Teaching and educational note

Valuing employee stock options under SFAS 123R using the Black–Scholes–Merton and lattice model approaches

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Abstract

In 2004, the Financial Accounting Standards Board (FASB) issued Statement of Financial Accounting Standard No. 123 (revised 2004), Share-Based Payments (SFAS 123R), requiring all entities to recognize as expense the fair value of stock options issued to employees for services provided. Because employee stock options cannot be traded publicly, their fair value must be estimated using a model, with the Black–Scholes–Merton (BSM) and lattice models being the most appropriate alternatives.

This teaching note provides an overview of employee stock options, followed by a discussion of the BSM and lattice valuation models, including their application and limitations. A project which has been used in financial accounting courses is also presented. The conceptual discussion coupled with illustrated examples will help students enhance their understanding of fair value estimation of and accounting for employee stock options under the recently adopted SFAS 123R.

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1. Introduction

Companies grant options to align the incentives of employees with the incentives of stockholders. Employee stock options are call options that give the holder the right, but not the obligation, to buy a share of their company’s stock for a fixed price, called the exercise or strike price, during a specified period of time. Both employees holding stock options and stockholders benefit when the stock price rises. In addition to aligning incentives, stock options enable companies to compensate employees without paying out cash, an advantage of particular importance to start up companies. Further, certain companies derive tax benefits from compensating employees with stock options rather than with cash.

Typical employee stock options have several features that distinguish them from options that are publicly traded. First, employee stock options cannot be sold or transferred by the employee. Second, employee stock options have a long period, typically 10 years, over which they can be exercised, as opposed to the shorter terms of publicly traded options. Third, most employee stock options have vesting restrictions requiring an employee to wait a specified period of time before exercising any options. This delay encourages the employee to continue serving the company rather than forfeit the options.

When stock options are awarded, the accounting objective is to recognize their value as compensation expense over the period the company benefits from the employee’s service. However, because employee stock options cannot be traded publicly, one cannot simply look to the market for a price to use as fair value. Two alternatives for valuing employee stock options were accepted prior to the issuance of SFAS 123R. The intrinsic value method based compensation expense on the intrinsic value of the option on the grant date, the amount by which the stock’s price exceeded the option’s exercise price. Since most employee options are granted “at the money”, the resulting compensation expense was zero.

In contrast, the fair value method based compensation expense on the fair value of the option on the date granted. An option’s fair value exceeds its intrinsic value because fair value incorporates the value created by the probability that the stock’s price will rise above the option’s exercise price at some point during the option’s term. With higher value comes higher compensation expense. Not surprisingly, most companies elected to measure compensation expense using the intrinsic value method, though they were required to disclose in their footnotes the fair value of the employee stock options granted.

In December 2004, the Financial Accounting Standards Board (FASB) issued Statement of Financial Accounting Standard No. 123 (revised 2004) Share Based Payments (SFAS 123R), requiring all entities to recognize as expense the fair value of equity instruments issued to employees for services provided. Companies can no longer measure compensation expense using the option’s intrinsic value. A discussion and illustrated examples of the BSM and lattice valuation models, two alternatives specified by SFAS 123R, follow. In addition, a project which has been used in financial accounting courses is presented. The conceptual discussion and the project will help students better understand the estimation of fair value of employee stock options under the recently adopted SFAS 123R.

2. Description of the models

The fair value of employee stock options must be estimated because the options are not transferable; they cannot be traded publicly. SFAS 123R allows entities to value options using either the BSM or lattice model, as long as the model selected is based on established
principles of financial economic theory and reflects all substantive characteristics of the option.

2.1. Black–Scholes–Merton model

The more widely used BSM model was designed to value publicly traded options with short exercise periods. The basic model assumes that the stock does not pay dividends and that the option can be exercised only at the expiration date. Later variations relaxed these assumptions. The value of a call option, \( C \), is defined as a function of five variables under the basic BSM model:

- \( S \) is the current price of the stock.
- \( X \) is the exercise price of the option.
- \( T \) is the expected life of the option (in years).
- \( \sigma \) is the volatility, the annualized standard deviation of the stock’s return.
- \( r \) is the risk-free interest rate.

