THE DEPENDENCE OF PAY–PERFORMANCE SENSITIVITY ON THE SIZE OF THE FIRM

Scott Schaefer*

Abstract—I analyze the relationship between firm size and the extent to which executive compensation depends on the wealth of the firm's shareholders. I use a simple agency model to motivate an econometric model of this relationship. Estimating this model on chief executive officer (CEO) compensation data using nonlinear least squares, I determine that pay–performance sensitivity (as defined by Jensen and Murphy (1990b)) appears to be approximately inversely proportional to the square root of firm size (however measured). I also analyze the properties of pay–performance sensitivity for ''teams'' of executives working for the same firm and show it to have similar properties as CEO pay–performance sensitivity.

I. Introduction

THE RELATIONSHIP between firm size and the *level* of executive compensation has received a great deal of scrutiny in economic literature. This paper studies an aspect of the relationship between compensation and size that has received far less attention. I analyze the relationship between firm size and the extent to which managers' compensation depends on the wealth of the firm's shareholders.

Jensen and Murphy (1990b) define pay–performance sensitivity as the change in chief executive officer (CEO) wealth associated with a one-dollar change in shareholder wealth. They estimate pay–performance sensitivity by regressing first differences of CEO compensation on first differences of the market value of the firm. This approach implicitly assumes that the sensitivity is independent of the market value of the firm. However, when Jensen and Murphy partition their sample based on market value, they find smaller firms offer more powerful incentives. This result has led some, notably Rosen (1992), to question whether the econometric specification employed by Jensen and Murphy is appropriate.

This paper uses a simple agency model to motivate an econometric model of the relationship between pay–performance sensitivity and firm size. Estimating this model, I determine that pay–performance sensitivity appears to be approximately inversely proportional to the square root of firm size (however measured).

This finding is important for three reasons. First, it provides evidence as to how the marginal return to executive effort varies with firm size. Since it is well established that the variance of shareholder wealth is larger for larger firms, the risk associated with a given pay–performance sensitivity is larger for the CEO of a larger firm. The fact that pay–performance sensitivity decreases with size implies that the value of providing incentives for effort does not increase with size as fast as the cost of risk bearing by the executive.

Second, the relationship between pay–performance sensitivity and size bears directly on the question of the appropriate specification for linear regressions of compensation on performance. As noted, the Jensen and Murphy specification implicitly assumes that pay–performance sensitivity is independent of firm size. The econometric model I develop is sufficiently flexible to allow the data to choose between Jensen and Murphy's specification and some plausible alternatives.

Third, as Holmstrom (1992, p. 214) notes, the finding that pay–performance sensitivity is decreasing with size is ''broadly supportive of the agency theoretic presumption that risk is traded off against incentives at the margin. . . . Indeed, in a straight portfolio analysis, without incentive effects, share percentages would be independent of size.''

I extend the analysis by examining how pay–performance sensitivity of ''executive teams'' varies with firm size. An alternative explanation for why CEO pay–performance sensitivity decreases with firm size arises if one thinks that the size of the relevant management team varies with the size of the firm. Under this hypothesis, if larger firms have larger teams and it is the sensitivity of team pay to performance that provides incentives, then CEO pay–performance sensitivity may decrease with size merely because the CEO is a decreasing fraction of overall team size. I find that ''executive team'' pay–performance sensitivity and CEO pay–performance sensitivity exhibit similar characteristics.

The remainder of the paper is organized as follows. In section II I present a selective review of the literature on pay–performance sensitivity. I discuss the econometric specifications suggested by various authors and identify the assumptions implicit in each. In section III I develop a simple agency model that highlights the relationship between pay–performance sensitivity and firm size. I use this analysis to develop an econometric model. In section IV I discuss data, estimation procedures, and results. In section V I analyze pay–performance sensitivity for groups of executives. Section VI summarizes and concludes the paper.

II. Measuring Pay–Performance Sensitivity

Using data from the *Forbes* Executive Compensation Survey, Jensen and Murphy (1990b) estimate the following linear model:

$$\Delta(WAGE)_{it} = a_0 + a_1\Delta(FIRM\ VALUE)_{it}. \tag{1}$$

Their estimated pay–performance sensitivity is 0.0000135, implying that CEOs get an extra 1.35 cents for each \$1000

Received for publication April 1, 1996. Revision accepted for publication June 19, 1997.

* Northwestern University.

I am indebted to Richard Crabb, Stephen Gray, Rachel Hayes, Paul Oyer, Peter Reiss, and especially John Roberts. Two anonymous referees offered suggestions that greatly improved this paper. This work was supported in part by a National Science Foundation Graduate Fellowship.

increase in shareholder wealth. They argue that while a_1 is statistically significant (their t-statistic for a_1 is 8.0), it is not economically significant in the sense that the pay–performance sensitivity is too low to provide adequate incentives for effort.[1] Jensen and Murphy then extend the definition of CEO wealth to include incentives generated by permanent increases in base pay, stock ownership, stock options, and threat of dismissal. Difficulties in measuring the value of these aspects of compensation lead Jensen and Murphy to attempt to derive an upper bound on CEO pay–performance sensitivity. They find CEO wealth from all sources increases by at most \$3.25 for each \$1000 increase in shareholder wealth.

