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The cost of granting executive stock options with strike prices adjusted by the cost of capital

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Abstract

Purpose – The purpose of this paper is to estimate the cost of granting executive stocks with strike prices adjusted by the cost of capital.

Design/methodology/approach – In the paper a Monte Carlo simulation approach developed in Longstaff and Schwartz is used in conjunction with the subjective valuation model developed in Ingersoll to value these executive stock options that are subject to performance hurdles.

Findings – The paper finds that standard European Black-Scholes-Merton option values overstate the true cost to the firm of granting these executive stock options. The option values also decrease with a higher dividend yield, a higher performance hurdle, a longer vesting period, and a shorter maturity.

Research limitations/implications – While the study in the paper is limited to the valuation of executive options, the methodology can be used to study incentive effects of executive stock options that have a performance hurdle.

Practical implications – The approach used in this paper to estimate the cost of granting executive stock options is a clear improvement over standard European option pricing approaches that often result in biased estimates.

Originality/value – This paper presents a first attempt to integrate the Ingersoll utility-theoretic model and the Longstaff and Schwartz least squares Monte Carlo algorithm to estimate the subjective value and the objective cost of executive stock options with a performance hurdle. This valuation approach will be useful in the study of other types of executive compensation.

Introduction

Executive stock options linked to earnings performance are commonplace. Orszag and Choudhary (2005) document that in 2003, amongst firms that made up the FTSE100, 79 percent of them used earnings per share growth as a performance hurdle while the remainder used other benchmarks such as total return to shareholders relative to a market index. Many prominent companies in Australia and New Zealand have implemented a performance hurdle in their executive stock options with two distinguishing features:

1. The options have a strike price that drifts upward at a rate set with reference to a cost of capital estimate.
2. Dividend protection that adjusts the strike price downward by the amount of any dividends paid\textsuperscript{1}.

A performance option attempts to link executive compensation to company performance as exercise will only occur when the cum-dividend return on the firm's shares surpasses a cost of capital estimate. Such performance options present two major challenges to attempts to value them. First, if we attempt to value a performance option as a marketable security, valuation is hindered by two factors:

1. Regular increases in the strike price that may trigger early exercise even though the options are dividend-protected (see Geske et al., 1983).
2. Dividend payments linked to the share price yield a strike price that is a path-dependent function of the share price.

Second, if a subjective valuation of the option is desired, path-dependency of the strike price means that standard valuation approaches, such as the use of utility functions in a binomial tree setting, would be impractical.

Cheung et al. (2006) tackle the first challenge by using the least squares Monte Carlo method developed in Longstaff and Schwartz (2001) to estimate the market value of performance options. We outline the least squares Monte Carlo methodology in Section 2. In this study, we tackle the second challenge of including a subjective valuation of performance options. This is made possible by a utility-theoretic model developed in Ingersoll (2006), which we discuss in Section 3. We integrate the Ingersoll model with the least squares Monte Carlo method to estimate subjective values and objective costs to the firm issuing performance options. The results are presented in Section 4. Our conclusions and a summary follow in Section 5.

Black-Scholes-Merton values of performance options

The Cheung et al. (2006) study

Cheung et al. (2006) investigate valuation biases that may arise from the common approach of using a modified version of option pricing formulas developed in Black and Scholes (1973) and Merton (1973) to value performance options. The modified Black-Scholes-Merton formula used is: Equation 1

In equation (1), \( C \) denotes the call option value, \( S^* \) and \( K^* \) denote the dividend adjusted stock price and the dividend and hurdle-rate adjusted strike price; \( h \) is the hurdle rate, \( r \) is the riskless interest rate, \( T \) is the time to option maturity, \( \sigma \) is the annual return volatility of the stock, and \( N(d) \) indicates the standard normal distribution probability for the value \( d \). \( S^* \) is computed as the initial stock price less the present value of a known sequence of dividends, i.e., \( D_1, D_2, \ldots, D_{T-e} \), where \( D_{T-e} \) is the last dividend payment made before option expiration. \( K^* \) is the initial strike price reset by a known sequence of hurdle rate and dividend adjustments.

