EMPLOYEE STOCK OPTION VALUATION: SUBOPTIMAL EARLY EXERCISE BEHAVIOR

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An employee stock option (**ESO**) is significantly different with respect to an exchange-traded option. The main difference is the **asymmetric** relationship between the writer of the option (i.e., the company) and the holder of the option (i.e., the employee). While in the case of the usual traded options both sides have similar rights (e.g., can sell the option, can hedge the option), in the case of ESO the holder is significantly impaired (e.g., cannot sell the option, cannot hedge the option because it is illegal to short the stock of your own company). Additionally, the holder of the option may not have a well-diversified portfolio (like the usual institutional investors involved in trade options). These impairments identified above for the holder of the ESO result in a significantly lower value that is attached by the employee to the ESO. This fact is reflected by the suboptimal early exercise behavior of the employee.

The valuation models developed based on this approach use as an input the early exercise behavior of the ESO holder. A practical solution is to assume that the employee is willing to exercise the option (once it is vested) as soon as the underlying crosses above a given value (Hull and White 2002a; Hull and White 2002 b; Hull and White 2004a; Hull and White 2004b). That value may be viewed as the exercise price multiplied by a constant factor. Usually, this results in a suboptimal early exercise, a fact that explains the name proposed for this model: Suboptimal Early Exercise Factor. The Suboptimal Early Exercise Factor model requires in fact two parameters: the frequency for early exercise checking, and the factor itself.

It should be noted that:

1. The payoff function for the Suboptimal Early Exercise Factor is the difference between the underlying value and the exercise value, and **not** the difference between the barrier value and the exercise value (or any fixed rebate). Therefore, the payoff for the Suboptimal Early Exercise Factor model is higher than the payoff from a usual barrier model.

2. Cases that justify an optimal early exercise for the American style Up & Out Call Barrier model will not trigger an early exercise for the Suboptimal Early Exercise Factor model. Excepting the expiration date, in the case of the Suboptimal Early Exercise Factor model exercise takes place only when the barrier is crossed.

3. The Suboptimal Early Exercise Factor model takes into consideration the pre-vesting and post-vesting forfeiture rate, a feature that is not available with the usual barrier models.

4. When the vesting period is taken into account, on the vesting date the underlying may be significantly above the barrier, no matter what is the frequency for early exercise checking. Under such a scenario, the payoff for the Suboptimal Early Exercise Factor model will be significantly higher than the payoff from a usual Bermuda style barrier.

When the vesting and valuation dates are identical, as the frequency for early exercise checking increases, the Suboptimal Early Exercise Factor model converges to the European style Up & Out Call Barrier model.

Due to the peculiarities listed above, the Suboptimal Early Exercise Factor model cannot be implemented using the usual Bermuda style barrier models. The Suboptimal Early Exercise Factor model has been implemented using new functions specially tailored for this case. The methods used by these functions are: binomial tree (OptionsLattice_EB); trinomial tree (OptionsLattice_EB); and Monte Carlo simulation (OptionsFlexMC_EB and OptionsFlexMC_SOEB).

Neither the binomial tree nor the Monte Carlo simulation is recommended as a first choice because of the:

1. Inherent problems of the binomial tree as applied to barriers; and

2. Significant computing efforts required by any Monte Carlo simulation.

Due to its speed and accuracy, we recommend the trinomial method as the best choice among the three methods presented above.

Both OptionsFlexMC_EB and OptionsFlexMC_SOEB have similar input probabilities. However, the significance of these probabilities is completely different for the two functions. While for OptionsFlexMC_SOEB the probabilities are annualized values, for OptionsFlexMC_EB the probabilities are valid for the specified dates. Moreover, for OptionsFlexMC_SOEB the Monte Carlo path may be terminated due to two causes: turnover, and voluntary early exercise. The input has a given probability for turnover and another probability for voluntary early exercise. Internally, the function computes the probability corresponding to both causes. For OptionsFlexMC_EB the specified probability is for all causes. Last, but not least, OptionsFlexMC_EB takes into account only the dates specified by the input matrix, while OptionsFlexMC_SOEB checks for all dates corresponding to the specified frequency (Steps per Year) in addition to the dates specified by the input matrix.

OptionsLattice_EB accepts a Suboptimal Exercise Factor that is greater or equal to zero and less than or equal to one. In this case we turn internally the factor to infinity. Therefore, there is no early exercise excepting for people leaving the company.

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