The Efficiency of Equity-Linked Compensation: Understanding the Full Cost of Awarding Executive Stock Options

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To properly align incentives using equity-linked compensation, the firm's managers must be exposed to firm-specific risks, but this concentrated exposure prevents optimal portfolio diversification. Because undiversified managers are exposed to the firm's total risk, but rewarded (through expected returns) for only the systematic portion of that risk, managers will value stock or option-based compensation at less than its market value. This paper derives a method to measure this deadweight cost, which empirically can be quite large: managers at the average NYSE firm who have their entire wealth invested in the firm value their options at 70% of their market value, while undiversified managers at rapidly growing, entrepreneurially-based firms, such as Internet-based firms, value their option-based compensation at only 53% of its cost to the firm. These estimates prompt questions of whether compensation plans in such firms are weighted too heavily towards incentive-alignment to be cost effective.

Finance theory has long made the case for the use of equity-linked compensation plans as an effective means to align managers' incentives with those of shareholders. In the last decade, finance practice, particularly in the United States, has embraced this prescription, with stock-options and restricted-stock plans forming a vastly increased proportion of senior management's total compensation. Although financial theory recognizes that the benefits from these plans are inevitably tempered by certain deadweight costs to the firm, relatively little empirical work has been devoted to identifying and measuring those costs. In essence, the exposure to firm-specific risk that is essential for generating the right managerial incentives also imposes a cost on managers by compelling them to hold less-than-fully-diversified investment portfolios. Every firm faces this unavoidable tension between incentive alignment and portfolio diversification; the optimal tradeoff between them will differ from firm to firm. This paper focuses on the costs associated with this tradeoff, where the cost reflects the difference between the market value of the instruments granted and the value placed on those instruments by the managers who receive them as substitutes for cash compensation.

As managerial diversification declines, the "efficiency" of awarding equity-linked compensation suffers. More precisely, the *value* of equity-linked compensation to undiversified managers may be much less than the *cost* of providing this compensation to the firm. The undiversified manager is exposed to the total volatility of the firm, whereas diversified investors bear (and are paid for) only the systematic portion of the firm's risk. The managers' expected returns are therefore too low to properly compensate them for the risks they face. Consequently, the value that undiversified managers place on equity-based compensation is less than its market value. Viewed in isolation from its incentive alignment benefits, this difference between

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the value of equity-based compensation to undiversified managers and the market value of the equity-linked security represents a deadweight loss to the firm. That is, the firm could receive the full value of equity-linked securities to a diversified investor by simply issuing such securities in the open market. The deadweight loss, then, consists of the non-negative difference between the higher value of the securities to a diversified investor and the lower value of the securities to the non-diversified employee.[1] This loss is greatest for high-volatility firms where managers have most of their personal wealth tied up in the firm.

This paper offers a technique to measure the difference in value between the firm's cost of issuing equity and the value that undiversified investors place on this form of compensation. The paper departs from the previous finance and accounting literature on private valuation of executive stock options by focusing on the costs explicitly incurred due to the loss of diversification.[2] The paper also advances our understanding of the cost of risk. Most principal-agent models assume that all types of risk, whether systematic or non-systematic, are equally costly to managers (agents). In contrast, this paper identifies non-systematic, firm-specific risk as more costly to managers, because the expected market return fairly compensates managers for bearing systematic risk, but does not compensate the managers for bearing non-systematic risk. And indeed, while financial engineering has the potential to reduce the manager's exposure to systematic risk, managers *must* be exposed to this non-systematic, firm-specific risk to produce the right incentives.

This paper then applies the suggested technique to measure the private value a manager places on the firm's stock, investigating the deadweight costs associated with stock- and option-based compensation for a broad sample of firms. The paper also examines these costs for a set of firms where the potential for which the costs are likely to be great—namely Internet-based firms. Such firms tend to have relatively high levels of insider ownership, and typically, much of the employees' pay comes from equity-linked compensation. Moreover, it is not uncommon for many employees to have nearly all of their wealth in company stock and options. Thus, the extreme volatility of stock returns in Internet-based firms represents a substantial risk for such employees.

This examination highlights a striking gap between firm cost and employee benefit of both stock and option awards. Undiversified managers of the average NYSE firm, for example, value their options at 70% of the cost of these options to the firm. As expected, the gap is larger for Internet-based firms, where the value placed on the options by an undiversified manager represents an average of 53% of the cost of these options to the Internet-based firm. The paper also extends this "efficiency" metric to incorporate the possibility that

[1]I call the gap between managers' private value and the firm's cost a "deadweight cost" to distinguish it from the market value of the firm's compensation, which is the usual definition of "cost" in the executive compensation literature.

[2]To be sure, a substantial literature investigates how features such as the probability of managerial departure (and subsequent option forfeiture), the non-tradability of options, and early exercise patterns affect option value. See, for example, Carpenter (1998) on how to adjust stock option value for the probability of forfeiture; see Detemple and Sundaresan (1999), Hall and Murphy (2000a), Hall and Murphy (2000b), Huddart (1994), Kulatilaka and Marcus (1994), and Lambert, Larcker, and Verrecchia (1991) on non-tradability, early exercise, and employee risk aversion; also, see Johnson and Tian (2000) on various other characteristics of executive stock options, such as re-pricing and re-loading. The existing literature, however, has not specifically addressed how the deadweight costs associated with the lack of diversification (the only feature that is inexorably bound to compensation designed to align incentives) affect managers' private value of the option. Because the principal-agent models employed in the prior literature have only one risky asset, diversification (or lack thereof) does not enter into those models. Jin (2000), departing from the standard practice of treating both systematic and non-systematic risk as equally costly for managers, investigates how firm-specific risk affects observed pay-performance patterns. He finds that, in practice, pay-performance sensitivity depends upon the firm's idiosyncratic (firm-specific) risk, but not its systematic risk.

managers have partially, but not fully, diversified portfolios. Of course, any analysis of the ultimate desirability of equity-linked compensation must weigh the deadweight costs against the incentive-alignment benefits produced by that compensation. This paper provides a starting point for that analysis by describing and estimating a largely unexplored cost of equity-based compensation, the loss experienced when managers hold undiversified portfolios. Section I describes the source of the inefficiency of equity-based compensation for certain firms, and Section II presents the method to estimate the magnitude of the inefficiency for both partially- and fully-diversified managers. Section III reports the results from an empirical evaluation of the inefficiency using a sample of all NYSE, AMEX, and NASDAQ-listed firms, with a separate analysis of Internet-based firms. Section IV explores the robustness of the efficiency measure and potential biases, and Section V concludes.

I. The Costs and Benefits of Equity-Linked Compensation

The increased prevalence of option-based compensation is due, in part, to the perceived need to align managers' interests with those of the shareholders: managers tend to think like owners only by becoming owners. This compensation structure can be especially useful when direct monitoring of management is difficult. This rationale may explain why Smith and Watts (1992) find that growth firms use equity-based compensation more frequently than other firms do: growth firms tend to change rapidly, which increases the opacity of the firms and their operations to outsiders.[3] Yermack (1995) reinforces this observation, reporting that firms award stock options more frequently when direct monitoring is difficult, that is, when accounting earnings contain large amounts of "noise."[4]

Many advocates of equity-based compensation focus almost exclusively on the benefits provided by such compensation, devoting less attention to its costs. Indeed, if the only result of equity-based compensation were incentive alignment, no natural "stopping-point" would exist: managers' compensation would be 100% equity-based. Yet, in practice, managers' pay has appeared to depend far less on firm performance than this naive recommendation would suggest. Jensen and Murphy (1990), for example, report that managers' share of increases in firm value averaged around 3%. In later work, Hall and Liebman (1998) find that by more exhaustively incorporating the value of executive stock options into the calculations, this sensitivity increases, but still remains relatively low.

What then prevents firms from increasing this pay-performance sensitivity? One answer is that the current sensitivity is enough to spur managers to better performance. Murphy (1985) and Core and Larcker (2000) provide some support for this hypothesis, with evidence presented by Larcker (1983), DeFusco, Zorn, and Johnson (1991), and McConaughy and Misha (1996) somewhat more mixed. Another answer is that there are costs to such compensation, such as encouraging managers to take too much risk. But theoretical and empirical work casts doubt on whether options cause excessive managerial risk-taking, and

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[3]Gaver and Gaver (1995)'s findings are consistent with those of Smith and Watts (1992).

[4]Incentive alignment is not the only perceived benefit of stock option plans. Dechow, Hutton, and Sloan (1997) report that when Congress restricted the tax deductibility of executive compensation that is not incentive-based to $1 million, most firms complied by replacing any cash compensation over the $1 million threshold with executive stock options. They also discuss a 1992 meeting FASB held with compensation consultants, who agreed that accounting provisions affected the design of stock option plans. Long (1992) investigates whether taxes or incentives motivate a firm's adoption of an executive stock option plan.

even suggests that options might provide managers with an incentive to decrease risk. See Carpenter (2000), Haugen and Senbet (1981), Detemple and Sundaresan (1999), Cohen, Hall, and Viceira (2000), and Rajgopal and Shevlin (1999).

Another cost associated with equity-based compensation is the deadweight loss incurred when a firm pays managers in a currency that they value less than its cost to the firm. The exposure to firm-specific risk is both necessary to produce the right incentives and inevitably results in managers losing some degree of diversification on their investment portfolios.[5] Managers' human capital investments in the firm,[6] pension fund holdings skewed towards the company's stock, and deferred compensation plans[7] all have the potential to substantially increase managers' idiosyncratic risk exposure.

Consequently, managers face an extraordinary level of risk, with respect to their personal portfolios, that outside investors who hold diversified portfolios do not face.[8] An investor with her wealth invested solely in the average NYSE firm, for example, faces an annual volatility of 45%, which is twice that of the 22% annual volatility faced by an investor who is all-equity invested in a diversified market basket of stocks. Undiversified investors in volatile, Internet-based firms face even higher risk, on average *five* times the risk borne by a diversified investor (the volatility of Internet-based firms averages 117%, as shown in Table I).

Even more importantly, managers are not compensated for this additional risk with higher expected returns. To adequately compensate the undiversified manager, the expected return of the stock would need to be commensurate with its total volatility and not only its systematic risk component. However, the expected return is set by the firm's incremental contribution to the volatility of the market portfolio, *not* the total volatility, and is therefore too low to fully compensate the manager for her risk exposure. Therefore, the manager will value equity-linked compensation at less than its market value, which represents the cost of the compensation to the firm.[9] The focus of this paper is this "wedge" between the firm's cost and the manager's value.[10] The wedge compels a firm with undiversified managers or employees to choose between issuing options to the market, and receiving their full value from outside investors, or granting the options to insiders, who will not value them as highly. Indeed, if one were to ignore the incentive-alignment benefits of equity-based compensation, the firm and its employees would be better off if the firm were to sell the options to outsiders, and then give the cash proceeds of such sales to its employees.

[5]Even a CEO's cash compensation is subject to firm-specific risk: Lambert and Larcker (1988) find that 25% of the time-series variation in a CEO's cash compensation is related to her firm's performance.

[6]Friend and Blume (1975) estimate that, on average, the human capital of individuals (including the value of any privately owned businesses) constitutes 52% to 87% of their total assets; some portion of that human capital will no doubt be specific to the firm. See Degeorge, Jenter, Moel, and Tufano (2000) for a discussion of how employee's human capital affects her decision to buy her employer's stock.

[7]Deferred compensation is a general liability of the firm, again exposing the manager to firm-specific risk.

[8]Managers may be able to reduce some of their risk through targeted financial instruments (see footnote 11). To account for the possibility that managers can reduce their exposure the analysis below specifically derives an efficiency metric for both a fully- and partially-diversified investor.

[9]Firms do buy back stock in the open market so that they can issue equity to managers without "diluting" the firm's shareholders. So, the market value of equity-based compensation seems a good estimate of the firm's cost, whether one considers it an opportunity cost (what the market would pay for the instrument), or a real one.

[10]Several papers provide good discussions of why managers value equity-linked compensation at less than the firm's cost of awarding that compensation. See, for example, Abowd and Kaplan (1999), Carpenter (1998), Lambert, Larcker, and Verrecchia (1991), Murphy (1998), or Smith and Zimmerman (1976).

Table I. Firm Characteristics: β, Volatility, Turnover, and Size

Beta (β) is estimated using the market model, 150 trading days of daily returns data from CRSP, and the value-weighted market composite (all NYSE, AMEX, and NASDAQ firms). Volatility is also estimated using 150 trading days of daily returns and annualizing the resulting daily volatility. Firms with fewer than 100 trading days of returns during this 150-day estimation window preceding 12/31/98 are not included. Yearly turnover is estimated by aggregating fourth quarter trading volume from CRSP, dividing by shares outstanding, and then annualizing this number.

