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MAY 2004 No. 04-10





## Valuing Stock Options with a Lattice Model

No question about the FASB's share-based-payment exposure draft has been more frequent than how to use a lattice model to measure the fair value of stock options granted to employees.[1] The exposure draft would require companies to recognize the grant-date fair value of equity instruments issued to employees from 2005 reporting periods and takes the position that a lattice model is preferable for measuring the fair value of option awards in the absence of a market-price alternative. This edition of *Defining Issues* is therefore devoted to explaining the nature and application of lattice models.

### WHICH MODEL?

The fair value of employee stock options is most often determined using either lattice or closed-form models. Lattice models include those called binomial. The closed-form model most widely used for valuing employee stock options is Black-Scholes-Merton. The exposure draft holds that both the model used to measure the fair value of employee stock options (ESOs) and the related inputs must be consistent with how willing parties to an exchange would value the same instruments. The FASB believes a lattice model meets this fundamental criterion better than Black-Scholes-Merton, assuming the information needed to apply it properly is available.

(1) FASB Exposure Draft, Share-Based Payment: an amendment of FASB Statements No. 123 and 95, March 31, 2004, available at www.fasb.org.

Lattice models are widely used in finance and investment to value complex options, and some companies have used them to value employee options for several years. Black-Scholes-Merton was developed to value options on a non-dividend-paying stock exercisable only at expiration and has been extended to value options on dividend-paying stocks exercisable only at expiration.

Black-Scholes-Merton can provide a reasonable estimate of the fair value of options. However, the FASB believes a lattice model is preferable because it can directly incorporate assumptions about employees' post-vesting behavior.

- Black-Scholes-Merton can measure early exercise behavior by employees only indirectly by using the expected rather than contractual term of the option. For example, the model cannot directly reflect the empirical finding that option exercises are common when the stock price hits certain multiples of an option's exercise price or the expectation that employee terminations will cause early exercise. Direct capture of early exercise behavior is one of a lattice model's clear advantages.
- Black-Scholes-Merton can use only a single set of estimates for expected volatility, dividend rate, and risk-free rate. These variables are important in valuing employee options, which often have lives up to ten years, during which movements in volatility, dividend rates, and risk-free rates are inevitable. A lattice model can include different estimates of these variables, although applying different estimates of volatility can become complex.

***Future Use of Black-Scholes-Merton.*** Given the FASB's preference for lattice-type models, companies are likely to begin to reduce their current reliance on Black-Scholes-Merton, particularly as support for the relevant inputs is gathered and as computerized comprehensive lattice models that directly take account of employees' early exercise behavior become more widely available. According to the exposure draft, Black-Scholes-Merton will remain important for companies that are unable, at least initially, to obtain all the information needed to use a more comprehensive lattice model.

## OVERVIEW OF A LATTICE MODEL

A lattice model estimates the fair value of stock options at the grant date by estimating the prices of the underlying stock at points in time up to and including the option's expiration date, determining the potential cash-flow amounts from the option *at the exercise date*, and then present valuing those cash-flow amounts back to the grant date. There are two broad steps in applying this kind of model.

1. Build a horizontal "tree" diagram representing estimated future stock prices at points in time from the grant date until the option expires. The "tree" is the "lattice."

   The tree diagram's progress represents later and later points in time. Each point on the tree is called a node. At any given node, it is assumed that the stock price will move either up or down. The up and down branches from each node identify the estimated range of up and down price movements. The estimated ranges should reflect specified influences on the stock price at each node. Nodes that represent possible share prices at the option's expiration are called terminal nodes.

2. Value the option by discounting the potential cash-flow amounts from the estimated future stock prices at the terminal nodes in the tree diagram back to the grant-date node, unless early exercise is assumed. The potential cash flow at a terminal node is the option's *intrinsic value* at that node, the excess of the estimated stock price over the option's exercise price. Because the stock prices in the tree diagram are not equally probable, the discounting process incorporates probability weighting. The sequence creates a valuation tree based on the intrinsic values at the terminal nodes. The discounted-cash-flow amount at the grant date is the value of the option.

   If early exercise is assumed, the company would determine the intrinsic values at each exercise-date node (again, the amount by which the estimated stock price at that point exceeds the exercise price). The intrinsic-value amounts are then probability-weighted and discounted back to the grant date, and the discounted present value at the grant date is the value of the option.

Increasing the number of nodes improves the reliability of the results.

## A LATTICE MODEL'S SCOPE

A company applying a lattice model must at a minimum take six inputs into account in creating stock-price and valuation trees. The stock price at grant date, the expected volatility of the stock, and the dividend rate are used in creating the stock-price tree. The exercise price and the expected exercise term are used only in the valuation tree. The risk-free rate affects both the stock-

price tree and the valuation tree, the risk-free rate being the discount rate for the valuation tree's present-value calculations.

