

# Quanto Himalayan Option Model

This article presents analytics for pricing quanto Himalayan options on equity, where the single best return is locked in each fixing period. Specifically, we considered the impact of the quanto adjustment term on calibration and the computation of option premium and hedge ratios

The equity price model is based on a discrete dividend treatment and results in shifted lognormal distributions for the equity price. A calibration step is required to obtain the required shifted-lognormal volatility parameters from the Black's term implied volatility inputs. Monte Carlo technique is employed to compute the price and the hedge ratios.

Himalayan options are a form of European-style, path-dependent, exotic option on a basket of equity underliers, in which intermediate returns on selected equities enter the payoff, while the equities are subsequently removed from the basket.

Like other exotic option, Quanto Himalayan may also have cap floor constraints and barrier conditions. The barrier option may knock out the trade before maturity, referred to as <https://finpricing.com/lib/EqBarrier.html>

For a set of  $d$  equities (stocks or equity indexes), let their respective prices at time  $t$  be  $Y_1(t), \dots, Y_d(t)$ . Given a collection of fixing dates,  $t_0, t_1, \dots, t_d$ , let the equity returns  $R_{i,j}$ , for  $i = 1, \dots, d, j = 1, \dots, d$  be defined as

$$R_{i,j} = \frac{Y_i(t_j)}{Y_i(t_0)}.$$

Moreover, let the integer-valued function  $k : \{1, \dots, d\} \rightarrow \{1, \dots, d\}$  be defined so as to satisfy the following condition, for  $i = 1, \dots, d$

$$R_{k(i),i} = \max_{j \in \{1, \dots, d\} \setminus \bigcup_{l=1}^i \{k(l)\}} R_{j,i}.$$

In other words,  $k(i)$  is the index of the equity with the highest return, at the fixing date  $t_i$ , among those equities, whose returns at the previous fixing dates were not the highest. Given a strike level,  $K$ , the Himalayan option payoff is

$$\max\left(\sum_{i=1}^d (R_{k(i),i} - K), 0\right).$$

The delta hedge ratio for  $i$ -th equity is defined as

$$\frac{\partial V}{\partial Y_i(t)},$$

where  $V$  is the option price and  $Y_i(t)$  is the price of the  $i$ -th equity on valuation date.

The cross-gamma hedge ratio for  $i$ -th and  $j$ -th equities is defined as

$$\frac{1}{Y_i(t)} \frac{\partial^2 V}{\partial Y_i(t) \partial Y_j(t)}.$$

The vega hedge ratio for  $i$ -th equity is defined as

$$\frac{1}{100} \sum_{j=1}^d \frac{\partial V}{\partial v_{B,i}(t_j)},$$

where  $v_{B,i}(t_j)$  is the  $t_j$ -term Black's volatility for equity  $i$ .

This definition is consistent with the one in the case of domestic equities, that is, in the absence of a quanto adjustment. In the quanto case, the effect of the change in the quanto adjustment resulting from a change in the volatility is ignored.

The rho hedge ratio for  $i$ -th equity is defined as

$$\frac{1}{10000} \sum_{j=1}^d \frac{\partial V}{\partial R_i(t_j)},$$

where  $R_i(t_j)$  is the  $t_j$ -term spot interest rate for the currency of equity  $i$ .

The theta hedge ratio is defined as

$$V(t+1) - V,$$

where  $V(t+1)$  is the option premium computed with the valuation date,  $t$ , shifted forward by one day.

With the exception of the theta, the hedge ratios are computed using Malliavin weights. The presence of the volatility calibration step requires an adjustment in the calculated Malliavin hedge ratios, according to the chain rule.

Let  $X(\cdot)$  be the  $d$ -dimensional vector of logarithms of the  $d$  gains processes. The vector process  $X(\cdot)$  will be assumed to follow the SDE

$$d\mathbf{X}(\tau) = \left( \mathbf{r}(\tau) - \mathbf{q}(\tau) - \frac{1}{2}\sigma^2(\tau) \right) d\tau + \mathbf{D}(\tau)\mathbf{L} d\mathbf{B}(\tau), \quad t < \tau,$$

$$\mathbf{X}(t) = \mathbf{x}_t, \quad \text{a.s.},$$

Let the known dividend schedule for equity  $i$  consist of payments  $\_i,1, \dots, \_i,m_i$  made at times  $\_i,1, \dots, \_i,m_i$ , all of which lie between the valuation date  $t$  and the last relevant fixing  $t_n$ . Furthermore, let the discount curve in the native currency of equity  $i$  be  $d_i$ , that is, for any time  $s$  greater than the valuation time  $t$ , let the discount factor be  $d_i(s - t)$ . For times  $t \leq s_1, t \leq s_2$ , let us define  $d_i(s_1, s_2) = d_i(s_2)/d_i(s_1)$ . We shall define

$$\tilde{D}_i(s) = \sum_{j=1}^{m_i} \kappa_{i,j} d_i(s, \tau_{i,j}) \mathbf{I}_{[t, \tau_{i,j}]}(s), \quad \text{and}$$

$$\tilde{\mathbf{D}}(s) = (\tilde{D}_1(s), \dots, \tilde{D}_d(s))'.$$

We employ the definitions of the respective hedge ratios, as stated in the section on the WM pricing method. With the exception of the theta, calculated through the finite difference technique, all hedge ratios are computed using the Malliavin weight approach. Additional considerations arise from the impact of the calibration procedure on the sensitivity ratios, as describe in the next section.

Moreover, as can be seen from the test results below, the relative error in the gamma hedge ratios can be quite large. These quantities are generally very small, making the relative error a poor indicator of agreement. Moreover, it appears that the Monte Carlo sampling error is quite large for the gamma hedge ratio.