	β	Volatility (Annualized)	Turnover (Ann. Vol/Shrs Out)	Firm Size ($ Millions)
Panel A. Individual Firm Statistics				
NYSE				
Mean	0.70	0.45	0.94	3,853.4
Median	0.67	0.42	0.69	522.2
Std. Dev. Mean	0.01	0.00	0.02	586.5
N	2787	2787	2758	2758
AMEX				
Mean	0.54	0.55	1.16	275.5
Median	0.45	0.50	0.36	63.2
Std. Dev. Mean	0.02	0.13	0.25	51.0
N	519	519	493	493
NASDAQ				
Mean	0.86	0.81	2.10	723.2
Median	0.79	0.76	1.11	102.5
Std. Dev. Mean	0.01	0.01	0.06	134.2
N	3544	3544	3439	3439
Internet-Based				
Mean	2.09	1.17	13.89	12,920.0
Median	2.23	1.16	8.90	1,080.9
Std. Dev. Mean	0.09	0.05	1.79	6,433.6
N	58	58	58	58
All Firms				
Mean	0.77	0.65	1.55	1,980.7
Median	0.71	0.58	0.83	183.3
Std. Dev. Mean	0.01	0.00	0.04	138.2
N	6850	6850	6690	6690
Panel B. Market Indices Statistics				
NYSE/AMEX Index	0.94	0.22		
NASDAQ Index	1.29	0.32		
H&Q Internet Index	1.57	0.43		
Market Composite Index	1.00	0.23		

Does the forced exposure to the firm's total risk impose a substantial cost on managers? On the one hand, firms do continue to issue options to their managers. On the other hand, managers appear to be taking any steps possible to reduce their risk exposures. Managers have, for example, been using swaps or zero-cost collars to reduce their risk.[11] And, it is the managers of especially risky firms, such as Internet-based firms, who sell their holdings at a higher rate than managers of other firms do. Meulbroek (2000a) reports that 93% of all corporate insider transactions in Internet-based firms are sales, versus 63% in non-Internet-based firms. These sales occur despite the hefty taxes that managers typically face upon selling their holdings, suggesting that managers put a high value on decreasing their risk by selling shares.

The importance of risk to managers is reinforced by the finding that managers frequently exercise their options prior to expiration, even on non-dividend paying stocks. Ofek and Yermack (2000) find that managers sell almost all shares acquired through option exercise, usually as soon as the options vest. Huddart and Lang (1996) report that early option exercise is more likely at riskier firms. These managerial sales have not gone unnoticed in the financial press—Rock (1999) in *Directors and Boards* notes that "despite the massive issuance of stock options, ownership levels of managers have not increased. Although touted as programs that make managers think like owners, stock option programs appear more like short-term bonuses, given the unwillingness of executives to retain their shares."

Of course, a desire to gain at least some degree of diversification in order to reduce risk is not the only reason managers sell stock or exercise options. That risk reduction is an important motive; however, it is supported by Meulbroek (2000a)'s finding that the market does *not* react negatively to managerial sales from Internet-based firms, differing significantly from the reaction to managerial sales in non-Internet-based firms. These results suggest that managerial sales in a set of risky firms do not appear to be motivated by managers' inside information, and that the market understands the great incentive that managers in such firms have to diversify.[12] Consistent with Meulbroek (2000a)'s results on executive stock sales, Carpenter and Remmers (2000) find that executive stock option exercises tend to take place for non-informational reasons. These findings suggest that the wedge between the firm's cost and the managers' private

[11]The manager obtains the swap or zero-cost collar over-the-counter, typically from an investment bank. Such instruments are economically similar to selling the stock, but have different tax implications, and seem not to attract the same degree of public scrutiny as straight stock sales do. Bettis, Bizjak, and Lemmon (2000) describe these contracts and report that the number of such transactions reported to the SEC has, so far, been relatively small. Bettis, et al. (2000) also find, however, that the SEC's reporting requirements for these transactions have only recently been clarified, so that the true incidence of zero-cost collars is perhaps higher than the historical statistics would suggest. Another way that managers might seek to limit their exposure to market risk is to short S&P 500 futures to offset the systematic risk inherent in their positions in company stock. While a theoretical possibility, in practice, few managers appear to engage in such transactions, perhaps because of the liquidity risk induced by this strategy. That is, managers would have to mark-to-market their S&P 500 positions daily, and post additional margin in case of a market increase, but they would not be able to use their holdings in company stock or options to meet the margin call. Managers can also reduce risk through equity swaps (see Bolster, Chance, and Rich (1986)), but changes in the tax code have made such swaps considerably less attractive. Boczar (1998) describes several (economically-equivalent) methods for an executive to manage risk, and the tax implications of such methods. See also Schizer (2000) on managerial hedging of stock option positions. Hedging of options can be difficult for managers because many firms prevent executive stock options from being pledged as collateral.

[12]Although publicly-traded Internet-based firms tend to be larger, on average, than other publicly-traded firms, and stock price responses in larger firms tend to be less informative than managerial sales at smaller firms, Meulbroek (2000a) reports that these results are robust to firm size: even managerial sales at small Internet-based firms are not interpreted by the market as information based.

value of equity-linked compensation can be large. The next section more directly investigates the magnitude of this wedge by developing a technique to estimate the undiversified investor's private value of the stock.

II. Adjusting the Value of Equity-Linked Compensation for the Loss of Diversification

The total cost imposed on the manager by her compelled holding of equity-based compensation has two components. The first is the cost associated solely with the loss in diversification. The second is the cost arising from the specific pattern of risk exposure created by the financial instrument the manager is required to hold (e.g., an option produces a certain dynamic exposure to risk over time, and that pattern may not represent the manager's preferred risk exposure, either in level or timing). Financial engineering can reduce or eliminate the second component of cost,[13] but the first component, the cost due to lost diversification, cannot be eliminated without destroying incentive alignment. That is, the cost due to lost diversification is the only *structural* cost associated with incentive-based compensation, and is therefore the focus of this paper.

To estimate this loss-of-diversification cost, we calculate the expected return a manager would require in order to be indifferent between holding a portfolio consisting only of the firm's stock, and holding an efficiently-diversified portfolio levered to a volatility level that equals that of the firm's stock. This method, which we call the Sharpe ratio approach, produces a lower-bound estimate of the actual cost from the manager's concentrated exposure because it does not account for that manager's individual preferences regarding the level or pattern of risk exposure she faces. A manager's utility function will determine the magnitude of this individual preference-based cost, which can be measured via a "certainty-equivalent" approach if the manager's utility function were known. Prior literature has focused on estimating the individual-specific component of cost, while implicitly assuming that there is no cost due to the loss in diversification.[14] The strength of our Sharpe ratio technique is that it isolates the one type of risk that is essential to properly aligning incentives, and this firm-specific risk imposes a common cost on all managers.[15]

Note that even the ability of managers to choose employers, and by extension, the type of compensation package they receive, cannot reduce the deadweight costs associated with

[13]Options indexed to the market are one way to eliminate systematic risk via financial engineering - see Johnson and Tian (2000), Meulbroek (2000b), Rappaport (1999), and Schizer (2000).

[14]For examples of this individual utility-based technique, see Hall and Murphy (2000a), Hall and Murphy (2000b), Huddart (1994), or Lambert, Larcker, and Verrecchia (1991). If one wanted to explicitly incorporate costs of lost diversification, then the models used in these papers would have to be modified to incorporate more than one risky asset, along the lines of Jin (2000). Even then, using a specific functional form of a manager's utility function to calculate a certainty-equivalent value conflates the effect of managerial preferences about the functional form of the compensation plan with the effect due to lost diversification. For example, a manager holding a stock perfectly correlated with the market will effectively be fully-diversified. The Sharpe ratio method used in this paper tells us that the efficiency of equity-based compensation is 100%; that is, the manager will value that stock at its full market value. Yet, the utility-function approach tells us that the manager values this stock at less than its market value, simply because the risk exposure created by holding that stock is unlikely to be the optimal risk exposure for that particular manager.

[15]To measure the full cost to managers imposed by any given compensation system, the Sharpe ratio method presented here could be combined with the certainty-equivalent method used in prior research. Specifically, the lack-of-diversification cost estimated via the Sharpe ratio method would be used as an input to a utility-based approach.

lost diversification. Such self-selection may serve to reduce the loss due to individual preferences, but any compensation plan that exposes managers to firm-specific risk will result in lost diversification no matter how closely the package otherwise fits individual preferences. In this sense, self-selection plays a role similar to that of financial engineering.

A. Derivation of an Efficiency Metric for Stock- and Option-Based Compensation for the Completely Undiversified Investor

We begin with the assumption that CAPM holds instantaneously in a continuous-time model, an assumption consistent with the underlying assumptions of the Black-Scholes option-pricing model, which we use later to value the executive options.[16] This assumption is not critical in the sense that the same method presented here could be adapted to incorporate any asset-pricing model (of course, the numerical estimates will change, but the technique will not). These assumptions produce mean-variance behavior. Interpreted in the context of this paper, mean-variance behavior implies that even people with high-risk tolerances, such as entrepreneurs, prefer the higher expected return produced by a leveraged fully diversified portfolio to the lower expected-return from an equally risky single-stock portfolio.

In the Black-Scholes model, and in continuous-time portfolio theory, the security market line relation is expressed in "instantaneous" expected-rates-of-return (i.e., exponential, continuous-compounding):

$$r_j = r_f + \beta_j \left(r_m - r_f \right) \tag{1}$$

Where $e^{r_f} \equiv \left(1 + R_f\right)$ where R_f represents the riskless arithmetic return, and r_f is, therefore, its continuously-compounded equivalent.

$e^{r_j} \equiv$ (1 + yearly expected rate-of-return of security *j* under CAPM pricing)

$e^{r_j^u} \equiv$ (1 + yearly expected rate of return on security *j* required by an *undiversified* mean-variance optimizing investor to make that investor indifferent between holding stock *j*, and holding a market portfolio with a volatility equal to that of stock *j*)

$\left(r_m - r_f\right) =$ The market's risk premium (continuously-compounded)

$r_m =$ The expected market return (continuously-compounded)

$\sigma_m =$ The market's volatility

$\beta_j =$ Firm *j*'s beta from CAPM

$\sigma_j =$ Firm *j*'s volatility

Define $s_j \equiv r_j^u - r_j$, as the instantaneous spread between the expected return required by

[16]Unlike the original single-period discrete-time version of the CAPM, the continuous-time version of the CAPM and its implied mean-variance optimizing behavior is consistent with limited-liability, log-normally-distributed asset prices, and concave expected utility functions. See Merton (1992) on the CAPM in continuous time. See also Black and Scholes (1973). Adopting a continuous-time approach, combined with log-normally distributed security returns yields mean-variance behavior without imposing the strict assumptions limiting the utility function to quadratic utility and normally distributed prices, as required by the discrete time model.

an undiversified investor relative to the CAPM-based expected return. This spread represents the compensation an undiversified investor must receive in order to be indifferent between holding only stock *j* in her portfolio, and holding the market portfolio.

1. Calculation of r_j^u and r_j, the Required Rates of Return under the CAPM by Undiversified and Diversified Investors

This section presents calculations designed to address the question: what expected return would an undiversified manager require to be indifferent between holding stock *j* in a single-stock portfolio, and holding a market portfolio levered to firm *j*'s volatility? In other words, at each point in time, we examine the actual volatility level associated with the manager's forced concentrated holdings, and ask what expected return on stock *j* would make that manager indifferent between stock *j* and the best portfolio possible.

If an undiversified investor had the market portfolio as an alternative investment opportunity, and were a mean-variance efficient investor, then she would require a risk-return ratio as good as the market's risk-return ratio in order to be indifferent between holding the market portfolio and a portfolio composed exclusively of stock *j*. To calculate the excess return commensurate with stock *j*'s risk-level, r_j^u, using the market's risk-return ratio as a benchmark, we use the Sharpe ratio:

$$\frac{r_m - r_f}{\sigma_m} = \frac{r_j^u - r_f}{\sigma_j} \quad \Rightarrow \quad r_j^u = r_f + \left[\frac{\sigma_j}{\sigma_m}\right]\left(r_m - r_f\right) \tag{2}$$

Knowing r_j^u and r_j yields s_j ($s_j \equiv r_j^u - r_j$), and

$$s_j = \left(\left[\frac{\sigma_j}{\sigma_m}\right] - \beta_j\right)\left(r_m - r_f\right) = \left[\frac{\sigma_j}{\sigma_m}\right]\left(1 - \rho_{jm}\right)\left(r_m - r_f\right) \tag{3}$$

Where ρ_{jm} is the correlation coefficient between firm *j*'s returns and the market returns. Figure I displays this return premium graphically.

2. Using s_j to Calculate the Value of Stock *j* to an Undiversified Investor

Let $V_j(t) \equiv$ Value of stock *j* at time *t* (the market price).

$T \equiv$ Date at which the undiversified investor is free to sell the stock.

$V_j^u(t) \equiv G(V_j(t), \tau, div_j, s_j)$, which is the private value placed on the stock of *j* by investor forced to hold the stock *j* position undiversified until date *T*, where $\tau \equiv T - t$ and div_j is firm *j*'s dividend rate.

