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Employee Stock Options as a Source of Compensation

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Abstract

Employee stock options (ESOs) have become a significant fringe benefit, particularly for salaried professionals. ESOs allow an employee to purchase shares of stock at a fixed price over a specified time horizon. This paper discusses key issues that arise in valuing stock options within a litigation environment and suggests that the Black-Scholes Model with minor adjustments can handle many situations.

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It has become commonplace for both middle and upper level executives to receive employee stock options as a fringe benefit from their employer.[1] Typically, such stock options allow individuals to purchase a specific number of shares of their employer's stock at a specified exercise price (also known as the "grant price" or the "strike price"), which is usually equal to or less than the market value of the stock on the date of issue.

Within the litigation setting, it is possible to encounter a variety of applications that require the valuation of employee stock options. In the divorce and probate settings, an analyst may need to value existing employee stock options. In personal injury, wrongful death, and employment termination cases, it may be necessary to forecast losses resulting from forced early exercise of existing options. In addition, when calculating full damages resulting from loss of earnings, it may be necessary to forecast and include the value of expected stock option grants, in the absence of injury, death or wrongful termination.

Valuation techniques for traded stock options are numerous and well documented.[2] However, employee stock option valuation requires special consideration. Key differences between employee stock options and traded options are:

> Employees cannot transfer or sell company stock options that have been granted to them;

[1] For example, Murphy (1998) reports that for a sample of 1,000 publicly traded companies over the period from October 1992 through June 1993, 67.2 percent granted options to their CEO.
[2] See for example, Hull (2000).

Tradable American style listed call options can be exercised at will, while employee stock options may have vesting restrictions;

Employee stock options are either exercised or terminated when the employee leaves the firm;

Employee stock options may have different tax liabilities; and

Employee stock options have a much longer time to expiration from date of issue (usually ten years) compared to listed call options that generally expire in at most six months from date of issue.

No general ESO valuation theory has resolved these problems. For these reasons, some practitioners use an intrinsic value approach. We argue that the intrinsic value approach fails to capture key components of option prices. We argue that within the litigation framework, a better approach is to modify known tradable option valuation formulas. These differences affect employee stock option valuation, requiring modification to the analytical models and/or parameters that are appropriate for tradable options.

This paper presents an approach to employee stock options valuation that is theoretically grounded, yet tractable enough to be useful in a litigation environment. The discussion focuses on valuation methodology, with examples related to both existing options, and the projection and valuation of future option grants by public companies.

Valuation Methodology

Terminology and Characteristics of Employee Stock Options

Unique characteristics of ESOs differentiate them from standard tradable options. Employee stock options are generally granted with an exercise period that is up to ten years from the date of issue. Typically, a vesting period restricts exercise over the first several years of the option grant. Employee stock options vary as to whether 100 percent vesting occurs after a certain number of years, or whether there is proportional vesting of the options occurring over a period of time. An option cannot be exercised until it is vested.

For tax purposes, employee stock options can be categorized as either incentive stock options or nonqualified options. When the employee exercises an incentive stock option, the employee does not have to recognize either the option grant or exercise as ordinary income for tax purposes. The employee is taxed solely on the capital gain following the sale of the actual shares of stock with the exercise price as the basis. However, there is the possibility of an alternative minimum tax liability on the difference between the value of the stock on the day that the option is exercised and the option exercise price. Nonqualified options are taxed twice: first as ordinary wage income in the first year that the option is vested and second as capital gains following the sale of the stock.[3] The capital gains tax is paid on the difference between the market price and the option exercise price the day that the option is exercised. Internal Revenue Service regulations govern the tax treatment of employee stock options and the extent to which companies can issue incentive stock options as opposed to nonqualified options.

Employee stock options are nontransferable. Normally, when an employee is terminated or voluntarily leaves the company, the employee has to exercise the option by the date of separation or else forfeit the option.[4] When an employee is terminated or leaves a company voluntarily, there is no opportunity to exercise unvested options. In the case of the death of an employee, some companies allow for the decedent's next-of-kin to hold the option until date of expiration. Companies may also allow retirees to keep their options until they expire. Typically, employee stock options are issued with a strike price either at or below the current market price of the company's stock. The strike is established at the time of grant. As a result, the option has no direct value to the employee unless company's stock price increases. To illustrate, assume that a firm issues an employee an ESO to buy 500 shares of his/her company's stock at $50.00 per share. At the time of issue, the price of the company's stock is $50.00 per share and a one-year vesting period is required before exercise is allowed. Suppose that over the next year the stock appreciates by ten percent to $55.00. With the vesting period met, the employee may exercise the option to buy 500 shares of stock for $50.00. The shares may then be sold for $55.00 per share, generating a $2,500 profit.[5] If on the other hand, the stock price falls to $45.00 per share, the executive would not exercise the option because he or she could purchase stock at $50.00 per share when it has a market value of only $45.00.

