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# cf_callmax

Let

- $T$ = maturity date $\quad (T > t)$
- $K$ = strike price
- $x1$ = spot1 price
- $x2$ = spot2 price
- $t$ = pricing date
- $\sigma 1$ = volatility1
- $\sigma 2$ = volatility2
- $\rho$ = correlation
- $r$ = interest rate
- $\delta 1$ = dividend1 yields
- $\delta 2$ = dividend2 yields
- $\theta = T - t$

Here, closed formulas due to Johnson and Stulz are presented [1],[2]. We set

- $d = \dfrac{\log \frac{x_1}{x_2} + \left(\delta_2 - \delta_1 + \frac{\sigma^2}{2}\right)\theta}{\sigma\sqrt{\theta}}$
- $\sigma = \sqrt{\sigma_1^2 + \sigma_2^2 - 2\rho\sigma_1\sigma_2}$
- $d_i = \dfrac{\log\left(\frac{x_i}{K}\right) + \left(r - \delta_i + \frac{\sigma_i^2}{2}\right)\theta}{\sigma_1\sqrt{\theta}}, \quad i = 1, 2$
- $\rho_1 = \dfrac{\sigma_1 - \rho\sigma_2}{\sigma}$
- $\rho_2 = \dfrac{\sigma_2 - \rho\sigma_1}{\sigma}$

and $M$ as the cumulative bivariate normal distribution function:

$$M(a, b; \rho) = \frac{1}{2\pi\sqrt{1-\rho^2}} \int_{-\infty}^{a} \int_{-\infty}^{b} e^{-\frac{x^2 - 2\rho xy + y^2}{2(1-\rho^2)}} dxdy.$$

# Call On Maximum Option

PAYOFF $C_T = (\max(S_T^1, S_T^2) - K)_+$

PRICE
$$C(t, x_1, x_2) = x_1 e^{-\delta_1 \theta} M(d_1, d; \rho_1) + x_2 e^{-\delta_2 \theta} M(d_2, -d + \sigma\sqrt{\theta}; \rho_2)$$
$$-Ke^{-r\theta}\left(1 - M(-d_1 + \sigma_1\sqrt{\theta}, -d_2 + \sigma_2\sqrt{\theta}; \rho)\right)$$

DELTA
$$\frac{\partial C(t, x_1, x_2)}{\partial x_1} = e^{-\delta_1 \theta} M(d_1, d; \rho_1)$$
$$\frac{\partial C(t, x_1, x_2)}{\partial x_2} = e^{-\delta_2 \theta} M(d_2, -d + \sigma\sqrt{\theta}; \rho_2)$$

## References

[1] H.JOHNSON. Options on the maximum ot the minimum of several assets. *J.Of Finance and Quantitative Analysis*, 22:227–283, 1987. 1

[2] R.STULZ. Options on the minimum or the maximum of two risky assets. *J. of Finance*, 10:161–185, 1992. 1