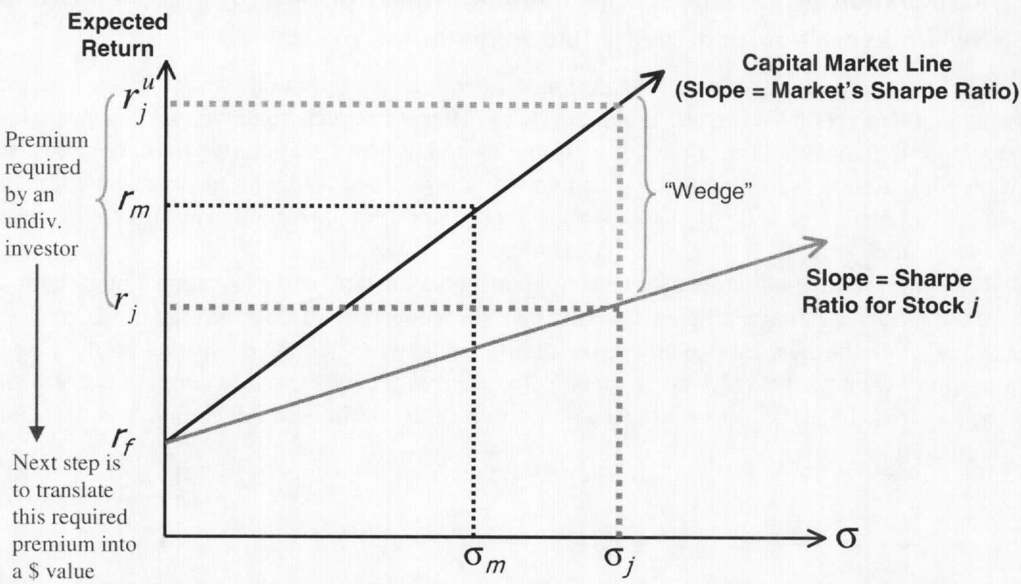
In the following analysis, we assume, for analytical simplicity, that the firm does not pay dividends during $t \le T$, the duration of the sale restrictions. The zero-dividend assumption seems reasonable for Internet-based firms and young entrepreneurial firms more generally.

By definition of r_j, we know that the discounted expected future value of firm *j* at time *T* equals today's stock price:

$$V_j(t) = e^{-r_j \tau} E_t\{V_j(T)\} \tag{4}$$

Figure I. Compensating the Manager for Total Firm Risk

What expected return will the manager need to be indifferent between holding stock j and holding the market while holding risk fixed at s_j? The point of indifference occurs when the Sharpe ratio of stock j equals that of the market.



where $E_t\{\bullet\}$ is the conditional expectation of the value of the shares of j at T, conditional on the information available at time t. Similarly, by definition of r_j^u, we know that the expected future value of the firm to the undiversified investor discounted by r_j^u is the value of the firm today to that investor.

$$V_j^u(t) = e^{-r_j^u \tau} E_t\{V_j^u(T)\} \quad (5)$$

But, at date T, the undiversified investor is free to sell her shares in the open market (think of T as being the time at which the shares vest)[17], so therefore, at date T for every outcome, the value of the stock to the undiversified investor, $V_j^u(t)$, will equal the market value of the firm: [18]

[17]Although the vesting period is treated as exogenously determined, one would expect that period to be shorter in highly volatile firms, which would be consistent with an effort to increase compensation efficiency. Such an outcome would be similar in spirit to Aggarwal and Samwick's (1999) finding that pay is less sensitive to performance in highly volatile firms, and Jin's (2000) result that it is specifically idiosyncratic risk that is associated with a lower pay-performance sensitivity.

[18]This assumption rules out the possibility of asymmetric information that would result in a departure of the firm's market value from its fundamental value. We do this to focus attention on the structural problems associated with loss of diversification. This assumption has the potential to affect our estimates of efficiency if we think information asymmetry exists among informed investors who may try to profit from their information by choosing to work at firms whose stock they believe to be undervalued by the market, thus hoping to be compensated in a security they know is worth more than its market price. It would be somewhat of a coincidence, however, if all investors who believed the stock to be undervalued possessed not only the proper skill set to work at such firms, but also that working at such firms was the most productive use of their skills. Indeed, even if the informed investors did possess the appropriate set of skills, a more direct (and lower cost) method of profiting from the information exists: the investor could buy the stock and not seek employment. Finally, structuring a compensation system around the assumption (or hope) that managers know the firm to be undervalued hardly seems a wise strategy.

$$V_j^u(T) = V_j(T)$$

Hence, this statement must hold expectationally as well:

$$E_t\{V_j^u(T)\} = E_t\{V_j(T)\} \tag{6}$$

By substituting Equation 6 into Equations 4 and 5, we have:

$$V_j^u(t) = e^{-r_j^u \tau} E_t\{V_j(T)\} = e^{-r_j^u \tau} \cdot e^{r_j \tau} \cdot V_j(t) = e^{-s_j \tau} V_j(t) \tag{7}$$

The manager's private value of the stock today is its market value today, discounted by the incremental amount required to compensate the manager for the firm's total risk. Figure II displays this process graphically.

$$\Rightarrow \mathcal{E} \equiv \textit{Efficiency of Stock Compensation} = \frac{V_j^u(t)}{V_j(t)} = e^{-s_j \tau} \tag{8}$$

The "efficiency" of stock compensation to an undiversified investor, ε, is the ratio of the stock's value to an undiversified employee relative to the cost of that compensation to the firm. This efficiency calculation does *not* assume or require that cash flows follow any particular pattern, nor does it depend upon any specific valuation model.

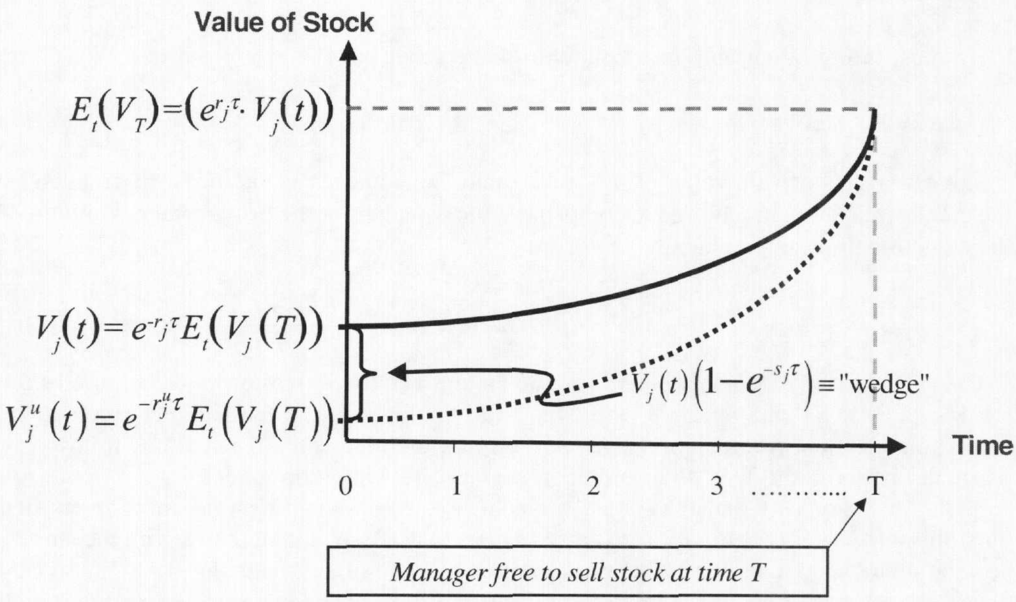
Equation 8 suggests that the longer a manager is constrained to hold an undiversified portfolio, the less it is worth to her. It also reveals that efficiency increases with the stock's correlation to the market: the higher the correlation–or the stock's beta–the closer the stock's expected return gets to the market's expected return, which lowers s_j, the undiversified manager's required expected return premium. In the limit, a manager holding a single-stock portfolio, which happens to be perfectly correlated with the market, will essentially be fully diversified, and will not require any additional return premium. Following Equation 8, a three-year vesting period and a 1% required expected return premium yields an efficiency of 97%. A 10% expected return premium decreases efficiency to 74%, and a 20% required expected return premium translates into a 54% efficiency level. Loss of diversification has the potential to significantly affect the manager's private value of the firm's stock.

Equation 8 also provides some support for our earlier conjecture that start-up companies in risky industries produce the greatest gap between the cost of equity-linked compensation and the value of such compensation to undiversified insiders. Start-up firms are likely to meet the conditions because they are often highly volatile, yet the volatility may, at first, be mostly a function of firm-specific factors (e.g., is the new product a success, can the firm get the necessary funding for its projects, do suppliers provide the expected raw materials in a timely fashion?), resulting in a low β. Over time, as the new firm becomes better-established and overcomes the many obstacles facing start-ups (logistical or otherwise), market risks may represent a larger proportion of the firm's total risk profile, so that β will increase even if σ remains unchanged. Today's market conditions create the potential for very low efficiency levels. That is, the confluence of rapidly-changing technology, the emergence of many start-up firms to capitalize on this technological change, coupled with a tendency for such firms to compensate management largely through equity-linked compensation all play a role in reducing efficiency levels.

3. Calculating the Efficiency of Option-Based Compensation

The derivation of the discount for lack-of-diversification on an option parallels that of the lack-of-diversification for the stock, presented above, but is more complex because both the

Figure II. Calculating the Private Value an Undiversified Manager Places on the Firm's Stock



expected return and the standard deviation of the option change at every point in time. As in the discussion of the stock discount, we assume that the employee will be indifferent between concentrated-versus-efficiently-diversified exposures if he or she is presented with the same (instantaneous) Sharpe ratio in either case, which again produces a lower-bound on the undiversified investor's discount. This lower-bound results from the willingness of some employees to give up an additional amount in expected return terms to change their total level of risk or to pursue a dynamic risk strategy that differs from that of an option.

We refer to the instantaneous expected return on the employee's option as r_{jo}, where j is the subscript representing the firm, and o represents "option". As shown in Merton (1992), the instantaneous expected return on the employee's option is given by:

$$r_{jo}=\frac{\left[\frac{1}{2}\sigma_j^2V_j^2f_{VV}+r_jV_jf_v-f_\tau\right]}{f} \tag{9}$$

Where $f(V,\tau)$ is the Black-Scholes value of the option and subscripts on f denote partial derivatives with respect to the share price V and time until expiration, τ.

Similarly, from Merton (1992), we have the instantaneous standard deviation of the return on the option, σ_{jo}, which can be written as:

$$\sigma_{jo} = \frac{\sigma_j V_j f_V}{f} \tag{10}$$

It follows from Equation 10 that the instantaneous expected excess return, $r_{jo} - r_f$, can be expressed as:

$$r_{jo} - r_f = \frac{\left[\frac{1}{2}\sigma_j^2 V_j^2 f_{VV} + r_j V_j f_V - f_\tau - r_f f\right]}{f} \tag{11}$$

By taking the ratio of Equation 11 to Equation 10, we then have the instantaneous Sharpe ratio of the option return given by:

$$\frac{r_{jo} - r_f}{\sigma_{jo}} = \frac{\left[\frac{1}{2}\sigma_j^2 V_j^2 f_{VV} + r_j V_j f_V - f_\tau - r_f f\right]}{\sigma_j V_j f_V} \tag{12}$$

Following the stock efficiency derivation—if we now require that the option be priced so that at every point in time it has a Sharpe ratio equal to the Shape ratio of the market portfolio—we have from Equation 12:

$$\sigma_j V_j f_V \left(\frac{r_m - r_f}{\sigma_m}\right) = \frac{1}{2}\sigma_j^2 V_j^2 f_{VV} + r_j V_j f_V - f_\tau - r_f f \tag{13}$$

By rearranging terms, f must satisfy the partial differential equation:

$$0 = \frac{1}{2}\sigma_j^2 V_j^2 f_{VV} + \left[r_j - \frac{\sigma_j}{\sigma_m}\left(r_m - r_f\right)\right] V_j f_V - r_f f - f_\tau \tag{14}$$

Noting that $\beta_j = \rho_{jm}\left(\sigma_j / \sigma_m\right)$ and substituting for r_j from Equation 1 into Equation 14:

$$0 = \frac{1}{2}\sigma_j^2 V_j^2 f_{VV} + \left[r_f - \underbrace{\left(1 - \rho_{jm}\right)\frac{\sigma_j}{\sigma_m}\left(r_m - r_f\right)}_{\equiv s_j \text{ from equation (3)}}\right] V_j f_V - r_f f - f_\tau \tag{15}$$

where $s_j \equiv r_j^u - r_j$, the return premium that an undiversified investor in the stock would require to make her indifferent between holding the stock and holding the market portfolio levered to the volatility level of the stock. From Equation 15 and the definition of s_j:

$$0 = \frac{1}{2}\sigma_j^2 V_j^2 f_{VV} + \left[r_f - s_j\right] V_j f_V - r_f f - f_\tau \tag{16}$$

By inspection, this equation is the partial differential equation for the Black-Scholes option-pricing formula on a stock which pays a proportional dividend at rate s_j (Merton, 1992). The well-known solution to this partial differential equation is the Black-Scholes formula for a proportional dividend on stock:

$$f = V_j e^{-s_j\tau} N\left(d_j\right) - X e^{-r_f\tau} N\left(d_j - \sigma_j\sqrt{\tau}\right) \tag{17}$$

Where:

$$d_j = \frac{\ln\left(V_j/X\right) + \left(r_f - s_j + \frac{1}{2}\sigma_j^2\right)\tau}{\sigma_j\sqrt{\tau}}$$

By substituting Equation 7,

$$V_j^u = V_j e^{-s_j\tau} \Rightarrow \ln\left(V_j^u\right) = \ln\left(V_j e^{-s_j\tau}\right) = \ln\left(V_j\right) - s_j\tau$$

into Equation 17, we find that:

$$f = V_j^u N\left(d_j\right) - X e^{-r_f\tau} N\left(d_j - \sigma_j\sqrt{\tau}\right) \tag{18}$$

Where:

$$d_j = \frac{\ln\left(V_j^u/X\right) + \left(r_f + \frac{1}{2}\sigma_j^2\right)\tau}{\sigma_j\sqrt{\tau}}$$

Equation 18 is the Black-Scholes formula with V_j^u as the stock price. Therefore, the pricing on an option that, at every point in time provides an instantaneous Sharpe-ratio equal to the instantaneous Sharpe ratio on the market portfolio, is exactly the Black-Scholes formula on a non-dividend paying stock where we replace the market price of the stock V_j by its discounted private value, V_j^u, as follows, where Φ represents the efficiency of the option.

$$\Phi \equiv \textit{Efficiency of Option Compensation} = \frac{f\,(V_j^u, T-t, \sigma_j, r_f, X = V_j)}{f\,(V_j, T-t, \sigma_j, r_f, X = V_j)} \tag{19}$$

where the exercise price (X) is V_j, the amount a manager would actually have to pay to exercise the option, and the denominator is the market value of the option. Note that as most executive stock options are issued at-the-money, for consistency we adopt the same convention.

