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ABSTRACT

This paper presents a parsimonious, structural model that captures primary economic determinants of the relation between firm value and managerial ownership. Supposing that observed firm size and managerial pay-performance sensitivity (PPS) maximize value, we invert our model to panel data on size and PPS to obtain estimates of the productivity of physical assets and managerial input. Variation of these productivity parameters, optimizing firm size and compensation contract, and the way the parameters and choices interact in the model, all combine to deliver the well-known hump-shaped relation between Tobin's Q and managerial ownership (e.g., McConnell and Servaes (1990)).

Our structural approach illustrates how a quantitative model of the firm can isolate important aspects of organization structure, quantify the economic significance of incentive mechanisms, and minimize the endogeneity and causation problems that so commonly plague empirical corporate finance. Doing so appears to be essential because, by simulating panel data from the model and applying standard statistical tools, we confirm that the customary econometric remedies for endogeneity and causation can be ineffective in application.

JEL Classifications: G32, G34, L20

The analysis of the relation between firm performance and managerial ownership represents a substantial and consistently-active segment of the empirical corporate finance literature. Important early contributions include Morck, Shleifer, and Vishny (1988), hereafter MSV, which documents a nonmonotonic relation between Tobin's Q and managerial stock ownership,[1] and McConnell and Servaes (1990), hereafter MS, which reports an "inverted-U" or "hump-shaped" relation between Q and managerial ownership. Numerous successors investigate the ownership-performance relation using different data, various measures of performance and ownership structure, and alternative empirical methods.[2]

One possible interpretation of the data is that shareholders maximize firm value if they can induce managers to own precisely the amount of stock associated with the peak of the performance-ownership relation. For example, based on McConnell and Servaes (1990, Table 1, Panel (B), regression (1), 1986 data), maximum Q requires about 37.5 percent inside (officers and directors) ownership. But if 37.5 percent managerial ownership maximizes value, why would other combinations of managerial ownership and Q appear in the data? One obvious possibility is that large transaction costs prevent a firm from moving to the optimum. Only when the distance away from the optimum is large will the benefits to shareholders of realigning ownership structure exceed the transaction costs of doing so. Within the bounds of those costs the data would trace the objective function that the firm would maximize in the absence of such costs.[3]

In our data, ownership of the CEO varies from 0.01% to 57.6%, with a standard deviation

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[1] Choosing the kink points to best fit the data, MSV find a positive relation between Q and inside ownership over 0 percent to 5 percent of outstanding shares, a negative relation over the 5 percent to 25 percent range, and a positive relation once again for managerial holdings exceeding 25 percent.

[2] See Demsetz and Lehn (1985), Kole (1995), Cho (1998), Himmelberg, Hubbard, and Palia (1999), Demsetz and Villalonga (2001), Palia (2001), and Claessens, Djankov, Fan, and Lang (2002), among others. The extent of interest in the performance-ownership relation is documented by H. Mathiesen, whose website (http://www.encycogov.com/A5OwnershipStructures.asp) catalogs approximately 100 academic studies on the topic published up through 1999. Many other papers on the topic have appeared since.

[3] See Stulz (1988) for a model containing offsetting costs and benefits of managerial ownership. In that model, firm incentive-alignment effects dominate when inside ownership is low but, as managerial ownership increases, these incentive benefits eventually are overtaken on the margin by the cost of an increased managerial ability to pursue non-value-maximizing activities without being disciplined by shareholders.

of 5.65%, and the point at which the maximum of the hump-shaped relationship between Q and ownership appears in our sample is 20.09%. Based on our estimates of the Q-performance relation, increasing CEO ownership by one standard deviation, from 14.41% to 20.06% implies an increase in firm value equal to $659 million on average. It seems implausible that the transaction costs of realigning CEO pay-performance sensitivity exceed that figure, much less the even greater amounts associated with larger departures of ownership from that which supports maximal Q. Based on this line of reasoning and plausible transaction costs, there is far more variation in observed ownership structure than one would expect.

An alternative interpretation is that the inverted-U pattern represents a value-maximizing relation between two endogenous variables. Under this view, if the empirical specification adequately captures the effects of all relevant exogenous variables, i.e. those structural parameters that drive both ownership and performance, that specification would be unlikely to detect any remaining relation between the jointly-determined endogenous variables (Demsetz and Lehn (1985)). Thus, one challenge for those who operate in the equilibrium paradigm, in this particular empirical context or any other, is to specify and estimate a structural model of the firm. Doing so offers the potential for understanding how exogenous factors that capture the relevant economic forces associated with the contracting environment operate to give rise to a relation between managerial ownership and firm performance.

We follow this second line of attack. In particular, we employ the principal-agent model of Holmström and Milgrom (1987), but augment that model with an investment decision that determines the scale of the firm. Exogenous parameters specify managerial risk aversion, standard deviation of returns, profit margin, how cash flow volatility depends on firm size, productivity of managerial input, and productivity of investment. The shareholders choose investment (i.e., assets) and ownership (i.e., compensation scheme) of the manager, realizing that the manager chooses input which cannot be observed by the shareholders. We then invert the model to data by matching value-maximizing managerial ownership and investment from the model to firm data from Execucomp and Compustat. In particular, for each firm-year observation, we estimate the productivity parameters for managerial input and investment that would give rise to the observed levels of ownership and investment as optimal choices in our model.

We confront the model with several classes of empirical tests. From least to most formal, first we find that the model is invertible - that is, the model is sufficiently flexible to accommodate what appears in the data. There always exist productivity parameters for physical assets and managerial input that support observed firm size and CEO pay-performance sensitivity as optimal.

Second, our estimates of managerial input versus physical capital appear to be significantly different across industries and vary as might be expected. For example, the relative productivity of managerial input compared to capital is high in personal and business services (including educational services, software development, and networking services) and business equipment (including computers) and low in metal mining and utilities. In the cross-section of industries, CEO pay-performance sensitivity is larger and firm size smaller when our measure of productivity of managerial input is high relative to measured productivity of capital.

Third, we examine whether the productivity parameters and our estimate of Q based on the model (call it Q^*) are correlated with actual Q and operating characteristics of the firm. We find that the correlations between model-generated Q^* and R&D intensity, sales, leverage, and advertising effort are statistically significant and have the same sign as the correlations with actual Q. Additionally, Q^* has significant power to explain actual Q (t = 8.79).

Finally, we examine the performance-ownership relation. The model produces the inverted-U relation when we regress Q^* on CEO ownership (t = 20.09) and its square (t = -14.12). Moreover, based on the estimated coefficients the maximal point of the performance ownership relation occurs at 21.34%, which is quite similar to what we obtain (20.09%) when we estimate the McConnell and Servaes (1990) specification using Execucomp and Compustat data. Furthermore, in a regression of actual Q on the two ownership variables (linear and quadratic), but also including on the right hand side simple transformations of the productivity parameters generated by our model, the productivity parameters displace almost all of the explanatory power normally supplied by CEO ownership (t = 1.19) and its square (t = -1.09). Thus, these exogenous structural parameters appear to capture some of the economic forces that determine jointly Tobin's Q and optimal contract form.

To supplement these results, we evaluate the statistical and economic relevance of the endogeneity problem in this empirical context. In particular, we generate a panel of data supposing that our model is the true model and that our estimated exogenous productivity parameters are correct. In this simulated data set, ignoring what we know about the true model that generates the data, we find that misspecified regression models continue to yield a relation between performance and ownership that is similar to that documented in McConnell and Servaes (1990). When using firm size (assets or sales), leverage, R&D expense, advertising expense, and industry to proxy for the structural productivity parameters, the spurious relation between Q and managerial ownership typically remains. These variables are ineffective instruments for the joint determinants of performance and contract form. Furthermore, we find that there are significant concerns associated with the use of fixed effects that are meant to control for unobserved heterogeneity in the contracting environment. Finally, we present evidence on the efficacy of specifying and estimating a system of simultaneous equations (2SLS). In the end, based on our simulated panel, we find that endogeneity can be a severe problem and that standard approaches used in the literature often fail to provide a solution, unfortunate conclusions which provide further impetus for application of a structural approach.

In broad terms, our analysis makes two classes of contributions. First, we provide an equilibrium explanation for an important and oft-examined empirical finding. In our framework, the Q-ownership relation represents the envelope of value-maximizing contract choice and firm size, both of which are jointly determined based on the exogenous firm-level parameters governing productivity of physical assets and managerial input. Though our model has a minimal number of elements, it appears to capture some of the essential economic factors that determine contract form, the boundaries of the firm, and market value, all in a way that is consistent with an important empirical regularity.

Second, the methodological implications of our analysis suggest research opportunities in empirical corporate finance. Our model is consistent with recent calls by Zingales (2000) and Himmelberg (2002), among others, for a quantitative theory of the firm that is empirically implementable and testable and that allows an assessment of the economic significance of various dimensions of the organization. Moreover, our approach can avoid the endogeneity and causation problems that commonly plague empirical corporate finance. Doing so is essential because, by simulating data from the model, we illustrate the difficulty of controlling for endogeneity and assessing causation using standard approaches often applied in this empirical context.

The remainder of the paper is organized as follows. Section 1 presents and analyzes a principal-agent model augmented by an investment/scale choice. Section 2 describes our sample. Section 3 describes our empirical strategy. In Section 4, we invert the model to data on managerial ownership and total assets, provide values for parameters that reflect the marginal productivity of managerial input and physical capital, and characterize the economic importance of changes in the structural parameters for investment, ownership, and our proxy for Tobin's Q. Section 5 examines variation across industries in the productivity parameters and Q^*. We also report the results of our analysis of the correlation between model parameters and firm characteristics. Section 6 shows that our model generates the hump-shaped relation between Tobin's Q and managerial ownership. We also provide the economic intuition. Section 7 examines the severity of the endogeneity problem and assesses the effectiveness of applying the standard econometric remedies. Section 8 concludes.

1. A Parsimonious Model of Ownership and Investment

Our model is an adaptation of the standard principal-agent problem (see Holmström (1979) and Holmström and Milgrom (1987), for example). In particular, the principal chooses the size of the firm as well as the ownership stake (compensation scheme) of the manager. In this model, shareholders choose both the wage contract and firm scale. While it is standard to think of shareholders choosing the managerial compensation scheme, perhaps it is more familiar to think of managers choosing investment. To the extent that investment in physical assets is observable by shareholders, however, it is equivalent to place the decision rights over investment with shareholders.

Firm cash flow is defined by

$$\tilde{f} \equiv pI^y g^z + I^x \tilde{\varepsilon} \tag{1}$$

where I is the firm's investment, or assets, and g is the manager's input. This input represents productive activities, such as effort, that the manager is reluctant to supply otherwise. Assets (I) can include property, plant, and equipment as well as various intangible assets. Managerial input and investment interact in the production function with parameters $y \in (0, 1)$ and $z \in (0, 1)$, which determine the productivity of assets and managerial input, respectively. Production is scaled by $p = Ap^+ > 0$, where $A > 0$ is the standard Cobb-Douglas production function scale factor and p^+ can be interpreted as operating profit margin net of all input costs *other* than the cost of initial assets and the manager's share. The disturbance term, $I^x\tilde{\varepsilon}$, is the product of $\tilde{\varepsilon} \sim N(0, \sigma^2)$ and a function of investment, I^x, where $x > 0$ is a "curvature" parameter defining how size affects cash flow risk. The disturbance term represents idiosyncratic firm risk, perhaps from a technology shock. We think it reasonable to assume that an additive cash flow shock depends on firm size.

The manager's utility function is exponential

$$U(m+\tilde{w},g) = -e^{[-r(m)(m+\tilde{w}-C(g))]} \tag{2}$$

where $\tilde{w}$ is the uncertain wage, m is other accumulated managerial wealth, $m+\tilde{w}$ is terminal wealth, $C(g)$ is the money equivalent cost of managerial input, and $r(m)$ is a parameter determining the degree of risk aversion. We focus on the case in which the manager has CARA, so $r(m) = r$, a constant. Nonetheless, our formulation permits risk aversion to depend on m so that later we can test the robustness of our results to using an approximation of CRRA. For algebraic convenience, we let the cost of managerial input be linear, $C(g) = g$, assume m is reservation wealth, and define the manager's reservation utility constraint as $E[U] \geq -e^{-r(m)m}$.

