

HOW TO VALUE EMPLOYEE STOCK OPTIONS

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ABSTRACT

One of the arguments often used against expensing employee stock options is that it is very difficult to calculate their fair value at the time they are granted. We present an approach that is practical, easy-to-implement, and theoretically sound approach to solving this valuation problem. Our approach explicitly considers the vesting period, the possibility that employees will leave the company during the life of the option, the inability of employees to trade their options, and dilution issues.

HOW TO VALUE EMPLOYEE STOCK OPTIONS ¹

It is now becoming increasingly accepted that companies should recognize the compensation their employees receive in the form of stock options as an expense on the income statement. One of the major difficulties in accounting for employee stock options in this way is the determination of the fair value of the options.

Standard methods have been developed for valuing the options that trade on an exchange and in the over-the-counter market. However, there are a number of features of a typical employee stock option that make it difficult to apply these standard methods to it. In particular:

1. There is usually a vesting period of during which the options cannot be exercised. This vesting period can be as long as four years.
2. When employees leave their jobs (voluntarily or involuntarily) during the vesting period they forfeit unvested options.
3. When employees leave (voluntarily or involuntarily) after the vesting period they forfeit options that are out of the money and they have to exercise vested options that are in the money immediately.
4. Employees are not permitted to sell their employee stock options. They must exercise the options and sell the underlying shares in order to realize a cash benefit or diversify their portfolios. This tends to lead to employee stock options being exercised earlier than similar regular options.

5. There is some dilution arising from the issue of employee stock options because if they are exercised new Treasury stock is issued.

The Financial Accounting Standards Board (1995) in their publication FASB 123 makes some suggestions as to how employee stock options should be valued from the viewpoint of the company granting them. Rubinstein (1995) was one of the first researchers to critically examine the FASB 123 proposals. In this paper we extend Rubinstein's ideas to create a practical approach for valuing employee stock options that is theoretically sound, easy to implement, and in the spirit of FASB 123.

FASB 123

The traditional way of accounting for stock options in the United States is the intrinsic value method. This is based on Opinion 25 issued in 1972. Under this method the compensation cost of an employee stock option is assumed to be the excess, if any, of the market price of the stock over the exercise price on the date the option is granted. In the most common situation where options are granted with an exercise price equal to the current market price, the intrinsic value method calculates the compensation cost as zero.

In October 1995 the Financial Accounting Standards Board published FASB 123 "Accounting for Stock Based Compensation". This statement encourages companies to adopt a fair-value-based method of accounting for stock options instead of the intrinsic-value-based method, but it does not require them to do so.² Following the publication of FASB 123 most companies continued to use the intrinsic-value-based method. Recently however, a number of companies such as Coca Cola and General Electric have adopted the fair-value-based method.

Appendix B of FASB 123 discusses the value of employee stock options in some detail.

It proposes a three-step procedure:

1. Estimate the expected life of the option
2. Use either Black and Scholes (1973) or Cox, Ross, and Rubinstein (1979) binomial tree method to value the option with the expected life as the time-to-maturity parameter
3. Adjust the value to allow for the possibility of the employee leaving the company during the vesting period

The procedure is best illustrated with an example. We will consider a company that grants the option shown in Table 1 to its employees.³

A normal 10-year European option with the parameters in Table 1 would be valued using the Black and Scholes model at 20.47. A normal 10-year American option would be valued using the Cox, Ross, and Rubinstein binomial tree model at 21.03. To value the employee stock option using the FASB 123 procedure we first must estimate two additional parameters:

1. The employee exit rate during the vesting period. This is the probability that an employee will leave the company each year during the vesting period and is referred to as the forfeiture rate in FASB 123.⁴
2. The expected life of the option, i.e., average time the option stays in existence assuming the employee does not leave during the vesting period

Suppose that the employee exit rate is 3% per year and the expected life of the option is estimated as 6 years. We reduce the option life parameter from 10 years to 6 years.

Assuming the Black-Scholes model is used, this reduces the value of the option from 20.47 to 17.15. The employee exit rate of 3% means that on average 3% of this value is lost each year during the vesting period because employees leave the company. The FASB 123 value of the option is therefore $0.97 \times 0.97 \times 0.97 \times 17.15 = 15.65$. If instead the binomial tree model is used, the value of a six-year option would be calculated as 17.25 and the FASB 123 value of the option would be $0.97 \times 0.97 \times 0.97 \times 17.25 = 15.75$.⁵

To determine the total value, the value of an individual option must be multiplied by the number of options of that type that are outstanding. Suppose that 100,000 options have been granted with the parameters in Table 1. Suppose further that the employee exit rate and expected life we have been using (3% and 6 years) are appropriate for all the options. The fair value of the options would be calculated as $100,000 \times 15.65 = \$1,565,000$ using the Black-Scholes model and $100,000 \times 15.75 = 1,575,000$ using the binomial tree model.⁶