Rosen (1992) claims that Jensen and Murphy's approach does not adequately control for size effects and argues that their estimates will be dominated by the largest firms in the sample. Rosen favors a specification chosen by Murphy (1985), who regresses the change in the log of compensation on the change in the firm's stock market return:

$$\Delta[\log(WAGE)]_{it} = b_0 + b_1\Delta(r)_{it}. \tag{2}$$

With this model, b_1 estimates the semielasticity of executive pay with respect to return. Since $dr \approx dV/V$ (where I denote firm value by V), this semielasticity is equivalent to

$$\frac{dWAGE}{dV} \cdot \frac{V}{WAGE}.$$

Murphy's estimates indicate a firm realizing a 10% return will increase executive salary plus bonus by about 1.8%, on average.

It is important to note the different assumptions implicit in these empirical specifications. While Jensen and Murphy assume that pay–performance sensitivity ($dWAGE/dV$) is constant across firms, Murphy's specification imposes that the semielasticity of pay with respect to return [$(dWAGE/dV) \cdot V/WAGE$] is constant across firms.

Another possible specification is suggested by Holmstrom (1992), who favors using changes in return along with changes in the level of executive compensation,

$$\Delta(WAGE)_{it} = c_0 + c_1\Delta(r)_{it}. \tag{3}$$

Here c_1 estimates $(dWAGE/dV)V$. This specification imposes that pay–performance sensitivity is inversely related to the market value of the firm.

III. Agency Model

Which of the above specifications is appropriate clearly depends on how pay–performance sensitivity varies across firms. In this section, I develop a simple agency model to examine this question. I use this analysis to develop an econometric model that will allow estimation of the relationship between size and pay–performance sensitivity.

Despite the large theoretical literature on principal–agent relationships, there have been few attempts to apply particular agency-theoretic models directly to data. In large part, this is due to the fact that, absent strong restrictions on the contracting environment, incentive contracts can take exceedingly complicated forms.[2] As Rosen (1992) points out, the fact that optimal incentive contracts are so dependent on the environment provides ''very few restrictions on the data and makes the theory difficult to apply.''

The model developed here follows closely a suggestion in Holmstrom (1992) and is a variant of the Holmstrom and Milgrom (1987) linear contracting model. Holmstrom and Milgrom present conditions on the agent's preferences and the available production technologies under which the optimal incentive contract is a linear function of observable signals of performance. The agent is assumed to take actions repeatedly over time with knowledge of current conditions. If the agent's preferences exhibit no wealth effects, then it is optimal to offer the same reward for performance at each point in time. This permits the contract to be a linear function of some aggregate measure of performance. While the linear contract implied by the Holmstrom and Milgrom model is convenient for the empiricist, the result comes at the expense of strong assumptions regarding preferences and production technologies.

This model is not an attempt to provide a complete theory of executive pay. Rather, the model provides one possible rationale for the econometric specification used by Jensen and Murphy. By focusing on the relationship between CEO pay and firm value, my analysis ignores the well documented dependence of pay on accounting measures such as sales and profits.[3] Holmstrom's (1979) informativeness principle suggests that optimal incentive contracts should be based on all signals that provide incremental information regarding performance. In the executive context, such signals could include accounting measures along with market- and industrywide averages.[4] One could question the validity of accounting measures on the grounds that CEOs may be able to manipulate these figures. However, the fact that bonus payments are often explicitly linked to accounting numbers verifies the importance of these performance signals.[5]

[1] Haubrich (1994) disputes the claim that this sensitivity is somehow too low, arguing that these estimates of pay–performance sensitivity are in line with what we might expect given reasonable levels of managerial risk aversion.

[2] See Hart and Holmstrom (1987) for a discussion of the often complex forms of optimal incentive contracts.

[3] See Lambert and Larcker (1987) for an analysis of the use of accounting measures in evaluating CEO performance. Rosen (1992) provides a comprehensive survey of empirical studies of CEO compensation.

[4] Holmstrom (1982) provides a theoretical justification for relative performance evaluation, while Antle and Smith (1986), Gibbons and Murphy (1990), and Janakiraman et al. (1992) attempt empirical tests using CEO compensation data.

[5] Healy (1985) argues that managers may shift discretionary accounting charges intertemporally to maximize payouts from incentive bonus plans tied to accounting measures of performance.

I assume the shareholders' objective is to maximize the market value of the firm. If the firm's value is a signal of executive effort, then one way to align the interests of CEOs and shareholders is to pay the CEO a fixed wage plus a share of the value of the firm,

$$WAGE = \alpha + \beta VALUE. \tag{4}$$

The pay–performance sensitivity β is determined by maximizing the total certainty equivalent of the two parties. The constant α serves only to allocate the surplus between the participants. Choice of α will depend on factors such as the relative bargaining ability of the two parties and the value of the CEO's outside opportunities.[6]

What factors determine how β varies with firm size? I use the model to show that β depends on the technology available to the CEO to create shareholder value, the CEO's cost of effort and degree of risk aversion, and the variance of the firm's market value. Changes in these parameters will vary the dependence of pay–performance sensitivity on size.