The BSM model formula is:

\[
C = SN(d_1) - Xe^{-rt}N(d_2)
\]

where

1. \( N(d_1) \) and \( N(d_2) \) refer to probabilities under the standard normal distribution,
2. \( e \) equals 2.71828, the base of the natural logarithm,
3. \( d_1 = \frac{\ln(S/X) + (r + \sigma^2/2)T}{\sigma \sqrt{T}} \) and \( d_2 = d_1 - \sigma \sqrt{T} \).

While the BSM model is complex and the formulas somewhat difficult to comprehend, the model is relatively simple to implement. Fig. 3 in Section 3.2 provides guidance for using Excel to measure an option’s value with the BSM model.

Despite the BSM model’s complexity, an understanding of the foundation ideas is easily grasped. Consider an option with the following data:

- \( S = $100 \)
- \( X = $100 \)
- \( T = 4 \) years
- \( \sigma = 40\% \)
- \( r = 5\% \).

In this example, the option’s intrinsic value is zero at the grant date because the stock price is equal to the option’s exercise price. If the stock price remains constant over the option’s life, the option’s intrinsic value remains zero. However, it is probable that the stock price will surpass the exercise price over the four-year life of the option. An option’s fair value incorporates this potential. With a risk-free rate of 5%, the stock price is expected to increase by 5% per year compounded continuously. Under the simplified scenario of 0% volatility, the stock price will rise to $122.04 after four years. The benefit to the option holder will then be $22.04, the option’s intrinsic value. To measure the option’s value at the grant date, the $22.04 intrinsic value at the exercise date is discounted at the 5% risk-free rate for four periods, generating a fair value of $18.13.
An option’s value increases with increases in both the life of the option, \( T \), and the risk-free rate, \( r \). The faster the stock price is expected to grow and the longer the stock price can grow, the higher the expected stock price at the option’s exercise date.

Much of the complexity of the BSM model relates to volatility, the degree of unpredictable change in the stock price over time. While this stock price change can be either increasing or decreasing, volatility adds value to the option. Potential increases in stock price increase the option’s intrinsic value and fair value. Conversely, potential decreases do not diminish value. If the stock price falls below the option’s exercise price, the option holder will choose to let the option expire. Consequently, when 40% volatility is incorporated in the example, the option’s fair value rises to $38.16.\(^1\)

While relatively easy to implement and understand at a fundamental level, the BSM model is difficult to modify and requires satisfying specific assumptions. Option valuation using the more adaptable lattice model is presented next.

2.2. Lattice model

The lattice model is based on a binomial probability distribution, one in which the underlying event has only two possible outcomes. In the case of employee stock options, the underlying event is the change in the stock price and the related intrinsic value of the option. During each period, the stock price can move either up or down. When multiple periods are considered in sequence, a distribution of possible stock prices is created. This binomial distribution is referred to as a lattice (or tree), reflecting it appearance graphically. More branches are created as the time horizon lengthens. Each point (stock price) on the lattice is referred to as a “node”.

Fig. 1 presents a stock price tree created in Excel using the same variable inputs used in the BSM model example previously presented. For illustration purposes, it is assumed that stock price movements occur annually. Conversely, the BSM model compounds stock price changes continuously. As the time periods for stock price movements are shortened under the lattice model, the option values for the two models converge.

At the option grant date, Year 0, the stock price is $100. The stock price is assumed to increase at the risk-free interest rate each year. Further, the stock price either increases or decreases each year based on the stock’s volatility. Starting with a stock price of $100 at Year 0, the grant date of the option, the stock price is expected to grow during the first year to $105 due to the 5% risk-free rate, and either increase or decrease by 40% of $105 due to the stock’s volatility. Thus at Year 1, there are two possible stock prices, $147 ($105 \cdot 1.40) and $63 ($105 \cdot 0.60). The probability of the stock price being $147 at Year 1 is .50, the same as the probability of the price being $63.

