EMPLOYEE STOCK OPTION VALUATION
UNIQUE CHARACTERISTICS

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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.

In order to take into account the particularities of the ESO, the suboptimal early exercise behavior can be simulated either as an exogenous process or as an endogenous process.

EXOGENOUS SUBOPTIMAL EARLY EXERCISE BEHAVIOR

The valuation models developed based on this approach use as an input argument 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 crossed 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. Of course, this model may be extended for time-varying factor (i.e., the underlying value that must be crossed in order to trigger early exercise can vary as a function of time).

The Suboptimal Early Exercise Factor model requires in fact two parameters: the frequency for early exercise checking, and the factor itself. When the frequency for early exercise checking increases, the Suboptimal Early Exercise Factor model converges to the Up & Out Call Barrier model. It should be noted that the payoff function for the Suboptimal Early Exercise Factor is the difference between the underlying and exercise values, and **not** the difference between the barrier and exercise values. Of course, when the frequency for early exercise checking increases, the underlying value (in case of early exercise) will converge to the barrier value. However, cases that justify an optimal early exercise for the Up & Out Call Barrier model may not trigger an early exercise for the Suboptimal Early Exercise Factor model.

Based on the features presented above, we recommend the usage of the Up & Out Call Barrier models (e.g., **BarrierBS**, **DoubleBarrierBin**, **DoubleBarrierFlexBin, OptionsFlexMC_SOEF**) as a quick first approximation of the Suboptimal Early Exercise Factor model. We recommend **OptionsFlexMC_EB** as a good quality implementation of the Suboptimal Early Exercise Factor model. This function uses a Monte Carlo lattice and takes into account the peculiarities of the ESO. We developed also **OptionsLattice_EB,** a binomial/trinomial lattice with similar features.

ENDOGENOUS SUB-OPTIMAL EARLY EXERCISE BEHAVIOR

The valuation models developed based on this approach must justify the early exercise behavior of the ESO holder based on different factors, such as:

1. **Employee's Nonoption Wealth.** This includes **<u>cash</u>** (or equivalent portfolio) at the risk-free interest rate (Kulatilaka and Marcus 1994; Rubinstein 1995; Huddart 1999; Detemple and Sundaresan 1999; Ingersoll 2002; Hall and Murphy 2002; Sircar and Xiong 2004), Capital Asset Pricing Model (CAPM) **<u>market portfolio</u>** (Ingersoll 2002), company **<u>stock</u>** (Ingersoll 2002; Hall and Murphy 2002; Sircar and Xiong 2004), and other **<u>options</u>** on the same company stock (Dayananda 2000). We should incorporate cash (or equivalent portfolio) at the risk-free interest rate, CAPM market portfolio, and company stock. However, this should be done developing different models.

2. **Forfeiture and Early Exercise Rate.** Carr and Linetsky (2000), Wu (2003) and Szimayer (2004) model the forfeiture rate and early exercise rate as an exogenous point process with random intensity dependent on the stock price. Most other models consider a constant value for the forfeiture rate and early exercise rate (Rubinstein 1995; Huddart 1999; Ingersoll 2002; Hull and White 2002a; Hull and White 2002 b; Pandher 2003; Sircar and Xiong 2004; Hull and White 2004a; Hull and White 2004b).

3. **Employee's Risk Aversion.** The utility function used to describe the employee's risk aversion is (Kulatilaka and Marcus 1994; Rubinstein 1995; Detemple and Sundaresan 1999; Hall and Murphy 2002):

$$U = [1/(1-b)]\, W^{(1-b)} \qquad \text{where } b > 0 \text{ and } b \neq 1$$

or

$$U = \ln W$$

where **W** is the total wealth. The commonly accepted value is **b** = 2.

Ingersoll (2002) uses a different approach based on the power utility function defined over lifetime consumption and bequest. Ingersoll (2002) $\boldsymbol{\gamma}$ may be related to (**1-b**).

4. Employee's Tax Rate. Rubinstein (1995) considers the marginal tax effect.

The software developed for these models may be based on Monte Carlo lattices, binomial lattices, or in some simplifying cases even closed end solutions.

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