Intrinsic vs. Actual Value

No general theory of ESO valuation handles all the problems associated with long times to maturity, vesting, nontransferability, and tax liability. For this reason, many practitioners have used an intrinsic value approach in the litigation environment.

If K is the exercise price when the ESO is issued and S is the market price of the stock, the intrinsic value of the ESO is equal to: $\max\{0, S - K\}$.

When the stock price exceeds the exercise price ($S>K$), i.e., the option is "in the money", the employee can exercise the ESO by purchasing stock at a price equal to K and can immediately sell the stock at a price of S. Thus, when $S>K$, the profit earned by exercising the ESO equals S - K, its intrinsic value.

When the stock price is less than the exercise price ($S<K$), i.e., the option is "out of the money", the employee is not able to profit by exercising it and hence the intrinsic value of the ESO is zero.

Prior to expiration, the intrinsic value of the employee stock option does not represent its actual value. The current value of the option can be viewed probabilistically as the expected value of the difference between the stock price on date of future exercise, less the exercise price discounted to

[3] This description of the taxation of nonqualified options applies to options granted to employees of publicly traded companies.

[4] In some cases, particularly with voluntary separations, companies will allow the employee to keep their options over a short window following the separation date, such as two months.

[5] Ignoring transaction costs.

present value. In the case of out of the money options, a probability of stock price appreciation prior to exercise remains. Hence, the actual value of the option is positive even though the intrinsic value is zero. In effect, the intrinsic value places a lower boundary on the actual value of the ESO. The intrinsic value also fails to capture the economic value of the option to wait for a more optimal exercise period.

Black-Scholes Model

The Black-Scholes Model (1973), including the Merton modification (1973) (hereafter BSM Model) is among the most commonly used methods of valuing tradable call options. The mathematical formulation of the BSM Model is shown in the Appendix A.

While the BSM Model was designed for so-called European options that can only be exercised at expiration, it is not optimal to exercise American style call options on non-dividend paying stocks prior to maturity. Hence, the BSM Model generally gives appropriate values for American style call options on non-dividend paying stocks. American style call options on dividend paying stocks, may be under some circumstances, optimally exercised prior to maturity. However, it is generally not optimal to exercise early prior to that date.[6] A second assumption of the BSM Model is that investors can hedge their option positions. We argue that while employees cannot directly trade their options, they can hedge their positions by maintaining an appropriate portfolio in the underling stock, which we assume is traded. Hence, we assume risk neutral valuation is acceptable for ESO valuation, and specifically utilize it in the vesting adjustment, which is derived in Appendix C.

The following parameters are used to compute BSM option values:

- Current stock price;
- Exercise price;
- Risk-free rate of return;
- Time to option expiration;
- The annual volatility of stock returns; and
- Constant dividend yield.

Note that the exercise price and the time to exercise are from the option contract.

The stock price and risk-free rate of return are observable from financial markets. Since traded options typically have short lives, dividend yields are forecast from recent dividend history.

However, volatility is not directly observable and is thus the most difficult parameter to estimate. One approach to estimating volatility is to use recent historic data. It is common to calculate continuously compounded daily rates of return for the past year as $\ln[S_1/S_0]$, where S_1 equals the current daily stock price and S_0 equals the previous daily closing price. If there are 250 trading days in the year and daily returns are independent of each other, then the volatility can be expressed as the standard deviation of the daily return multiplied by the square root of 250. An alternative approach to estimating volatility is to recover the volatility assumption that is "implied" in traded option values. Given the current market price of an option, current stock price, exercise price, dividend yield and interest rate, iterative numerical methods can be used to solve for the implied volatility.

