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# cf_putin_kunitomoikeda

Let

- $T =$ maturity date $\quad (T > t)$
- $K =$ strike price
- $L =$ lower barrier
- $U =$ upper barrier
- $x =$ spot price
- $t =$ pricing date
- $\sigma =$ volatility
- $r =$ interest rate
- $\delta =$ dividend yields
- $\theta = T - t$
- $b = r - \delta$

The exact value for double barrier call/put options is given by the Ikeda-Kunitomo formula [1], which allows to compute exactly the price when the boundaries suitably depend on the time variable $t$. More precisely, set

$$U(s) = Ue^{\delta_1 s} \qquad L(s) = Le^{\delta_2 s}$$

where the constants $U, L, \delta_1, \delta_2$ are such that $L(s) < U(s)$, for every $s \in [t, T]$. The functions $U(s)$ and $L(s)$ play the role of *upper* and *lower* barrier respectively. $\delta_1$ and $\delta_2$ determine the curvature and the case of $\delta_1 = 0$ and $\delta_2 = 0$ corresponds to two flat boundaries.

*In the software, we consider only flat boundaries.*

The numerical studies suggest that in most cases it suffices to calculate the leading five terms of the series giving the price of the knock-out and knock-in double barrier call options.

Let $\tau$ stand for the first time at which the underlying asset price $S$ reaches at least one barrier, i.e.

$$\tau = \inf\{s > t\,;\, S_s \leq L(s) \text{ or } S_s \geq U(s)\}.$$

We define the following coefficients:

- $$\mu_1 = 2\frac{b - \delta_2 - n(\delta_1 - \delta_2)}{\sigma^2} + 1$$
- $$\mu_2 = 2\frac{n(\delta_1 - \delta_2)}{\sigma^2}$$
- $$\mu_3 = 2\frac{b - \delta_2 + n(\delta_1 - \delta_2)}{\sigma^2} + 1$$

# Knock-In Put Option

## References

[1] N.KUNIMOTO N.IKEDA. Pricing options with curved boundaries. *Mathematical finance*, 2:275–298, 1992. 1