The modified Black-Scholes-Merton option pricing formula assumes a known sequence of dividends over the life of the option. This assumption is unrealistic in the case of executive stock options since their maturities at issuance typically range from five to ten years. A more
plausible assumption is a constant dividend yield, where the cash dividend is a constant percentage of the observed share price. However, this has the effect of making the strike price a path-dependent function of the stock price. Path dependence and the possibility of early exercise make exact analytic valuation of these options intractable. To handle the problem of path dependence, Cheung et al. (2006) estimate the value of performance options using the least squares Monte Carlo (LSM) approach proposed by Longstaff and Schwartz (2001). They find that the modified Black-Scholes-Merton option pricing formula materially understates the value of path-dependent performance options.

**Least squares Monte Carlo valuation**

Monte Carlo simulation has long been used to estimate the conditional expectation of the payoff of a European-style option (see Boyle, 1977). However, for some time it was not clear how US options could be valued using Monte Carlo simulations. Longstaff and Schwartz (2001) credit Bossaerts (1989) for providing the earliest solution to the problem of valuing an American option with Monte Carlo simulations. Further development is provided in Tilley (1993), Barraquand and Martineau (1995), Carriere (1996), Broadie and Glasserman (1997), Broadie et al. (1997), Raymar and Zwecher (1997), Carr (1998), and Fu et al. (2001). Longstaff and Schwartz (2001) make the important contribution of developing a parsimonious algorithm that significantly increases computational efficiency. Moreno and Navas (2003) and Stentoff (2004) find that the least squares Monte Carlo approach proposed by Longstaff and Schwartz (2001) is quite robust and provides an efficient method to value US options when alternative methods are infeasible.

The key insight of the least squares Monte Carlo (LSM) approach to estimating conditional expectations is that the information required for estimating expected payoffs from continuation without exercise is already contained in the set of simulated price paths. To process this information, the LSM approach uses a cross-sectional least squares regression of in-the-money options on each decision date. Fitted values from the cross-sectional regression provide estimates of the expected payoffs from continuation. Comparing these expected payoffs with the value of immediate exercise results in an exercise strategy that maximizes the simulation value of the option.

Let $X_{k,t}$ denote the non-negative intrinsic value of the option on date $t$ along the $k^{th}$ simulated price path. Also let $V_{k,t}$ be the optimal value of the option on date $t$ along the $k^{th}$ path. The LSM algorithm begins by setting option values equal to intrinsic values at maturity, i.e. $V_{k,T} = X_{k,T}$. Then the set of option values at date $T$ along the price paths with strictly positive intrinsic values at date $T-1$, i.e. the set with $X_{k,T-1} > 0$, are regressed on a polynomial function of the strictly positive intrinsic values $X_{k,T-1}$. Fitted values from the polynomial regression represent conditional expected values used to make an exercise decision. Early exercise is optimal if a fitted value is lower than the corresponding value of immediate exercise, in which case option value is updated by the immediate exercise value. Specifically, if option intrinsic value at date $t-1$ along the $k^{th}$ path is greater than the discounted expected value from continuing without exercise, then the option value $V_{k,t-1}$ is set equal to the intrinsic value $X_{k,t-1}$; otherwise, option value is set equal to the discounted value of continuing without exercise, i.e. $e^{-r} V_{k,t}$, where $r$ is the riskless single-period discount rate. Options with zero intrinsic value on date $t-1$ along the $k^{th}$ path not included in the regression have their values set equal to the discounted value from continuing without exercise. Mathematically, the option values $V_{k,t-1}$ are determined as follows: Equation 2
The procedure is repeated at each decision date recursively from option maturity back to the current date. We apply the same valuation approach in this paper and extend it to incorporate a subjective valuation using the utility-theoretic model developed in Ingersoll (2006) described in the next section.

The Ingersoll model

It is commonly recognized that risk-averse executives value stock option awards by an amount less than a risk-neutral valuation suggests. The subjective discount is attributed to the risk exposure of a suboptimal holding of company shares imposed upon the executive by conditions such as vesting and post-exercise sales restrictions. Thus the executive is obliged to hold a portfolio with excess exposure to a single stock (or its derivatives) and consequently places a subjective value lower than a risk-neutral valuation on these holdings.

Subjective valuation of financial assets is usually performed in an expected utility framework. Studies that use utility of wealth to model a subjective discount or early exercise of executive stock options include Hall and Murphy (2000, 2002), Lambert et al. (1991), Corrado et al. (2001), and Detemple and Sundaresan (1999). These studies typically value an executive option using the expected utility of total wealth rather than just option payoffs in a binomial setting. Ingersoll (2006) develops an ingenious new approach to the subjective valuation of stock-based compensation. He applies the constrained optimization method of Cvitanic and Karatzas (1992) to solve for the constrained optimal portfolio of an undiversified executive to determine the executive's indirect utility function. The marginal utility hence derived is used as a subjective state price process to value stock-based compensation. An important theoretical advantage of using such a marginal utility function as a martingale pricing process is that under modest simplifying assumptions the approach reduces to the standard Black-Scoles-Merton approach.