A step-by-step calculation of a Black-Scholes call option is shown in Table 1. The effects of changes in individual parameters on BSM call values are shown in Table 2. In particular, it should be noted that a longer time to expiration is associated with a higher call value because time allows more opportunities for profitable exercise. Higher stock price volatility also increases the value of an option. In effect, higher volatility creates a larger upside stock price potential, but adds no additional downside risk, as the minimum call option value is zero. The effects of changes in volatility estimates on value, while holding other BSM values constant are shown in Table 3. Note that an ESO valued by its intrinsic value would not change as volatility and time to maturity change. In the examples shown in Table 3, the intrinsic value is zero, regardless of volatility and time to maturity.

Table 1. Illustration of the BSM Value for a Single Call Option with an Exercise Price (K) = \$1.00, Stock Price (S) = \$1.00, Annual Risk Free Rate = 5.00 Percent, Volatility (σ) = 0.1, Time to Expiration (T) = One Year and Annual Dividend Yield = 1.00 Percent.

$$\delta = \ln(1+0.01) = 0.0010$$

$$i = \ln(1+0.05) = 0.0488$$

$$\text{Cumulative Volatility} = \sigma\sqrt{T} = 0.1 * \sqrt{1} = 0.1000$$

$$d_1 = \frac{\ln\left(\frac{S}{K}\right) + \left(i - \delta + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}$$

$$= \frac{\ln\left(\frac{1.00}{1.00}\right) + \left(0.0488 - 0.0010 + \frac{0.1000^2}{2}\right) * 1}{0.1000}$$

$$= 0.4383$$

$$d_2 = d_1 - \sigma\sqrt{T} = 0.4383 - 0.1000 = 0.3383$$

$$N(d_1) = 0.6695$$

$$N(d_2) = 0.6325$$

$$\text{BSM Value} = e^{-\delta T} S N(d_1) - e^{-iT} K N(d_2) = 0.0605$$

Table 2. The Effects of Changes in Individual Parameters on BSM Call Values.

Parameter	**Effect of Increase on Black-Scholes Call Value**
Current stock price	+
Exercise Price	-
Risk free rate of return	+
Time to option expiration	+
Annual volatility of stock returns	+
Dividend yield	-

[6] See Hull (2000), pp. 259-263 for discussion of early exercise.

Table 3. BSM Values for a Single Call Option with an Exercise Price = $1.00, Stock Price = $1.00, Risk Free Rate = 5.00 Percent, and Dividend Yield = 1.00 Percent.

Time to Expiration = One Year

Volatility	Black-Scholes Values
0.1	$ 0.060
0.2	0.098
0.3	0.136
0.4	0.174

Time to Expiration = Four Years

Volatility	Black-Scholes Values
0.1	$ 0.160
0.2	0.221
0.3	0.286
0.4	0.351

Note: Values increase with volatility and with time to maturity.

Adjustments for Employee Stock Options

The BSM Model is designed to value European tradable options that pay no dividends or a constant dividend yield. Although ESOs share many of the characteristics of tradable call options, there are unique characteristics of employee stock options that violate some assumptions of the BSM. In particular, employee stock options have a vesting period. Appendix C shows that under the assumptions of no arbitrage and risk neutrality, the value of an option grant with vesting equals the probability of vesting times the value of a corresponding fully vested call option.[7]

In addition, ESOs are not transferable. They must be exercised to generate cash flow and this creates an incentive for early exercise, which theoretically may reduce the value of an option. For example, employee stock options are subject to forfeiture if the employee leaves the firm prior to vesting. Hence, departing employees will always exercise in-the-money vested options. Likewise, long-term employees have an incentive to exercise deep in-the-money options to capture price appreciation. It is not surprising that Huddart and Lang (1996) find that the fraction of employee stock options that are exercised in a particular month are positively correlated with prior stock price performance and are unrelated to subsequent stock price performance. Huddart and Lang's results are certainly consistent with risk averse behavior.

However, the overall impact of early exercise on employee option values may not be too severe for valuation purposes in the litigation environment. In particular, the BSM Model may provide reasonable estimates if the time to expiration is adjusted to reflect the possibility of early exercise and adjustments for the likelihood of vesting. As evidence, consider Carpenter (1998), who uses data on employee stock option exercises to compare:

The option values obtained using a binomial American[8] option pricing model with exogenous exercise;
A model that treats the option exercise decision within a utility maximizing framework; and
The BSM Model with the option's actual expiration replaced with the option's expected life.