How well does the basic FASB 123 approach deal with the five features of employee stock options listed at the beginning of this article? The first feature (that options cannot be exercised during the vesting period) is not incorporated. The Black-Scholes model assumes no exercise until the end of the expected life; the binomial tree model assumes exercise at any time until the end of the expected life. The second feature concerns the possibility of employees leaving during the vesting period. FASB 123 handles this by

estimating an employee exit rate during the vesting period. It can be argued that this rate is negatively correlated with the stock price because a) employees are more likely to be fired when the company is doing badly and b) employees are less likely to choose to leave a company voluntarily if their employee stock options are in the money. It is therefore likely that FASB 123's procedure for handling this feature of employee stock options understates the value of the options. Estimating the negative correlation between employee exit rates and the stock price is difficult. Luckily however, the impact of the correlation appears to be very low.⁷

The third feature and fourth feature listed at the beginning of this article lead to options being exercised earlier than if they were regular exchange-traded or over-the-counter options. FASB 123 handles these features by reducing the life of the option. The problem is that it is very difficult to estimate the reduction in life that is appropriate. Setting the life of the option equal to an estimate of the average time the options will remain unexercised may give reasonable results in many situations, but it does not have a solid theoretical basis. The 'true' value of an option once it has vested is determined by a) the exercise strategy of the employee and b) the possibility that the employee may be forced to exercise the option early or abandon it because he or she leaves the company. There is no reason why the FASB 123 estimation procedure should produce a value close to the 'true' value. The final feature of employee stock options concerns dilution. The basic FASB 123 method does not deal with this.

Enhanced FASB 123

In this section we present an enhancement to FASB 123 that deals better with the features listed at the beginning of this article and overcomes its theoretical weakness.⁸ Our “Enhanced FASB 123” model differs from the basic FASB 123 model in that

1. It explicitly considers the possibility that the employee will leave the company after the vesting period. It requires the company to use employee turnover rates to estimate an employee exit rate, e , which applies to both the pre-vesting period and the post-vesting period.
2. It explicitly incorporates the employee’s early exercise policy. It does this by assuming that early exercise happens when the stock price is a certain multiple, M , of the exercise price.

The employee exit rate, e , can be directly estimated from historical data on employee turnover rates for the category of option holders being considered. The early exercise multiple, M , is likely to be more difficult to estimate in many situations. Whenever sufficient data is available, it should be set equal to the average ratio of the stock price to the strike price when employees have in the past made voluntarily early exercise decisions when these decisions are not immediately after the end of the vesting period.

The binomial model can be extended to value employee stock options in the Enhanced FASB 123 model. The tree is constructed in the usual way. The rules for calculating the value of the option at each node of the tree are:

1. Options can be exercised only after the vesting period.

2. A vested option is exercised prior to maturity if the stock price is at least M times the exercise price.
3. There is a probability $e \delta t$ that the option will be forfeited in each short period of time during the vesting period.
4. There is a probability $e \delta t$ that the option will terminate in each short period of time δt after the end of the vesting period. When this happens the option is forfeited if it is out of the money and exercised immediately if it is in the money.

Suppose that there are N time steps of length δt in the tree. Suppose further that $S_{i,j}$ is the stock price at the j th node of the tree at time $i \delta t$, and $f_{i,j}$ is the value of the option at this node. Define K as the strike price of the option and v as the time when the vesting period ends. The equations describing the backwards induction through the tree are:

$$f_{N,j} = \max(S_{N,j} - K, 0)$$

When $0 \leq i \leq N - 1$

$$\begin{aligned} \text{If } i\delta t > v \text{ and } S_{i,j} \geq KM \quad & \text{then } f_{i,j} = S_{i,j} - K \\ \text{If } i\delta t > v \text{ and } S_{i,j} < KM \quad & \text{then } f_{i,j} = (1 - e\delta t)e^{-r\delta t} [pf_{i+1,j+1} + (1-p)f_{i+1,j}] \\ & \quad + e\delta t \max(S_{i,j} - K, 0) \\ \text{If } i\delta t < v \quad & \text{then } f_{i,j} = (1 - e\delta t)e^{-r\delta t} [pf_{i+1,j+1} + (1-p)f_{i+1,j}] \end{aligned}$$

The value of the option is f_{00} .⁹

The early exercise strategy we are assuming leads to the employee stock option being a type of barrier option. As explained in Hull (2003) it is computationally more efficient to use a trinomial rather than a binomial tree when valuing a barrier option. Three branches

emanate from each node and the spacing between the stock prices considered is adjusted so that there are nodes on the tree where the stock price equals KM . The probabilities on the tree are chosen so that the expected change and standard deviation of change in the stock price in a short period of time are correct in a risk-neutral world.