Specifically, in the Ingersoll mode, the subjective value $C^5$ of a standard European call option written on a stock with a constant dividend yield $q$ is given by: Equation 3 Equation 4 Equation 5

The previous formula is the same as the standard Black-Scoles-Merton formula but with transformed values for the riskless interest rate $r$ and dividend yield $q$. The transformed values $r'$ and $q'$ in equations (3)-(4) are functions of three additional parameters relevant to a subjective valuation of the option. The first parameter, $\alpha$, is the excess proportionate holdings of the firm's shares above the optimal level the executive would otherwise hold. The second parameter, $\alpha$, is a measure of relative risk aversion. The third parameter, $\nu$, is the residual risk of the stock under some assumed factor model. For risk-averse managers ($\alpha > 0$) constrained to hold an excess proportion of wealth in the firm's stocks ($0 < \alpha < 1$), a higher dividend yield ($q' > q$) and a lower riskless rate ($r' < r$) under the subjective process imply that the subjective value of the option is lower than the Black-Scoles-Merton value.

In the case of a US option, the higher subjective dividend yield $q'$ also increases the likelihood of early exercise, even for a stock that does not pay dividends. To estimate the subjective value of executive stock options allowing early exercise, Ingersoll (2006) adopts a barrier-derivative approximation approach developed in Ingersoll (1998) with the subjective rather than the standard risk-neutral stochastic process. The adopted barrier-derivative approach assumes a constant barrier that will trigger an early exercise and then finds the
barrier (and therefore the early exercise strategy) that maximises the value of the option. Under this approach, three option values can be computed – the risk-neutral value, the subjective value, and the objective value. The risk-neutral value is the value of the option to an unconstrained holder. It is calculated using the standard risk-neutral price process and an optimal early exercise barrier. The subjective value is the value of the option to the portfolio-constrained executive. It is calculated using the subjective price process and an early exercise barrier that is optimal to the constrained agent though suboptimal to the unconstrained agent. The objective value is the cost to the firm of granting the executive option. It is calculated using the standard risk-neutral price process in combination with the constrained executive’s suboptimal exercise barrier.

Ingersoll’s approach allows a straightforward computation of the risk-neutral value, subjective value, and objective value of executive stock options relevant for valuation and financial reporting purposes5. In addition, the ease of comparing subjective and objective values under this approach greatly simplifies costs-benefit assessments of executive remuneration schemes. In the next section, we apply Ingersoll’s valuation model in conjunction with the least squares Monte Carlo method described in Section 2.2 to an examination of dividend-protected options with performance hurdles.

**Valuation results and cost-effectiveness of hurdle rate options**

**Combining the approaches of Longstaff and Schwartz and Ingersoll**

In Section 2.1, we noted that the strike price of a performance option rises by a cost of capital estimate minus the dividend yield and consequently a constant dividend yield makes the strike price a path-dependent function of the stock price. While Ingersoll (2006) demonstrates that in the case of a standard executive stock option early exercise can be handled using a barrier-derivative approximation under a subjective price process, it is not clear that the same approach can be modified to value a path-dependent option. On the other hand, while the Longstaff and Schwartz (2001) least squares Monte Carlo approach can be used to estimate the value of an option with a path-dependent strike price, it has not yet been demonstrated how the approach can be applied to estimate the subjective value of an executive stock option. In this section, we employ the Ingersoll subjective price process to simulate prices and use these subjective prices in the least squares Monte Carlo methodology to value dividend-protected performance options.