In general, Carpenter's results suggest little difference between the BSM values and the values obtained via the other two methodologies.[9] Given its relative computational ease, the BSM Model appears justified for use in valuing ESOs in the litigation environment, as long as specific adjustments are made. In particular, to factor in early exercise of options, company data or estimates of the average life of existing ESOs can be obtained from annual reports and 10-K filings. As companies comply with Financial Accounting Standards No. 123, more information concerning historic ESO exercise patterns is appearing in footnotes to financial statements (see below). See Appendix B for more information on SFAS 123.

Since ESOs have much longer time to expiration than do tradable options, the use of volatility and dividend yield estimates are especially important. Implied volatilities based upon market values of tradable call options may be problematic given that tradable options typically expire in less than a year and employee stock options have times to expiration of five to ten years. Analogously, the use of recent historic data to measure volatility requires the analyst to assume that recent volatility will persist over an extensive period into the future. Hence, when available, implied volatilities from LEAPS may be more appropriate. To estimate the dividend yield, either the current dividend yield can be used or an econometric model can be developed to forecast dividend yields.

Valuation of Existing Employee Stock Options

It may be necessary to value an existing employee stock option in a divorce action or when an employee is either terminated or disabled prior to vesting. Within this setting, the BSM Model, with the previously identified adjustments can be used to estimate the current value of the existing option.

Analysis of In the Money Option

Assume that an employee was granted options to buy 100 shares of Acme stock at an exercise price of $15.00 per share on July 1, 1999. At the time of the grant, the exercise price equaled the market price of the stock. The options expire ten years after issue and do not vest until two years after issue. Based upon the footnotes in Acme's financial statements, that

[7] Yook (1997) uses this result, but does not present the derivation.

[8] In the literature on tradable stock options, American put options may have an early exercise premium. The binomial model (Cox, et. al., 1979) captures the value of early exercise of American put options.

[9] Without adjusting the time to expiration to reflect actual firm exercise patterns and likelihood of vesting, employee stock option values computed using the Black-Scholes Model are overstated.

Table 4. Valuation of In the Money Employee Stock Option to Buy 100 Shares of Acme Stock, Option Vests in One Year, Expected Expiration of Option is in Four Years, 6.50 Percent Risk Free Rate, 1.00 Percent Dividend Yield Volatility Equal to 0.2 and Probability of Vesting Equals 0.9.

				Value of Option that Expires in Four Years	
Number Of Shares	**Exercise Price**	**Current Stock Price**	**Intrinsic Value**	**BSM Value with no Vesting Restrictions**	**BSM Value with Vesting Restrictions**
100	$15.00	$16.00	$100.00	$448.33	$403.50

Table 5. Valuation of Out of the Money Employee Stock Option to Buy 100 Shares of Acme Stock, Option Vests in One Year, Expected Expiration of Options is in Four Years, 6.50 Percent Risk Free Rate, 1.00 Percent Dividend Yield Volatility Equal to 0.2 and Probability of Vesting Equal to 0.9.

				Value of Option that Expires in Four Years	
Number Of Shares	**Exercise Price**	**Current Stock Price**	**Intrinsic Value**	**BSM Value with no Vesting Restrictions**	**BSM Value with Vesting Restrictions**
100	$15.00	$14.00	$0.00	$301.15	$271.35

Table 6. BSM Option Values (Including Vesting Restriction) as Percent of Salary, Options Vests Two Years After Issue, Expected Life of Option is Five Years after Issue, 6.50 Percent Risk Free Rate, 1.00 Percent Dividend Yield and Volatility Equal to 0.2.

Year	**Salary**	**Number Shares**	**Exercise Price**	**Stock Price On Grant Date**	**Value of Options**	**Value of Options as Percent of Salary**
1	$100,000	3,000	$ 15.00	$ 15.00	$ 10,875.85	10.9%
2	104,000	2,400	18.00	18.00	10,440.82	10.0%
3	109,000	2,800	16.50	16.50	11,165.87	10.2%
4	113,000	2,100	21.00	21.00	10,658.33	9.4%
					Average	**10.1%**

disclose historic exercise patterns, the expected maturity of the option is five years.

Suppose that one year after the date of issue it is necessary to place a current value on the options. To illustrate the valuation, assume that the stock price has appreciated to $16.00 per share and the current intrinsic value of the option grant is $100.00. However, due to the vesting restriction, the employee cannot exercise the option for another year. Based on historical exercise patterns, the remaining term of the option is four years. The volatility parameter equals 0.20 and is assumed to be based upon the historic return volatility measured over the most recent four years of daily return data.[10] The 6.50 percent risk free interest rate is assumed to be the current yield on a four-year U.S. Treasury strip and the 1.0-percent dividend yield is a forecasted dividend yield for ACME. As shown in Table 4, the option has a BSM value equal to $448.33. This would be the value of the option grant in the absence of the vesting restriction.