The influence of the six inputs on the value of the option can be seen from the table below:

| Input | Effect on Option Value of Increase in Input |
|---|---|
| Stock price at grant date | higher |
| Exercise price | lower |
| Expected term | higher |
| Expected volatility | higher |
| Dividend rate | lower |
| Risk-free rate | higher |

Black-Scholes-Merton must bring the same six inputs to bear. However, a lattice model can explicitly consider early exercise behavior. In this way, the notion of "expected term" is treated differently by the two models. In the case of a lattice model the input for "expected term" is the input or inputs on early exercise behavior. Depending on the circumstances, inputs on early exercise behavior could result in lattice-model option values substantially different from those produced by Black-Scholes-Merton. These inputs and their effect on the valuation are briefly described below.

- ***"Suboptimal Exercise" Factor.*** Exercise is the only way an employee can obtain liquidity from an ESO, because these kinds of options cannot be sold on an exchange. Several studies have found that options tend to be exercised when the stock price reaches a specific multiple of the exercise price. For example, Huddart and Lang reported that, on average, options in their study were exercised when the stock price was 2.2 times the exercise price.[2] A lattice model can be created that assumes option exercise when the stock price hits a pre-determined multiple of the exercise price. The FASB calls this "suboptimal exercise" because the option would be worth more if the employee continued to hold it. The suboptimal factor can be different for different groups of employees.
- ***Post-Vesting "Termination" Rate.*** After vesting, employees may exercise stock options early because they are leaving the company and have, for example, only 90 days within which to exercise their options. For purposes of the exposure draft, "termination" can be voluntary or involuntary. Vested options that are in-the-money during the 90-day period will be exercised; vested options that are out-of-the-money will not. The employee turnover rate will tend to reduce an option's expected term and therefore lower the option's value. Under the requirements proposed in the exposure draft, the option's fair value would not be adjusted for potential forfeitures during the vesting period. Instead the recognition of compensation cost would be adjusted for forfeitures.

## BUILDING A STOCK-PRICE TREE

Stock-price trees are based on the concept that during each interval of time, a stock can make only two possible movements, up or down. Thus at each node starting with the stock price on the grant date, the stock price branches up and down, representing the range of up and down price movements. The model generates the range using the core assumptions of volatility, risk-free rate, and dividend yield, which are applied to the stock price over the term of the option. Repeating this process through intervals of time from the grant to the expiration date creates a tree of possible stock prices.

The probabilities of the underlying stock reaching prices on the tree differ. Outlier stock prices (those either very high or very low) are less likely than mid-range prices. In addition, unlike a coin toss, the probability of an up or down price movement may not be equal.

The lattice model assumes that stock prices will increase at the risk-free rate less the dividend rate. As observed in the marketplace, a company's stock price is typically reduced by an amount that approximates its dividends.

The historical volatility of the underlying stock for a period comparable to the option's expected term has generally been used to estimate the expected volatility of that stock. The exposure draft lists additional factors that should be considered. In addition to historical volatility, it lists the implied volatility of exchange traded options on the company's stock, the length of time the business has been public, the tendency of volatility to return to its "mean" or long-term average, and "appropriate and regular" intervals for price observations.

(2) Steven Huddart and Mark H. Lang, "Employee Stock Option Exercises: An Empirical Analysis," *Journal of Accounting and Economics*, February 1996.

Companies would be required by the FASB's proposed requirements to consider implied volatility when estimating expected volatility. Implied volatility is the volatility implicit in the prices of a company's currently traded options. By taking the prices of traded options along with the other inputs in the model, one can estimate the level of volatility implied by the market price. This estimate of volatility is generally interpreted as the market's estimate of volatility over the term of the traded option. In practice, most companies would probably obtain implied volatility data from financial-information-reporting data service providers.

Judgments are called for in applying implied volatility because the instruments will never be identical. Traded options with the same expiration date but different exercise prices may have different volatilities. More importantly, the term of an exchange-traded option tends to be significantly shorter than an employee stock option, which limits its effectiveness as a market indicator of the stock's volatility. Companies should also consider the volatility of other instruments with option-like characteristics, such as debt with embedded warrants. Instruments with features similar to options should be relied on as indicators of implied volatility only if they trade in active markets.

## VALUING THE OPTIONS

Options are valued based on the intrinsic values at the terminal nodes in the stock-price tree, unless early exercise is assumed. These amounts are present valued using the risk-free rate and probability weighting, starting at the terminal nodes and working back to the grant-date node. Out-of-the-money stock prices are given a value of zero. Thus, absent early exercise behavior, the process moves from the expiration date to the grant date and is based on the differences between the estimated stock prices at the terminal nodes and the exercise price.