This logic continues through Years 2, 3, and 4, with the probability of a single node or outcome after \( n \) periods being \( 0.50^n \). At the end of the second period, Year 2, Fig. 1 shows four possible stock prices, each with a .25 (.50^2) probability of occurring. Eight

\(^1\) The BSM valuation calculation presented in five steps follows:

\[
\begin{align*}
  d_1 & = \frac{(\ln(100/100)) + ((0.05 + ((0.40/2)/2)) \cdot 4)}{(0.40 \cdot (4^{1/2}))} = 0.65 \\
  d_2 & = 0.65 - (0.40 \cdot (4^{1/2}) = -0.15 \\
  N(d_1) & = N(0.65) = 0.742154 \\
  N(d_2) & = N(-0.15) = 0.440382 \\
  C & = (100 \cdot 0.742154) - ((100 \cdot (e^{-0.05 \cdot 4}) \cdot 0.440382) = 38.16
\end{align*}
\]
stock prices are possible at Year 3, each with a .125 (.50^3) probability, and 16 are possible at Year 4, each with a .0625 (.50^4) probability of occurring.

After developing the stock price lattice, the next step is calculating the fair value of the option. Assuming that the option holder will wait until Year 4, the expiration date, to exercise the option, the option’s value depends on the possible stock prices at Year 4. The option’s exercise price is subtracted from the stock price to determine the option’s intrinsic value for each of the 16 Year 4 nodes. For the Year 4 node with a stock price of $466.95, the intrinsic value is $366.95, the amount the stock price exceeds the exercise price. In contrast, the option’s intrinsic value is zero for all nodes with stock prices less than the $100 exercise price because the option holder has no obligation to exercise the option.
There are five nodes with non-zero intrinsic values at Year 4. Each is multiplied by its probability of occurring, .0625, to determine its probability-weighted intrinsic value. Each probability-weighted intrinsic value is then discounted to Year 0, to determine its present value at the grant date of the option. The sum of these probability-weighted present values, $39.46, represents this option’s fair value.

Typically, however, employees exercise their options prior to the expiration date. Cash needs coupled with the restrictions placed on the transfer or sale of employee stock options may drive this decision. Fig. 2 illustrates the lattice model adapted to reflect expected early exercise behavior by the option holder.

Stock Price Tree, Lattice Model, Early Exercise Allowed

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<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
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<td>Risk-Free Interest Rate</td>
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</table>

<table>
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<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Value</th>
<th>Intrinsic Value</th>
<th>Probability</th>
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</tbody>
</table>

Fig. 2. Stock price tree, lattice model, early exercise allowed.
For illustration purposes, it is assumed that with no vesting restrictions the employee will exercise the option when the stock price first exceeds the exercise price. Because the Year 1 node representing an upward price movement has a stock price possibility of $147, $47 greater than the option’s exercise price, the holder will exercise the option immediately. The option’s $47 intrinsic value is multiplied by the probability of this stock price possibility, .50, and discounted to Year 0 to generate a probability-weighted present value for this possibility of $22.38. This branch of the stock price tree is truncated with the presumed exercise of the option.

One other branch of the stock price tree bears a node representing a possibility with the option having intrinsic value. When the stock price moves down in Year 1, then up in both Year 2 and Year 3, the $136.14 stock price exceeds the exercise price. The option’s $36.14 intrinsic value is multiplied by the probability of this stock price possibility, .125 (.50^3), and discounted to Year 0 to generate a probability-weighted present value for this possibility of $3.90. The nodes at the end of the six branches that continue through Year 4 represent stock prices that are less than the option’s exercise price. Because these branches add no value, the value of the option under this early exercise scenario is $26.28, the sum of the value added by the two nodes discussed above. Thus, the option’s value decreases from the $39.46 value in Fig. 1 when the likelihood of early exercise is modeled.

2.3. Comparing the two valuation models

In the exposure draft issued prior to finalizing SFAS 123R, the FASB expressed a preference for the lattice model approach to valuing employee stock options. However, no explicit preference is stated for one model over the other in the final standard. Not only would such a designation effectively require companies to use the preferred model, it could interfere with the subsequent development and adoption of improved models for valuing employee stock options. SFAS 123R requires instead that any model used for estimating the value of employee stock options have the following characteristics:

- can be generally applied in the field and is based on established principles of financial economic theory;
- is consistent with the objective of fair value measurement; and,
- reflects all the substantive attributes of employee stock options.