4. Stock Efficiency Versus Option Efficiency

The efficiency of the option will always be less than the efficiency of the underlying stock. To see this, note that by the homogeneity property (Merton, 1992) and the property that a lower exercise price leads to a higher option value, we have:

$$F(V_j^u, X) = F(e^{-s\tau}V_j, X) < F(e^{-s\tau}V_j, e^{-s\tau}X) = e^{-s\tau}F(V_j, X)$$

Dividing by $F(V_j, X)$ then reveals that the option efficiency, Φ, must always be less than the stock efficiency, ε.

$$\Phi = \frac{F(V_j^u, X)}{F(V_j, X)} < \frac{e^{-s\tau}F(V_j, X)}{F(V_j, X)} = e^{-s\tau} = \varepsilon$$

The dynamics of option efficiency are similar to those for stock efficiency. As the expected rate of return premium increases, option efficiency decreases, and as vesting periods increase, option efficiency decreases. Changes in the required expected rate of return premium have a larger effect on the option efficiency than do changes in the vesting period. In addition, as the time until option maturity increases, efficiency increases, but only slightly. Tables II and III, discussed later, illustrate these results.

B. An Efficiency Metric for Stock- and Option-Based Compensation for the Partially-Diversified Investor

The efficiency measures previously outlined assume that the manager is compelled to hold *all* of her wealth in equity or options of the firm and is therefore completely undiversified. While this assumption may be a good approximation for managers in Internet start-up firms, managers in more mature firms may have investment portfolios that are better diversified. If the manager is able to at least partially diversify her holdings, then the efficiency of equity-based compensation will rise, but by how much? Under partial diversification, the volatility faced by the manager will be a mix of the firm's volatility and the volatility of the manager's other holdings, and, as a consequence, the premium required by the manager, s_j, will decrease. If we assume that the manager achieves this partial diversification by investing some of her holdings in the market portfolio (scaled by the riskless asset), we can again derive the value of equity-linked compensation to this partially diversified manager (Appendix A contains this derivation). For this partially-diversified investor with weight w invested in stock j and (1-w) in the market portfolio, where σ_p equals the standard deviation of the combined market plus stock j portfolio, the efficiency is:

$$\varepsilon^* = \text{Stock Efficiency} = \frac{V_j^*(t)}{V_j(t)} = e^{-(r_j^*-r_j)\tau}, \quad \text{where } r_j^* - r_j = \left[\frac{1}{w}\left[\frac{\sigma_p - \sigma_m}{\sigma_m}\right] + (1-\beta_j)\right](r_m - r_f)$$

The option efficiency calculation parallels that for the case of the completely undiversified investor.

Figures III and IV demonstrate graphically how partial diversification affects stock and option efficiency respectively, corresponding to a hypothetical firm with the same mean and volatility of the average firm (the equally-weighted average beta for all NYSE, NASDAQ and AMEX firms is 0.77, with volatility of 65%). We can see that the ability to partially diversify helps, but perhaps not as much as one might expect. For example, the ability to diversify by holding 50% of one's wealth in the market portfolio increases option efficiency to 63% (from the completely-undiversified baseline of 54%).

III. Illustrating Use of the Efficiency Metric Using Firm-Specific Data for NYSE, AMEX, NASDAQ, and Internet-Based Firms

This section applies the efficiency metrics derived above to a broad sample of firms to better understand how economically significant the loss in efficiency for equity-based compensation might be. Specifically, we calculate stock and option efficiency metrics for all NYSE, AMEX, and NASDAQ firms listed as of December 31, 1998, examining separately the results for a sample of Internet-based firms defined by the Hambrecht & Quist (H&Q) *Internet Index*.[19]

The efficiency metrics require estimates of β and σ for each firm as inputs. To estimate a firm's β, we use the market model, incorporating the last 150 trading days of returns data prior to December 31, 1998, and using CRSP's value-weighted market composite index. We use these same 150 trading days of returns data to estimate each individual firm's s. The estimate of the market's volatility, σ_m uses the returns of CRSP's value-weighted market composite index over this same time period. We assume a risk-premium of 7.5% (7.2% continuously-compounded), the historical average amount by which the value-weighted market index exceeds the long-term government bond rate (monthly data begins in 1926).

Table II displays the summary statistics of the stock efficiency metric, ε^*, applied to each individual firm in the sample, for varying levels of managerial diversification and stock restriction periods. Panel A of Table II shows these summary statistics for all Internet-based firms, Panel B NYSE firms, Panel C AMEX firms, Panel D NASDAQ firms, and Panel E all firms. Managers of NYSE firms have, on average, much higher stock efficiency levels than managers of Internet-based firms or NASDAQ firms, at all levels of portfolio diversification. A completely undiversified manager in an NYSE firm experiences a mean 77% stock efficiency level (for a three-year required holding period on the stock), which drops to 66% for the longer five-year vesting period. One would suspect that managers of NYSE firms are likely to be better diversified than managers of Internet-based firms. If a manager of an NYSE firm had only 25% of her total wealth invested in the firm, then that manager would, on average, value stock compensation at 91% of its cost to the firm for a three-year vesting period, and 85% for a five-year vesting period.

The higher volatility of NASDAQ and Internet-based firms results in efficiency levels that are substantially lower than those associated with NYSE firms. A completely undiversified manager with all of her wealth invested in an Internet-based firm values stock compensation

[19]The H&Q *Internet Index* comprises a sub-sample of Internet-based firms, and is not confined to H&Q clients. The *Internet Index* is widely cited and viewed as a reliable reflection of Internet-based activity. Appendix B lists these firms, grouped by function.

Figure III. Sensitivity of Stock Compensation Efficiency to Portfolio Diversification

This figure assumes beta and volatility are equal to the average and the manager is free to sell stock in three years.

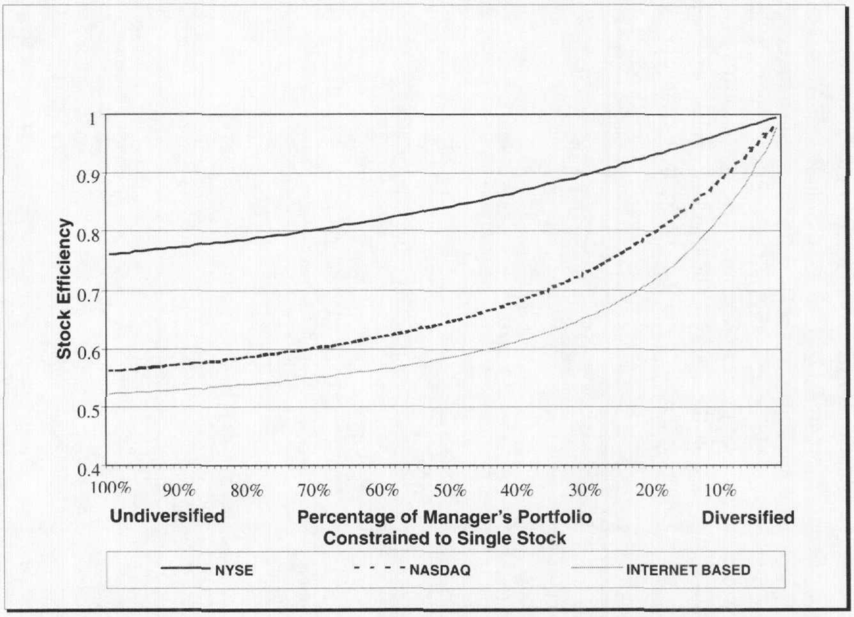


Figure IV. Sensitivity of Option Compensation Efficiency to Portfolio Diversification

This figure shows the manager free to sell option in three years and a ten-year option issued at-the-money. Other assumptions are the same as in Figure III.

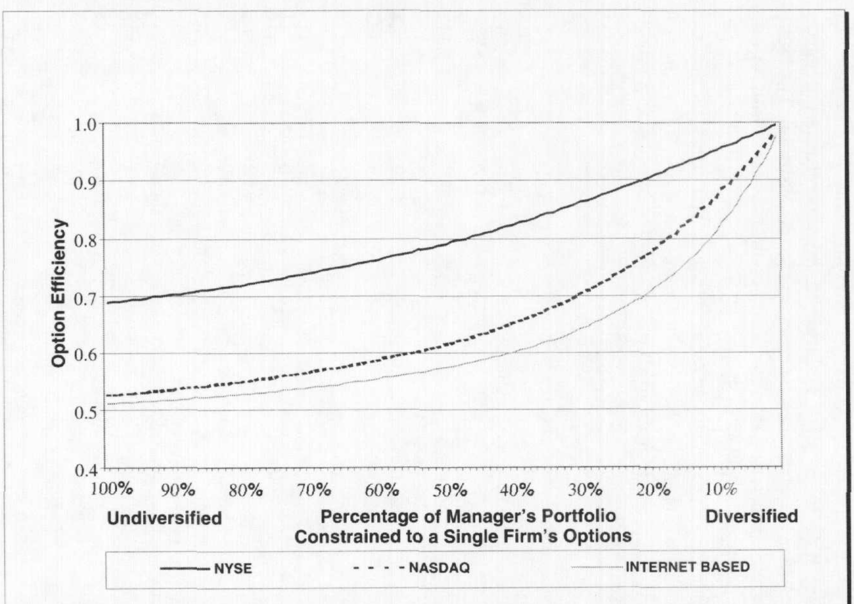


Table II. Sensitivity of Stock-Based Compensation Efficiency to Portfolio Diversification

Beta (β) is estimated using the market model, 150 trading days of daily returns data from CRSP, and the value-weighted market composite (all NYSE, AMEX, and NASDAQ firms). Annual volatility is also estimated using 150 trading days of daily returns and annualizing the resulting daily volatility. Firms with fewer than 100 trading days of returns during this 150-day estimation window preceding 12/31/98 are not included. A market premium of 7.5% (7.23%, continuously compounded) is assumed. The "return premium (s_j)" is the percent premium above the firm's equilibrium market return required by an undiversified investor to make that investor indifferent between holding the market and holding an undiversified portfolio, and is calculated using the market's composite Sharpe ratio. Efficiency of Equity (V_j^u/V_j) is the ratio between the value of the stock options to the partially-diversified manager to the firm's cost of those stock options. The Black-Scholes option pricing formula is used to price the options. The dividend yield is assumed to be zero. Omega (ω) is the percentage of a manager's portfolio constrained by a single stock (ω = 100% for the completely undiversified manager). Vesting Period (τ) is the time in years until the manager is free to sell her shares.