Expected utility is

$$E[U(m+\tilde{w},g)] = -e^{\left[-r(m)[m+E(\tilde{w})-\frac{r}{2}\sigma^2(\tilde{w})-g]\right]}. \tag{3}$$

Following Holmström and Milgrom (1987) **?** (also see Hellwig and Schmidt (2002)), the optimal contract that specifies the manager's claim is linear in the observable outcome: $\phi(\tilde{f}) = \tilde{w} = \alpha + \delta\tilde{f}$. Thus, maximizing expected managerial utility is equivalent to maximizing

$$m + \alpha + \delta p I^y g^z - \frac{r(m)}{2}\delta^2 I^{2x}\sigma^2 - g. \tag{4}$$

Given the parameters of the contract and initial investment, solving the first-order condition for g yields the manager's optimal input:

$$g^* = (z\delta p I^y)^{\frac{1}{1-z}}, \tag{5}$$

which is increasing in ownership (or slope of the compensation scheme, $\phi'(\tilde{f})$)$= \delta$), scaled margin,

p, investment, I, and parameters that determine the marginal productivity of managerial input, z, and investment, y.[4] Shareholders maximize expected total surplus

$$S = E\{[\tilde{f}] - E[\phi(\tilde{f})] - I\} + \{E[m + \phi(\tilde{f})] - \frac{r(m)}{2}\delta^2 I^{2x}\sigma^2 - g - m\} \tag{6}$$

subject to the reservation utility constraint that

$$m + \alpha + \delta E[\tilde{f}] - \frac{r(m)}{2}\delta^2 I^{2x}\sigma^2 - g = m + \alpha + \delta p I^y g^z - \frac{r(m)}{2}\delta^2 I^{2x}\sigma^2 - g \geq m, \tag{7}$$

the incentive constraint (5), and the requirement for shareholder participation that $S \geq 0$.

For notational convenience we define $n \equiv \frac{z}{1-z}$, with $n \in (0, \infty)$ for $z \in (0,1)$. Substituting optimal managerial input in (6) yields

$$S = (pI^y)^{n+1}\left(\frac{n}{n+1}\right)^n \delta^n - I - \frac{r(m)}{2}\delta^2 I^{2x}\sigma^2 - (pI^y)^{n+1}\left(\frac{n}{n+1}\right)^{n+1}\delta^{n+1} \tag{8}$$

The first-order conditions for the principal's choice of ownership, δ, and assets, I, are

$$\frac{\partial S}{\partial \delta} = \delta\left[-(pI^y)^{n+1}\left(\frac{n}{n+1}\right)^{n+1}(n+1)\delta^{n-1} + n(pI^y)^{n+1}\left(\frac{n}{n+1}\right)^n \delta^{n-2} - r(m)I^{2x}\sigma^2\right] = 0 \tag{9}$$

$$\frac{\partial S}{\partial I} = I^{y(n+1)-1}\left(\frac{n}{n+1}\right)^n \delta^n y^{(n+1)}\left[1 - \delta\left(\frac{n}{n+1}\right)\right]p^{n+1} - r(m)x\delta^2\sigma^2 I^{2x-1} - 1 = 0 \tag{10}$$

Sufficient conditions for any maximum are that the determinants of the principal minors of the matrix of second cross partial derivatives alternate in sign at that critical point. We eliminate all other maxima in favor of the global maximum.

Exogenous parameters are z (or n), y, x, $r(m)$, σ^2, and p. Of course, m also is exogenous,

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[4] It is simple to show that the second-order condition holds for the agent's choice of input.

but CRRA is not our primary focus so we suppress it in the notation until it becomes relevant for the discussion. Optimal ownership and investment, denoted by $\delta^* = \delta^*(z, y, x, r, \sigma^2, p)$ and $I^* = I^*(z, y, x, r, \sigma^2, p)$, arise from solving (9) and (10), and optimal α, denoted by α^*, is given by substitution in the reservation utility constraint. Despite the simplicity of the model, solving the first-order conditions is non-trivial.[5] Accordingly, we use numerical methods to solve (9) and (10) and verify the conditions for a global maximum.

Our single-period model yields a conceptually natural definition for Tobin's Q. Model-generated Q^* equals maximized surplus, S^*, plus optimal initial investment, I^*, plus the random shock, all normalized by optimal initial investment, or

$$Q^* = \frac{S^* + I^* + I^{*x}\tilde{\varepsilon}}{I^*} \tag{11}$$

$Q^* = Q^*(z, y, x, r, \sigma^2, p)$ arises endogenously from the production function, the manager's choice of input, value-maximizing choices of ownership and size, exogenous parameters, and the realization of the random disturbance. Define expected model-generated Q, written as EQ^*, as Q^* with the random shock set equal to zero.

2. Sample Collection and Characteristics

To examine the relation between managerial ownership and firm performance we use data from the Execucomp database covering the years 1993 through 2000. For each firm-year we compute the sensitivity of CEO wealth to changes in shareholder wealth (the effective ownership share or pay-performance sensitivity of the CEO). In computing our measure of pay-performance sensitivity

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[5] It is possible, however, for certain parameter values. For example, if $z = .5$ (so $n = 1$), then (9) yields solutions of $\delta = 0$ and $\delta = \left(1 + \frac{2r(m)\sigma^2}{p^2 I^{y(2)-2x}}\right)^{-1}$ and the larger solution supports the global maximum. Of course, (9) still needs solving simultaneously with (10) and, in general, analytical solutions are unavailable. For a polynomial of degree q (an integer) > 4 there is no general algebraic solution. See Conkwright (1941) and Hungerford (1974). Exponents that are not integers pose further difficulties.

we include the effects of the CEO's direct stock ownership, restricted stock, and existing and newly granted stock options. For direct stock ownership and restricted stock, the pay-performance sensitivity is computed as the number of shares of stock held by the CEO divided by the number of shares outstanding.

For stock options, we follow Yermack (1995) and compute the pay-performance sensitivity arising from stock options as the option delta from the Black-Scholes option pricing model (the change in the value of the stock option for a one dollar change in the stock price) multiplied by the ratio of the number of options on shares granted to total shares outstanding. Following Core and Guay (2002), we compute option deltas separately for new option grants and existing options. For newly granted options, we assume a maturity of seven years, because executive stock options are generally exercised early (e.g., Carpenter (1998), Huddart and Lang (1996), and Bizjak, Bettis, and Lemmon (2005)). For existing options, we assume that unexercisable options (i.e., those that are not vested) have a maturity of six years and that exercisable options (i.e., those that are vested) have a maturity of four years. The risk-free rate and volatility estimates for each firm year are given in Execucomp. We compute the effective ownership share of the CEO, which corresponds to δ^* in our model, as the sum of the ownership shares from the CEO's stock ownership, restricted stock, and stock options.

We rely on Compustat for other data. To measure firm performance we use Tobin's Q, computed as the book value of total assets minus the book value of equity plus the market value of equity all divided by total assets. We use data on the book value of total assets and sales as measures of firm size. As control variables we include research and development expenditures and advertising expenses, each scaled by total assets, to measure asset intangibility and growth opportunities.[6] Book leverage is calculated as long-term debt divided by total assets. In some regression specifications we include either industry dummies for each two-digit standard industrial code (SIC) in the sample

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[6] Following Bizjak, Brickley, and Coles (1993), we set missing values of R&D and advertising expense to zero.

or firm fixed effects. The control variables include those used most often in other studies.

Table 1 reports summary statistics for our sample of 8,576 firm-year observations. The mean effective ownership share of the CEO is 0.033 (median = 0.013) indicating that the CEO's wealth increases 3.3 (1.3) cents for every dollar increase in shareholder wealth. The standard deviation of the CEO's effective ownership share is 0.057. These values are in line with estimates of pay-performance sensitivities reported by Murphy (1999) over a similar time period. Book assets of firms in the sample are \$9,654 million on average and range from a minimum of \$5.88 million to a maximum of \$902,210 million (Citigroup in year 2000).[7] Sales average \$4,255 million and range from \$0.394 million to \$206,083 million (Exxon Mobil in 2000). Leverage averages 0.188, and the mean values of R&D and advertising expense scaled by total assets are 0.031 and 0.011, respectively. Finally, average Tobin's Q for firms in the sample is 2.11, the maximum is 45.3, and the minimum is 0.30.

3. The Empirical Strategy

A. Inverting the model

Using the Execucomp and Compustat data, we invert our model to extract productivity parameters that support the observed CEO ownership shares and book assets as value-maximizing choices. We assume the observed effective ownership and assets correspond directly to $\delta^*(z, y, x, r, \sigma^2, p)$ and $I^*(z, y, x, r, \sigma^2, p)$ in the model. For a reasonable domain of productivity parameters, if the model has sufficient range then these functions will be numerically invertible for restrictions that reduce the dimensionality of the parameter space to two. For our case, we fix x, r, σ^2, and p, and allow z and y to vary so as to match (δ^*, I^*) with data. That is, we invert the model to extract the combination of z and y that would give rise to observed CEO ownership and firm

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[7] Our sample includes financial firms. Excluding financials does not materially change any of the results reported below.

total assets as optimizing choices in the model. We require $z + y \leq 1$ so as to exclude increasing returns to scale.

To reduce the dimensionality of the parameter space, we fix $p = Ap^{+} = 40$, $\sigma = 0.333$, and $r = 4$. The value of p is chosen to equate the average and median levels of Q^{*} from the model to the average and median levels of actual Q from the data. For our assumption on absolute risk aversion, see Haubrich (1994). Our estimate for σ is based on the median annualized volatility of monthly stock returns for all firms in our data. Stock return data come from the Center for Research in Security Prices (CRSP). To obtain an estimate of the curvature parameter, x, using the cross-section of firms we regress $\ln(\sigma^{e})$ on $\ln(I)$, where I is total book assets of the firm. As a proxy for cash flow volatility, σ^{e}, we use the standard deviation of dollar returns (e.g., Aggarwal and Samwick (1999)) using monthly data on stock returns from CRSP over the 48 months preceding the observation year. We exclude firm-year observations with less than 24 months of prior return data. Our point estimate of x is quite close to $x = 0.5$, and x reliably falls between 0.4 and 0.6. Nevertheless, we perform the calculations for several values of x so as to gauge the effect of changing the relation between firm scale and volatility. The values of x we consider are $x = 1.0$, 0.75, 0.50, and 0.30. The additive cash flow shock is given by $I^{x}\tilde{\varepsilon} \sim N(0, I^{2x}\sigma^{2})$. When $x = 1.0$, standard deviation of the shock increases linearly in total assets and, when $x = 0.50$, variance increases linearly in scale. Based on our estimate, the latter appears to be more realistic.[8]

For each firm (j = 1,2,..., J) year (t = 1,2,..., T) observation in the sample, as described above, we use numerical techniques to find the values of y_{it} and z_{it} that produce optimal choices of δ^{*} and I^{*} from the model that match the ownership shares and book assets values in the data, δ_{it} and I_{it}. Based on the calculated values of y_{it} and z_{it}, observed $\delta^{*} = \delta_{it}$ and $I^{*} = I_{it}$, as well as x and simulated cash flow shocks, we also calculate Q_{it} predicted by the model. When the meaning

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[8] The point estimate of $x = 0.50$ represents increasing cash flow risk (standard deviation) in size but at a decreasing marginal rate. Perhaps larger firms operate in more lines of business and are more diversified and less risky per dollar invested.

is clear, for simplicity hereafter we suppress the firm-year subscripts. Recall that model-predicted Q is $Q^* = \frac{S^*+I^*+I^{*x}\tilde{\varepsilon}}{I^*}$. To calculate the additive shock, for each firm-year observation we draw a randomly generated value of $\tilde{\varepsilon}$ from $N(0, \sigma^2)$. Again, $EQ^* = \frac{S^*+I^*+}{I^*}$ is Q^* with the random shock set equal to zero.

The inversion approach that we employ is similar to the methodology used in Baker and Hall (2004) to investigate the relationship between CEO incentives and firm size. Nevertheless, our"calibration" is somewhat non-standard, but does bear some similarity to calibration models that have been employed so successfully in other areas, such as macroeconomics. A more typical calibration approach would specify a reasonable joint distribution of the parameters, $(z, y, x, r, \sigma^2, p)$, and filter the distribution through the model to generate a joint distribution of firm size, CEO pay-performance sensitivity, Q^*, and possibly other variables.

Our procedure, though similar in motivation, modifies this calibration approach. Recall that we reduce our modeling flexibility by specifying fixed values for parameters (x, r, σ^2, p). These fixed parameters are estimated from data, but not from those data with which we directly test the model, and hence can be considered under-informed by the data relative to the standard calibration approach. Then, using data on ownership shares and book assets, δ_{it} and I_{it}, we invert the model to find the values of y_{it} and z_{it} for every firm-year in the data. One might consider these parameters, relative to those derived from other estimation methods, to be over-informed by the data. That is, most traditional methods, which we discuss in more detail in Section VI.D., would create degrees of freedom by using multiple observations on δ and I to estimate productivity parameters that are restricted to be the same for all firms in an industry and/or the same for a given firm for all years. In contrast, our method accommodates variation of firm size and contract form both across and within industries and through time as well. The question we can address with our approach is whether the economic phenomena represented by our model do a good job explaining variation of firm size and contract form across and within industries and through time. Accordingly, our approach also allows us to identify the type of variation, time-series or cross-sectional (within or across industries), that drives the hump-shaped relation between performance and contract form.