**Subjective values and objective costs of dividend-protected performance options**

Cheung et al. (2006) apply the least squares Monte Carlo (LSM) approach to estimate European and US values of performance options and compare them to values obtained using the modified Black-Scholes-Merton formula in equation (1). They find that the LSM values are usually materially higher. For instance, for a typical option contract based on a 1,000 shares, the value calculated from the LSM approach is about 25 percent higher than a corresponding Black-Scholes-Merton formula value. Moreover, they find that the dividend-protection feature does not provide complete protection as the LSM US option value falls as the dividend yield increases. They also document that, ceteris paribus, the LSM value of a performance option decreases with the hurdle rate and increases with the time to maturity6.
While the Cheung et al. (2006) study has established that the modified Black-Scholes-Merton formula generally understates the risk-neutral value of a performance option, it does not address the issue that the risk-neutral value can overstate the objective cost of the option grant to the firm. This is because the risk-neutral value is calculated under the assumption of an optimal exercise strategy, while the executive is likely to follow a suboptimal exercise strategy due to risk aversion and diversification constraints. Also, the study was unable to address issues such as the incentive effects of a performance hurdle feature. These limitations can only be addressed when the subjective risk preference of the executive is integrated into the analyses.

In a related study, Boyle et al. (2006) employs the Ingersoll (2006) methodology in a binomial setting to explore the sensitivity of the objective cost of standard stock option grants to varying degrees of executive risk aversion and diversification constraints. They urge caution in the practice of using the risk-neutral value for financial reporting since they find that the objective cost is highly sensitive to individual characteristics. Their study examines only the objective cost of standard stock options with a constant strike price. In this paper, we focus on performance hurdle options with comparisons across the subjective, objective, risk-neutral values of these options.

In the analysis below, we standardise on a performance hurdle option contract based on 1,000 shares with parameter values for this base contract set as follows: stock price $S$=$1$, initial strike price $K$=$1$, contract maturity $T$=six years with two-year vesting, interest rate $r$=7 percent, volatility $a$=30 percent, hurdle rate $h$=12 percent, and dividend yield $q$=3 percent. We also set values required in the Ingersoll model for a representative executive with risk aversion $\alpha$=5, excess share holdings $\delta$=50 percent, and residual risk $\nu$=20 percent.

To calculate the subjective value of the base option contract under the LSM approach, share prices are simulated using the transformed risk free rate in equation (3) and the transformed dividend yield in equation (4). Similarly, the risk-neutral value is estimated using the original risk free rate $r$ and dividend yield $q$ in the simulations. The cost of the option to the issuing firm is the objective value. It differs from the risk-neutral value because of the suboptimal exercise strategy of the constrained executive. The objective value is estimated via a combination of the risk-neutral price process with the constrained executive's early exercise strategy. The objective value is based on stock prices simulated via the risk-neutral price process in combination with the constrained executive's early exercise decisions determined by stock prices simulated via the subjective price process. Importantly, the same random number sequence is used to compute risk-neutral, subjective, and objective option values. At this point it should be noted that the LSM approach has a built-in mechanism to find an optimal early exercise strategy. In this way, the LSM algorithm has an advantage over the approach in Ingersoll (2006) where an optimal early exercise strategy is approximated by a constant barrier.

A higher dividend yield has two opposing effects on the value of a dividend-protected performance option. First, it lowers the stock price and hence reduces option value. Second, it lowers the strike price and hence increases option value. The numerical results stated in Table I indicate that the former effect dominates. All three values (risk-neutral, subjective, and objective) fall as the dividend yield increases. The dividend protection feature built into the performance option does not provide complete protection against a fall in option value. Subjective option values are about 62 percent of the corresponding risk-neutral values and
objective option values are about 92 percent of the corresponding risk-neutral values. These proportions remain almost the same across all dividend yield examples. Since objective option values are only about 8 percent below risk-neutral values in these examples, the early exercise decisions of the constrained executive closely resemble those of an unconstrained investor.

We also include in Table I corresponding European option values calculated using the Black-Scholes-Merton formula in equation (1). While Cheung et al. (2006) show that these values significantly understate the risk-neutral value of performance options; the biases are less pronounced when compared to objective values. Nevertheless, the difference between objective values and Black-Scholes-Merton values widens at higher dividend yields. This suggests that even though the constrained executive's exercise strategy (used to calculate objective value) is suboptimal, it is still superior to an option contract lacking an early exercise opportunity.

A higher performance hurdle increases the strike price and hence, ceteris paribus, reduces the value of the option. Furthermore, an increasing strike price encourages early exercise and therefore raises the proportionate value of the early exercise premium. These effects can be seen in Table II where all option values decrease as the hurdle rate increases. The early exercise premium, measured as the risk-neutral value minus the Black-Scholes-Merton value, increases in both absolute and relative terms at higher hurdle rates. This relationship between performance hurdles and early exercise premia can also be seen for instance by examining objective values in Table II. For example, at a 4 percent performance hurdle where early exercise is less beneficial, the constrained executive's suboptimal exercise strategy leads to an objective value less than the European Black-Scholes-Merton value. However, at higher hurdle rates where early exercise is more valuable, objective values are increasingly higher than the corresponding Black-Scholes-Merton values despite the suboptimal exercise strategy.