Panel A. Internet-Based Firms

Percentage of Manager's Portfolio Constrained to a Single Stock	β	Annual Volatility (%)	Return Premium (s_j, in %)	Efficiency of Equity (V_j^u/V_j, in %) τ = 3 Years	τ = 5 Years	τ = 10 Years
Completely Undiversified (ω = 100%)						
Mean	2.09	117	22	55	38	18
Median	2.23	116	20	55	37	13
Std. Dev. Mean	0.09	4.8	1.3	2.1	2.3	2.1
Max.	3.49	193	5	91	85	72
Min.	0.61	42	3	23	9	1
75% Undiversified (ω = 75%)						
Mean	2.09	117	20	57	40	20
Median	2.23	116	19	57	39	15
Std. Dev. Mean	0.09	4.8	1.3	2.1	2.4	2.2
Max.	3.49	193	47	92	87	76
Min.	0.61	42	3	24	10	1
50% Undiversified (ω = 50%)						
Mean	2.09	117	18	60	45	23
Median	2.23	116	17	61	44	19
Std. Dev. Mean	0.09	4.8	1.2	2.1	2.5	2.4
Max.	3.49	193	43	94	90	81
Min.	0.61	42	2	27	11	1
25% Undiversified (ω = 25%)						
Mean	2.09	117	13	69	55	33
Median	2.23	116	12	70	55	30
Std. Dev. Mean	0.09	4.8	1.0	1.9	2.4	2.8
Max.	3.49	193	34	97	94	89
Min.	0.61	42	1	36	18	3

Table II. Sensitivity of Stock-Based Compensation Efficiency to Portfolio Diversification (*Continued*)

Panel B. NYSE Firms

Percentage of Manager's Portfolio Constrained to a Single Stock	β	Annual Volatility (%)	Return Premium (s_j, in %)	Efficiency of Equity (V_j^u/V_j, in %) $\tau = 3$ Years	$\tau = 5$ Years	$\tau = 10$ Years
Completely Undiversified (ω = 100%)						
Mean	0.70	45	9	77	66	45
Median	0.67	42	8	79	68	46
Std. Dev. Mean	0.01	0.4	0.1	0.2	0.3	0.3
Max.	3.05	219	56	98	97	93
Min.	-0.65	6	1	19	6	0
75% Undiversified (ω = 75%)						
Mean	0.70	45	8	80	70	51
Median	0.67	42	6	82	72	52
Std. Dev. Mean	0.01	0.4	0.1	0.2	0.3	0.4
Max.	3.05	219	54	99	98	95
Min.	-0.65	6	0	20	7	0
50% Undiversified (ω = 50%)						
Mean	0.70	45	6	84	76	60
Median	0.67	42	5	87	79	63
Std. Dev. Mean	0.01	0.4	0.1	0.2	0.3	0.4
Max.	3.05	219	50	99	99	98
Min.	-0.65	6	0	22	8	1
25% Undiversified (ω = 25%)						
Mean	0.70	45	3	91	85	74
Median	0.67	42	2	93	88	78
Std. Dev. Mean	0.01	0.4	0.1	0.2	0.2	0.3
Max.	3.05	219	41	100	100	99
Min.	-0.65	6	0	29	13	2

Table II. Sensitivity of Stock-Based Compensation Efficiency to Portfolio Diversification (*Continued*)

Panel C. AMEX Firms

Percentage of Manager's Portfolio Constrained to a Single Stock	β	Annual Volatility (%)	Return Premium (s_j, in %)	Efficiency of Equity (V_j^u/V_j, in %)		
				τ = 3 Years	τ = 5 Years	τ = 10 Years
Completely Undiversified (ω = 100%)						
Mean	0.54	55	13	69	55	33
Median	0.45	50	12	71	56	31
Std. Dev. Mean	0.02	1.3	0.4	0.6	0.8	0.8
Max.	2.53	254	86	99	99	97
Min.	-0.83	10	0	8	1	0
75% Undiversified (ω = 75%)						
Mean	0.54	55	12	72	59	39
Median	0.45	50	10	74	61	37
Std. Dev. Mean	0.02	1.3	0.4	0.7	0.8	0.9
Max.	2.53	254	83	99	99	98
Min.	-0.83	10	0	8	2	0
50% Undiversified (ω = 50%)						
Mean	0.54	55	9	77	66	48
Median	0.45	50	8	80	69	47
Std. Dev. Mean	0.02	1.3	0.3	0.6	0.8	1.0
Max.	2.53	254	78	100	99	99
Min.	-0.83	10	0	10	2	0
25% Undiversified (ω = 25%)						
Mean	0.54	55	6	85	78	63
Median	0.45	50	4	89	82	67
Std. Dev. Mean	0.02	1.3	0.3	0.5	0.7	1.0
Max.	2.53	254	65	100	100	99
Min.	-0.83	10	0	14	4	0

Table II. Sensitivity of Stock-Based Compensation Efficiency to Portfolio Diversification (*Continued*)

Panel D. NASDAQ Firms

Percentage of Manager's Portfolio Constrained to a Single Stock	β	Annual Volatility (%)	Return Premium (s_j, in %)	Efficiency of Equity (V_j^u/V_j, in %) τ = 3 Years	τ = 5 Years	τ = 10 Years
Completely Undiversified (ω = 100%)						
Mean	0.86	81	19	58	42	20
Median	0.79	76	17	60	42	18
Std. Dev. Mean	0.01	0.8	0.2	0.2	0.3	0.2
Max.	3.49	1743	552	91	85	72
Min.	-1.35	20	3	0	0	0
75% Undiversified (ω = 75%)						
Mean	0.86	81	18	61	46	24
Median	0.79	76%	16	63	46	21
Std. Dev. Mean	0.01	0.8	0.2	0.2	0.3	0.3
Max.	3.49	1743	549	92	87	76
Min.	-1.35	20	3	0	0	0
50% Undiversified (ω = 50%)						
Mean	0.86	81	15	66	52	30
Median	0.79	76	13	68	53	28
Std. Dev. Mean	0.01	0.8	0.2	0.3	0.3	0.3
Max.	3.49	1743	545	94	90	81
Min.	-1.35	20	2	0	0	0
25% Undiversified (ω = 25%)						
Mean	0.86	81	10	76	65	45
Median	0.79	76	8	79	67	45
Std. Dev. Mean	0.01	0.8	0.2	0.2	0.3	0.4
Max.	3.49	1743	530	98	96	92
Min.	-1.35	20	1	0	0	0

Table II. Sensitivity of Stock-Based Compensation Efficiency to Portfolio Diversification (*Continued*)

Panel E. All Firms

Percentage of Manager's Portfolio Constrained to a Single Stock	β	Annual Volatility (%)	Return Premium (s_j, in %)	Efficiency of Equity (V_j^u/V_j, in %) τ = 3 Years	τ = 5 Years	τ = 10 Years
Completely Undiversified (ω = 100%)						
Mean	0.77	65	15	67	53	31
Median	0.71	58	12	69	54	29
Std. Dev. Mean	0.01	0.5	0.1	0.2	0.2	0.2
Max.	3.49	1743	552	99	99	97
Min.	-1.35	6	0	0	0	0
75% Undiversified (ω = 75%)						
Mean	0.77	65	13	70	57	36
Median	0.71	58	11	72	58	34
Std. Dev. Mean	0.01	0.5	0.1	0.2	0.2	0.3
Max.	3.49	1743	549	99	99	98
Min.	-1.35	6	0	0	0	0
50% Undiversified (ω = 50%)						
Mean	0.77	65	11	75	63	44
Median	0.71	58	9	77	65	43
Std. Dev. Mean	0.01	0.5	0.1	0.2	0.2	0.3
Max.	3.49	1743	545	100	99	99
Min.	-1.35	6	0	0	0	0
25% Undiversified (ω = 25%)						
Mean	0.77	65	7	83	74	58
Median	0.71	58	5	86	78	61
Std. Dev. Mean	0.01	0.5	0.1	0.2	0.2	0.3
Max.	3.49	1743	530	100	100	99
Min.	-1.35	6	0	0	0	0

at 55% of its cost to the firm, for the three-year vesting period, a number that decreases to 38% if the vesting period lasts five years. The stock efficiency ratings for NASDAQ firms are similar to the Internet-based firms, but somewhat higher. Partial diversification helps increase efficiency, but its absolute level remains low. The mean stock efficiency for an Internet-based manager with 50% of his wealth invested in the firm is 60% for the three-year vesting period, only five percentage points higher than the manager with 100% of her wealth invested in the firm. If the vesting period increases to five years, then the mean stock efficiency decreases to 45% for the manager able to hold 50% of her wealth outside the firm.

Table III, with Panels A through E shares a similar structure to Table II, but provides summary statistics for option efficiency levels for varying levels of diversification, vesting periods, and option maturity levels. We approximate the value of an executive stock option using the Black-Scholes option pricing formula. Strictly speaking, the Black-Scholes formula provides the approximate value, rather than the exact value, of an executive stock option.[20] For simplicity and clarity, however, we present the results using the Black-Scholes value, recognizing that the estimates are only approximate.

The completely undiversified manager values executive stock options at 53% of their cost to the mean Internet-based firm by assuming a three-year vesting period and ten-year options. This number increases to 55% if the manager is able to keep 25% of her wealth outside the firm, or 59% if the manager is able to keep 50% of her wealth outside the firm. See Appendix C for a more detailed display of stock- and option-efficiency levels for individual Internet-based firms. As with the stock efficiency numbers, the mean option efficiencies for NASDAQ firms are very similar to those of Internet-based firms. Finally, the mean gap between the manager's private value of executive stock options and the cost of those options to the firm is lower for NYSE firms, but it is not insignificant. The mean efficiency associated with a three-year vesting period and a ten-year option is 70% for the NYSE manager who has 100% of her wealth invested in the company, and this figure increases to 83% if that manager is able to invest 75% of her wealth outside the firm. Overall, the order of magnitude of the results is striking, and illustrates that equity-linked compensation can cost the firm much more than it is worth to managers.

IV. Robustness of the Efficiency Measure

This section explores the robustness of our approach to measuring the cost efficiency of stock options for incentive compensation, as well as the effects of other departures from our initial assumptions.

A. Effect of Alternative Asset Pricing Dynamics

The preceding analysis and development of our efficiency measure assumes that the risk-free interest rate is constant over time and that geometric Brownian-motion processes describe

[20] The formula is an approximation because executive stock options have some of the features of American options (i.e., exercisable at any time after the options vest, whereas the Black-Scholes formula prices European options), and because the options issued by the firm, like warrants, may dilute the ownership stake of the existing shareholders. See Merton (1992) on warrant dilution. This dilution can have a significant effect on option value if firms use many stock options. In addition, see Section III, which discusses the effect of early exercise, option forfeiture by managers who leave the firm, and the re-pricing of out-of-the-money options.

Table III. Efficiency of Option-Based Compensation By Firm Type and Manager's Ability to Diversify

Beta (β) is estimated using the market model, 150 trading days of daily returns data from CRSP, and the value-weighted market composite (all NYSE, AMEX, and NASDAQ firms). Annual volatility is also estimated using 150 trading days of daily returns and annualizing the resulting daily volatility. Firms with fewer than 100 trading days of returns during this 150-day estimation window preceding 12/31/98 are not included. A market premium of 7.5% (7.23%, continuously compounded) is assumed. The "return premium (s_j)" is the percent premium above the firm's equilibrium market return required by an undiversified investor to make that investor indifferent between holding the market and holding an undiversified portfolio, and is calculated using the market's composite Sharpe ratio. Option Efficiency is the ratio between the value of the stock options to the partially-diversified manager to the firm's cost of those stock options. The Black-Scholes option pricing formula is used to price the options. The dividend yield is assumed to be zero. Omega (ω) is the percentage of a manager's portfolio constrained to a single firm's options (ω = 100% for the completely undiversified manager). Vesting Period (τ) is the time in years until the manager is free to sell her shares.

Panel A. Internet-Based Firms

				Option Efficiency for 10-Year Options (%)		
Percentage of Manager's Portfolio Constrained to Firm's Options	**β**	**Annual Volatility (%)**	**Return Premium (s_j, in %)**	**τ = 3 Years**	**τ = 5 Years**	**τ = 10 Years**
Completely Undiversified (ω = 100%)						
Mean	2.09	117	22	53	36	16
Median	2.23	116	20	54	36	12
Std. Dev. Mean	0.09	4.8	1.3	1.9	2.1	1.8
Max.	3.49	193	5	87	80	63
Min.	0.61	42	3	23	9	1
75% Undiversified (ω = 75%)						
Mean	2.09	117	20	55	39	17
Median	2.23	116	19	56	38	14
Std. Dev. Mean	0.09	4.8	1.3	2.0	2.2	1.9
Max.	3.49	193	47	89	83	68
Min.	0.61	42	3	24	9	1
50% Undiversified (ω = 50%)						
Mean	2.09	117	18	59	43	21
Median	2.23	116	17	60	42	17
Std. Dev. Mean	0.09	4.8	1.2	2.0	2.3	2.2
Max.	3.49	193	43	92	87	75
Min.	0.61	42	2	27	11	1
25% Undiversified (ω = 25%)						
Mean	2.09	117	13	69	53	32
Median	2.23	116	12	69	54	29
Std. Dev. Mean	0.09	4.8	1.0	1.8	2.3	2.6
Max.	3.49	193	34	95	92	85
Min.	0.61	42	1	36	18	3

Table III. Efficiency of Option-Based Compensation By Firm Type and Manager's Ability to Diversify (*Continued*)

Panel B. NYSE Firms

Percentage of Manager's Portfolio Constrained to a Firm's Options	β	Annual Volatility (%)	Return Premium (s_j, in %)	Option Efficiency Based Upon Maturity of Option (%) τ = 3 Years	τ = 5 Years	τ = 10 Years
Completely Undiversified (ω = 100%)						
Mean	0.70	45	9	70	55	30
Median	0.67	42	8	71	56	30
Std. Dev. Mean	0.01	0.4	0.1	0.2	0.2	0.2
Max.	3.05	219	56	96	94	88
Min.	- 0.65	6	1	19	6	0
75% Undiversified (ω = 75%)						
Mean	0.70	45	8	74	61	38
Median	0.67	42	6	76	63	38
Std. Dev. Mean	0.01	0.4	0.1	0.2	0.3	0.3
Max.	3.05	219	54	97	95	91
Min.	- 0.65	6	0	24	9	1
50% Undiversified (ω = 50%)						
Mean	0.70	45	6	80	70	50
Median	0.67	42	5	82	71	50
Std. Dev. Mean	0.01	0.4	0.1	0.2	0.3	0.4
Max.	3.05	219	50	98	97	95
Min.	- 0.65	6	0	22	8	1
25% Undiversified (ω = 25%)						
Mean	0.70	45	3	88	82	68
Median	0.67	42	2	90	84	71
Std. Dev. Mean	0.01	0.4	0.1	0.2	0.2	0.3
Max.	3.05	219	41	99	99	98
Min.	- 0.65	6	0	29	13	2