B. **Adapting the model: Approximating CRRA**

The primary case we consider is based on CARA utility. We also consider an approximation of CRRA utility in order to see whether variation in risk aversion across executives (and firms) changes the ability of the model to explain the data. Instead of fixing $r = 4$, we specify $r(m) = \frac{r}{m\gamma}$, where m represents accumulated wealth of the manager.[9] Our empirical approximation of m_{it} is based on the assumptions in Baker and Hall (2004), who assume that CEO wealth is roughly equal to six times salary and bonus. The elasticity of CEO salary and bonus to firm size in our sample is 0.28 (similar to the 0.3 reported in Murphy (1999)). Because most CEOs have nontrivial accumulated wealth, our empirical approximation is $m_{it} = \max[\$5 \text{ million}, 6 \times 0.28 ln(\text{assets}_{it})]$, where we rely on Baker and Hall for the \$5 million minimum. Note that this is only an approximation of CRRA. So as to simplify the optimization problem and characterization of the solution, we include only accumulated other wealth, m, but not terminal wealth, $m + \tilde{w}$, in the denominator of the risk aversion coefficient.

4. The Productivity of Managerial Input and Physical Capital

A. **Lower moments of Q^*, z, and y**

While a large literature considers estimation of production function parameters, to our knowledge no study provides an estimate of the productivity of "organizational capital" or executive input,

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[9] This procedure is meant to accommodate differences in risk aversion (DARA) depending on wealth. Though our primary intention is to increase the flexibility of the model, note that this procedure also could represent sorting of managers. Our focus is on the agency (moral hazard) problem where contract form is determined by factor productivity (i.e., the investment opportunity set), as represented by z and y. But if we were to emphasize adverse selection and sorting of managers, one natural way to do so would be to allow risk aversion to vary in fitting the model. For now, however, our strategy focuses on differences in contract form and firm size being driven by variation in production opportunities rather than by differences in managerial preferences.

such as effort and expertise.[10] Table 2 presents summary statistics for z and y from inverting the model to actual total assets and CEO pay-performance sensitivity. Considering first CARA with x=0.5 (Panel A), the mean value of z is 0.00128, and the median value is 0.00004. The mean value of y is 0.561 and the median value is 0.567. The Pearson (Spearman) correlation between z and y is -0.107 (-0.523) ($p < 0.01$ (0.01)). The negative correlation between z and y is consistent with the previously-documented negative relation between effective CEO ownership (wealth to performance sensitivity) and firm size (e.g., Bizjak, Brickley, and Coles (1993), Schaefer (1998), and Baker and Hall (2004)). In our data, the Pearson (Spearman) correlation between ownership and total assets is -0.108 (-0.556) ($p < 0.01$ (0.01)). CEOs in larger firms have smaller ownership shares. This is consistent with our model in that idiosyncratic risk (in dollar terms) increases in firm size according to I^x.[11]

Table 2 also reports summary statistics of the modeled values of Tobin's Q, Q^*, for two values of the parameter that defines how firm size affects idiosyncratic cash flow risk, x = 0.50, 0.75. With CARA (Panel A) with x = 0.50, the average value of the model-generated Tobin's Q is Q^* = 1.83, with a standard deviation of 0.36. When x = 0.75, the average value is Q^* = 1.86, with a standard deviation of 0.44. Note that even though our model-generated Q^* values include a random disturbance term based on actual cash flow variation, they are still less variable than the actual Q values observed in the data (Table I). This is not surprising, since actual Q is likely to be influenced by additional forces outside of our model. Nonetheless, this comparison of the lower moments of actual Q and model-generated Q^* suggests that the model represents some of the forces that drive

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[10] The issues in this literature include productivity of inputs (e.g., capital, labor, other materials, and energy), returns to scale, productivity growth, efficiency of public versus private firms, international comparisons of productivity and efficiency, productivity in specific industries (e.g., electric power and agriculture), various functional forms of production functions (Cobb-Douglas, translog, etc.), and the measurement of welfare. The most closely related study to ours we could find is Hellerstein, Neumark, and Troske (1999). This study estimates translog production parameters for four types of workers, and one of those classes contains all professional workers and the management team.

[11] Again, our model is based on moral hazard, but an alternative would be to focus on adverse selection and sorting of managers (as do Gabaix and Landier, 2006). In our modeling framework, good (high z) managers could be sorted to productive (high y) firms, so estimated z and y would be positively correlated in the data. We find the opposite.

firm structure.

Panel B of Table 2 reports results for approximate CRRA. The moments of Q^*, z, and y are quite similar to those for CARA. The primary differences are a higher mean and more range in z and slightly greater range in Q^*. Otherwise, the moments are almost identical between CARA and approximate CRRA and CRRA Q^* bears the same relation to actual Q as CARA Q^*. Thus, hereafter we focus on CARA, though we also continue to provide some results for CRRA where appropriate.

B. Model comparative statics

One significant benefit of fitting a structural model to data is the opportunity to gauge the economic significance of the underlying structural parameters as determinants of organization form. In our model, the shareholders choose scale of the firm and the managerial compensation scheme (effective ownership) to maximize value. Exogenous variables include scaled margin ($p = Ap^+$), risk aversion (r), unscaled standard deviation (σ), and the scale factor for cash flow risk (x). The parameters governing productivity of managerial input (z) and assets (y) also are exogenous. Table 3 presents estimates of the effect of each of these parameters on the optimizing choice of size, effective ownership, and model-generated expected Q in the CARA model. Because δ^* and I^* are highly nonlinear in the structural parameters (see the first-order conditions, (9) and (10)) and, thus, so is EQ^*, we calculate optimal ownership and size for a benchmark level of the parameter plus and minus a perturbation in that parameter and then calculate the percentage changes in δ^*, I^*, and EQ^*. We perturb p, r, σ, x, z, and y by 10 percent relative to the benchmark levels. In all calculations, we use $p = Ap^+ = 40$, $r = 4$, $\sigma = 0.33$, and $x = 0.50$ as the benchmark levels of the exogenous parameters that do not vary across firms. For the estimated productivity parameters, z and y, we use the medians (Table 2, Panel A) as benchmark levels.

Table 3 indicates that a 10 percent increase in z, which increases the marginal productivity of managerial input, implies a 4.85 percent change in the optimal effective ownership level of the CEO, all else equal. Accordingly, CEO ownership and z are highly-correlated in the data (Pearson (Spearman) correlation = 0.823 (0.998)). A 10 percent increase in y, which increases the marginal productivity of investment, induces a 4.63 percent decrease in the optimal ownership level of the manager. This effect should be stronger when x is larger because cash flow volatility is more sensitive to scale and compensating the manager for additional risk-bearing is costly. All else equal, a 10 percent increase in z induces a small decrease in firm size and has no discernible effect on EQ^*. In contrast, a 10 percent increase in the value of y induces a very large increase (283.8 percent) in firm size and a 9.13 percent decrease in EQ^*.

Consistent with the operation and basic predictions of our augmented principal-agent model, increases in managerial risk aversion or volatility have a substantial negative effect on the optimal level of CEO ownership. Increases in risk aversion and volatility, however, have only negligible effects on investment and expected Q^*. All else equal, an increase in profit margin, p, increases the optimal size of the firm, but has negligible effects on ownership and EQ^*. Increasing x, which determines the extent to which scale affects cash flow volatility, decreases ownership but has very little effect on EQ^* and scale. When the values of the parameters are decreased by 10 percent from their benchmark levels, the changes in the endogenous variables have opposite sign and are somewhat different in magnitude, presumably because of the nonlinearities in the model.

There is another benefit of these comparative statics calculations. In particular, they can be combined with the distribution of extracted z and y to gain intuition about how the optimizing values of the endogenous variables vary together. This will be particularly useful in Section VI which discusses the inverted-U relation between Q and managerial ownership.

5. Does the Model Conform to Real Data?

The prior section shows that the model survives basic scrutiny on two levels. First, it is invertible for both CARA and approximate CRRA. There always exist productivity parameters for physical assets and managerial input that support observed firm size and CEO pay-performance sensitivity as optimal. Thus, the model satisfies a basic hurdle for validity. Moreover, the lower moments of model-generated Q^* (both CARA and CRRA) are similar to those of actual Q. In this section, we provide more detailed tests of external validity, that is, the ability of the model to conform to real data.

A. Variation across industries

Table 4 reports median values of the estimated structural parameters, z and y, endogenous inside ownership and investment, δ^* and I^*, and predicted Q (including the random disturbance term), Q^*, across industries defined following the taxonomy of Fama and French (1997).[12] For both CARA and approximate CRRA, the Pearson χ^2 test of goodness-of-fit rejects the null hypothesis that any of z, y, z/y, δ^*, and Q^* do not vary across industries.

A related informal test of our model is whether our estimates of the relative productivity of managerial inputs versus physical capital appear to vary as one might expect across industries. The data in Panel A of Table 4 are sorted by CARA $z \times 10^4/y$. (Note that the ordering of industries based on CRRA in Panel B differs only slightly.) The ratio $z \times 10^4/y$, a relative measure of the importance of managerial input versus physical capital in the production process, is high in a broad spectrum of industries, ranging from Personal and Business Services (which includes educational services, software development, and networking services), Business Equipment (including computers), Healthcare, and Recreation (which includes the movie industry). The lowest ratios are in industries such as Precious Metals and Metal Mining, Tobacco Products, Utilities (Elec-

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[12] See http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/index.html.

tric, Gas, and Sanitary Services), and Communications. In absolute terms, physical capital is most productive in Financials, Tobacco Products, Aircraft, Ships, and Railroads, Utilities, and Communications, while managerial input is most productive in Personal and Business Services, Restaurants, Healthcare, Business Equipment, and Recreation. Accordingly, median investment is quite large in Tobacco Products, Financials, and Communications, while median managerial ownership is quite large in Recreation, Healthcare, and Personal and Business Services. These results are consistent with economic intuition about how the productivity of physical and human capital should vary across industries as a function of the technology.

B. **Variation within industry**

We next examine variation within industry. It is quite plausible that steel companies and service companies have different marginal productivity parameters. But does heterogeneity in those parameters really explain variation in size and contract within the steel and service industries? To address this question, Table 4 reports within industry standard deviations for z, y, and $z \times 10^4/y$. The standard deviation across industries for the average values of $z \times 10^4$, y, and $z \times 10^4/y$ are 9.80, 0.035, and 19.97, respectively. In most industries, the within industry standard deviation of the productivity parameters exceeds the cross-industry standard deviation. This suggests that production technology can significantly vary across firms even within the same industry, which is consistent with the large dispersion in firm size and CEO wealth-performance sensitivity within industries observed in the data.

Another interesting question concerning within industry effects relates to the correlation between extracted y and z. Large firms, such as GM, generally have small δ^*, while a small startup firm in the same industry likely would have larger pay-performance sensitivity. Of course, this could be explained by the model if extracted y and z are forced to be negatively correlated within industry. Observe, however, that the structure of the model does not necessarily require this negative correlation in order to fit such data. Larger y implies larger size, I^*. Larger I^* implies larger idiosyncratic cash flow risk, arising from the disturbance $I^{*x}\tilde{\varepsilon}$, which implies lower δ^*. Thus, the structure of the model does not necessarily require z to be lower when y is higher in order to generate lower δ^*. The data, however, if δ^* falls substantially in size, may yield such a result. To examine this further, for each industry we calculate the correlation between z and y. The average within-industry Pearson correlation is -0.18, which is less negative than the cross-industry correlation (of means) of -0.25. In order to support observed size and CEO pay-performance sensitivity as optimal choices, the model does not require more negatively correlated productivity parameters within industry than across industries.

A final aspect of variation within industries relates to the possibility that the approximate CRRA formulation is more flexible than the CARA case. The argument is that the CARA model potentially places unreasonable demands on only two parameters, z and y, to explain variation in the data. Certainly it is plausible that the productivity parameters explain variation across industries, but can we really expect the variation of the Cobb-Douglas exponents to explain variation of size and pay-performance sensitivity within each industry? Allowing variation in managerial risk aversion, along with variation in the productivity parameters, may provide more explanatory power, particularly within industries. Thus, we examine whether inverting the CRRA model delivers less variation in the productivity parameters that support δ^* and I^* as optimal choices than does inverting the CARA model. The answer is no. The standard deviation of y within industry tends to be very similar across the CRRA and CARA formulations. In contrast, CRRA requires *more* variation within industry of implied z and z/y than does CARA.