Both the BSM and lattice models can be applied in the field and are grounded in economic theory. Moreover, both models provide reasonable measures of fair value, incorporating the same information that market participants would use in valuing options in an exchange transaction. However, the lattice model can directly accommodate all the unique features of employee stock options, while the BSM model can accommodate these features only indirectly.

Note that other approaches including a trinomial model or a Monte Carlo simulation have been mentioned as possibilities for valuing employee stock options. However, the bulk of the discussion on valuing employee stock options has centered on the BSM and lattice models.

To better understand this advantage of the lattice model it is useful to compare how the substantive characteristics of employee stock options are incorporated by each of the models. When the underlying stock price exceeds the option’s exercise price, the fair value of an unexpired option consists of two components: intrinsic value and time value. In most cases, an exchange-traded option is not exercised prior to expiration because the holder would sacrifice the time value. Instead, the holder sells the exchange-traded option at a price that incorporates this time value.

In contrast, employees often exercise their options prior to the end of the exercise period. The holders forgo the time value of these options because they cannot be traded. Numerous compelling reasons have been advanced to explain why employees exercise their vested options early: lack of confidence in the company’s prospects, diversification, termination of employment, divorce, etc.

Early exercise behavior can be built into the lattice model directly using historical exercise patterns developed from company data. This behavior can be modeled to depend on the stock price movement, how deep in the money the option is, and the length of time until the option expires. Moreover, the lattice model can accommodate exercise behavior that varies over the term of the option.

Because the BSM model was developed for exchange-traded options assuming that investors act optimally, it assumes that exercise occurs on the final day of the option’s contractual term. To incorporate the likelihood of early exercise, the BSM model must utilize a weighted-average life for the option rather than its contractual term. As an equation that can be solved for a given set of inputs, the closed form BSM model cannot directly accommodate possible early exercise.

Another feature distinguishing employee stock options from exchange-traded options is their longer term, typically 10 years versus 90 days. The BSM model assumes that both the risk-free interest rate and the stock’s price volatility remain constant, an unreasonable assumption for employee options with 10-year terms. As a result, when valuing employee stock options using the BSM model, companies must input weighted averages for the anticipated risk-free interest rate and volatility over the option’s weighted-average life. In contrast, the lattice model’s greater flexibility enables users to assume different rates and volatilities for each time period. In fact, companies using the lattice model can incorporate different scenarios along selected paths of the stock price tree.

Compared to the BSM model, the more adaptable lattice model should result in a better estimate of an option’s fair value. While commercial software is available for both models, companies implementing a lattice model must make and document a number of company specific assumptions and subjective judgments. For example, they must extract and analyze historical data on the exercise behavior of employees holding options to specify and support the assumptions included in their models. And, while unable to directly incorporate the substantive characteristics of employee stock options, companies selecting the BSM model can do so indirectly by using the expected weighted averages as inputs.

Thus, the choice depends on the cost savings of the BSM model versus the likely superior valuation estimate of the lattice model and the related financial statement impact. The BSM model may provide a satisfactory valuation in cases where employee stock option expense is immaterial.
3. Option valuation project

This section describes a project requiring the use of Microsoft Excel to value a simple employee stock option with both the BSM and lattice models. Successfully employed at the undergraduate (intermediate accounting) and graduate (accounting theory) levels, the project demonstrates the impact that changes in assumptions have on the fair values estimated. The project’s solution is presented followed by assessment data.

3.1. Microsoft Excel Project: Duke Dog Technologies

Lynn Malkani, a senior accountant in the Financial Reporting Department at Duke Dog Technologies, has been assigned to assist the Controller, Tom Amico, with implementation issues arising from the recently revised Statement of Financial Accounting Standards No. 123 (revised 2004) Share-Based Payment (FAS 123R). More specifically, Tom would like Lynn to evaluate the feasibility of Duke Dog Technologies switching from valuing the cost of employee stock options using the Black–Scholes–Merton (BSM) option pricing model to using a lattice model.

Tom mentioned that from his understanding of the FASB’s deliberations leading up to the issuance of the revised standard, the lattice model was considered a better approach for valuing employee stock options than the BSM model. Tom said that as a “numbers” guy, he would like to see some computations, and he thought that by having Lynn do computations using both models, she could gain some insight on how the models work and then report back to Tom with her thoughts on the merits of each approach.