The value of a call option generally increases with maturity. However, this may not be the case for a European option with a strike price that increases through time since the fall in option value due to a higher strike price can exceed the increase in value from a longer maturity. However, the possibility of early exercise may pre-empt such an effect. In Table III, European Black-Scholes-Merton option values for our base contract reach a peak at a maturity of eight years and monotonically decline at longer maturities8. On the other hand, the three American option values (risk-neutral, subjective, and objective) increase with maturity, though increases in subjective and objective values are less than the corresponding increases in risk-neutral values. This is because executives tend to exercise their options prematurely and so a longer maturity only adds a modest value. The results shown in Table III urge caution in the use of European values to value performance hurdle options, especially options that have a long maturity.

A longer vesting period reduces the number of early exercise opportunities and in general lowers the risk-neutral value of the option. The same effect prevails for subjective values since executives would consider an option with a longer vesting period less desirable and hence place a lower value on it. However, the objective value of an option could in fact increase when the vesting period is lengthened. Since the objective value is calculated using payoffs under a constrained executive's suboptimal exercise strategy, it is possible that a longer vesting period restricts suboptimal early exercise and therefore enhances objective
value. We investigate the effects of changing the vesting period on our base contract in Table IV. Lengthening the vesting period from one to four years lowers the risk-neutral value of the option by about $7, or just under 4 percent. This indicates that optimal early exercise usually occurs after the fourth year. Lengthening the vesting period from one to four years lowers the objective value of the option by about $9, or just above 5 percent. This indicates that suboptimal early exercise by a constrained executive also usually occurs after the fourth year. By contrast, the drop in subjective value is about $20, or over 16 percent, reflecting a higher loss in subjective value due to increased early exercise restrictions.

In this section, we have shown that the objective cost to a firm granting a performance hurdle option to an archetypal executive can be materially below the option's risk-neutral value. The difference between the risk-neutral value and objective cost is due to a risk-averse executive's inclination to exercise options earlier than optimal. Ad hoc valuation methods such as the use of an arbitrary but shorter option maturity to price an executive stock option have been proposed as a means to recognise that executive options are worth less than their risk-neutral values. These ad hoc methods may be insufficient for financial reporting standards when impartial and uniform valuation treatments are required. While computationally demanding, the valuation approach used in this study can be readily applied to value different types of executive stock options.

**Conclusion and summary**

This study presents a first attempt to integrate the Ingersoll (2006) utility-theoretic model and the Longstaff and Schwartz (2001) least squares Monte Carlo algorithm to estimate the subjective value and the objective cost of a dividend-protected executive stock option with a performance hurdle. In so doing, we extend the Cheung et al. (2006) study and produce a more comprehensive investigation into the values of performance hurdle options. We find that while risk-neutral values are a clear improvement over European Black-Scholes-Merton values, they overstate the true cost to the firm due to a constrained executive's suboptimal early exercise strategy. Similar to risk-neutral values of performance hurdle options, subjective and objective values decrease with a higher dividend yield, a higher performance hurdle, a longer vesting period, and a shorter maturity.

Dividend-protected performance hurdle options represent but one example of an American path-dependent executive stock option. The approach followed in this study can be readily applied to executive stock options with other non-standard or exotic features. The ability to incorporate subjective parameters in the valuation of executive stock options permits the estimation of subjective values and objective costs. We believe this valuation approach will provide a broad contribution to the study of executive compensation.
\[ C = S^*N(d) - K^*e^{-rT}N(d - \sigma\sqrt{T}) \]
\[ d = \frac{\ln(S^*/K^*) + (r + \sigma^2/2)T}{\sigma\sqrt{T}} \]
\[ S^* = S - \sum_{t=1}^{T} D_t e^{-rt} \]
\[ K^* = Ke^{hT} - \sum_{t=1}^{T-1} D_t e^{h(T-t)} - D_{T-h} \]  
\[ \text{(1)} \]

**Equation 1**

\[ V_{k,t-1} = \begin{cases} 
X_{k,t-1} & \text{if } X_{k,t-1} > e^{-rE(V_{k,t})} \\
e^{-rV_{k,t}} & \text{otherwise} 
\end{cases} \]