As an example, suppose CEO effort translates into shareholder value by the following rule:

$$V_t = V_{t-1} + S_{t-1}e_t + S_{t-1}\epsilon_t.$$

Here V_t is the value of the firm at time t, S_t is the size of the firm at time t, e_t is the (unobserved) effort expended by the CEO, and ϵ_t is a random error affecting the firm's value. I assume ϵ_t to have mean zero and variance σ^2. The technology implies value is an informative, if noisy, signal of executive effort. The optimal incentive contract maximizes the total certainty equivalent of the two parties subject to the agent's incentive constraint. If the CEO has a quadratic cost of effort $C(e) = \frac{1}{2}ce^2$ and a coefficient of absolute risk aversion ρ, the optimal incentive contract is the solution to the following:

$$\max_{e_t,\beta_t} V_{t-1} + S_{t-1}e_t - \frac{c}{2}e_t^2 - \frac{1}{2}\rho\beta_t^2 S_{t-1}^2\sigma^2 \tag{5}$$

subject to

$$e_t \in \operatorname*{argmax}_e \beta_t S_{t-1}e - \frac{c}{2}e^2.$$

I solve for β_t and e_t to obtain

$$\beta_t^* = \frac{1}{1 + \rho c\sigma^2} \tag{6}$$

$$e_t^* = \frac{S_{t-1}}{c(1 + \rho c\sigma^2)}. \tag{7}$$

The optimal contract features a pay–performance sensitivity β_t^* that is independent of the size of the firm. Pay–performance sensitivity is decreasing in the executive's coefficient of absolute risk aversion ρ and cost parameter c. A higher variance of the firm's return, as measured by σ^2, also results in a lower pay–performance sensitivity. The fact that β_t^* is not related to S_{t-1} means this specification of technology and preferences would provide one possible rationale for the econometric model estimated by Jensen and Murphy.

The model predicts CEOs of larger firms should exert higher levels of effort. This implication is not satisfactory if effort is interpreted as a measure of the CEO's workload. It seems unreasonable to expect CEOs of larger firms to put in longer work days than leaders of small firms. However, if effort is interpreted as some aggregate of workload and ability, then the result seems less unlikely. It may be reasonable to expect larger firms to hire more able managers. Rosen (1982) presents a model of a hierarchical firm in which the CEO's effort and ability ''percolate'' through the firm, enhancing the productivity of each worker below him or her. In his model, the most talented worker should be placed at the top level of the hierarchy, in order to boost the productivity of as many workers as possible. Thus, one might expect large firms to attract the most talented CEOs. Alternatively, if one thinks of the CEO's role as choosing projects, higher levels of executive effort might correspond to the CEO choosing projects with higher returns to the firm and lower direct returns to the CEO.

How could one adjust the assumptions made above to generate a pay–performance sensitivity that depends on the size of the firm? I introduce the parameters γ and ϕ that affect the marginal return to executive effort and the variance of the firm's market value, respectively. Consider the following relationship between CEO effort and shareholder value:

$$V_t = V_{t-1} + S_{t-1}^{\gamma}e_t + S_{t-1}^{\phi}\epsilon_t \tag{8}$$

where $0 \leq \gamma, \phi \leq 1$. Imposing the previous assumptions of linear contracts and quadratic effort costs, I solve the following program for the optimal effort and incentive terms:

$$\max_{e_t,\beta_t} V_{t-1} + S_{t-1}^{\gamma}e_t - \frac{c}{2}e_t^2 - \frac{1}{2}\rho\beta_t^2 S_{t-1}^{2\phi}\sigma^2$$

subject to

$$e_t \in \operatorname*{argmax}_e \beta_t S_{t-1}^{\gamma}e - \frac{c}{2}e^2.$$

The solution is characterized by

[6] This model is clearly static in that it ignores the possibility that current performance can be rewarded by increases in *future* compensation. In particular, a dynamic model of incentive contracting would allow the possibility that α depends on prior years' performance. This analysis shares the fairly restrictive assumption that performance and reward are contemporaneous with much of the literature on executive compensation.

$$\beta_t^* = \frac{1}{1 + \rho c \sigma^2 S_{t-1}^{2(\phi-\gamma)}} \tag{9}$$

$$e_t^* = \frac{S_{t-1}^{\gamma}}{c(1 + \rho c \sigma^2 S_{t-1}^{2(\phi-\gamma)})}.$$

The optimal contract is

$$WAGE_t = \alpha_t + \frac{1}{1 + \rho c \sigma^2 S_{t-1}^{2(\phi-\gamma)}} V_t. \tag{10}$$

The technology used to derive this contract is a generalization of that used to derive equations (6) and (7). Depending on the values of the parameters γ and ϕ, the sensitivity of pay to performance may be increasing, constant, or decreasing with the size of the firm. If $\gamma > \phi$, then β_t^* will increase with the firm's size. If $\gamma = \phi$ (as in the previous example, where both are 1), then pay–performance sensitivity will be independent of size. If $\gamma < \phi$, then larger firms will offer weaker incentives.