**Required:**
1. Construct an Excel worksheet that calculates the value of a call option using the BSM model. Make sure the worksheet is correct by testing its calculations using the assumptions from the example in Section 2.1. For simplicity calculate $d_1$, $d_2$, $N(d_1)$, $N(d_2)$ and $C$ in progressive steps. Excel functions that will be helpful follow:
   - LN( ), returns the natural log function.
   - EXP( ), returns e raised to the power of that within the parentheses.
   - NORMSDIST( ), returns the standard normal cumulative distribution function.
2. Using the model you created in #1 above, calculate the value of a call option with the following assumptions:
   - Stock price at date of grant $80
   - Exercise price $80
   - Risk-free rate 4.5%
   - Time to maturity 4 years
   - Volatility 30%
   - No dividends
   (a) What is the value of the call option with these assumptions?
   (b) What is the value of the option if volatility is increased to 40%?
   (c) What is the value of the option if volatility is decreased to 20%?
   (d) With the original volatility of 30%, what is the value of the option if time to maturity is increased to 10 years?
Using the original data, what is the value of the option when the risk free rate is decreased to 3%?

3. Lattice approach. Construct a lattice model stock price tree in a new worksheet and value a call option using the following assumptions:

- Stock price at date of grant: $80
- Exercise price: $80
- Risk-free rate: 4.5%
- Time to maturity: 4 years
- Volatility: 30%
- No dividends

Calculate the intrinsic value for each Year 4 node on the stock price tree. Next, probability-weight the intrinsic values and determine their present values at Year 0. Finally, aggregate these values to determine the option’s value at the grant date. Refer to Section 2.2 for further guidance.

4. The lattice model allows explicit consideration of the likelihood that option holders will exercise the option prior to its expiration date. Using the above assumptions, determine the value of the option assuming that the option will be exercised whenever the stock price exceeds the exercise price by 50% or more. Be sure to apply the appropriate number of periods when discounting from the presumed exercise nodes.

5. Write a memorandum to Tom outlining your results in #1–4 above and then discuss the pros and cons of each employee stock option valuation approach.

3.2. Project solution

Requirements 1 and 2:

(a) What is the value of the call option with these assumptions? $24.65
(b) What is the value of the option if volatility is increased to 40%? $29.95
(c) What is the value of the option if volatility is decreased to 20%? $19.37
(d) With the original volatility of 30%, what is the value of the option if time to maturity is increased to 10 years? $40.78
(e) Using the original data, what is the value of the option when the risk free rate is decreased to 3%? $22.67

Requirement 3: option value: $24.07
Requirement 4: option value with early exercise assumption: $22.48
Requirement 5:

Some of the key points to be included in the memorandum follow:

- Employee stock option value increases as volatility, time to maturity, and risk-free rate increase.
- Employee stock option value is most sensitive to changes in volatility and time to maturity.
- Advantages of the BSM model.
  - easier to implement,
  - less costly to implement.
Advantages of the lattice model. 
- allows for explicit consideration of the option being exercised prior to maturity, 
- more dynamic – allows for consideration of presumed changes in volatility and risk-free rates over the option’s life.

3.3. Classroom assessment

As a means of assessing the effectiveness of the project, survey data were collected from 46 undergraduate intermediate accounting students and 15 students in graduate accounting theory. Exhibits 1 and 2 summarize the results. The survey instrument included seven response items, each meant to capture the students’ level of understanding with respect to employee stock options and the models used to estimate their fair value. Post-project data were collected in the intermediate classes, while in the graduate theory class both pre- and post-project data were collected. Students recorded their responses using a six-point Likert-type scale.

Exhibit 1 summarizes the responses obtained from students in the undergraduate intermediate accounting classes. These students found that their levels of understanding with respect to employee stock options, the BSM and lattice models, and the factors influencing valuation increased by completing the project. For example, students indicated that they agreed (4.96/6.0) with the fourth statement, “My understanding of the BSM option pricing model was increased by the case.”