[10] This is consistent with SFAS 123. Daily data is used over the four-year period because this maximizes the number of observations over this period. Campbell, et. al. (1997) have shown that the accuracy of the estimate of volatility from historic returns increases with the number of observations.

Assume that there is a 90 percent probability that the employee will vest in one year.[11] As shown in Appendix C, the BSM value of the option grant in the absence of the vesting restrictions should be multiplied by 0.9 to reflect the reduction in value that results from the vesting restriction. As shown in Table 4, the value of the option grant equals $403.50, as compared to an intrinsic value of $100.00. The difference between the intrinsic value and the BSM value with vesting restrictions reflects the effects of both the likelihood of vesting and the probabilities of future upside movements in Acme stock.

Note that the analysis in Table 4 makes no effort to compare the exercise patterns of the individual employee in question with the patterns of the company as a whole. If information concerning the individual's past exercise patterns is available, it may be used to adjust expected option life reported in the footnotes to the financial statement.

Analysis of Out of the Money Option

In Table 5, the calculations are repeated under the same assumptions, except that the stock is currently trading at a price equal to $14.00 per share, as compared to the $15.00 per share exercise price. As shown in Table 5, even though the option grant has no intrinsic value, it has a positive BSM value after factoring investing restrictions since the volatility measure allows for a positive probability of upward movement in the stock price.

Forecasting Future Option Grants

Forecasting the value of foregone option grants due to injury or wrongful termination requires a determination of option values at time of grant. This allows the analyst to project values that reflect the uncertainty concerning whether the option will be in the money at the time of exercise.

In Table 6, hypothetical historic option grants by Acme to an employer are shown for four years, along with their salary. For ease of computation, it is assumed that the average life of all options are five years and that all of the options vest two years after issue.[12] In addition, the risk free rate is assumed to be 6.50 percent, the dividend yield is assumed to be 1.00 percent and volatility is assumed to be equal to 0.2. It is also assumed for simplicity that there is an 85 percent probability at time of grant that vesting will occur after two years. In this example, the BSM values of the option grants have an average value equal to 10.1 percent of salary, which can be applied to future forecasted salary values, in order to obtain future option values.[13] The analysis in Table 6 assumes that from the viewpoint of the corporation, salary, stock options and other elements of compensation are substitutes.

[11] In an actual case, the probability of vesting could be obtained from examining data or vesting patterns in the company. Another approach might be to utilize the LPE approach used by many economists as an alternative to worklife estimation (Brookshire and Smith, 1990).
[12] Assuming review of footnotes to Acme's financial statements.
[13] This analysis does not include the necessary adjustment to the BSM values that would have to be made as the employee approaches retirement age because the employee may have to forfeit the options within a certain time period that is less than the actual time to expiration.

Conclusion

This paper has suggested the use of the BSM Model to ESO values in litigation. Although there are theoretical problems with the BSM Model, it can be used in the context of valuing employee stock options and is analytically tractable. The approach is also a considerable improvement over using intrinsic values to estimate ESO values. Although there are valuation methods that may appear to be more theoretically sound, it is not all clear that the gains from using these methods at all outweigh the costs associated with the additional complexity. With appropriate adjustments, the BSM Model can be used to deal with complexities inherent in vesting restrictions and likelihood of early exercise.

APPENDIX A

Merton Modified Black Scholes-Model

Merton's (1973) modification of the Black-Scholes value for a European call is

$$(1) \qquad C = e^{-\delta T} S N(d_1) - e^{-iT} K N(d_2)$$

Where i is the continuously compounded annual risk free rate, T is the time until expiration of the options in years, δ is the constant continuously compounded dividend yield, S is the current stock price, K is the is exercise price and $N(d_i)$ represents the probability that a normally distributed variable has a value less than d_i. The expressions for d_1 and d_2 are:

$$(2) \qquad d_1 = \frac{\ln\left(\frac{S}{K}\right) + \left(i - \delta + \frac{\sigma^2}{2}\right)}{\sigma\sqrt{T}}$$

$$(3) \qquad d_2 = d_1 - \sigma\sqrt{T}$$

where σ is the standard deviation of the annual return of the stock.