**Equation 2**

\[ C^S = Se^{-q'(T-t)}N(d) - Ke^{-r'(T-t)}N(d - \sigma\sqrt{T - t}) \]
\[ d = \frac{\ln(S/K) + (r' - q' + \sigma^2/2)(T - t)}{\sigma\sqrt{T - t}} \]  
\[ \text{(2)} \]

**Equation 3**

\[ q' = q + \alpha(1 - \theta)\theta\nu^2 \]

**Equation 4**

\[ r' = r - \alpha\theta^2\nu^2 \]

**Equation 5**
Table I
Performance option values with varying dividend yields

<table>
<thead>
<tr>
<th>Dividend yield (q)</th>
<th>Subjective value</th>
<th>Objective value</th>
<th>Risk-neutral value</th>
<th>Black-Scholes-Merton value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0(%)</td>
<td>$126</td>
<td>$188</td>
<td>$204</td>
<td>$188</td>
</tr>
<tr>
<td>2(%)</td>
<td>$118</td>
<td>$174</td>
<td>$189</td>
<td>$150</td>
</tr>
<tr>
<td>6(%)</td>
<td>$110</td>
<td>$162</td>
<td>$176</td>
<td>$121</td>
</tr>
<tr>
<td>9(%)</td>
<td>$103</td>
<td>$151</td>
<td>$164</td>
<td>$97</td>
</tr>
</tbody>
</table>

Notes: Option contract values are based on 1,000-share contracts with stock/strike prices $S = K = $1, contract maturity $T = $six years with a two-year vesting, interest rate $r = 7$ percent, volatility $\sigma = 50$ percent, residual risk $\nu = 20$ percent and dividend yields as indicated. Each Monte Carlo price is an average from 250,000 simulation experiments. European Black-Scholes-Merton values are calculated from the formula in equation (1) using the original interest rate $r$ and dividend yield $q$.

Table II
Performance option values with varying performance hurdles

<table>
<thead>
<tr>
<th>Maturity (T)</th>
<th>Subjective value</th>
<th>Objective value</th>
<th>Risk-neutral value</th>
<th>Black-Scholes-Merton prices</th>
</tr>
</thead>
<tbody>
<tr>
<td>4(%)</td>
<td>$108</td>
<td>$155</td>
<td>$165</td>
<td>$143</td>
</tr>
<tr>
<td>6(%)</td>
<td>$118</td>
<td>$174</td>
<td>$189</td>
<td>$150</td>
</tr>
<tr>
<td>8(%)</td>
<td>$122</td>
<td>$185</td>
<td>$204</td>
<td>$151</td>
</tr>
<tr>
<td>10(%)</td>
<td>$125</td>
<td>$192</td>
<td>$215</td>
<td>$148</td>
</tr>
</tbody>
</table>

Notes: Option contract values are based on 1,000-share contracts with stock/strike prices $S = K = $1, a vesting period of two years, interest rate $r = 7$ percent, volatility $\sigma = 30$ percent, hurdle rate $h = 50$ percent, residual risk $\nu = 20$ percent, and contract maturities as indicated. Each Monte Carlo price is an average from 250,000 simulation experiments. European Black-Scholes-Merton values are calculated from the formula in equation (1) using the original interest rate $r$ and dividend yield $q$.

Table III
Performance option values with varying maturities

<table>
<thead>
<tr>
<th>Vesting period</th>
<th>Subjective value</th>
<th>Objective value</th>
<th>Risk-neutral value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$124</td>
<td>$175</td>
<td>$190</td>
</tr>
<tr>
<td>2</td>
<td>$118</td>
<td>$174</td>
<td>$189</td>
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<td>3</td>
<td>$110</td>
<td>$170</td>
<td>$186</td>
</tr>
<tr>
<td>4</td>
<td>$104</td>
<td>$166</td>
<td>$183</td>
</tr>
</tbody>
</table>

Table IV
Performance option values with varying vesting periods

Notes: Option contract values are based on 1,000-share contracts with stock/strike prices $S = K = $1, a contract maturity $T = $six years, interest rate $r = 7$ percent, volatility $\sigma = 30$ percent, hurdle rate $h = 12$ percent, dividend yield $q = 50$ percent, residual risk $\nu = 20$ percent, and vesting periods (in years) as indicated. Each Monte Carlo price is an average from 250,000 simulation experiments.

References


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