C. Correlation

We now consider another class of tests of the model. In particular, we examine correlations among Q^*, actual Q, and firm and market characteristics that are completely outside the model

(R&D intensity, sales, leverage, and advertising effort).

Table 5 provides Pearson and Spearman correlations for the relevant variables. For both CARA and approximate CRRA we report results based on $x = 0.5$, but the results are similar for other values of x. The Pearson and Spearman correlation coefficients for Q^* and Q are 0.24 ($p < 0.01$) and 0.29 ($p < 0.01$) for both CARA and CRRA. A different incarnation of this same result appears later in Table 8, which presents the results of regressing actual Q on EQ^* (t = 8.79). It appears that modeled Q^* has some power to explain actual Tobin's Q.

Actual Tobin's Q is negatively correlated with sales and leverage, and positively correlated with R&D and advertising. Similarly, both CARA and CRRA model-generated Q^*s display statistically significant correlations of the same sign with sales leverage, R&D, and advertising.

In sum, Q^* and actual Q have similar lower moments, Q^* has power to explain actual Q, and the cross moments of Q^* with variables outside of the model accord well with those same cross moments of actual Q. These results suggest that the form of our model and the fitted structural parameters capture some of the economic determinants of firm size, CEO pay-performance sensitivity, and firm performance.

6. Getting Over the Hump: The Relation Between Ownership and Performance

This section reports results for an important class of tests of external validity. One test examines whether there is a hump-shaped relation between Q^* and δ^*. The other examines whether simple functions of z and y, the parameters in our model that are purported to determine δ^*, I^*, and Q together, displace or explain the observed hump-shaped relation between actual Q and δ^*.

A. The link between CEO ownership and firm performance

Consider the often-reported result of an “inverted-U” or “hump-shaped” relation between ownership and Tobin’s Q (e.g., McConnell and Servaes (1990) and Himmelberg, Hubbard and Palia (1999)). One conventional interpretation of this finding is that the incentive effects associated with higher ownership are strong for low to medium levels of ownership, but that entrenchment effects become dominant at high levels of CEO ownership (Stulz (1988)). This explanation requires substantial costs of adjusting managerial ownership. Our alternative is that these results could also arise as the outcome of value-maximizing choices of organizational form driven by underlying features of the contracting environment. The question becomes whether our model can serve to explain the inverted-U. The answer is yes.

Table VI reports pooled OLS regressions of Tobin’s Q from the actual data and noisy Q^* from our model on the ownership share of the CEO (δ) and its squared value. Throughout, all test statistics are adjusted for heteroscedasticity and clustering within firms (per Petersen (2006), see Rogers (1993)). The first model in Table VI reports the results using actual Q as the dependent variable. Consistent with the results reported in many prior studies, our data also reflect the inverse U-shaped relation between Tobin’s Q and ownership. The coefficient estimate on the CEO’s ownership share is 8.61 (t-statistic = 9.00), and the coefficient estimate on the squared ownership of the CEO is -21.46 (t = -8.38). The ratio of the coefficient estimates of the linear term to that of the squared term is -0.40, which corresponds to a maximum Q at CEO ownership of 20.09 percent. The adjusted R-squared of the regression is essentially the same as that reported by Himmelberg, Hubbard, and Palia (1999, Table 5) for the same regression specification.

The remaining columns in Table VI present results using as the dependent variable Q^* values generated by the model for different values of the volatility curvature parameter, x. For our primary case, with CARA and $x = 0.50$ (model 2), the coefficient on the ownership share variable is 4.76 (t = 20.09) and the coefficient on the squared ownership share is -11.11 (t = -14.12). The ratio of the coefficients on the linear term to that on the squared term is -0.427, which corresponds to a maximum Q^* at CEO ownership of 21.34 percent.

Similar results arise in both CRRA models ($x = 0.5$ in model 4 and $x = 0.3$ in model 5) and for CARA when we use $x = 0.3$ (not reported). The estimated relation between Q^* and ownership is concave, and the level of managerial ownership that defines the top of the hump is similar.

Note, however, that the model is capable of delivering a different relation between Q^* and CEO ownership. Though we focus on $x = 0.50$, as estimated from our Execucomp firms, the analogous estimate for all firms on Compustat is 0.75. Holding all other parameters in our model constant, this would imply an increasing convex relation between Q^* and CEO ownership, which is not consistent with the patterns observed in our data. Ownership data on many more firms would be required to examine the shape of the Q-ownership relation for all firms on Compustat. Though our model can give rise to shapes other than the inverted-U, the most natural assumptions for our data ($x = 0.5$) generate the hump.[13] Moreover, if risk aversion is smaller, CARA $r = 2$ for example, the relation for x = 0.75 again is *concave*. In our model, lower x and lower r tend to favor a concave relation between Q^* and CEO ownership.

B. How the model works

We now explain why the model gives rise to the observed relation between Q and CEO ownership. Consider an increase in the productivity of physical capital, y. As Table 3 indicates, this implies a large increase in investment, a decrease in managerial ownership, and, thus, a decrease in EQ^* and, consequently, Q^*. On the other hand, Table 3 also shows that an increase in productivity of managerial input, z, implies an increase in CEO ownership, very little increase in investment (so as to avoid magnifying the exposure of the manager to increased risk), and very little effect on Q^*.

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[13] Variation in empirical findings across studies of the Q-ownership relation could be driven by variation in x across samples (e.g., Compustat versus Execucomp). See Demsetz and Villalonga (2001, Figure 1) for a representation of the spectrum of results in the literature on the relation between Q and managerial ownership.

Also recall that the estimated productivity parameters, z and y, are negatively correlated in the full sample (Table 5), though the absolute value of that correlation is not particularly large.

Consider first the set of firms for which z and y are negatively related. Increasing z and decreasing y will lead to an increase in CEO ownership as the effects of increasing z and decreasing y reinforce each other. In addition, investment (size) declines and Q^* increases. For firms represented in this part of the sample, δ^* and Q^* will move together. In contrast, consider the subset of sample firm for which z and y increase together. Referring again to Table 3, the effect on managerial ownership is ambiguous. For large sensitivity of cash flow risk to scale (large x), increasing investment exposes the manager to substantially more risk. This is expensive for the principal, who must compensate the agent (higher α), so optimal managerial ownership falls as the suppressive effect of increasing y on δ^* more than offsets the effect on δ^* of increasing z. Q^* decreases as well. In this case, once again, δ^* and Q^* will move together. On the other hand, for smaller x, the effect of increasing z dominates the effect of increasing y, so managerial ownership increases on net because increased scale does not unduly expose the manager to higher risk. Thus, size and managerial ownership move together, but Q^* declines, in which case, for firms in this part of the sample, increasing δ^* is associated with decreasing Q^*. It remains to be seen, of course, whether both of these effects and underlying intuition are reflected in the results from inverting the model.

To explicitly examine the above intuition, Table 7 displays median values of the exogenous productivity parameters, endogenous choice variables, and model-generated Q^*, all by observed CEO ownership deciles. For deciles one through nine, y falls and z increases. Thus, optimal investment falls relative to optimal CEO ownership and, as a consequence, Q^* increases as the importance of human assets increases relative to other assets. While, in general, z and y are negatively correlated, it is with substantial error. The top ownership decile contains firms with both high y and high z. Thus, as the comparative statics results in Table 3 suggest, while z, y, optimal ownership, and CEO input are high, so is investment (at least relative to decile 9), and the negative effect on Q^* of higher y and investment is larger than the positive effect on Q^* of higher z and managerial input. In this way, the structure of the model and distribution of the exogenous productivity parameters in the data combine to yield a hump-shaped, endogenous relation between Q^* and managerial ownership.

C. The power of δ^* versus the productivity parameters to explain actual Q

Table 8 presents results on the relative power of δ^* versus EQ^* and the productivity parameters to explain performance. For the purposes of comparison, models 5 and 6 present results when the performance measure is Q^*. Relative to model 2 of Table 6, these two regressions illustrate that including simple transformations of z and y (model 6) or EQ^* (model 5) usurps the explanatory power of the quadratic in CEO ownership. Of course, this exercise is rigged. Notwithstanding the overly simple functional forms of z and y, it would be quite surprising if the results were different. After all, the exogenous productivity parameters and the model determine the endogenous variables Q^*, δ^*, and I^*. In contrast, in no way was construction of the model and estimation of the productivity parameters informed by matching the model to data on actual Q. Thus, the real question is whether the same results arise when we go outside the model to consider Q calculated from Compustat data.

The benchmark for comparison is Model 1 of Table 6, which represents how the hump-shaped relation between actual Q and CEO ownership appears in our data. The estimated coefficients are 8.61 on δ^* (t = 9.00) and -21.46 on the square of δ^* (t = -8.38). The question is whether EQ^* or the productivity coefficients diminish the explanatory power of δ^* and its square in the regression.

Model 3 confirms that simple transformations of z and y displace almost all of the explanatory power normally supplied by CEO ownership (t = 1.19) and its square (t = -1.09). This suggests that we have identified and calculated (by way of the model) exogenous characteristics of the firm that drive both Tobin's Q and CEO ownership together.

As model 2 indicates, however, including model-generated EQ^* instead of z and y on the right-hand side does not render the ownership variables insignificant, although the magnitudes of the coefficient estimates decline substantially compared to those reported for Model 1 in Table 6. Thus, despite the empirical success of our approach, it is doubtful that our model encompasses all of the relevant economic determinants of firm size and managerial ownership. Perhaps no parsimonious model can. Nonetheless, our simple model does provide substantial explanatory power. We discuss this further in subsection VI.E.

D. Additional analysis

Many studies on ownership and performance use a broader measure of managerial ownership (e.g., the total ownership of all officers and directors reported in the proxy statement). Thus, we repeat the analysis using our ownership measure aggregated over the top executive group as specified in Execucomp. The results are very similar. In our sample, top executive ownership averages 0.049 and varies from less than 0.001 to 0.810. The ownership of top executives is highly correlated with CEO ownership (Pearson correlation = 0.865, p-value < 0.01). Accordingly, it is not surprising that the results using top-executive ownership are very similar to those reported above based on CEO ownership. For $x = 0.50$, the mean values of the calibrated productivity parameters y and z are 0.563 and 0.002, respectively. The tests on lower moments, industry, and correlations all yield similar results. Regressing modeled Q^* on total executive ownership yields coefficients on ownership and ownership squared of 3.882 ($p < 0.01$) and -6.758 ($p < 0.01$), respectively. By way of comparison (to McConnell and Servaes (1990)), regressing actual Q on the broad measure of ownership and its squared value yields coefficient estimates of 7.745 ($p < 0.01$) and -15.687 ($p < 0.01$), respectively. Repeating the analysis in reported in Table 8, we again find that the extracted productivity parameters usurp the power of δ and its square to explain Q^* and Q.

Relative to the way in which they are defined in the model, investment and ownership are likely to suffer from measurement error in the time series. By inverting the model, this measurement error will be transferred to the calculated values of the productivity parameters y and z. To attempt to minimize measurement error we calculate the time-series average of CEO ownership and firm size for each firm in the sample and then invert the model, as before, to obtain a cross-section of parameters, z and y. The results, which come purely from the cross section of firms, are very similar to those we report and are consistent with reduced measurement error in ownership and assets. For $x = 0.50$, the mean values of the calibrated productivity parameters y and z are 0.561 and 0.001, respectively. Regressing modeled Q^* on average ownership yields coefficients on CEO ownership and ownership squared of 5.099 ($p < 0.01$) and -14.246 ($p < 0.01$), respectively. By way of comparison, regressing the time-series average of actual Q on the time-series average value of ownership and its squared value yields coefficient estimates of 9.872 ($p < 0.01$) and -26.505 ($p < 0.01$), respectively. Based on time-series averages, simple functions of average z and y eliminate the power of average δ and δ^2 to explain average Q^* and Q.

Our modified-calibration approach calculates the pair (z_{jt}, y_{jt}) that Solves the first-order conditions $S_\delta(\delta_{jt}, I_{jt}, z_{jt}, y_{jt}, x, r, \sigma^2, p) = 0$ and $S_I(\delta_{jt}, I_{jt}, z_{jt}, y_{jt}, x, r, \sigma^2, p) = 0$, for firms j = 1,2, $\ldots$, J and time t = 1,2, $\ldots$,T (while assuring a global maximum). Other more traditional methods could be employed. For example, we could assume that the productivity parameters are the same for all firms within an industry through time. One could then apply GMM or MLE to observations on (δ_{jt}, I_{jt}), for firms j = 1,2, $\ldots$, J and time t = 1,2, $\ldots$,T, to estimate (z_k, y_k) for industries k = 1,2, $\ldots$,K. We do so and find cross-industry variation in productivity parameters much like that presented in Table 4.