The responses received from students in the graduate theory class presented in Exhibit 2 were consistent with those from the intermediate classes. The graduate theory students perceived the project as greatly improving their understanding of employee stock options, the BSM model, and the lattice model. For example, the average student response to
survey question number seven, “Overall, I understand the issues surrounding the measurement of the fair value of employee stock options,” improved from 3.0/6.0 to 5.2/6.0. The most impressive result dealt with the students’ understanding of the lattice model. Student responses to survey question number four, “I understand lattice models,” improved from an average of 1.4/6.0 to 5.5/6.0.

The survey instrument provided space for students to make qualitative comments. The written comments received mirrored the numerical survey results. Representative comments are presented in Exhibit 3. Overall, the students reported the project took from 2 to 5 hours to complete and improved their understanding of employee stock option valuation. A number of students suggested that more precise directions for constructing the Excel spreadsheets be provided. We wanted students to work through the ideas and concepts of the models, rather than simply replicating an example. Reinforcing this approach, students agreed most strongly with the statements “I understand lattice models,” and “My understanding of lattice models was increased by the case.”
4. Summary

Estimating the fair value of employee stock options for purposes of recording compensation expense represents one of the greatest challenges in implementing SFAS 123R. The conceptual discussion coupled with illustrated examples of stock option accounting and valuation will enhance student understanding of the issues.

Appendix. Accounting for stock options

The following example illustrates the accounting for employee stock options under SFAS 123R. On January 1, 2006, Duke Corporation grants 100 options to an employee. The options have an exercise price of $10, the same as the stock price on the grant date. Further, the options vest at the end of three years, expire after 10 years, and have an estimated fair value on the grant date of $450 (100 options \( \times \) $4.50/option). Because all the options are expected to vest, a total compensation expense of $450 is recognized evenly over the three-year service period, 2006–2008, the period between grant and vesting during which the employee will perform services. Accordingly, Duke Corporation will make the following journal entry at the end of each year.

\[
\begin{align*}
12/31/06 & \quad \text{Compensation expense} \quad $150 \\
& \quad \text{Paid-in capital-stock options} \quad $150 \\
& \quad \text{(To recognize annual compensation expense: $450/3 years)}
\end{align*}
\]

No liability is reported because the company is not obligated to sacrifice cash or other assets when the stock options are exercised.
Next, assume that the employee exercises the options on January 31, 2009 when the stock price is $30 per share. If Duke Corporation’s common stock is no-par stock, it records the exercise as follows:

\[
\begin{align*}
1/31/09 & \quad \text{Cash (}$10 \text{ exercise price} \times 100 \text{ options}$) & \quad $1000 \\
& \quad \text{Paid-in capital-stock options (account balance)} & \quad 450 \\
& \quad \text{No-par common stock} & \quad $1450 \\
& \quad (\text{To record the issuance of stock upon exercise of options})
\end{align*}
\]

Because compensation expense is not continually adjusted to reflect changes in the market price of the stock, the stock’s price at the exercise date does not impact this journal entry. While the opportunity cost is $2000, the difference between the $3000 (\$30/\text{share} \times 100 \text{ shares}) market price of the shares on the exercise date and the cash received, Duke’s total compensation expense remains unchanged at $450 as measured at the grant date.

If the employee chooses instead to let the options expire, Duke Corporation would make the following journal entry:

\[
\begin{align*}
12/31/15 & \quad \text{Paid-in capital-stock options (account balance)} & \quad $450 \\
& \quad \text{Paid-in capital-expired stock options} & \quad $450 \\
& \quad (\text{To record the expiration of stock options})
\end{align*}
\]

The employee would let the options lapse if the stock’s price failed to rise above the option’s exercise price during the exercise period. The journal entry simply re-titles Duke Corporation’s paid-in capital. As is the case when the options are exercised, the company’s compensation expense is unaffected by the expiration of the options.

This example assumes that Duke Corporation’s stock option plan qualifies as an incentive plan. Because the company receives no deduction upon exercise of the options, there are no tax consequences. Alternatively, if the plan does not qualify as an incentive plan, Duke must recognize a deferred tax asset along with compensation expense, reflecting the temporary difference between accounting and tax income. If the eventual tax savings, the market value of the shares issued upon exercise less the cash received from the option holder, differs from the deferred tax asset created, the difference is recognized as equity.

Reference