Table III. Efficiency of Option-Based Compensation By Firm Type and Manager's Ability to Diversify (*Continued*)

Panel C. AMEX Firms

Percentage of Manager's Portfolio Constrained to a Firm's Options	β	Annual Volatility (%)	Return Premium (s_j, in %)	Option Efficiency Based Upon Maturity of Option (%)		
				$\tau = 3$ Years	$\tau = 5$ Years	$\tau = 10$ Years
Completely Undiversified (ω = 100%)						
Mean	0.54	55	13	61	45	21
Median	0.45	50	12	63	45	19
Std. Dev. Mean	0.02	1.3	0.4	0.5	0.6	0.6
Max.	2.53	254	86	99	98	95
Min.	- 0.83	10	0	8	1	0
75% Undiversified (ω = 75%)						
Mean	0.54	55	12	66	51	27
Median	0.45	50	10	67	51	25
Std. Dev. Mean	0.02	1.3	0.4	0.6	0.7	0.7
Max.	2.53	254	83	99	98	96
Min.	- 0.83	10	0	8	2	0
50% Undiversified (ω = 50%)						
Mean	0.54	55	9	73	60	38
Median	0.45	50	8	74	61	36
Std. Dev. Mean	0.02	1.3	0.3	0.6	0.8	0.9
Max.	2.53	254	78	99	99	98
Min.	- 0.83	10	0	10	2	0
25% Undiversified (ω = 25%)						
Mean	0.54	55	6	83	74	57
Median	0.45	5	4	86	77	59
Std. Dev. Mean	0.02	1.3	0.3	0.5	0.7	0.9
Max.	2.53	254	65	100	99	99
Min.	- 0.83	10	0	14	4	0

Table III. Efficiency of Option-Based Compensation By Firm Type and Manager's Ability to Diversify (*Continued*)

Panel D. NASDAQ Firms

Percentage of Manager's Portfolio Constrained to a Firm's Options	β	Annual Volatility (%)	Return Premium (s_j, in %)	Option Efficiency Based Upon Maturity of Option (%): τ = 3 Years	τ = 5 Years	τ = 10 Years
Completely Undiversified (ω = 100%)						
Mean	0.86	81	19	54	37	14
Median	0.79	76	17	55	37	13
Std. Dev. Mean	0.01	0.8	0.2	0.2	0.2	0.2
Max.	3.49	1743	552	87	80	63
Min.	- 1.35	20	3	0	0	0
75% Undiversified (ω = 75%)						
Mean	0.86	81	18	57	41	18
Median	0.79	76	16	59	41	16
Std. Dev. Mean	0.01	0.8	0.2	0.2	0.2	0.2
Max.	3.49	1743	549	89	83	68
Min.	- 1.35	20	3	0	0	0
50% Undiversified (ω = 50%)						
Mean	0.86	81	15	63	47	24
Median	0.79	76	13	65	48	22
Std. Dev. Mean	0.01	0.8	0.2	0.2	0.3	0.2
Max.	3.49	1743	545	92	87	75
Min.	- 1.35	20	2	0	0	0
25% Undiversified (ω = 25%)						
Mean	0.86	81	10	74	62	40
Median	0.79	76	8	76	64	40
Std. Dev. Mean	0.01	0.8	0.2	0.2	0.3	0.3
Max.	3.49	1743	530	95	92	85
Min.	- 1.35	20	1	0	0	0

Table III. Efficiency of Option-Based Compensation By Firm Type and Manager's Ability to Diversify (*Continued*)

Panel E. All Firms

Percentage of Manager's Portfolio Constrained to a Firm's Options	β	Annual Volatility (%)	Return Premium (s_j, in %)	Option Efficiency Based Upon Maturity of Option (%) τ = 3 Years	τ = 5 Years	τ = 10 Years
Completely Undiversified (ω = 100%)						
Mean	0.77	65	15	61	45	21
Median	0.71	58	12	63	45	19
Std. Dev. Mean	0.01	0.5	0.1	0.2	0.2	0.2
Max.	3.49	1743	552	99	98	95
Min.	- 1.35	6	0	0	0	0
75% Undiversified (ω = 75%)						
Mean	0.77	65	13	65	50	27
Median	0.71	58	11	67	50	24
Std. Dev. Mean	0.01	0.5	0.1	0.2	0.2	0.2
Max.	3.49	1743	549	99	98	96
Min.	- 1.35	6	0	0	0	0
50% Undiversified (ω = 50%)						
Mean	0.77	65	11	71	57	36
Median	0.71	58	9	73	59	34
Std. Dev. Mean	0.01	0.5	0.1	0.2	0.2	0.3
Max.	3.49	1743	545	99	99	98
Min.	- 1.35	6	0	0	0	0
25% Undiversified (ω = 25%)						
Mean	0.77	65	7	81	71	53
Median	0.71	58	5	84	74	54
Std. Dev. Mean	0.01	0.5	0.1	0.2	0.2	0.3
Max.	3.49	1743	530	100	99	99
Min.	- 1.35	6	0	0	0	0

stock price dynamics. This prototypical model of financial markets implies that asset returns are jointly distributed log-normally with non-stochastic expected returns, variances, and covariances. With the further assumption of frictionless and continuous trading, those posited dynamics assure that the continuous-time version of the CAPM and the original version of the Black-Scholes option-pricing model are valid for equilibrium pricing. The prototypical model provides clarity and concreteness to our derivation and development of the intuition underlying the cost of inadequate diversification that is a necessary consequence of incentive compensation. It also offers computational simplicity with respect to quantifying our efficiency measure of that cost. However, as a well-known empirical matter, this model is not adequate to capture fully the richness of real-world asset-return distributions and option prices. For example, real-world interest rates do change over time, as do measured variance and covariances of asset returns. Asset-return distributions appear to have "fatter-tails" or more outliers than a lognormal distribution would predict. These departures from the prototypical model result in a stochastic investment opportunity set, and it is likely that there will be other dimensions of risk besides market risk that will "matter" to investors and hence will be "priced."[21]

Such departures from the prototypical model have two potential effects. First, they may add another risk factor to the asset-pricing model. Second, they will affect which specific option-pricing model is appropriate for the task at hand. With other dimensions of risk that matter, we can no longer be sure that the "first-stage" discounting of the individual stock price to equate its instantaneous Sharpe ratio to that of the market portfolio will leave the investor indifferent between the undiversified single-stock holding and the equivalent-volatility holding of the market portfolio and the risk-free asset. Furthermore, the stochastic nature of the market's Sharpe ratio will make the multi-year discounting technique used to arrive at the overall initial discount more complicated in much the same way that stochastic interest rates complicate multi-period bond pricing, or for that matter, any capital budgeting DCF problem.

If one knew the structure of the "true" ICAPM, then a multi-dimensional version of our Sharpe ratio analysis could be used to find the discount on the stock price necessary to match the "best" risk-return tradeoff available for each of the dimensions of priced risks. Indeed, such a multi-dimensional procedure could also be applied if either the Ross (1976) Arbitrage Pricing Theory or the Fama and French (1992) three-factor model were the governing asset pricing model. In all these models, the elimination of risk through holdings of "well-diversified" portfolios is a central element in equilibrium pricing. Therefore, in the absence of knowing which of these models is the best descriptor of real-world pricing, the simplified procedure of the preceding section may give an incomplete, but not necessarily any less accurate, estimate of the cost of imposing a single-stock exposure on an individual investor. Moreover, as indicated at the outset, our objective is to accept lower-bound (versus best) estimates of the costs in return for simplicity and robustness of the analysis. In that spirit, the multiple dimensions of risks in these more complex models, in which securities serve hedging as well as diversification roles, will make securities less perfect substitutes for one another, and are therefore likely to increase the shadow cost of imposing single stock holdings for much of an investor's wealth.

The choice of option-pricing model will also reflect deviations from the prototypical case outlined above. One long-recognized empirical departure from that case is stock return distributions that have "fatter-tails" than a lognormal distribution would predict, perhaps as

[21] The Intertemporal Capital Asset Pricing Model (ICAPM) is the resulting generalized model. See Breeden (1979) and Merton (1992).

a result of a jump process, stochastic interest rates, or stochastic volatility. Fortunately, there is an extensive academic and practitioner literature on how to modify the Black-Scholes model for each of these generalizations.[22] Thus, although a stochastic investment opportunity may change the quantitative valuation, it does not change the basic two-stage methodology developed in the preceding section.

There are, of course, an uncountable number of variations possible for asset pricing models and so any review of the robustness of our procedure cannot be exhaustive. However, for any given deviation from the prototypical case, we can modify the formulas of the two-stage process for calculating the efficiency cost of stock options, and thereby improve our estimates over the prototypical case. Nonetheless, without knowing the specific structural variation, the signs of risk premiums on all risk factors other than diversification (that is, market risk) are not signed *a priori* and thus, the error in the estimated efficiency numbers from neglecting these factors can be either positive or negative.

Under all the various models, no matter how many risk factors, the essential point remains unchanged: creating incentive alignment for firm-specific activities will always require that the executive be exposed to idiosyncratic risks through a less-than-efficiently diversified holding. Hence, given the same expectations, the executive will *always* place a lower value on equity-based compensation than the market would pay for that same instrument. Furthermore, a common and important element of risk in all equilibrium asset models is the risk that cannot be eliminated in well-diversified portfolios. This is the market risk identified explicitly in our analysis of the preceding sections. In general, the option pricing formulas used in stage two of our process will be affected materially by stochastic volatility and interest rates. However, if volatility levels are very large (as they are for Internet-based firms), then the estimates of the loss-of-diversification costs will be of similar order of magnitude to the ones described in the prototypical case.

B. Does the Market Value of Equity-Linked Compensation Accurately Reflect the Firm's Cost?

In deriving the efficiency measures, we assumed that the firm's cost of equity-based compensation was adequately captured by the market value of that compensation under the theory that the market value reflected the firm's opportunity cost of issuing those equity-linked instruments. But we also know that executive stock options tend to be exercised as soon as they vest (but well before they expire), and that managers must sometimes forfeit their options when they leave the firm, voluntarily or involuntarily, under conditions that would not occur if diversified investors were the holders of these instruments. Is it possible that these early exercises and forfeitures reduce the firm's cost of equity-based compensation below its market value, thereby increasing efficiency?

While early exercises and forfeitures will indeed reduce the firm's cost, they will also eliminate the incentive-alignment benefit associated with options. That is, both early exercises and forfeitures require that the firm issue additional options to re-align incentives, either to existing managers or to new hires.[23] These conditions are state contingent: managers exercise early only when options are "in the money," and presumably, managers are more likely to leave the firm (and forfeit options) when the firm is doing poorly. Firms also tend to re-price options to re-align incentives when the stock price falls and options are too far out-of-the money to provide effective incentives. Cuny and Jorion (1995) show that this correlation significantly increases the value of the option above its Black-Scholes "market" value (which is the value used in this paper to measure the firm's cost of awarding options).

Because the firm always seeks incentive alignment, we should really consider the "cost" of

[22]For stochastic volatility, see Hull and White (1987), Johnson and Shanno (1987), Wiggins (1987), Scott (1987), and Goldenberg (1991); for stochastic interest rates and jump processes, see Merton (1992).

[23]See Gilson and Vetsuypens (1993).

incentive alignment as a continual stream of payments. When we posit that the market value of a ten-year option is much higher than the firm's cost of that option due to early exercise or forfeiture, we ignore the duration of the option. Consider the oft-used example in capital budgeting of a wooden bridge and a steel bridge. The wooden bridge may cost $1 million to build, and last three years, while the steel bridge may cost twice as much, and last nine years. If we directly compare the $1 million cost of the wooden bridge to that of the $2 million steel bridge, without considering the life of the project, we would conclude that the wooden bridge is cheaper than the steel bridge. But if we want a bridge for the next nine years, it is "cheaper" to build the more expensive steel bridge because it need not be replaced as often.

The same logic holds with executive stock options. A ten-year option granted to managers may be "cheaper" than a ten-year option issued on the open market, but the effective life of the investment differs. If the manager exercises the ten-year option after, say, two years, the firm must replace those options to maintain incentive alignment: an option with a ten-year maturity may not deliver ten years of incentive alignment. The market value of the ten-year option approximates the firm's cost to the extent that it approximates issuing five successive grants of options that the manager exercises after two years.[24] In sum, early exercise and forfeiture may reduce the firm's cost of the option below its market value, but not as much as one might initially suspect after taking account of the need to continually maintain incentive alignment through future option grants.

V. Conclusions

Boards and their compensation advisors attempt to measure the value of the compensation packages they award, but rarely do they study the real *cost* of these plans, measured as the difference between the market value of the instruments granted in these plans and the *value* placed on those instruments by the managers who receive them as compensation. These costs arise because the exposure to firm-specific risk that aligns incentives is costly to managers, who can no longer fully diversify their portfolios. Financial engineering, either by the firm or by the managers, can eliminate the systematic portion of managers' risk exposure, but cannot eliminate managers' firm-specific exposure without forfeiting the incentive alignment benefits of such compensation. Without the ability to fully diversify, managers will always value their equity-based compensation at less than its market value, and the firm will always face a tradeoff between the benefit of incentive-alignment, and the cost of paying managers with instruments that the firm could otherwise issue at a higher price in the market.