The reason we follow our procedure is to be able to focus on firm-level managerial productivity, CEO pay-performance sensitivity, and variation in the ratio of market value to book value. All are dimensions of the firm that have received great attention in the academic literature and in practice at the level of the individual firm. Our method allows us to evaluate whether the economic phenomena represented by our model do a good job explaining variation of size and contract form both across and within industries.[14]

E. Further discussion

Based on both informal and formal comparisons with the data, our model of the performance-ownership relation appears to be empirically successful and, we would argue, conceptually successful as well. Nonetheless, there are opportunities for improvement and further work.

One observation is that the model itself generates a linear contract. But we include options when we estimate effective CEO ownership. This is an inconsistency in application of the model to data, but we believe the model to be a reasonable first approximation. A second-generation model would generate a mix of stock and options as an optimal solution to the contracting problem (see, for example, Lambert and Larcker (2004)). Such a model could treat the incentives to alter the riskiness of investment policy and financial policy (see Coles, Daniel, and Naveen (2006)). Potential approaches to fitting such a model to the data include the one presented herein, as well as standard estimation methods.

Ownership by outside shareholders is the obverse of managerial ownership, so illuminating the determinants of one reveals some of the determinants of the other. Thus, our approach and results are likely to be relevant for recent work on why and how U.S. firms become more widely held after IPO (e.g., Helwege, Pirinsky, and Stulz (2005), Mikkelson, Partch, and Shah (1997)). For future work we leave both the application of a structural approach to that issue and further exploration of whether the specific model in this paper explains outside ownership.

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[14] Another approach that allows both within- and cross-industry variation and familiar types of statistical tests is simulated method of moments. The procedure is to impose a probability distribution on (x, r, σ^2, p) draw repeatedly from that distribution (N times), and invert the model to retrieve (z, y) for each draw for (δ, I), and then repeat the same process for each and every remaining firm-year observation on (δ_{jt}, I_{jt}). This would yield N (not just 1) observations on (z, y) for each firm-year in the sample. Multiple simulated observations for each firm-year would generate the degrees of freedom required to perform standard statistical tests. Nonetheless, the nature of the tests would be quite similar to the tests presented in this paper.

As Table 8 demonstrates, despite the empirical success of our approach, it is doubtful that our model encompasses all of the relevant economic determinants of firm size and managerial ownership.[15] We do not suggest, however, that these and other forces are unimportant. There is plenty of evidence in the literature, as well as in our own empirical analysis, to suggest they are. It is quite likely that factors other those represented in EQ^* (model 2), other even than z and y, affect managerial ownership, investment, and firm size. Such variables include the mechanics of stock and option accumulation by managers through the managerial life cycle, factor (e.g., energy) prices, takeovers, exchange rates, monetary and fiscal policy, government regulation, tax law, the marginal tax rate, and exchange rates. Our model can be nested within a model that includes additional such factors, in which case formal statistical tests of their explanatory power would be simple to perform. This is a logical next step.

Along similar lines, we do not provide a formal test of our model versus any of the existing stylized models, such as that of Stulz (1988). Such a test would require nesting entrenchment, perquisite-taking, or other forces in the model. For example, one model might build on ours to include a parameter representing managerial preference for size. One possibility is that managers have a positive preference for span of control or size. The other possibility is that managers prefer smaller firms, a preference that could be driven by risk avoidance. After calculating the relevant parameter for each firm (manager)-year observation, standard methods would test for whether the average manager has any preference for size and whether that preference differs across managers as a function of proxies for the level of managerial entrenchment. We leave this for future work. For the time being, our analysis does illustrate the difficulty of discriminating among alternative interpretations in the absence of a well-specified model of firm behavior. Furthermore, our analysis demonstrates the opportunities for doing so in a model such as ours.

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[15] Moreover, actual Q could arise from a different functional form for utility, production, or cash flow volatility.

7. Econometric Approaches to the Endogeneity Problem

In empirical corporate finance, many inferences are based on estimated coefficients from reduced-form regressions of either performance on structure or of structure on other structure variables. Structural dimensions of particular interest include managerial compensation, board composition, board size, ownership structure, debt policy, investment policy, dividend policy, leadership structure, antitakeover protections, and product market strategy. Performance measures include accounting profit, stock returns, debt returns, and Tobin's Q. Most studies mention the possibility of endogeneity, and a good number implement standard econometric approaches, such as fixed effects and simultaneous equations methods.

It is possible that the endogeneity problem in practice has little economic or statistical importance, because either reduced-form OLS regression methods are appropriate or implementing the standard econometric antidotes is effective. The alternative, which is less appealing, is that some results are driven by omission of some important aspect of the environment that determines both the dependent and independent variables together, in which case the results reveal little about causation or the underlying structure of the economic problems organizational choices are purported to solve. Himmelberg (2002), which provides a clear and persuasive discussion of this issue, notes that this complaint applies with equal force to regressions of either performance or governance features on other governance features.

So our purpose, in this section, is to assess the empirical importance in corporate finance of the endogeneity problem. The opportunity to do so arises because we specify and fit a structural model to the data. Of course, based on the model "calibration," managerial ownership and total assets from the model perfectly match those in the sample of actual firms. So we turn the model around. We assume the model and productivity parameters are correct and then use the model to generate simulated data, specifically endogenously-determined Q^*. In essence, we create a data panel for which we *know* the underlying structural model and appropriate empirical specification.

Regardless of whether one believes our model is the *right* model, this approach provides a relatively clean framework for evaluating the severity of the endogeneity problem.

A. **When we know the model**

Knowing the model, as we do, provides a convenient point of departure. Even after adding a scaled, randomly-generated disturbance term, we should be able to fit Q^* to the underlying, structural parameters, so long as we include all relevant exogenous variables in the correct functional form. Based on the results in model 4-6 of Table 8, we already know this works. Including EQ^*, which encompasses the productivity parameters, optimal choice of ownership and size, and the correct formulation for Q, provides explanatory power for Q^* (model 4) and also appropriates power from the quadratic in δ^* (model 5). Of course, it is possible that the researcher does not know the exact functional form to use for the exogenous parameters. Thus, model 6 uses a relatively simple set of nonlinear functions of z and y to control for the structural determinants of Q^* (and δ^* and I^*). The approximation does a very good job of explaining variation in model-generated Q, the estimated parameters on δ^* and δ^{*2} are insignificant and small, and δ^* and δ^{*2} together have little explanatory power. In our simulated data, including the exogenous variables in the regression eliminates the "spurious" relation between two endogenous variables. Effort directed toward identifying such variables and collecting the relevant data is likely to be worthwhile.

B. **Instruments for omitted variables**

Inverting the model yields estimates of both z and y for each firm-year observation in the sample. But, in general, z and y (as well as p, r, σ, and x) are not observable to the econometrician, though the parameters will be correlated with the endogenous choices, δ^* and I^*, and performance, Q^*. One established approach to this omitted variable problem is to include additional control variables (instruments) that should proxy for the unobservable exogenous variables, z and y. Perhaps the most common of these is some measure of firm size (e.g., Morck, Shleifer, and Vishny (1988), McConnell and Servaes (1990), and Himmelberg, Hubbard, and Palia (1999)). The idea is that if CEOs generally own smaller stakes in large firms and if Q is negatively correlated with firm size, then omitting firm size from the regressions will lead to a spurious positive relation between CEO ownership and Q.

To investigate this issue, Table 9 presents results from misspecified (excluding z, y, EQ^*) regressions of both actual and modeled Q values on CEO ownership, squared CEO ownership, measures of firm size, and additional control variables used elsewhere in the literature. The primary tests are those that take place entirely within the model, with Q^* (x = 0.50) as the dependent variable (models 4-6), but for comparison purposes we also estimate the same specifications with actual Q on the left-hand side (models 1-3). To measure firm size, we follow Himmelberg, Hubbard, and Palia (1999) and include the natural log of assets (sales) and its squared value. Note that, in our model, total assets also is endogenously determined. Thus, we use the natural log of sales as an alternative instrument. In some specifications we also include leverage, the ratio of R&D expense to total assets, the ratio of advertising expense to total assets, and indicator variables for each two-digit industry in the sample.

Consider the three specifications based on Q^*. When book assets is used to measure firm size, the coefficients on the ownership variables change sign from their values in the corresponding regressions reported in Table 6. The coefficient on CEO ownership becomes negative and the coefficient on the squared term becomes positive. Both coefficients are significant at the 1 percent level. In this case, we know that firm size is endogenously determined along with Q^* and ownership, and thus the dramatic change in the coefficient must be the result of model misspecification.[16] In particular, the results suggest that the relation between the endogenous variables is non-linear. In contrast, when sales is used to measure firm size, the coefficients on CEO ownership and squared ownership

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[16] Parameter estimates from ordinary least squares regressions will be biased when the regressors are endogenously determined along with the dependent variable. See, for example, Kennedy (1992).

retain their signs from the regressions in Table 6 (model 2), although the absolute magnitudes of the coefficient estimates are reduced by about half. Nevertheless, the coefficient estimates on both variables remain statistically significant at the 1 percent level. Finally, model 6 shows that adding standard control variables does not usurp the explanatory power of the ownership variables, both of which remain statistically significant at the 1 percent level.

The results are quite similar when we depart from simulated data to employ actual Q as the dependent variable. Using book assets (model 1) as a control, the coefficients on both CEO ownership and the squared ownership variable are reduced in absolute magnitude compared to model 1 of Table 6. The linear term remains statistically significant at the 10 percent level (t = 1.69) and the squared term is significant at 5 percent (t = -2.20). Actual Q is significantly negatively related to the log of assets, and the relationship is convex as the coefficient estimate on the squared term is positive. When sales is used to measure firm size, the coefficients on CEO ownership and the squared ownership variables are closer to the values from the benchmark regressions (Table 6, model 1). Moreover, both coefficients are significant at the 1 percent level. Adding leverage, R&D, advertising, and dummy variables to control for industry effects does not eliminate the explanatory power of the ownership variables. The hump-shaped relation remains and the estimated coefficients on both ownership and ownership squared continue to be both large and statistically-significant at the 1 percent level.

In general, the results in this subsection highlight two main issues. First, many of the natural candidates for control variables (e.g., book assets) may also be endogenously-determined along with CEO ownership and firm performance, leading to unreliable inferences in regressions. Second, even using control variables that are not necessarily endogenous is unlikely to eliminate serious specification problems in the absence of a structural model relating firm performance to ownership, size, and other exogenous variables associated with the contracting environment. In our setting, the specification issues arise both from the unobservability of the underlying exogenous parameters and from the fact that the relationship between Tobin's Q and ownership is driven by a nonlinear function of these exogenous variables.

C. Fixed effects and unobserved firm heterogeneity

Himmelberg, Hubbard and Palia (1999) suggest using firm fixed-effects to control for unobserved heterogeneity in the contracting environment (e.g., differences in managerial quality). This procedure relies on time-series variation alone to identify the relation between firm performance and ownership. In this subsection, we examine the use of firm fixed effects to control for unobserved firm heterogeneity in our model-generated data. Since we match the model to observed values of ownership and book assets in each firm and year, our model-generated data contain any firm-specific attributes associated with the contracting environment that do not vary (or vary only slightly across time).

We follow Himmelberg, Hubbard, and Palia (1999) and include only firms with three years or more of data in our panel. This creates a panel of data consisting of 7,562 firm-year observations from 1,458 different firms. The last four columns in Table 10 use modeled Q^* as the dependent variable. Model 5 includes firm fixed effects only. Although the magnitudes of the regression coefficients on the ownership variables are reduced relative to those in the benchmark model of Table 6 (model 2), both remain statistically significant at the 1 percent level, so fixed effects is far from a complete "solution." Moreover, when the fixed-effects specification also uses book assets to control for firm size (model 6), the coefficients on CEO ownership and its squared term flip signs compared to the coefficients reported for model 5 and the benchmark, though neither coefficient is statistically significant at conventional levels. Alternatively, when sales is used to control for firm size (model 7), the signs of the coefficients flip back and the linear term is significant at the 1 percent level. The coefficient on the squared ownership variable continues to be negative, but it is no longer significant at conventional levels. Model 8, which also includes additional control variables, yields similar results. In sum, firm fixed effects in our simulated data panel, both with and without the standard control variables, do not tend to solve the endogeneity problem.