Note that the parameter γ measures the marginal productivity of the CEO's effort, while ϕ determines how the amount of risk faced by the CEO varies with the size of the firm. If $\gamma < \phi$, then the marginal productivity of effort increases with size more slowly than the amount of risk faced by the CEO. Larger firms therefore find it optimal to forego powerful incentives in favor of better risk sharing. This generates the smaller pay–performance sensitivity for larger firms. When $\gamma = \phi$, both risk and marginal productivity increase with size at exactly the same rate, causing the efficient incentive term to be constant.

A simple econometric model can be derived from the optimal contract in equation (10) by taking first differences,

$$\Delta(WAGE)_{it} = \Delta\alpha + \frac{V_{it}}{1 + \rho c \sigma^2 S_{it-1}^{2(\phi-\gamma)}} - \frac{V_{it-1}}{1 + \rho c \sigma^2 S_{it-2}^{2(\phi-\gamma)}} + u_{it}. \tag{11}$$

This model is clearly more general than either equation (1) or equation (3). The model does not impose an assumption regarding how pay–performance sensitivity varies with size; rather, it allows the data to determine the nature of this relationship. If the estimated value of $\phi - \gamma$ is zero, then we may infer that Jensen and Murphy's specification is appropriate. On the other hand, a finding that $\phi - \gamma$ is close to ½ would lend support to Holmstrom's suggestion.

While this econometric model can help distinguish between equations (1) and (3), it is not sufficiently flexible to encompass equation (2). One of the central themes of agency theory is that it is the marginal sensitivity of pay to performance that provides incentives for effort. As noted above, the econometric model of equation (2) imposes that the marginal sensitivity of pay to performance, *dWAGE/dV* is inversely related to the ratio of the firm's market value to the CEO's wage, *V/WAGE*. Agency theory offers no compelling reason why pay–performance sensitivity might be systematically related to the *level* of executive pay. With its assumption of no wealth effects, the Holmstrom and Milgrom agency model makes this point starkly. The fixed component of executive pay α is determined by market forces or by some bargaining process if a rent or quasi-rent is present. There is no necessary connection between the level of pay and the efficient pay–performance sensitivity. While elasticities may be useful in studies of the factors that determine the level of executive pay, it is not clear that they are appropriate instruments for analyses of the marginal sensitivity of pay to performance.

IV. Data and Results

I perform the empirical analysis using data from the Compustat ExecuComp database. This data source contains different measures of compensation for top executives at large American firms between 1991 and 1995. I select two measures of compensation for this analysis. Executive salary plus bonus is directly comparable to the *Forbes* salary plus bonus measure used by Jensen and Murphy. A broader measure of compensation is the change in CEO-pay-related wealth in year *t*. This measure includes salary, bonus, payouts from long-term incentive plans, other forms of annual compensation, the value of restricted stock grants, the Black–Scholes value of any stock options granted in year *t*, and the change in the value of any stock held by the executive at the beginning of the fiscal year. One serious limitation of the Compustat ExecuComp database is that it does not contain information on the changes in the value of options granted in *previous* years. Changes in the value of these options can be an important incentive device for top managers.[7] Despite this limitation, the compensation measures provided by ExecuComp are substantially more comprehensive than those typically obtained from surveys such as that published by *Forbes.* Other firm performance data are taken from the standard CRSP and Compustat sources.

I begin with the 38,105 executive-years in the ExecuComp database. In this part of the analysis, I concentrate on pay–performance sensitivity for CEOs only, so I delete the executives who are not listed as CEO, leaving 7155 observations. Deleting financial services firms and those for whom data are missing leaves 4258 CEO-years for which salary plus bonus data are available. Data on changes in CEO wealth are available for 3041 CEO-years. Summary statistics are presented in table 1.

To compare these data to those used by Jensen and Murphy, I estimate equation (1) using ordinary least squares

[7] Simulation results reported by Jensen and Murphy (1990a) show that the Black–Scholes value of an at-the-money stock option changes by approximately 60 cents for a one-dollar change in the value of the underlying security.

TABLE 1.—MEANS AND STANDARD DEVIATIONS FOR CEO COMPENSATION DATA

	Salary + Bonus Data	CEO Wealth Data
Change in compensation	0.098 (0.366)	8.325 (115.00)
Assets	3775.49 (13456.26)	3824.08 (13825.89)
Market value	2927.91 (7053.12)	2932.81 (7155.18)
Change in market value	408.23 (2072.05)	463.44 (2323.53)
Number of observations	4258	3041

Note: Dollar values in millions; standard deviations in parentheses.

TABLE 2.—ESTIMATES OF PAY–PERFORMANCE SENSITIVITY FROM EQUATION (1)

Independent Variable	Change in Salary + Bonus (1)	Change in CEO Wealth (2)
Change in shareholder wealth	0.0000241 (0.0000038)	0.0125 (0.0075)
R^2	0.0391	0.0830
Sample size	4258	3041

Note: 59 industry-specific intercepts not reported; heteroskedastic-consistent standard errors in parentheses.