The exposure draft would require companies applying a lattice model to consider suboptimal early exercise. If the stock price on the stock-price tree hits a predetermined multiple of the exercise price, early exercise is assumed. The stock-price tree can be monitored to identify nodes at which the stock price has reached the set multiple of the exercise price. The option-value tree can also consider early exercise based on a probability estimate of termination at each node. When early exercise is assumed, the estimated intrinsic values at the early-exercise nodes are subjected to probability-weighted present valuing, which continues for the remaining nodes until the grant-date node.

Dividends can influence early exercise behavior. Prior to the stock going ex-dividend, the holder may decide to exercise the option in order to secure the dividend and to offset a reduction in the price of the stock from the outflow of dividends. The model can identify these situations by checking, at each pre-expiration node, whether the discounted terminal option value is lower than the estimated intrinsic value, assuming exercise at that node. If the intrinsic value exceeds the discounted terminal value, early exercise is assumed and the estimated intrinsic values at the exercise nodes are then discounted and probability weighted.

## VESTING PERIODS

Under the FASB's proposed requirements, companies would estimate the value of the instruments to which the employees will become entitled when they have rendered their requisite service and satisfied other vesting conditions. Neither service nor performance conditions for vesting would enter the valuation process. They would instead be reflected by recognizing compensation costs only for the options that ultimately vest. Exercisability conditions would be incorporated into the measurement of the fair value of an instrument. For example, a condition under which an option cannot be exercised until the stock trades above $20 for 10 consecutive days would be incorporated into the measurement of fair value.

Vesting conditions are included in a lattice model by considering early exercise only at nodes that represent periods after the vesting date. Based on the proposed requirements, a graded vesting award, which has a number of different dates at which portions of an award may vest, would be divided into vesting tranches, and each tranche would be valued separately. Because options with longer vesting periods may not be exercised as early as options with shorter vesting periods and longer-lived options are more valuable than shorter ones, a lattice model calculates a higher value for longer-termed options. Black-Scholes-Merton does too.

## RELATIONSHIP TO BLACK-SCHOLES-MERTON RESULTS

Companies should not expect a switch from Black-Scholes-Merton to a lattice model to automatically decrease reported option values. A lattice model that uses the same input assumptions as Black-Scholes-Merton will produce substantially the same value. Different values will come about from additional input assumptions, such early exercise behaviors, that will have to be supportable.

Companies now use expected term in Black-Scholes-Merton models to reflect the effects of early exercise behavior. When using a comprehensive lattice model, a company will start with the contractual term and add inputs for early exercise behavior directly on the option-value tree. Using the FASB's early exercise factors will tend to reduce the value of an option, but using the option's contractual term by itself, rather than the expected term, will tend to increase the value of the options. Thus the net effect of changing models on option values depends on the interaction among these factors and need not be uniform.

## SUPPORTING THE ASSUMPTIONS

Proper use of a lattice model will require carefully supported assumptions about early exercise behavior and post-vesting termination. This may often require segregating groups of option grants based on similar exercise behavior and employee demographics (e.g., age, salary-level, marital status, level within the organization). Input assumptions will need to be updated to reflect the company's experience.

Companies that develop historical information will have to consider whether the historical relationships can be relied on to predict early exercise on the basis of their statistical significance. Key drivers of early exercise behavior may not be readily reflected in the relationships. These may include divorce, purchase of a vacation home, children's college tuition, and investment decisions.

Because a lattice model can accommodate the use of different volatilities at different nodes and for different periods, companies will likely spend more time estimating this input.

## AVAILABILITY OF LATTICE MODELS

At this stage, the expanded lattice models envisaged by the exposure draft are not widely available. FASB members acknowledged this in their deliberations, but they do expect models to be made available quickly. At the moment, companies are actively seeking lattice models. Over time, the models are likely to become as widely available as Black-Scholes-Merton is today, but they may be less uniform.

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Lattice models depend on estimates that meet the test of reasonableness. Management may therefore want to begin the process of accumulating and analyzing the inputs necessary to value share options using lattice models.

Companies should not treat the descriptive and summary statements about the exposure draft as if they represent what the FASB will ultimately adopt. Nor should companies treat the statements in this presentation about potential accounting and valuation requirements as if they pertain to any company's unique circumstances. Companies should refer to the text of the final FASB Statement when it is completed and published and should consult their accounting and legal advisors.

This is a publication of KPMG's Department of Professional Practice—Audit and Risk Advisory (212) 909-5600

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