It is not surprising that an undiversified manager values equity-linked compensation at less than its market value; however, the striking result of this paper is how sizeable this difference is. This paper presents a straightforward, broadly applicable method to estimate the cost to managers of their loss in diversification. The proposed method measures the cost of holding an employer's stock relative to holding a diversified market portfolio, and then applies that method to a large sample of firms. We find that an undiversified manager of an Internet-based firm, for example, values her option-based compensation at an average of 53% of its cost to the firm; if that manager can partially diversify, holding 50% of her assets in the market portfolio, the value of her compensation still remains quite low, at 59% of its cost to the firm. The numbers for NYSE firms are somewhat higher, with undiversified managers valuing their stock options at an average of

[24] The question of interest then becomes, how much does it cost the firm to provide ten (or any other number) years of incentive alignment? See Ofek and Yermack (2000) and Huddart and Lang (1996) for data concerning early exercise of options and resulting stock sales. Carpenter (1998) proposes and tests two option-pricing models that explicitly incorporate early exercise and forfeiture. Acharya, John, and Sundaram (2000); Brenner, Sundaram, and Yermack (2000); and Chance, Kumar, and Todd (2000) analyze (both theoretically and empirically) the effect of resetting (decreasing) option strike prices to maintain incentive alignment when the options move too far out-of-the-money.

70% of their cost to the firm. If that manager holds the majority of his wealth *outside* the firm (say 75%), the efficiency increases to 88%.

Not only is the magnitude of the gap between the firm's cost and the employee's value remarkably large, it is likely an *underestimate* of the true loss managers experience through their compelled holding of equity-linked compensation. The method produces a lower bound on the true loss since it excludes the effect of manager-specific preferences about risk exposures. That is, some managers would willingly exchange a portion of their expected return from the benchmark leveraged market portfolio for better tailoring the form of compensation to meet their preferences (e.g., changing overall volatility levels or changing to another form of contingent claim).

One notable implication of these results is that managers can believe that their firm's stock is significantly *undervalued*, and nevertheless have a strong incentive to sell the stock whenever they are not restricted from doing so. Indeed, the numbers above suggest that a manager of an Internet-based firm can believe that the stock of her firm is 47% too low, and still benefit from selling the stock. This finding underscores the difficulty of interpreting managers' sales in such firms as a clear signal that managers believe the firm to be overvalued.

The relatively large magnitude of the deadweight costs associated with equity-based compensation suggests that its corresponding benefits must also be great, if firms are compensating managers optimally. On average, firms appear to recognize the tradeoff between the costs and benefits of such compensation, behaving as if the costs relate to the level of firm-specific risk that managers are required to bear: Jin (2000) finds that pay becomes less sensitive to performance as firm-specific risk increases. However, the vast differences that we observe in compensation packages raises the issue of whether some compensation plans are weighted too heavily towards equity-linked compensation to be cost effective. At one end of the spectrum is Amazon.com, which pays founder and 34% owner, Jeffrey Bezos, exclusively in cash, a practice consistent with the belief that it deems Bezos' incentives appropriately aligned without any additional equity-based compensation (Appendix C shows that Amazon.com's efficiency metric is 57%). At the other end of the spectrum is Dell Computer Corp., whose founder and 12% owner Michael Dell receives most of his compensation in options. In 1998, for example, Mr. Dell received $3.4 million in cash, and 6.4 million options, with a market value of at least $152 million.[25] Depending on one's assumptions about how much of Mr. Dell's wealth is outside of the firm, Dell Computer spent $152 million to pay Mr. Dell compensation worth $76-$106 million to him.[26] That Mr. Dell regularly sells his Dell Computer shares "to diversify" (according to a company spokesperson) supports the notion that he values the options at less than their market value, an interpretation which makes Dell Computer's cash/option compensation mix choice difficult to understand.

Such differences in compensation practices also highlight the need for periodic re-evaluation of compensation practices. Just as the benefits offered by equity-based compensation will change over time as the firm grows and matures, the costs will change as well. And as market conditions change, compensation practices may need to change: today's firms are more volatile on average (both in terms of total and idiosyncratic risk), and more of their compensation is equity-based, conditions which increase the deadweight costs of such compensation over prior levels.[27] Certainly, with advances in financial engineering, the costs of exposing managers to risk can be minimized, but the base levels as measured in this paper cannot be decreased.■

[25]According to S&P's ExecuComp. Mr. Dell's 1999 cash compensation was $2.5 million, and he received 805,000 stock options, which had a market value of at least $22 million

[26]Dell Computer's estimated "efficiency" is between 50% and 70%.

[27]Campbell, Lettau, Malkiel, and Xu (2001) document that firm-level (idiosyncratic) variance of stocks has doubled during their 1962-1997 sample period (relative to market volatility), while the correlations between stock returns and market returns have decreased, which in turn, lowers the average stock's excess return.

Appendix A. Derivation of an Efficiency Metric for Stock- and Option-Based Compensation for the Partially-Diversified Investor

Let p represent the portfolio of a partially-diversified investor with w fraction of her wealth in stock j, and (1-w) fraction of her wealth in the market portfolio.

Then:

$e^{r_p} =$ (1+ yearly expected rate of return for portfolio p under CAPM-pricing).

$e^{r_p^*} =$ (1+ yearly expected rate of return for portfolio p required by a partially diversified investor who holds w fraction of her wealth in the market portfolio with the market portfolio as an alternative investment).

$e^{r_j^*} =$ (1+ yearly expected rate for return on asset j that would be required by the investor to be indifferent between holding portfolio p (with weight w in stock j) and the market portfolio.

By definition of p:

$$r_p = (w)\, r_j + (1-w)\, r_m = r_f + \beta_p\,(r_m - r_f) \qquad (9)$$

$$r_p^* = (w)\, r_j^* + (1-w)\, r_m \qquad (10)$$

$$\Rightarrow r_p^* - r_p = (w) r_j^* + (1-w) r_m - w r_j - (1-w) r_m = w\left[r_j^* - r_j\right]$$

and the volatility of portfolio p, σ_p is:

$$\sigma_p = \sqrt{w^2\sigma_j^2 + (1-w)^2\,\sigma_m^2 + 2w(1-w)\sigma_{jm}} = \sigma_m\sqrt{w^2\left(\frac{\sigma_j}{\sigma_m}\right)^2 + (1-w)^2 + 2w(1-w)\beta_j} \qquad (11)$$

For a mean-variance-optimizing investor to be indifferent between portfolio p and the market portfolio, the investor requires a return with a risk-return profile equal to that of the market. We again use the Sharpe ratio to estimate this return, and substituting in Equation 10 for r_p^*:

$$r_p^* = r_f + \left[\frac{\sigma_p}{\sigma_m}\right]\left(r_m - r_f\right) = (w)\ \ r_j^* + (1-w)\ \ r_m$$

Appendix A. Derivation of an Efficiency Metric for Stock- and Option-Based Compensation for the Partially-Diversified Investor (*Continued*)

Substituting in Equation 10 for r_p^*, subtracting $(w)r_j$ from each side and collecting terms,

$$(w)r_j^* + (1-w)r_m = r_f + \left[\frac{\sigma_p}{\sigma_m}\right](r_m - r_f) \;\Rightarrow\; w\left[r_j^* - r_j\right] = w\left(r_m - r_j\right) + \left[\frac{\sigma_p - \sigma_m}{\sigma_m}\right](r_m - r_f) \tag{12}$$

Using CAPM (Equation 1) to substitute for r_j in Equation 12, we have

$$w\left[r_j^* - r_j\right] = w\left[r_m - \left(r_f + \beta_j\left(r_m - r_f\right)\right)\right] + \left[\frac{\sigma_p - \sigma_m}{\sigma_m}\right](r_m - r_f) = (r_m - r_f)\left[w(1-\beta_j) + \left[\frac{\sigma_p - \sigma_m}{\sigma_m}\right]\right]$$

$$\Rightarrow r_j^* - r_j = \left[\frac{1}{w}\left[\frac{\sigma_p - \sigma_m}{\sigma_m}\right] + (1-\beta_j)\right](r_m - r_f) \tag{13}$$

By applying $r_j^* - r_j$ to Equation 7, the value of stock j to the partially-diversified investor is:

$$V_j^*(t) = e^{-\left(r_j^* - r_j\right)\tau} V_j(t)$$

and the efficiency of stock and option compensation for that partially-diversified can be calculated using Equation 8,

$$\mathcal{E}^* = \text{Stock Efficiency} = \frac{V_j^*(t)}{V_j(t)} = e^{-\left(r_j^* - r_j\right)\tau}$$

Therefore, following the proof for the fully-diversified case, the efficiency of option-based compensation to the partially-diversified investor is:

$$\Phi^* = \text{Option Efficiency} = \frac{F\left(V_j^*,\, T-t,\, \sigma_j,\, r_f,\, X = V_j\right)}{F\left(V_j,\, T-t,\, \sigma_j,\, r_f,\, X = V_j\right)}$$

Appendix B. Composition of Hambrecht & Quist's (H&Q) Index of Internet-Based Firms by Business Description, as of December 31, 1998

Company By Classification	Value of Equity ($ Millions)
Panel A. Commerce Technologies and Services	
Amazon Com Inc.	16,950
Beyond Com Corp.	104
CDNow Inc.	318
Cendant Corp.	16,475
Checkfree Holdings Corp.	1,216
Cybercash Inc.	236
Cyberian Outpost Inc.	607
Doubleclick Inc.	740
E Trade Group Inc.	2,655
Ebay Inc.	9,714
Egghead Com Inc.	515
Network Solutions Inc.	545
Onsale Inc.	769
Peapod Inc.	117
Preview Travel Inc.	250
Sterling Commerce Inc.	4,255
Ubid Inc.	168
Xoom Com Inc.	132
Panel B. Communications Technologies and Services	
24 7 Media Inc.	434
Ascend Communications Inc.	14,263
At Home Corporation	9,153
Cisco Systems Inc.	145,994
Citrix Systems Inc.	4,139
Earthlink Network Inc.	1,626
Exodus Communications Inc.	1,303
Mindspring Enterprises Inc.	1,585
N2K Inc.	186
Psinet Inc.	1,082
USWeb Corp.	1,201
Verio Inc.	737

Appendix B. Composition of Hambrecht & Quist's (H&Q) Index of Internet-Based Firms by Business Description, as of December 31, 1998 (*Continued*)

Company By Classification	Value of Equity ($ Millions)
Panel C. Content Services	
America Online Inc.	71,070
Broadacst Com Inc.	1,308
C M G I Inc.	2,458
C N E T Inc.	905
Excite Inc.	2,215
Geocities	1,058
Infoseek Corp.	1,556
Intuit Inc.	4,337
Lycos Inc.	2,386
Sportsline USA Inc.	298
TheGlobe Com	102
Ticketmaster Online Citysrch Inc.	392
Yahoo Inc.	23,384
Panel D. Internet Software	
Broadvision Inc.	786
Earthweb Inc.	82
Inkotmi Corp.	3,213
Microsoft Corp.	342,558
Netgravity Inc.	227
Netscape Communications Corp.	6,046
Open Market Inc.	409
RealNetworks Inc.	1,080
Spyglass Inc.	330
Sun Microsystems Inc.	32,988
Verisign Inc.	1,365
Panel E. Security	
Axent Technologies Inc.	760
Networks Associates Inc.	8,950
Security Dynamics Techs Inc.	953

Appendix C. Internet Firms: Efficiency of Stock- and Option-Based Compensation Paid to Executives with Completely Undiversified Investment Portfolios

Beta (β) estimated with 150 days of daily returns (ending 12/31/98) and the value-weighted market composite market index. Firms with fewer than 42 days of returns during the window were dropped. Return premium (s_j) is the expected return needed to make an undiversified manager indifferent between holding a single-stock portfolio of her firm's stock and holding a market portfolio levered to an equivalent volatility level. Efficiency of Equity (V_j^u/V_j) equals the value of the stock to an undiversified investor divided by market value. Efficiency of Options is the value of an option to an undiversified manager divided by the market value of the option. The assumed market risk premium is 7.5%. The option efficiency measure uses the Black-Scholes option-pricing model, assuming no dividends. Vesting period equals three years.