By way of comparison, the first four regressions in Table 10 report the results from fixed-effects regressions using actual Q as the dependent variable. When only CEO ownership and its squared term are included in the regression (model 1), neither coefficient is statistically significant. Adding additional control variables (models 2 through 4) does not change this conclusion. These results are consistent with those reported by Himmelberg, Hubbard, and Palia (1999). One interpretation of this finding is that the inclusion of firm fixed effects adequately controls for the endogeneity problem, so that no relation between firm performance and ownership is detected in the fixed-effects regression specifications. Of course, this would also mean that the use of firm fixed effects obscures what is interesting and important about the contracting and size decisions. In the end, it is desirable to isolate and quantify the economic determinants of variation in organization form.

Another interpretation, however, is that the fixed-effects regression tests lack power because they rely purely on time-series variation within firms to identify the relation between ownership and firm performance (see Zhou (2001)). In this case, z, which represents managerial ability, should vary in the cross-section but, if CEO turnover is low for example, it may not vary much through time. We find that the between-firm variance in the exogenous parameters, z and y, is considerably larger than the within-firm variance of these parameters. Specifically, the between between-firm standard deviation in y (z) is 0.0837 (0.0052), while the within-firm standard deviation in y (z) is 0.0163 (0.0005). As one might expect, there is very little time series variation in the contracting environment, which reduces the signal to noise ratio in the fixed effects regressions. Though outside of our simulated data panel, these results suggest that unobserved heterogeneity at the firm level is likely to be important, but that such a simple specification as firm fixed-effects is also likely to appreciably affect test power.[17]

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[17] Per results reported above in subsection VI.D, we know that the hump-shaped relation between Q and the quadratic form in ownership appears in the cross-section of time-series averages.

D. Simultaneous equations: 2SLS

Paralleling the work that explores the relation between Tobin's Q as the dependent variable and ownership structure as an independent variable is another branch of the literature that reverses the roles of these variables.[18] The idea is that Tobin's Q represents the investment opportunity set and that firms with more growth opportunities, as measured by Q, will need to provide more incentive compensation to managers. Q could be associated with the difficulty of monitoring growth opportunities, which are potentially more subject to managerial discretion, or the ability of the manager to shift the distribution of outcomes (e.g., profits or returns) to the right.

The fact that Tobin's Q and managerial ownership each have served on both sides of the regression specification has prompted other authors, such as Loderer and Martin (1997), Cho (1998), Palia (2001), and Demsetz and Villalonga (2001), to address the endogeneity issue through a simultaneous equations approach to the Q on ownership question. Using the simulated data, we follow these authors by specifying a simultaneous equations system relating Tobin's Q to managerial ownership. We restrict the issues we examine here to those related primarily to specification error.[19]

Table 11 presents the results from estimating three two-equation systems using 2SLS. The upper panel displays coefficient estimates and t-statistics from the second-stage equation where firm performance is the dependent variable and the lower panel presents results from the first-stage equation where managerial ownership is the dependent variable.

In the first system, which is meant to serve as a benchmark for the other two specifications, firm performance (i.e., Q^*) is modeled as a linear function of managerial ownership and functions of z and y. Managerial ownership is a linear function of firm performance and functions of z and y. We choose a parsimonious set of functions of z and y and identify the system by excluding $1/z$

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[18] Early empirical contributions include Clinch (1991), Smith and Watts (1992), Bizjak, Brickley, and Coles (1993), Mehran (1995), and Gaver and Gaver (1993). Another thread in the literature, including Demsetz and Lehn (1985), Aggarwal and Samwick (1999), and Core and Guay (2002), focuses on the debate over the effect of risk on δ.

[19] Related to subsection VII.B. above, note that 2SLS is one computational method often used for implementing the use of instrumental variables. The advantage of 2SLS is that it can efficiently combine information from multiple instruments for over-identified regressions (fewer covariates than instruments).

from the performance equation and $1/y$ from the ownership equation. If the functions of z and y adequately capture the relevant aspects of the contracting environment, then ownership should have little power to explain Q^*, and expected Q^* should have little power to explain ownership. Model 1 in Table 10 confirms this outcome. The estimated coefficients on ownership and EQ^* are close to zero and statistically insignificant.

Of course, the exogenous parameters, productivity of managerial input (z) and physical investment (y) in our case, generally are not directly observable by the researcher. The difficulty then is specifying valid instruments that represent the structural characteristics of the economic problem and also can be used to identify the system of equations. In this spirit, we estimate two systems specifications that are similar to those in the literature. Instruments include leverage, R&D scaled by total assets, advertising scaled by total assets, cash flow volatility, and firm size. Size is measured either by the logarithm of total assets or by the logarithm of sales. As a proxy for cash flow volatility we use the standard deviation of dollar returns (e.g., Aggarwal and Samwick (1999)) using monthly data on stock returns from the Center for Research in Security Prices (CRSP) over the 48 months preceding the observation year. We exclude firm-year observations with less than 24 months of prior return data leaving a final sample of 7,913 firm years.

Model 2 of Table 11 reports the results based on size measured by the logarithm of total assets. CEO ownership depends negatively and significantly on Q^* ($p < 0.001$), as in Bizjak, Brickley, and Coles (1993) and Demsetz and Villalonga (2001), among others. Q^* is positively-related to CEO ownership but the estimated coefficient is not significant ($p = 0.115$). Model 3 relies on the logarithm of sales as the measure of firm size. Again, CEO ownership depends negatively and significantly on EQ^* ($p < 0.001$). Q^* is positively-related to CEO ownership and the estimated coefficient is highly-significant ($p < 0.001$).

Two conclusions immediately follow. One is that the instruments we use do not successfully capture variation in the underlying structural parameters. Regardless of whether our model captures all of the important aspects of the contracting problem, actual leverage, research intensity, advertising effort, cash flow volatility, and size do not capture enough variation in the underlying structural parameters that correspond to productivity of managerial input and physical capital in our model. In this case, the simultaneous equations approach does not eliminate the relationships between the endogenous variables.

The other is that the results are quite sensitive to the instruments chosen. It is likely that total assets and sales are the two most commonly used measures of firm size in empirical work in corporate finance. Using the logarithm of total assets yields a statistically-insignificant relation between Q^* and CEO ownership (Model 2, Table 11). In contrast, using the logarithm of total sales gives rise to a statistically-significant relation between Q^* and CEO ownership (Model 3, Table 11), a result we know to be spurious (based on Model 1).

Overall, we use our model of the performance-ownership relation to illustrate the difficulties in choosing appropriate instruments for simultaneous equation models. If it is possible to extrapolate our conclusions beyond our specific experiment, model misspecification (in either variables or functional form) can significantly affect the inferences drawn from application of simple simultaneous equations methods to other empirical experiments in corporate finance.

8. Conclusion

This paper specifies a structural model of the firm, the Holmström and Milgrom (1987) model augmented with an investment decision, and then uses that model to conduct and evaluate empirical work on the connection between performance and ownership. Inverting the model to data from Execucomp and Compustat, for each firm-year observation we calculate the productivity parameters for input and investment that would give rise to observed ownership and investment as optimal choices in our model. In terms of the economic importance for firm design of the structural productivity parameters, increasing the productivity of managerial input has a strong positive effect on the slope of the optimal contract but very little effect on firm scale and model-generated Q^*. On the other hand, increasing investment productivity has a substantial positive effect on optimal firm scale and a strong negative effect on the slope of the compensation contract and Q^*.

Having estimated the structural parameters from the data, we confront the model with several classes of tests. The bottom line on testing is that if our model is a poor representation of the forces operating in the firm, then the characteristics of model-generated Q^* will not match the data in the same way that actual Q does, the productivity parameters z and y will have little power to explain the data, and the model will not deliver the hump-shaped relation between performance and CEO wealth-performance sensitivity. Then some alternative model could be more suitable. On the other hand, if the empirical examination proposed here shows the model is a good match to the data, then we will conclude that our model captures some of the important determinants of the structure of the firm. Our empirical analysis supports the conclusion that our model performs well.

First, the lower moments of model-generated Q^* accord reasonably well with the same moments of actual Q. We also find that Q^* has significant power to explain actual Q. Second, estimated firm-level productivity parameters vary significantly and as expected across industries. Third, we find that the correlations between model-generated Q^* and R&D intensity, sales, leverage, and advertising effort are statistically significant and have the same sign as the correlations between these variables and actual Q.

Our fourth and final test is based on using the model to examine the performance-ownership relation. The model produces the inverted-U relation when we regress Q^* on CEO ownership and its square. Furthermore, in a regression of actual Q on the CEO ownership, but also including simple transformations of the productivity parameters generated by our model on the right-hand side, the productivity parameters displace almost all of the explanatory power normally supplied by CEO ownership and its square.

Including model-generated EQ^* instead on the right-hand side, however, does not render the ownership variables insignificant. Thus, despite the empirical success of our approach, it is doubtful that our model encompasses all of the relevant economic determinants of firm size and managerial ownership. Nonetheless, variation in the estimated productivity parameters and how those parameters operate through our model of optimal investment and ownership are consistent with the hump-shaped relation between Tobin's Q and managerial ownership. While an established interpretation of the hump is based on a tradeoff between incentive alignment and entrenchment effects, our augmented principal-agent model lends credence to the idea that Q and ownership vary together endogenously, as their underlying determinants, marginal productivity of investment and input, vary in the cross-section and through time. Thus, our model provides an explanation of the empirical relationship between performance and managerial ownership.

We also generate a simulated data panel for which we know the underlying structural model and appropriate empirical specification to examine the importance of specification error and endogeneity in empirical work. In the empirical setting of the connection between performance and ownership, instrumental variables, fixed effects, and simultaneous equations (2SLS) are not particularly successful. Standard approaches to the endogeneity problem typically fail to provide a solution in our empirical context.

In addition to providing an explanation for a prominent empirical reqularity, the construction of our model and its application to data provide one illustration of how quantitative structural models can be applied to a spectrum of empirical questions in corporate finance. The good news is that our procedure provides an example of how a structural model of the firm can isolate the important aspects of governance and quantify the economic significance of incentive mechanisms. Moreover, though we do not do so in this paper, this approach is more likely to permit well-specified tests of competing hypotheses and present the opportunity for conducting analysis of economic policies aimed at changing exogenous aspects of the underlying contracting environment.

As Himmelberg (2002) points out, this is a line of attack that has been employed successfully in other branches of economics. Moreover, our approach is consistent with recent calls by Zingales (2000) and Himmelberg (2002), among others, for a quantitative theory of the firm that is empirically implementable and testable and that allows an assessment of the economic significance of various dimensions of the organization.

There is no reason to assume that the literature on the Q-ownership relation is uniquely amenable to our approach. Other important features of the organization include board composition, leadership structure, compensation policy, dividend policy, capital structure, the corporate charter, poison pills, anti-takeover charter amendments, whether the firm is divisionally or functionally organized, diversification strategy, and product market strategy. Empirical work has used Q, accounting return, and market return as performance measures. The literature has provided reduced-form empirical analysis of almost every possible combination of performance and structure and of structure and structure. We chose the Q-ownership relation because it continues to attract significant attention and resources from researchers. We believe that other empirical questions could benefit from our approach.

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Table 1

Summary Statistics: Effective CEO Ownership and Firm Characteristics

This table provides summary statistics for effective CEO ownership and sample firm characteristics. Data are obtained from the Execucomp and Compustat and consist of 8576 firm-year observations from 1993 to 2000. The effective ownership share of the CEO (δ^*) is computed as the fractional direct stock ownership of the CEO plus the effective fractional ownership arising from the CEO's stock option holdings. Leverage is the ratio of long-term debt to total book assets. Missing values of R&D and advertising expenses are set to zero. Tobin's Q is computed as the book value of assets less the book value of equity plus the market value of equity all divided by the book value of assets.

	Mean	Std. Dev.	Min.	Max.
Effective Ownership Share of CEO (δ^*)	0.0328	0.0565	0.0001	0.5757
Book Assets (I^*) ($Millions)	9654	35507	5.8810	902210
Sales ($Millions)	4270	11297	0.3940	206083
Leverage (Debt) Ratio	0.1879	0.1577	0.0000	0.9993
R&D / Book Assets ($Millions)	0.0314	0.0763	0.0000	2.0907
Advertising / Book Assets ($Millions)	0.0108	0.0360	0.0000	0.5821
Tobin's Q	2.1017	2.0421	0.2983	45.333

Table 2

Summary Statistics: Estimated Productivity Parameters and Modeled Q^*

This table presents summary statistics for endogenous Q^* and exogenous productivity parameters y and z, all based on the model described in Section III. For the calculation of y, z, and "Modeled Tobin's Q^* (x = 0.5)", exogenous parameters are $p = 40$, $r = 4$, $\sigma = 0.333$, and $x = 0.5$. For the calculation of "Modeled Tobin's Q^* ($x = 0.75$)", x = 0.75, while all other exogenous parameters remain the same. Panel A reports the results for CARA utility, while Panel B displays the results for CRRA utility. For comparison purposes, the actual Tobin's Q (from Table 1) is reported in Panel C.