TABLE 3.—ESTIMATES OF PAY–PERFORMANCE SENSITIVITY FOR SAMPLE PARTITIONED BY SIZE MEASURES AT END OF FISCAL 1990

	Change in Salary + Bonus		Change in CEO Wealth	
Independent Variable	Small (1)	Large (2)	Small (3)	Large (4)
Sample Partitioned by Market Value				
Change in shareholder wealth	0.00010 (0.000034)	0.000019 (0.0000037)	0.0121 (0.0052)	0.0124 (0.0078)
R^2	0.0515	0.0569	0.1459	0.1048
Sample size	1831	2107	1306	1470
p-value	0.0184		0.5129	
Sample Partitioned by Assets				
Change in shareholder wealth	0.000094 (0.000030)	0.000018 (0.000004)	0.023 (0.0099)	0.012 (0.0076)
R^2	0.0475	0.0462	0.1734	0.1142
Sample size	1881	2318	1349	1648
p-value	0.0057		0.1820	

Note: 59 industry-specific intercepts not reported; heteroskedastic-consistent standard errors in parentheses. p-value is a one-tailed test of the hypothesis that pay–performance sensitivity for larger firms is less than or equal to that for smaller firms.

and industry fixed effects.[8] Results are presented in table 2. Using change in salary plus bonus as a dependent variable, I obtain a pay–performance sensitivity of 0.0000241, which suggests that CEO salary plus bonus changes by 2.41 cents for each $1000 change in shareholder wealth. This is somewhat higher than Jensen and Murphy's estimate of 0.0000135, indicating perhaps that pay–performance sensitivities have risen slightly over time.[9] Employing change in pay-related wealth as a dependent variable, I get a pay–performance sensitivity of 0.0125, which translates to a change in CEO wealth of $12.50 for each $1000 change in shareholder wealth. However, this estimate is not significantly different from zero at the 5% level. This compares to an estimate of 0.0020 that Jensen and Murphy (1990b, p. 234) get using their broadest definition of compensation.[10]

I verify that pay–performance sensitivity depends on size by partitioning the sample based on market value and assets.[11] I partition the set of firms into large and small groups using the fiscal year 1990 levels of these two variables. Limits on availability of 1990 market values restrict me to 3938 observations for the salary plus bonus sample and 2776 observations for the executive wealth sample. Similarly, I am limited by the availability of 1990 assets to 4199 and 2997 observations, respectively. I estimate equation (1) with industry fixed effects on each group. Results are reported in table 3. I perform one-tailed tests of the hypothesis that pay–performance sensitivity for the set of larger firms is less than or equal to that of the smaller firms and present p-values in the tables. When salary plus bonus is used as a dependent variable, the results are consistent with Jensen and Murphy's finding that pay–performance sensitivity appears to be inversely related to size. I cannot reject the null hypothesis using CEO wealth as a dependent variable.

I use nonlinear least squares to estimate equation (11) using industry fixed effects. As measures of size (S_{it-1} and S_{it-2} in equation (11)), I use both market value and assets.[12] The resulting estimator is consistent and asymptotically normal under the standard regularity conditions (see Amemiya (1985)). I correct for the possibility that the additive disturbance terms are not identically distributed by reporting asymptotic standard errors that correct for heteroskedasticity.[13]

[8] Industry fixed effects are computed using two-digit SIC codes.

[9] These regressions are not directly comparable, since Jensen and Murphy do not use fixed effects. My results are similar when I drop the industry fixed effects.

[10] While my salary plus bonus measure is directly comparable to that used by Jensen and Murphy, their definition of the change in CEO wealth differs somewhat from mine. Their measure, taken from a sample of 73 manufacturing firms between 1969 and 1983, includes total current pay, change in the value of stock held or controlled by the CEO, change in the value of stock options held by the CEO, and the present value of the current period's change in salary plus bonus. Jensen and Murphy justify the inclusion of this last measure by arguing that salary increases are often permanent.

[11] As a measure of size, market value is subject to the criticism that it is a function of the firm's choice of capital structure. Similarly, the book value of a firm's assets depends on discretionary accounting choices such as depreciation schedules. As a robustness check, I performed this analysis using sales to measure size. Since the results are comparable to those presented, I omit this analysis.

[12] Lagged values of assets are missing for 29 observations for the salary plus bonus sample and 17 observations for the CEO wealth sample.

[13] This correction is analogous to that suggested by White (1980) for use with ordinary least squares. See Amemiya (1983) for a summary of

TABLE 4.—NONLINEAR LEAST-SQUARES ESTIMATES OF PARAMETERS IN EQUATION (11)

	Market Value		Assets	
Parameter	Change in Salary + Bonus (1)	Change in CEO Wealth (2)	Change in Salary + Bonus (3)	Change in CEO Wealth (4)
$\phi - \gamma$	0.1914 (0.0268)	0.0380 (0.0619)	0.2313 (0.0267)	0.1810 (0.0164)
$\rho c \sigma^2$	877.94 (431.76)	37.98 (41.40)	448.10 (200.17)	1.922 (0.579)
R^2	0.1075	0.0832	0.1154	0.1200
Sample size	4258	3041	4229	3024

Note: 59 industry-specific intercepts not reported; asymptotic standard errors in parentheses.