Table 2 shows the price of the option in Table 1 for different assumptions about M and e .

Empirical Evidence on Exercise Behavior

There are relatively few statistics available on the actual exercise behavior of employees in different types of companies to assist in choosing the early exercise multiple, M .

Huddart and Lang (1995) and Carpenter (1998) provide some results. Carpenter looked at a sample of option exercises by top executives at 40 firms between 1979 and 1994. All the options had 10-year lives. The average vesting period was 1.96 years; the average time of exercise was 5.83 years; and the stock price at the time of exercise was 2.8 times the exercise price. Huddart and Lang looked at five firms, but considered all employees not just top executives. They found that the average time of exercise was 3.4 years and the average ratio of the stock price to the exercise price at the time of exercise was 2.2.

Unfortunately the average ratio of the stock price to the exercise price at the time of exercise is only an approximate estimate of an employee's exercise policy. This is because at the end of the vesting period the stock price might be well above the minimum necessary to trigger exercise. Also at the end of the life of an option, exercise will take place for all stock prices above the exercise price.

The average time to exercise and the ratio of the stock price to the strike price at the time of exercise is lower for the Huddart and Lang sample than for the Carpenter sample. This suggests that top executives may wait longer than more junior employees before exercising. We can conjecture that this may be because they have less need to exercise options for personal liquidity reasons.

Dilution

In many situations the amount of equity underlying employee stock option plans is very small in relation to the total amount of equity issued by a company and the impact of dilution can be safely ignored. In this section we argue that the impact of dilution can be ignored in other situations as well.

To understand the nature of dilution consider a company where 100,000 shares are outstanding and the current share price is \$50. The company decides to grant 100,000 stock options to its employees with a strike price of \$50 and a vesting period of three years. If the market anticipates this decision there is no impact on the stock price. The adverse effect (if any) of this action is already reflected in the current \$50 stock price. If the action is unanticipated, and the market sees little benefit to the shareholders from the employee stock options in the form of reduced salaries and more highly motivated managers, the stock price will decline immediately after the announcement of the employee stock options. Suppose that the stock price declines to \$45. The dilution cost to the current shareholders is \$5 per share or \$500,000 in total.

Suppose that the company does well during the vesting period so that by the end of the vesting period the share price is \$100. Suppose further that all the options are exercised at

this point. The payoff to the employees is \$50 per option. It is tempting to argue that there will be further dilution in that 100,000 shares worth \$100 per share are now merged with 100,000 shares for which only \$50 is paid so that a) the share price reduces to \$75 and b) the payoff to the option holders is only \$25 per option. However, this argument is flawed. The exercise of the options is anticipated by the market and already reflected in the share price.

Researchers such as Galai and Schneller (1978) have modeled the situation where a company makes a single warrant issue. They assume that the total of all equity (shares plus warrants) follows geometric Brownian motion. This model is potentially useful to senior executives who wish to estimate the potential cost of a large issue of employee stock options that is not anticipated by the market. Our focus in this article is a little different. We are interested in estimating the cost of stock options once they have been granted. We can do this by observing the stock price immediately after the grant of the stock options is announced and then assuming a stochastic process for the stock price. The stock price immediately after the grant of the stock options is announced fully incorporates any dilution.

The natural assumption about the process for the stock price is geometric Brownian motion. When this assumption is made we are effectively in the same position as when we ignore dilution providing we base our value of the option on the post-grant rather than the pre-grant stock price. An alternative more theoretically correct assumption is to assume that the value of the stock plus all outstanding employee stock options (as well as warrants and convertibles if any) follow geometric Brownian motion. This assumption is

consistent with what Galai and Schneller do. Unfortunately it is extremely difficult to extend their work to the situation where there is more than one option issue outstanding.

To test the assumption that the stock price follows geometric Brownian motion we considered the case where there is only one stock option issue and compared the assumption with the assumption in the Galai-Schneller model that the stock plus options follow geometric Brownian motion. Except in cases of extreme dilution we found the price difference between the two models to be very small. This is reassuring.

It is instructive to compare an employee stock option once it has been granted with an over-the-counter or exchange-traded option that has exactly the same terms. Assume for simplicity that both are plain vanilla European options and that the employee exit rate is zero. The only difference between the options is that the employee stock option, if it is exercised, will lead to the issue of more stock whereas the other option will not. As we have explained in this section the stock price already incorporates the impact of expected dilution. The payoffs from the two options are therefore the same and they should be valued similarly. It is standard practice when valuing European exchange-traded and over-the-counter options to assume a Black-Scholes model (possibly with a volatility skew). Deviations from lognormality caused by outstanding employee stock options, warrants, convertibles, etc are not explicitly considered. We should do the same when valuing employee stock options. Generalizing from this, we should always value employee stock options in the same way as the corresponding over-the-counter or exchange-traded options and ignore dilution. The only proviso is that we should base our valuations on the post-grant-announcement stock price, not the pre-grant-announcement price.