Panel A: CARA

	Mean	Median	Std. Dev.	Min.	Max.
y (x=0.5)	0.56108	0.56752	0.08499	0.11911	0.75179
z (x=0.5)	0.00128	0.00004	0.00632	0.00000	0.14690
Modeled Tobin's Q* (x=0.5)	1.8305	1.7586	0.3673	1.3308	8.1486
Modeled Tobin's Q* (x=0.75)	1.8647	1.7636	0.4383	1.3247	8.4258

Panel B: CRRA

	Mean	Median	Std. Dev.	Min.	Max.
y (x=0.5)	0.56108	0.56751	0.08499	0.11911	0.75179
z (x=0.5)	0.00229	0.00006	0.01191	0.00000	0.34865
Modeled Tobin's Q* (x=0.5)	1.8304	1.7597	0.3673	1.3296	8.6398
Modeled Tobin's Q* (x=0.75)	1.7824	1.7256	0.5124	-8.1137	8.1976

Panel C: Tobin's Q from Compustat

	Mean	Median	Std. Dev.	Min.	Max.
Actual Tobin's Q (for comparison)	2.1017	1.5049	2.0421	0.2983	45.333

Table 3

Comparative Statics Results for Ownership, Investment, and Model Q^*

This table presents comparative statics results for Effective Ownership (δ^*), Investment (I^*), and Model EQ^* in exogenous parameters z, y, σ, r, p, and x based on the CARA model described in Section I and III.A. The benchmark values for the exogenous parameters are z=0.00004, y=0.56752 (median values, based on CARA from Panel A of Table 2), p=40, r=4, σ=0.333, and x=0.5.

Percent Changes for a 10% increase in parameter

	baseline	z	y	p	r	σ	x
CEO Ownership (δ^*)	0.0125	4.849	-4.626	0.000	-4.626	-9.129	-30.171
Investment ($I*$)	1367.59	-0.005	283.797	24.663	0.000	-0.001	-0.004
Modeled Tobin's EQ^*	1.7618	0.000	-9.091	0.000	0.000	0.000	0.000

Percent Changes for a 10% decrease in parameter

	baseline	z	y	p	r	σ	x
CEO Ownership (δ^*)	0.0125	-5.101	5.374	0.000	5.373	10.923	43.090
Investment ($I*$)	1367.59	0.005	-65.123	-21.627	0.000	0.001	0.004
Modeled Tobin's EQ^*	1.7618	0.000	11.112	0.000	0.000	0.000	0.000

Table 4

Estimated Parameters and Endogenous Variables by Industry

This table presents median values for estimated parameters (δ^* and assets I^*) as well as median values and standard deviations for endogenous variables (y, $z \times 10^4$, and $\frac{z}{y} \times 10^4$) for 30 different industry groups, sorted descending by $\frac{z}{y} \times 10^4$. N denotes the number of observations in each industry group. Panel A displays estimates for the CARA model described in Section III.A, while Panel B shows estimates for the CRRA model described in Section III.B. Industry groups are based on Ken French's classification available at http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/index.html.

Panel A: CARA Utility

				Median Values			**Standard Deviation**		
Industry Name	N	I^*	δ^*	y	$z \times 10^4$	$\frac{z}{y} \times 10^4$	y	$z \times 10^4$	$\frac{z}{y} \times 10^4$
Recreation	130	1,047	0.025	0.555	1.425	2.737	0.097	38.55	73.79
Personal business	639	557	0.023	0.519	1.219	2.479	0.073	102.27	216.73
Healthcare	677	616	0.023	0.526	1.058	2.395	0.106	26.75	60.58
Restaurants	163	467	0.022	0.510	1.175	2.112	0.077	25.83	50.48
Business Equipment	911	642	0.021	0.528	0.954	1.904	0.084	44.98	84.15
Apparel	118	470	0.019	0.509	0.911	1.689	0.055	71.90	133.11
Retails	540	1,102	0.018	0.557	0.772	1.423	0.071	60.74	125.96
Textiles	74	924	0.017	0.548	0.692	1.235	0.038	82.30	185.14
Transportation	223	1,308	0.016	0.564	0.746	1.170	0.068	143.25	277.69
Consumer Goods	151	1,208	0.015	0.562	0.551	1.051	0.073	46.75	87.14
Construction	297	998	0.015	0.551	0.477	0.970	0.063	94.32	196.84
Beer and Liquor	20	6,406	0.014	0.620	0.507	0.915	0.047	5.22	9.08
Wholesale	302	1,205	0.014	0.561	0.461	0.869	0.067	35.39	66.24
Products Machinery	341	731	0.013	0.536	0.422	0.802	0.066	24.88	56.34
Others	175	1,330	0.012	0.566	0.352	0.611	0.080	72.80	158.40
Steel Works	242	1,179	0.011	0.560	0.326	0.564	0.058	113.09	197.19
Printing, Publishing	155	1,224	0.011	0.562	0.305	0.551	0.050	14.27	28.16
Automobiles Trucks	205	1,537	0.011	0.573	0.321	0.549	0.084	19.31	37.69
Electrical	96	1,058	0.011	0.555	0.268	0.499	0.058	31.60	59.11
Financials	1,177	11,277	0.01	0.651	0.307	0.487	0.068	71.43	127.58
Aircraft, Ships, Railroads	62	3,677	0.009	0.611	0.224	0.364	0.054	38.40	73.75
Food Product	214	2,276	0.009	0.589	0.188	0.364	0.076	98.98	242.20
Chemicals	276	1,477	0.008	0.571	0.161	0.268	0.067	22.66	49.40
Business Supplies	237	2,090	0.007	0.587	0.141	0.245	0.072	13.66	27.53
Petroleum, Gas	379	1,972	0.007	0.585	0.134	0.227	0.070	8.21	14.53
Mining	97	769	0.005	0.538	0.056	0.122	0.066	0.57	1.13
Communication	204	9,146	0.005	0.644	0.064	0.102	0.092	48.29	91.35
Tobacco Products	16	26,426	0.003	0.635	0.033	0.058	0.078	0.10	0.19
Utilities	455	4,223	0.003	0.616	0.019	0.032	0.047	1.82	3.11

Panel B: CRRA Utility

				Median Values			**Standard Deviation**		
Industry Name	N	I^*	δ^*	y	$z \times 10^4$	$\frac{z}{y} \times 10^4$	y	$z \times 10^4$	$\frac{z}{y} \times 10^4$
Recreation	677	616	0.023	0.525	2.218	4.972	0.105	83.94	214.86
Personal business	639	557	0.023	0.518	2.233	4.673	0.074	232.27	637.15
Healthcare	130	1,047	0.025	0.555	1.948	4.402	0.096	87.18	148.25
Restaurants	911	642	0.021	0.528	1.723	3.270	0.084	79.76	176.17
Business Equipment	163	467	0.022	0.510	1.612	3.245	0.077	72.43	153.47
Apparel	118	470	0.019	0.508	1.371	2.986	0.056	96.45	190.11
Retails	74	924	0.017	0.548	1.222	2.239	0.039	134.55	318.88
Textiles	540	1,102	0.018	0.557	1.071	2.007	0.071	128.88	289.68
Transportation	223	1,308	0.016	0.564	1.025	1.819	0.070	256.88	556.14
Consumer Goods	297	998	0.015	0.551	0.730	1.411	0.063	157.87	389.38
Construction	302	1,205	0.014	0.560	0.704	1.333	0.067	60.41	121.19
Beer and Liquor	151	1,208	0.015	0.562	0.609	1.197	0.073	36.78	72.86
Wholesale	341	731	0.013	0.535	0.577	1.100	0.066	58.12	131.08
Products Machinery	242	1,179	0.011	0.560	0.551	1.013	0.058	120.21	217.07
Others	175	1,330	0.012	0.566	0.484	0.866	0.080	100.14	221.50
Steel Works	155	1,224	0.011	0.562	0.409	0.786	0.050	21.31	42.98
Printing, Publishing	205	1,537	0.011	0.573	0.399	0.724	0.084	25.20	57.77
Automobiles Trucks	96	1,058	0.011	0.555	0.368	0.711	0.057	48.66	92.47
Electrical	20	6,406	0.014	0.620	0.432	0.679	0.047	4.92	8.59
Financials	1,177	11,277	0.01	0.651	0.348	0.559	0.069	122.94	247.40
Aircraft, Ships, Railroads	276	1,477	0.008	0.571	0.217	0.430	0.067	53.07	118.72
Food Product	214	2,276	0.009	0.590	0.240	0.415	0.079	218.28	590.08
Chemicals	379	1,972	0.007	0.585	0.196	0.334	0.070	12.03	23.46
Business Supplies	237	2,090	0.007	0.587	0.168	0.304	0.072	21.33	44.14
Petroleum, Gas	97	769	0.005	0.538	0.119	0.231	0.066	1.45	2.98
Mining	62	3,677	0.009	0.611	0.114	0.170	0.054	128.57	246.31
Communication	204	9,146	0.005	0.644	0.061	0.094	0.092	76.38	151.21
Tobacco Products	455	4,223	0.003	0.616	0.035	0.062	0.047	8.13	13.98
Utilities	16	26,426	0.003	0.635	0.014	0.025	0.078	0.04	0.08

Table 5
Pearson/Spearman Correlation Matrix

Correlation matrix of Ownership share of the CEO (δ^*), Book Assets (I^*), Sales, Leverage, R&D, Advertising, Actual Tobin's Q, and Modeled Tobin's Q* values generated from calibrations of the model described in Section III for CARA and CRRA utility. Pearson correlations are below the diagonal and Spearman rank-correlations are above the diagonal. R&D and advertising are scaled by book value of assets. Data are obtained from the Execucomp and Compustat databases and consist of 8576 firm-year observations from 1993 to 2000. Superscripts *a*, *b*, and *c* indicate levels of significance of 1%, 5%, and 10%, respectively.

								CARA Utility			**CRRA Utility**		
	δ^*	I*	Sales	Debt Ratio	R&D	Advertising	Act. Q	Mod. Q*	y	z	Mod. Q*	y	z
Ownership		-.56^a	-.52^a	-.10^a	.07^a	-.01	.11^a	.55^a	-.56^a	.99^a	.55^a	-.56^a	.98^a
Assets (I^*)	-.11^a		.86^a	.19^a	-.26^a	-.08^a	-.29^a	-.99^a	.99^a	-.52^a	-.99^a	.99^a	-.63^a
Sales	-.13^a	.58^a		.19^a	-.34^a	.05^b	-.16^a	-.85^a	.86^a	-.49^a	-.85^a	.86^a	-.61^a
Debt Ratio	-.02^b	-.04^a	.01		-.41^a	-.06^b	-.28^a	-.19^a	.19^a	-.08^a	-.19^a	.19^a	-.09^a
R&D	.03^c	-.07^a	-.10^a	-.25^a		-.18^a	.41^a	.26^a	-.25^a	.05^a	.26^a	-.25^a	.09^a
Advertising	.04^c	-.10^a	-.08^a	-.09^a	-.10^a		.12^a	.08^a	-.08^a	-.01	.08^a	-.08^a	-.01
Actual Q	.07^a	-.09^a	-.04^a	-.22^a	.29^a	.04		.29^a	-.29^a	.09^a	.29^a	-.29^a	.09^a
CARA													
Modeled Q^*	.24^a	-.27^a	-.30^a	-.18^a	.52^a	.10^a	.24^a		-.99^a	.51^a	.99^a	-.99^a	.62^a
y (x=0.5)	-.32^a	.41^a	.42^a	.16^a	-.41^a	-.11^a	-.24^a	-.91^a		-.53^a	-.99^a	.99^a	-.64^a
z (x=0.5)	.84^a	-.04^a	-.05^a	.01^a	-.04^a	.04	.01	.07^a	-.13^a		.51^a	-.53^a	.97^a
CRRA													
Modeled Q^*	.24^a	-.27^a	-.30^a	-.18^a	.52^a	.10^a	.24^a	.98^a	-.90^a	.06^a		-.99^a	.62^a
y (x=0.5)	-.32^a	.41^a	.42^a	.16^a	-.41^a	-.11^a	-.24^a	-.91^a	.99^a	-.13^a	-.90^a		-.64^a
z (x=0.5)	.77^a	-.04^a	-.05^a	.00	-.02	.02	.04^a	.13^a	-.19^a	.85^a	.10^a	-.19^a	

Table 6

Pooled OLS Regressions of Actual Q and Modeled Q^* on Ownership

Pooled OLS regression of actual Q and modeled Q^* (Section III) on the ownership share of the CEO(δ) and the squared ownership share of the CEO (δ^2). Data are obtained from the Execucomp and Compustat databases and consist of 8576 firm-year observations from 1993 to 2000. Robust t-statistics are given in parentheses (Rogers (1993)). Superscripts a, b, and c indicate levels of significance of 10%, 5%, and 1%, respectively.