Results are presented in table 4. The parameter of primary interest is $\phi - \gamma$. Under Jensen and Murphy's implicit hypothesis that pay–performance sensitivity is independent of firm size, one would expect this parameter to be zero. Using estimates in columns (1), (3), and (4), I can reject this hypothesis. However, when market value is used as a measure of size and change in CEO wealth is used as a dependent variable, I cannot reject this hypothesis. This squares with the finding in table 3 that the estimated pay–performance sensitivities for large and small firms ranked by market value are not significantly different. Interestingly, while the estimates in table 3 do not allow me to reject the hypothesis that large and small firms ranked by assets have different CEO wealth pay–performance sensitivities, the estimates in column (4) of table 4 do imply a relationship between size and pay–performance sensitivity. The more general econometric model picks up within-group variations in pay–performance sensitivity that are ignored by the procedure that generated table 3. This analysis also rejects the hypothesis implicit in Holmstrom's suggested regression equation (3), namely, that pay–performance sensitivity is proportional to the inverse of size. These estimates therefore imply that both regression equations (1) and (3) suffer from specification error. The relationship between pay–performance sensitivity and size is intermediate between the assumptions imposed by the two linear models. From this analysis, pay–performance sensitivity appears to be approximately proportional to the inverse of the square root of size.

The estimates of $\rho c \sigma^2$ are also of interest. Most notable is the fact that the estimates of this quantity are substantially higher for the salary plus bonus regressions than for the CEO wealth regressions. Recall from the agency model in section III that ρ is the executive's coefficient of absolute risk aversion, c is the second derivative of the agent's cost of effort function, and σ^2 is the variance of the firm's market value. Higher values for all these exogenous parameters would imply lower values for the optimal incentive term. The pay–performance sensitivity implied by the salary plus bonus data is much lower than that for CEO wealth, and the model attempts to attribute this fact to either more managerial risk aversion, higher costs of executive effort, or higher variance of market value.

As a check of the reasonableness of these estimates, I calculate the implied pay–performance sensitivity for firms in the 25th and 75th percentiles of the sample by the two size measures. Recall from equation (9) that pay–performance sensitivity is given by

$$\beta_t^* = \frac{1}{1 + \rho c \sigma^2 S_{t-1}^{2(\phi-\gamma)}}.$$

For a firm in the 25th market value percentile of this sample (value of approximately \$315 million), the model predicts a sensitivity of salary plus bonus to performance of 0.000126 and a sensitivity of CEO wealth to performance of 0.0167. For a firm in the 75th percentile by market value (approximate value \$2.27 billion), the predictions are 0.000059 and 0.0144, respectively. A firm in the 25th asset percentile of the sample (assets worth approximately \$288 million) is predicted to have a salary plus bonus sensitivity of 0.000163 and a CEO wealth sensitivity of 0.0628. The model predicts sensitivities of 0.000058 and 0.029, respectively, for a firm in the 75th asset percentile (assets worth approximately \$2.65 billion). These point estimates are comparable to the pay–performance sensitivities estimated from the partitioned samples in table 3.

V. Pay–Performance Sensitivity for Groups of Executives

In this section, I explore a possible alternative rationale for why pay–performance sensitivity for CEOs may be decreasing with the size of the firm. If firms are run by teams of top managers, then it may be reasonable to assume that pay–performance sensitivity for the entire team is the instrument shareholders use to provide incentives. If the management team members interact repeatedly and their actions are somewhat observable to each other, then these teams may be able to circumvent the free-rider problem inherent in such arrangements and act to maximize the overall welfare of the team.

Suppose team pay–performance sensitivity is the same across firms. If small-firm CEOs have a large share of total team pay–performance sensitivity and large-firm CEOs have a small share of total pay–performance sensitivity, then examination of CEOs alone would show an inverse relationship between size and pay–performance sensitivity. One may be able to detect this effect by examining pay–performance sensitivity for groups of executives. If, for example, small firms tend to have teams of three managers (so that the fourth best paid manager has a pay–performance sensitivity close to zero) and large firms tend to have teams of four, then an examination of the groups of the four best

asymptotic properties of nonlinear least-squares estimators when errors are not identically and independently distributed.

TABLE 5.—MEANS AND STANDARD DEVIATIONS FOR COMPENSATION DATA FOR GROUP OF FOUR BEST PAID EXECUTIVES

	Salary + Bonus Data	Executive Wealth Data
Change in group compensation	0.275 (0.689)	11.17 (49.80)
Assets	3733.84 (13099.60)	3464.89 (11733.47)
Market value	3135.64 (7867.42)	2838.59 (6966.89)
Change in market value	506.14 (2389.07)	578.72 (2722.78)
Number of observations	2671	1307

Note: Dollar values in millions; standard deviations in parentheses.

paid managers should reveal no relationship between pay–performance sensitivity and size.