APPENDIX B

SFAS 123

The Financial Accounting Standards Board Statement of Financial Accounting Standards No. 123 (SFAS 123), *Accounting for Stock-Based Compensation* requires public companies to at a minimum include the fair market value of stock-based compensation in footnotes to financial statements. SFAS 123 suggests, but does not require companies to use the Black-Scholes Model to calculate fair market values of stock options. SFAS 123 also suggests the use of the binomial option pricing model (Cox, et. al., 1979), but the Black-Scholes Model is much less complicated to use than the binomial model. SFAS 123 allows companies to factor in separations and retirements in order to compute an average option life, as part of the calculation of fair market value via the Black-Scholes Model. As a result, SFAS 123 improves the ability of the Black-Scholes Model to generate employee option stock values.

Yook (1997) has suggested that to be consistent with SFAS 123, the risk-free rate used in a Black-Scholes calculation should be the yield, as of date of grant, on a U.S. Treasury strip with a maturity matching the expected life of the option. In order to compute the value under SFAS 123, the dividend yield should be the yield that should be expected to apply over the future until option exercise. A practical approach is to use a historic average dividend yield, which is adjusted for expected future differences from past dividend experience. Alternatively the dividend yield can be forecasted.

In theory, the Black-Scholes Model requires the use of a parameter that reflects expected future volatility. SFAS 123 recommends that historic volatility be estimated over the most recent period that is equal to the expected life of the option.

APPENDIX C

The vesting requirement introduces two important complications to employee stock option valuation. First we must factor in the probability that the employee may leave or terminate prior to vesting. Suppose that an ESO becomes fully vested with probability ρ, at some future time t_1. We assume ρ may be estimated from historical length of employment patterns or agreed upon by parties. Let C_1 be the value of the option grant at vesting. The present value of ESO, C_0, is the appropriately discounted expected value of the option at vesting or:

(1) $$C_0 = e^{-r(t_1-t_0)}\rho\hat{E}[C_1]$$

where $\hat{E}$ denotes risk neutral expectation.
The second, and much more difficult complication, is determining $\hat{E}[C_1]$. In general, the expected future value of an option is a function of option values integrated over the distribution of future stock prices.
While the preceding general solution is beyond the scope of this paper, two special cases arise in which $\hat{E}[C_1]$ is easily determined. Hull (1993) shows that if the ESO is designed so that the strike price is set equal to the underlying stock price at the time of vesting then

(2) $$\hat{E}[C_1] = \hat{E}\left[C_0^* \frac{S_1}{S_0}\right]$$

where S_1 and S are the underlying stock prices at time t_1 and t_0, and C_0^* is the current value of an at-the-money option on S with the same maturity as the ESO. Under risk neutral valuation, $\hat{E}[S_1] = S_0 e^{r(t_1-t_0)}$ giving

(3) $$C_0 = \rho C_0^*$$

In the special case where the ESO strike price is determined at the time of vesting, its current value is the probability of vesting times the current value of an at-the-money option with the same time to maturity.

We arrive at equation (3) because the particular ESO is at-the-money when it vests and because under the BSM model, an at-the-money call option is proportional to the stock price. Nevertheless, practitioners often use equation (3) to approximate the value of an ESO with vesting, even if the strike price is set when granted. See for example Yook (1997). Since readers may encounter equation (3) in practice, we show how to arrive at equation (3) by making the assumption that the forward price of an asset is an unbiased estimator of the expected future price.

Let C_0^* be a traded option with the same strike and maturity as the ESO and where the ESO strike is determined at time of grant. Suppose we were to write a forward contract on C_0^*. The standard arbitrage free forward price F would be:

(4) $$F = C_0^* e^{r(t_1-t_0)}$$

Now if we make the strong assumption that the forward price is an unbiased estimator of the future price, then

(5) $$F = \hat{E}(C_1^*)$$

However, at time t_1, C_1 and C_1^* have the same payoffs and hence the same value. Combining equations (1), (4), and (5) gives:

(6) $$C_0 = \rho C_0^*$$

If we assume that the forward price is an unbiased estimator of the expected future price, then the value of an option with a probability ρ of becoming fully vested, is equal to ρ times the value of a corresponding option with no vesting requirement. While this assumption may not be completely accurate, it provides a very tractable solution. In any event, practitioners encountering equation (3) will at least know the assumption needed to generate the result.

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