						Efficiency of Options (%)	
Company	β	Annual Volatility (%)	Stock Price ($)	Return Premium (s_j, in %)	Efficiency of Equity (%)	Exp. in 3 Years	Exp. in 10 Years
24 7 Media Inc.	3.23	171	28	30	40	37	40
Amazon Com Inc.	2.20	110	321 1/4	19	57	49	56
America Online Inc.	1.90	70	155 1/8	8	78	67	75
Ascend Communications Inc.	1.55	64	65 3/4	9	77	64	73
At Home Corporation	2.30	97	74 1/4	14	66	57	64
Axent Technologies Inc.	1.68	78	30 9/16	12	69	57	66
Beyond Com Corp.	2.44	135	20 3/4	25	48	42	47
Boundless Corp.	0.82	111	5	29	42	32	40
Broadacst Com Inc.	2.33	125	76 1/2	22	51	44	50
Broadvision Inc.	1.34	118	32	27	44	36	43
C M G I Inc.	3.49	125	106 1/2	14	65	60	65
C N E T Inc.	2.04	120	53 1/4	23	50	43	49
CDNow Inc.	2.61	155	18	30	41	36	41
Cendant Corp.	1.70	86	19 5/16	15	64	53	62
Checkfree Holdings Corp.	1.72	119	23 3/8	25	47	40	46
Cisco Systems Inc.	1.70	53	92 13/16	4	88	78	64
Citrix Systems Inc.	1.66	61	97 1/16	7	81	69	77
Cybercash Inc.	1.59	121	15	26	45	37	44
Cyberian Outpost Inc.	2.88	193	27 1/2	40	30	28	30
Cylink Corp.	1.16	183	3 5/8	49	23	20	23
Dialog Corp.	0.71	106	4 1/2	28	43	33	41
Doubleclick Inc.	2.64	125	44 1/2	20	55	48	54
E Trade Group Inc.	2.20	114	46 25/32	20	55	47	54
Earthlink Network Inc.	2.36	114	57	19	57	50	56
Ebay Inc.	2.51	164	241 1/4	34	37	33	36
Edify Corp.	1.22	93	8 5/16	20	54	43	52
Egghead Com Inc.	2.84	190	20 13/16	39	31	29	31
Excite Inc.	2.68	115	42 1/16	17	60	53	59
Exodus Communications Inc.	1.87	103	64 1/4	19	57	47	55
Geocities	3.29	140	33 5/8	20	55	50	54
Infoseek Corp.	2.20	108	49 3/8	18	58	50	57
Inkotmi Corp.	2.39	133	129 3/8	24	48	42	47
Intuit Inc.	2.37	80	72 1/2	8	78	70	76
ISS Group Inc.	1.54	97	55	19	56	45	54
Lycos Inc.	2.96	116	55 9/16	15	64	57	63
Microsoft Corp.	1.38	42	138 11/16	3	91	81	87
Mindspring Enterprises Inc.	2.39	107	61 1/16	16	61	53	60
N2K Inc.	1.84	167	13 1/16	39	31	27	31

Appendix C. Internet Firms: Efficiency of Stock- and Option-Based Compensation Paid to Executives with Completely Undiversified Investment Portfolios (*Continued*)

Company	β	Annual Volatility (%)	Stock Price ($)	Return Premium (s_j, in %)	Efficiency of Equity (%)	Efficiency of Options (%) Exp. in 3 Years	Efficiency of Options (%) Exp. in 10 Years
Netgravity Inc.	3.31	173	16 3/4	30	40	37	40
Netscape Communications Corp.	2.68	118	60 3/4	18	59	52	58
Network Solutions Inc.	2.25	124	130 7/8	23	50	44	50
Networks Associates Inc.	1.45	63	66 1/4	9	76	62	72
Newsedge Corp.	0.61	157	11 5/8	45	26	22	26
Onsale Inc.	3.11	185	40 1/16	36	34	32	34
Open Market Inc.	2.64	184	11 11/16	39	31	29	31
Pea Pod Inc.	1.31	132	6 13/16	32	38	32	38
Preview Travel Inc.	2.99	141	18 7/16	23	50	45	50
Psinet Inc.	2.25	99	20 7/8	15	64	55	62
RealNetworks Inc.	2.41	125	35 7/8	22	52	45	51
Security Dynamics Techs Inc.	2.35	108	23	17	60	52	59
Sportsline USA Inc.	1.46	129	15 9/16	30	41	34	40
Spyglass Inc.	2.31	107	22	17	60	52	59
Sterling Commerce Inc.	1.25	72	45	14	67	52	63
Sun Microsystems Inc.	1.35	53	85 5/8	7	82	68	77
USWeb Corp.	2.34	119	26 3/8	21	54	47	53
Verio Inc.	1.60	108	22 3/8	22	51	42	49
Verisign Inc.	1.33	84	59 1/8	17	60	48	57
Yahoo Inc.	2.37	85	236 15/16	10	75	66	73

References

Abowd, J.M. and D.S. Kaplan, 1999, "Executive Compensation: Six Questions that Need Answering," NBER Working Paper Series #7124.

Acharya, V.V., K. John, and R.K. Sundaram, 2000, "On the Optimality of Resetting Executive Stock Options," *Journal of Financial Economics* 57, 65-101.

Aggarwal, R. K. and A.A. Samwick, 1999, "The Other Side of the Trade-Off: The Impact of Risk on Executive Compensation," *Journal of Political Economy* 107, 65-105.

Bizjak, J.M., M.L. Lemmon, and L. Naveen, 2000, "Has the Use of Peer Groups Contributed to Higher Levels of Executive Compensation?" Working Paper.

Black, F. and M. Scholes, 1973, "The Pricing of Options and Corporate Liabilities," *Journal of Political Economy* 81 (May-June), 637-654.

Boczar, T.J., 1998, "Stock Concentration Risk Management After TRA'97; Taxpayer Relief Act of 1997," *Trusts and Estates* 137, 45.

Bolster, P., D. Chance, and D. Rich, 1986, "Executive Equity Swaps and Corporate Insider Holdings," *Financial Management* 25, 14-24.

Breeden, D., 1979, "An Intertemporal Asset Pricing Model with Stochastic Consumption and Investment Opportunities," *Journal of Financial Economics* 7, 265-296.

Brenner, M., R.K. Sundaram, and D. Yermack, 2000, "Altering the Terms of Executive Stock Options," *Journal of Financial Economics* 57, 103-128.

Campbell, J.Y., M. Lettau, B.G. Malkiel, and Y. Xu, 2001, "Have Individual Stocks Become More Volatile? An Empirical Exploration of Idiosyncratic Risk," *Journal of Finance* 56, 1-43.

Carpenter, J.N., 1998, "The Exercise and Valuation of Executive Stock Options," *Journal of Financial Economics* 48, 127-158.

Carpenter, J.N., 2000, "Does Option Compensation Increase Managerial Risk Appetite?," *Journal of Finance* 55, 2311-2332.

Carpenter, J.N. and B. Remmers, 2000, "Executive Stock Option Exercises and Inside Information," NYU Stern School of Business Working Paper.

Chance, D.M., R. Kumar, and R.B. Todd, 2000, "The 'Repricing' of Executive Stock Options," *Journal of Financial Economics* 57, 129-154.

Cohen, R.B., B.J. Hall, and L.M. Viceira, 2000, "Do Executive Stock Options Encourage Risk Taking?" Harvard Business School Working Paper.

Core, J.E. and D.F. Larcker, 2000, "Performance Consequences of Mandatory Increases in CEO Stock Ownership," University of Pennsylvania, Wharton School Working Paper.

Cuny, C.J. and P. Jorion, 1995, "Valuing Executive Stock Options with Endogenous Departure," *Journal of Accounting and Economics* 20, 193-205.

Dechow, P.M., A.P. Hutton, and R.G. Sloan, 1997, "Economic Consequences of Accounting for Stock-Based Compensation," *Journal of Accounting Research* 34 (Supplement 1996).

DeFusco, R.A., T.S. Zorn, and R.R. Johnson, 1991, "The Association between Executive Stock Option Plan Changes and Managerial Decision Making," *Financial Management* 20, 36-43.

Degeorge, F., D. Jenter, A. Moel, and P. Tufano, 2000, "Selling Company Shares to Reluctant Employees: France Telecom's Experience," Harvard Business School Working Paper Series.

Detemple, J. and S. Sundaresan, 1999, "Nontraded Asset Valuation with Portfolio Constraints: A Binomial Approach," *The Review of Financial Studies* 12, 835-872.

Fama, E.F. and K.R. French, 1992, "The Cross-Section of Expected Stock Returns," *Journal of Finance* 46, 427-465.

Friend, I. and M.E. Blume, 1975, "The Demand for Risky Assets," *American Economic Review* 65, 901-922.

Gaver, J.J. and K.M. Gaver, 1995, "Compensation Policy and the Investment Opportunity Set," *Financial Management* 24, 19-32.

Gilson, S.C. and M.R. Vetsuypens, 1993, "CEO Compensation in Financially Distressed Firms: An Empirical Analysis," *Journal of Finance* 48, 425-458.

Goldenberg, D., 1991, "A Unified Method for Pricing Options on Diffusion Processes," Troy, New York, Rensselaer Polytechnic Institute.

Hall, B.J. and J.B. Liebman, 1998, "Are CEOs Really Paid Like Bureaucrats?" *The Quarterly Journal of Economics* 113, 653-691.

Hall, B.J. and K.J. Murphy, 2000a, "Optimal Exercise Prices for Executive Stock Options," *American Economic Review* 90, 209-214.

Hall, B.J. and K.J. Murphy, 2000b, "Stock Options for Undiversifed Executives," National Bureau of Economic Research Working Paper.

Haugen, R.A. and L.W. Senbet, 1981, "Resolving the Agency Problems of External Capital through Options," *Journal of Finance* 36, 629-647.

Huddart, S., 1994, "Employee Stock Options," *Journal of Accounting and Economics* 18, 207-231.

Huddart, S. and M. Lang, 1996, "Employee Stock Option Exercises: An Empirical Analysis," *Journal of Accounting and Economics* 21, 5-43.

Hull, J.C. and A. White, 1987, "The Pricing of Options on Assets with Stochastic Volatilities," *Journal of Finance* 42, 281-300.

Jensen, M.C. and K.J. Murphy, 1990, "Performance Pay and Top-Management Incentives," *Journal of Political Economy* 98, 225-265.

Jin, L., 2000, *CEO Compensation, Risk Sharing, and Incentives: Theory and Empirical Results*, Cambridge, MA, Massachusetts Institute of Technology.

Johnson, H. and D. Shanno, 1987, "Option Pricing When the Variance Is Changing," *Journal of Financial and Quantitative Analysis* 22, 143-152.

Johnson, S.A. and Y.S. Tian, 2000, "The Value and Incentive Effects of Nontraditional Executive Stock Option Plans," *Journal of Financial Economics* 57, 3-34.

Kulatilaka, N. and A.J. Marcus, 1994, "Valuing Employee Stock Options," *Financial Analysts Journal* 50, 46-56.

Lambert, R.A. and D.F. Larcker, 1988, "An Analysis of the Use of Accounting and Market Measures of Performance in Executive Compensation Contracts," *Journal of Accounting Research* 25 (Supplement 1987), 85-125.

Lambert, R.A., D.F. Larcker, and R.E. Verrecchia, 1991, "Portfolio Considerations in Valuing Executive Compensation," *Journal of Accounting Research* 29, 129-149.

Larcker, D.F., 1983, "The Association between Performance Plan Adoption and Corporate Capital Investment," *Journal of Accounting and Economics* 5, 3-31.

Long, M.S., 1992, "The Incentives Behind the Adoption of Executive Stock Option Plans in U.S. Corporations," *Financial Management* 21, 12-21.

McConaughy, D.L. and C.S. Misha, 1996, "Debt, Performance-Based Incentives, and Firm Performance," *Financial Management* 25, 37-51.

Merton, R.C., 1992, *Continuous-Time Finance*, Cambridge, MA, Blackwell Publishers.

Meulbroek, L.K., 2000a, "Does Risk Matter? Corporate Insider Transactions in Internet-Based Firms," Harvard Business School Working Paper 00-062.

Meulbroek, L.K., 2000b, "Executive Compensation Based Upon Relative Performance: Are Indexed Stock Options More Efficient?" Harvard Business School Working Paper 01-021.

Murphy, K.J., 1985, "Corporate Performance and Managerial Remuneration: An Empirical Analysis," *Journal of Accounting and Economics* 7, 11-43.

Murphy, K.J., 1998, "Executive Compensation," in O. Ashenfelter and D. Card, Ed., *Handbook of Labor Economics*, Amsterdam, North-Holland.

Ofek, E. and D. Yermack, 2000, "Taking Stock: Equity-Based Compensation and the Evolution of Managerial Ownership," *Journal of Finance* 55, 1367 - 1384.

Rajgopal, S. and T. Shevlin, 1999, "Stock Option Compensation and Risk Taking: The Case of Oil and Gas Producers," University of Washington Working Paper.

Rock, R.H., 1999, "The New Physics of Stock Options," *Directors and Boards* 23, 3.

Ross, S.A., 1976, "Arbitrage Theory of Capital Asset Pricing," *Journal of Economic Theory* 13, 341-360.

Schizer, D.M., 2000, "Executives and Hedging: The Fragile Legal Foundation of Incentive Compatibility," *Columbia Law Review* 100, 440-504.

Scott, L., 1987, "Option Pricing When the Variance Changes Randomly: Theory, Estimation and Application," *Journal of Financial and Quantitative Analysis* 22, 419-438.

Smith, C. and R. Watts, 1992, "The Investment Opportunity Set and Corporate Financing, Dividend, and Compensation Policies," *Journal of Financial Economics* 32, 263-292.

Smith, C.W. and J.L. Zimmerman, 1976, "Valuing Employee Stock Option Plans Using Option Pricing Models," *Journal of Accounting Research*, 357-364.

Wiggins, J.B., 1987, "Options Values under Stochastic Volatility: Theory and Empirical Estimates," *Journal of Financial Economics* 19, 351-373.

Yermack, D., 1995, "Do Corporations Award CEO Stock Options Effectively?" *Journal of Financial Economics* 39, 237-269.