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Importance of the three Greeks used for VaR calculation:

- Delta: the potential change in the option's value associated with a unit shift in the underlying asset's price;
- Gamma: important role in VaR calculations as the underlying asset price fluctuates more significantly;
- Theta: time decay is a major factor in the approximation of the overall risk of the portfolio.

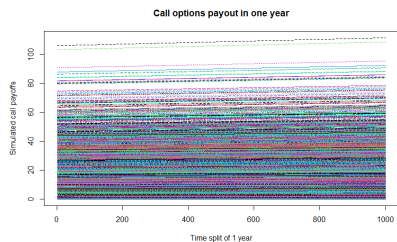


(a) Call option path prices

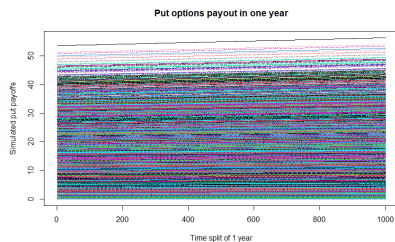


(b) Put option path prices

Figure: Call option path prices and put option path prices of stock S

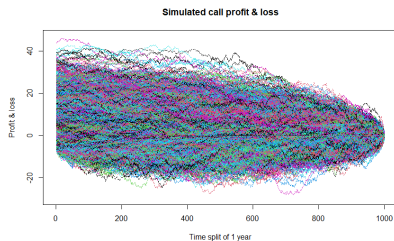


(a) Call option payoffs path

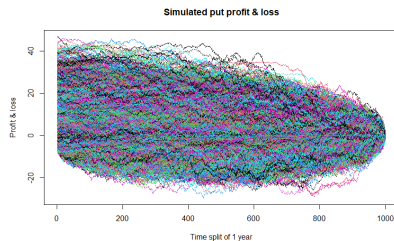


(b) Put option payoffs prices

Figure: Call option payoffs prices and put option payoffs path of stock S

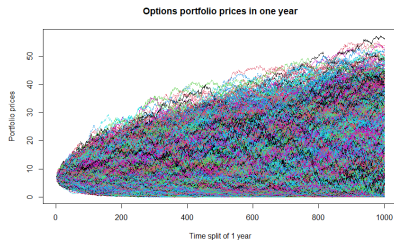


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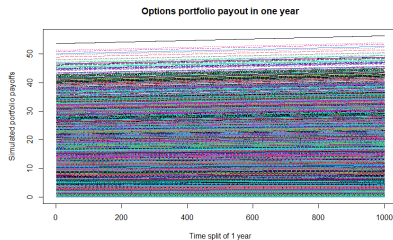


(b) Put option payoffs prices

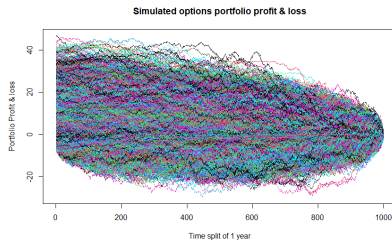
Figure: Call option P&L paths and put option P&L path of stock S



(a) Portfolio prices paths



(b) Portfolio payoffs paths



(c) Portfolio profit & loss paths

Figure: Profit and loss diagram for the portfolio at time 0

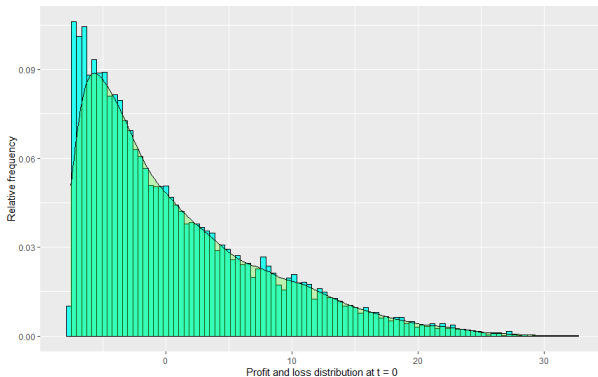


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