Conclusions

We have discussed practical issues in valuing employee stock options. The basic FASB 123 method uses the expected life of the option as an input. This is a theoretical weakness because option-pricing models are constructed so that the correct input is the total potential life of the option (i.e., the maximum time that can elapse until the option is exercised). We have proposed a modification to the basic FASB 123 that overcomes this weakness. This involves parameterizing the holder's early exercise strategy by estimating the amount by which the stock price must exceed the strike price to trigger early exercise.

The main focus of this paper has been on the most common type of employee stock option plan where a) the exercise price of an option remains constant during the option's life, b) the option can be exercised at any time during its life after an initial vesting period, and c) the employee cannot continue to hold the options after he or she has left the company. The approach we suggest can be extended to value other options, for example those where the exercise price changes through time and those where the exercise price is linked to the value of a stock index.

Notes

1. We are grateful to the Ontario Teachers Pension Plan for funding this research.
2. Companies electing not to use the fair value based method must make pro forma disclosures of the effect of using the fair value based method.
3. This is based on an example that appears in Appendix B of FASB 123.
4. We prefer the term employee exit rate because as we discuss later employees may leave the company after the vesting period. In this case they forfeit their options only if they are out of the money.
5. An alternative to adjusting for the employee exit rate during the vesting period is to assume that all options will vest and then later reverse the charge to income for those that do not vest.
6. In practice under FASB 123 options are divided into groups where the employee exit rate and expected life for the options in each group are considered to be approximately the same.
7. In an example considered by Rubinstein (1995), the use of a correlated forfeiture rate increases the option value from 30.75 to 31.63.
8. There should be no problem in using the Enhanced FASB 123 method. To quote from paragraph 154 of FASB 123: “The Board’s intent in this Statement is for the ... illustrations in Appendix B to be sufficiently broad that employers may adopt future refinements in the models that improve their application to employee stock options without requiring the Board to amend this statement.”

9. These equations assume that the employee exit rate is expressed with continuous compounding. If u is the annual employee turnover rate, $e = \ln(1+u)$. If the company wants to assume that all options vest and later reverse the charge for those that do not, it should set $e = 0$ when $i \delta t < v$.

References

Black, F. and M. Scholes. 1973. "The Pricing of Options and Corporate Liabilities"

Journal of Political Economy, vol. 81 no. 3(May-June): 637-59.

Cox, J.C., S. Ross, and M. Rubinstein. 1979. "Option Pricing: A Simplified Approach"

Journal of Financial Economics, vol. 7 (September): 224-64.

Carpenter, J. 1998. "The Exercise and Valuation of Executive Stock Options," *Journal*

of Financial Economics, vol. 48, no. 2 (May): 127-58.

Financial Accounting Standards Board. 1995. *FASB 123: Accounting for Stock-Based*

Compensation.

Galai D. and M. Schneller. 1978. "Pricing Warrants and the Value of the Firm" *Journal*

of Finance, vol. 33, no. 5 (December): 1333-42.

Huddart S. and M. Lang. 1996. "Employee Stock Option Exercises: An Empirical

Analysis," *Journal of Accounting and Economics*, vol.21, no. 1 (February): 5-43.

Hull, J.C. 2002. *Options, Futures and Other Derivatives*. Fifth edition. Prentice Hall, NJ.

Rubinstein M. 1985. "On the Accounting Valuation of Employee Stock Options",

Journal of Derivatives, vol. 3, no. 1 (Fall): 8-24.

Table 1: Sample Option	
Life of option	10 years
Vesting period	3 years
Stock price	\$50
Exercise price	\$50
Risk-free rate	7.5%
Expected volatility	30%
Expected dividend yield	2.5%

**Table 2: Impact on Valuation of Option in Table 1
of Alternative Values of M and e .**

The parameter, M , is the ratio of the stock price to the exercise price necessary to trigger voluntary early exercise. The parameter e is the employee exit rate (assumed to be the same pre-vesting and post-vesting).

	$e = 3\%$	$e = 5\%$	$e = 7\%$	$e = 10\%$
$M = 1.2$	13.13	12.28	11.47	10.33
$M = 1.5$	15.13	14.06	13.07	11.69
$M = 2.0$	17.09	15.80	14.61	12.97
$M = 2.5$	17.97	16.57	15.28	13.53
$M = 3.0$	18.34	16.89	15.56	13.75