To examine this hypothesis, I study pay–performance sensitivity for groups of executives. The Compustat Execu-Comp database reports compensation levels for up to five executives for each firm in the sample. I use this information to construct compensation measures for groups of the three, four, and five best paid executives at each firm. For conciseness, I report the analysis using groups of the four best paid executives. The results, however, are qualitatively invariant to this choice.

My procedure for analyzing these data will mimic that I used in analyzing CEO data in section IV. I first present OLS estimates of group pay–performance sensitivity using Jensen and Murphy's regression equation. Then I partition the sample by market value and assets to confirm the dependence of pay–performance sensitivity on size. Finally, I estimate equation (11) to learn more about the relationship between group pay–performance sensitivity and size.

I am able to construct first differences in total salary and bonus paid to the four best paid executives for 2671 firm-years. Executive team wealth measures are available for a subset of 1307 of these observations. While the summary statistics presented in table 5 are comparable to those of the CEO sample presented in table 1, one might be concerned about the effects of sample selection in comparing the CEO and group samples. To allow for a better comparison between CEO and group incentives, I create a restricted sample of CEO compensation, including only those firms for which data on the four best paid executives are available.

OLS estimates of equation (1) using group compensation data in are presented in table 6. In table 7 I partition the sample based on size and test the hypothesis that pay–performance sensitivity for the set of larger firms is less than or equal to that of the smaller firms. I reject this hypothesis at better than the 3% level for each of the four cases.

Table 8 presents results from estimation of equation (11) using both group data and the restricted sample of CEO data. Using the restricted sample of CEO compensation, I find estimates similar to those obtained from the full sample. As

TABLE 6.—ESTIMATES OF PAY–PERFORMANCE SENSITIVITY FROM EQUATION (1) FOR GROUPS OF FOUR BEST PAID EXECUTIVES

Independent Variable	Change in Group Salary + Bonus (1)	Change in Group Wealth (2)
Change in shareholder wealth	0.000040 (0.0000086)	0.0058 (0.0024)
R^2	0.0574	0.1445
Sample size	2671	1307

Note: 59 industry-specific intercepts not reported; heteroskedastic-consistent standard errors in parentheses.

in table 4, the estimates are sharper when assets is used as the measure of size. Estimates of $\phi - \gamma$ using group compensation data range from 0.2104 to 0.2749. In none of the four cases is the estimate of $\phi - \gamma$ from group data smaller than that obtained using CEO data. While the argument sketched above suggests that group pay–performance sensitivities should be less closely related to size than CEO pay–performance sensitivities, the data offer no support for this assertion. The estimates for $\phi - \gamma$ indicate that group pay–performance sensitivities decrease slightly faster with firm size than CEO pay–performance sensitivities.

It is important to note the limitations of this analysis of group compensation data. I am unable to refute definitively the hypothesis that CEO pay–performance sensitivity is related to firm size simply because the size of the relevant management team is increasing with firm size. The difficulty stems in part from an inability to define precisely the size of the relevant management team. For example, if small firms tend to have groups of three managers and large firms tend to have groups of thirty, then pay–performance sensitivities of

TABLE 7.—ESTIMATES OF PAY–PERFORMANCE SENSITIVITY FOR THE GROUP OF THE FOUR BEST PAID EXECUTIVES FOR SAMPLE PARTITIONED BY SIZE MEASURES AT END OF FISCAL 1990

Independent Variable	Change in Group Salary + Bonus: Small (1)	Change in Group Salary + Bonus: Large (2)	Change in Group Wealth: Small (3)	Change in Group Wealth: Large (4)
Sample Partitioned by Market Value				
Change in shareholder wealth	0.000218 (0.000022)	0.000026 (0.0000085)	0.0049 (0.014)	0.0052 (0.0025)
R^2	0.0952	0.0921	0.3866	0.1535
Sample size	1162	1288	569	627
p-value	0.0027		0.0001	
Sample Partitioned by Assets				
Change in shareholder wealth	0.00019 (0.000079)	0.000028 (0.0000086)	0.041 (0.011)	0.0052 (0.002)
R^2	0.0850	0.0840	0.2959	0.1711
Sample size	1220	1422	598	698
p-value	0.0219		0.0010	

Note: 59 industry-specific intercepts not reported; heteroskedastic-consistent standard errors in parentheses. p-value is a one-tailed test of the hypothesis that pay–performance sensitivity for larger firms is less than or equal to that for smaller firms.

TABLE 8.—NONLINEAR LEAST-SQUARES ESTIMATES OF PARAMETERS IN EQUATION (11) FOR RESTRICTED SAMPLE OF CEOS AND GROUPS OF FOUR BEST PAID EXECUTIVES

A. CEO DATA

	Market Value		Assets	
Parameter	Change in CEO Salary + Bonus (1)	Change in CEO Wealth (2)	Change in CEO Salary + Bonus (3)	Change in CEO Wealth (4)
$\phi - \gamma$	0.1548 (0.0409)	0.1697 (0.1048)	0.2594 (0.0258)	0.2421 (0.0670)
$\rho c \sigma^2$	2140.53 (2873.41)	2106.11 (4645.34)	282.90 (122.26)	1.541 (1.299)
R^2	0.0981	0.1657	0.1003	0.2147
Sample size	2671	1307	2658	1302