	Actual Q	**Modeled Q***			
		CARA		**CRRA**	
	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	1.9112	1.7223	1.7375	1.7244	1.7189
	(76.17^c)	(359.4^c)	(272.75^c)	(345.56^c)	(197.4^c)
$\delta = \delta^*$	8.6069	4.7574	3.2549	4.6143	5.0937
	(9.00^c)	(20.09^c)	(9.54^c)	(18.16^c)	(9.61^c)
$\delta^2 = (\delta^*)^2$	-21.4634	-11.1475	4.6179	-10.4713	-24.2490
	(-8.38^c)	(-14.12^c)	(3.19^c)	(-11.81^c)	(-10.29^c)
Adjusted R^2	0.0116	0.1161	0.3069	0.1114	0.1833

Table 7

Productivity Parameters and Endogenous Variables by Ownership Decile

This table ranks firms into CEO effective ownership deciles and reports the median values of optimal investment (I^*, in \$ millions), effort (g^*), effective CEO ownership (δ^*), model-generated Q*, as well as the calibrated productivity parameters z and y for every decile. Data are obtained from the Execucomp and Compustat databases and consist of 8576 firm-year observations from 1993 to 2000. Calibration of the model is described in Section III.

Decile	δ^*	**I***	**g***	**Q***	**y**	**z**
small = 1	0.001328	12,146	0.000009	1.5309	0.653069	0.000000
2	0.003120	5,101	0.000073	1.6030	0.623280	0.000003
3	0.005283	3,871	0.000239	1.6317	0.612765	0.000007
4	0.007706	2,041	0.000425	1.7057	0.586088	0.000015
5	0.011140	1,292	0.000812	1.7667	0.564844	0.000031
6	0.015534	910	0.001615	1.8211	0.547129	0.000058
7	0.022341	678	0.003038	1.8838	0.531309	0.000114
8	0.033136	529	0.008995	1.9345	0.517142	0.000255
9	0.054762	423	0.034220	1.9872	0.503719	0.000679
large = 10	0.136734	540	0.863668	1.9307	0.515008	0.004730

Table 8

Nonlinear Regression of Tobin's Q on Ownership and Productivity Parameters

Correctly specified nonlinear OLS regression of actual Q and modeled Q^* on the ownership share of the CEO (δ), squared ownership share of the CEO (δ^2), model-generated expected EQ^*, and control variables. Data are obtained from the Execucomp and Compustat databases and consist of 8576 firm-year observations from 1993 to 2000. Robust t-statistics are given in parentheses (Rogers (1993)). Superscripts a, b, and c indicate levels of significance of 10%, 5%, and 1%, respectively.

	Actual Q			**Modeled Q^***		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	-0.3553	-0.3071	-31.8452	0.0043	0.0045	-0.2494
	(-1.30)	(-1.10)	(-0.91)	(1.45)	(1.48)	(-0.91)
EQ^*	1.3424	1.2880		0.9977	0.9974	
	(8.79)	$(7.94)^c$		$(603.09)^c$	$(561.44)^c$	
$\delta = \delta^*$		2.4967	2.1258		0.0082	-0.0088
		$(2.49)^b$	(1.19)		(0.87)	(-0.34)
$\delta^2 = (\delta^*)^2$		-7.1228	-51.92		-0.0085	0.5891
		$(-2.99)^c$	(-1.09)		(-0.33)	(0.65)
y			44.59			0.4271
			(0.77)			(0.97)
z			215.81			-4.2794
			(0.82)			(-0.86)
y^2			-22.38			-0.2567
			(-0.67)			(-1.03)
z^2			-532.81			1.2267
			(-1.41)			(0.17)
$\frac{1}{y}$			10.36			1.0603
			(1.23)			(15.43)
$\frac{1}{z}$			0.0000			0.0000
			(0.05)			(0.96)
$\frac{1}{y^2}$			-0.8242			-0.0052
			(-1.32)			(-0.95)
$\frac{1}{z^2}$			0.0000			0.0000
			(0.52)			(-0.72)
yz			-100.12			2.2996
			(-0.44)			(0.56)
$\frac{1}{yz}$			0.0000			0.0000
			(-0.09)			(-0.92)
Adjusted R^2	0.0575	0.0584	0.0672	0.9982	0.9982	0.9982

Table 9

Pooled OLS Regression of Tobin's Q on CEO Ownership and Control Variables

Misspecified pooled OLS regression of actual Q and modeled Q* (x=0.5) on CEO ownership and control variables. Data are obtained from the Execucomp and Compustat databases and consist of 8576 firm-year observations from 1993 to 2000. Models 1 and 4 regress actual Q and modeled Q* on the ownership share of the CEO (δ) and the squared ownership share of the CEO (δ)and add the natural logarithm of assets and its squared value as control variables. Models 2 and 5 use the natural logarithm of sales and its squared value as control variables instead, and Models 3 and 6 add leverage ratio, research and development (R&D) and advertising expenditures (both scaled by book value of assets). To control for industry effects, Models 3 and 6 also include unreported dummy variables for the 2-digit SIC codes. Robust t-statistics are given in parentheses (Rogers (1993)). Superscripts a, b, and c indicate levels of significance of 10%, 5%, and 1%, respectively.

	Actual Q			**Modeled Q***		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	6.6502	6.5486	N/A	5.2162	3.9709	N/A
	(11.97^c)	(10.67^c)		(38.09^c)	(27.09^c)	
$\delta = \delta^*$	1.6203	4.0251	3.1556	-0.2772	1.1163	0.6192
	(1.69^a)	(4.33^c)	(3.24^c)	(-3.19^c)	(9.34^c)	(5.28^c)
$\delta^2 = (\delta^*)^2$	-5.0150	-10.2879	-7.3724	0.7013	-2.3890	-1.1514
	(-2.20^b)	(-4.51^c)	(-3.20^c)	(3.46^c)	(-7.09^c)	(-4.05^c)
ln(Assets)	-1.0053			-0.7477		
	(-7.39^c)			(-21.59^c)		
ln(Assets)^2	0.0494			0.0372		
	(6.13^c)			(17.71^c)		
ln(Sales)		-1.1327	-0.2296		-0.4658	-0.3926
		(-6.82^c)	(-1.87^a)		(-11.64^c)	(-10.86^c)
ln(Sales)^2		0.0661	0.0129		0.0215	0.0168
		(6.05^c)	(1.61)		(8.19^c)	(7.13^c)
Leverage			-2.1615			-0.1858
			(-12.21^c)			(-10.11^c)
R&D/Assets			4.6580			0.7215
			(3.71^c)			(2.93^c)
Advertising/Assets			2.2226			0.2542
			(3.92^c)			(4.59^c)
Industry Dummies	no	no	yes	no	no	yes
Adjusted R^2	0.0574	0.0579	0.2085	0.8675	0.6722	0.7625

Table 10

Fixed Effects Regression of Tobin's Q on Ownership and Control Variables

Misspecified firm fixed effects regression of actual Q and modeled Q* (x=0.5) on CEO ownership (δ) and control variables. Data are obtained from the Execucomp and Compustat databases. Following Himmelberg et al (1999), we require 3 years of data, which reduces the sample size to 7562 firm-years from 1993 to 2000. Models 1 and 5 regress Q and modeled Q* on the ownership share of the CEO and the squared ownership share of the CEO. Models 2 and 6 add the natural logarithm of investment and its squared value as control variables. Models 3 and 7 use the natural logarithm of sales and its squared value as control variables, and Models 4 and 8 add leverage ratio, as well as research and development (R&D) and advertising expenditures (both normalized by book value of assets). Robust t-statistics are given in parentheses (Rogers (1993)). Superscripts a, b, and c indicate levels of significance of 10%, 5%, and 1%, respectively.

	Actual Q				**Modeled Q***			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
$\delta = \delta^*$	1.1205	0.7031	2.0267	2.2566	1.5519	-0.0606	0.6598	0.5255
	(0.89)	(0.55)	(1.60)	(1.80)	(8.70^c)	(-0.53)	(4.13^c)	(3.87^c)
$\delta^2 = (\delta^*)^2$	-2.4550	-2.0842	-4.0254	-4.4785	-2.0488	0.3903	-0.6204	-0.6255
	(-0.67)	(-0.56)	(-1.09)	(-1.23)	(-3.92)	(1.18)	(-1.33)	(-1.58)
ln(Assets)		-0.9197				-0.9262		
		(-6.86^c)				(-77.09^c)		
ln(Assets)^2		0.0630				0.0483		
		(7.16^c)				(61.28^c)		
ln(Sales)			-0.0918	-0.0134			-0.2327	-0.1965
			(-0.96)	(-0.14)			(-19.32^c)	(-19.14^c)
ln(Sales)^2			0.0204	0.0189			0.0057	0.0040
			(2.89^c)	(2.71^c)			(6.40^c)	(5.35^c)
Leverage				-1.9868				-0.1815
				(-12.06^c)				(-10.17^c)
R&D/Assets				0.8929				1.7079
				(2.70^c)				(47.73^c)
Advertising/Assets				0.1265				-0.0172
				(0.17)				(-0.22)
Adjusted R^2	0.6422	0.6451	0.6442	0.6527	0.8525	0.9415	0.8839	0.9163

Table 11

Two-Stage Least-Squares Regressions of CEO Ownership and Tobin's Q

Two-Stage Least-Squares Regressions of CEO ownership and modeled Q* ($x = 0.5$) and control variables. Data are obtained from the Execucomp and Compustat databases and consist of 7913 firm-year observations from 1993 to 2000. Panel A displays regressions on modeled Q*. Panel B shows corresponding regressions on CEO effective ownership ($\delta = \delta^*$). Control variables include the leverage ratio, research and development (R&D) and advertising expenditures (both scaled by book value of total assets) and the natural logarithm of total assets (ln(Total Assets)) and of sales (ln(Sales)). ln(CF Volatility) is the natural logarithm of cash flow volatility. Robust t-statistics are given in parentheses (Rogers (1993)). Superscripts a, b, and c indicate levels of significance of 1%, 5%, and 10%, respectively.

Panel A: Independent Variable is Modeled Q*

	Model 1		**Model 2**		**Model 3**	
	Coefficient	**t-stats**	**Coefficient**	**t-stats**	**Coefficient**	**t-stats**
Intercept	0.0326	(-1.04)	1.3665	(-1.38)	1.3530	(3.85)^a
δ	0.0055	(-0.03)	15.1784	(-1.58)	15.3422	(4.40)^a
y	-0.0531	(-0.84)				
y^2	0.0293	-0.8				
$\frac{1}{y}$	0.9933	(426.85)^a				
z	-0.9535	(-0.29)				
z^2	-3.6562	(-0.2)				
yz	-0.4643	(-0.44)				
Leverage/Assets			-0.0808	(-1.29)	-0.0795	(-1.29)
R&D/Assets			2.145	(3.65)^a	2.146	(8.40)^a
Advertising/Assets			-0.4902	(-1.31)	-0.4439	(-1.19)
ln(Assets)			-0.011	(-0.12)		
ln(Sales)					-0.0104	(-0.32)

Panel B: Independent Variable is effective CEO Ownership ($\delta = \delta^*$)

	Model 1		**Model 2**		**Model 3**	
	Coefficient	**t-stats**	**Coefficient**	**t-stats**	**Coefficient**	**t-stats**
Intercept	0.1264	(5.64)^a	0.2157	(10.59)^a	0.1512	(8.01)^a
EQ*	-0.0040	(-1.37)	-0.0391	(-5.93)^a	-0.0196	(-3.21)^a
y	-0.2346	(-4.35)^a				
y^2	0.0997	(2.46)^b				
z	15.508	(46.87)^a				
z^2	-85.7237	(-89.69)^a				
$\frac{1}{z}$	0.0000	(-3.60)^a				
yz	-4.4732	(-7.33)^a				
ln(CF Volatility)			-0.0016	(-2.25)^b	-0.0047	(-6.72)^a
ln(Assets)			-0.0141	(-10.79)^a		
ln(Sales)					-0.0086	(-7.10)^a