B. GROUP DATA

	Market Value		Assets	
Parameter	Change in Group Salary + Bonus (1)	Change in Group Wealth (2)	Change in Group Salary + Bonus (3)	Change in Group Wealth (4)
$\phi - \gamma$	0.2104 (0.0439)	0.2225 (0.0754)	0.2664 (0.0244)	0.2749 (0.0519)
$\rho c \sigma^2$	352.76 (302.16)	1.694 (2.027)	121.38 (44.45)	0.588 (0.394)
R^2	0.1298	0.1988	0.1335	0.2297
Sample size	2671	1307	2658	1302

Note: 59 industry-specific intercepts not reported; asymptotic standard errors in parentheses.

the four best paid managers might be expected to show characteristics similar to those for CEOs.

VI. Conclusion

In this paper, I have developed a simple linear agency-theoretic model of executive pay and used it to study the relationship between pay–performance sensitivity and firm size. The agency model illustrated a central lesson of agency theory: that the optimal incentive contract trades off the provision of incentives with the cost of loading risk on the agent at the margin. I derived and estimated a nonlinear econometric model based on the efficient incentive contract in the agency model.

Using data from Compustat's ExecuComp database, I first replicated Jensen and Murphy's finding of an inverse relationship between pay–performance sensitivity and size in a sample partitioned by size. Estimation of the nonlinear econometric model revealed that CEO pay–performance sensitivity appears to be approximately inversely related to the square root of the size of the firm, where size is measured by either market capitalization or assets. Since the variance of shareholder wealth is increasing with size, a larger firm that increases its executive's pay–performance sensitivity reduces the total certainty equivalent by more than a small firm. It would be efficient for a large firm to do this only if the value created by the resulting increase in executive effort more than offsets the loss due to executive risk aversion. Since the data showed that larger firms choose smaller pay–performance sensitivities, the agency model suggests that the marginal return to executive effort does not increase as fast with size as the marginal costs of risk bearing by the executive.

Finally, I explored the possibility that CEO pay–performance sensitivity decreases with firm size merely because the size of the relevant management team decreases with the size of the firm. I examined groups of the four best paid executives at each firm and found that group pay–performance sensitivities exhibit characteristics similar to those of CEOs. The analysis offered no support for the notion that pay–performance sensitivity declines due to a management-team-size effect.

REFERENCES

Amemiya, T., "Non-linear Regression Models," in Z. Griliches and M. Intriligator (eds.), *Handbook of Econometrics*, vol. 1. (Amsterdam: North-Holland, 1983).

——— *Advanced Econometrics* (Cambridge, MA: Harvard University Press, 1985).

Antle, R., and A. Smith, "An Empirical Investigation of the Relative Performance Evaluation of Corporate Executives," *Journal of Accounting Research* 24 (1986), 1–39.

Gibbons, R., and K. J. Murphy, "Relative Performance Evaluation for Chief Executive Officers," *Industrial and Labor Relations Review* 43 (1990), 30s–51s.

Hart, O., and B. Holmstrom, "The Theory of Contracts," in T. Bewley (ed.), *Advances in Economic Theory, Fifth World Congress* (Cambridge, UK: Cambridge University Press, 1987).

Haubrich, J. G., "Risk Aversion, Performance Pay, and the Principal–Agent Problem," *Journal of Political Economy* 102 (1994), 258–276.

Healy, P., "The Effect of Bonus Schemes on Accounting Decisions," *Journal of Accounting and Economics* 7 (1985), 85–107.

Holmstrom, B., "Moral Hazard and Observability," *Bell Journal of Economics* 10 (1979), 74–91.

——— "Moral Hazard in Teams," *Bell Journal of Economics* 13 (1982), 324–340.

——— Comments, in L. Werin and H. Wijkander (eds.), *Contract Economics* (Cambridge, MA: Blackwell, 1992).

Holmstrom, B., and P. R. Milgrom, "Aggregation and Linearity in the Provision of Intertemporal Incentives," *Econometrica* 55 (1987), 308–328.

Janakiraman, S., R. A. Lambert, and D. F. Larcker, "An Investigation of the Relative Performance Evaluation Hypothesis," *Journal of Accounting Research* 30 (1992), 53–69.

Jensen, M. C., and K. J. Murphy, "A New Survey of Executive Compensation: Full Survey and Technical Appendix," Working Paper 90-067, Harvard Business School (1990a).

——— "Performance Pay and Top-Management Incentives," *Journal of Political Economy* 98 (1990b), 225–255.

Lambert, R. A., and D. F. Larcker, "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.

Murphy, K. J., "Corporate Performance and Managerial Remuneration: An Empirical Analysis," *Journal of Accounting and Economics* 7 (1985), 11–42.

Rosen, S., "Authority, Control and the Distribution of Earnings," *Bell Journal of Economics* 13 (1982), 311–323.

——— "Contracts and the Market for Executives," in L. Werin and H. Wijkander (eds.), *Contract Economics* (Cambridge, MA: Blackwell, 1992).

White, H., "A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity," *Econometrica* 48 (1980), 817–838.