Structural Models and Endogeneity in Corporate Finance

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ABSTRACT

First, this paper specifies a structural model of the firm, the standard principal-agent model augmented with an investment decision, and then uses that model to conduct empirical work on the connection between performance and ownership. We calibrate the model exactly to data on managerial ownership and the level of investment in productive assets from Execucomp and Compustat. For each firm-year observation, this generates estimates of structural productivity parameters for both investment and managerial input. Based on variation in these exogenous parameters, we find that Tobin's Q and managerial ownership exhibit the patterns documented in McConnell and Servaes (1990). Thus, our augmented principal-agent model can explain the hump-shaped empirical relation between performance and managerial ownership. No additional factors, such as managerial entrenchment overtaking incentive alignment at high ownership levels, are required.

Second, the calibration creates a data panel for which we *know* the underlying structural model and appropriate empirical specification. This allows us to quantify the statistical and economic importance of specification error and endogeneity in empirical work. Including firm fixed effects or controls for firm size (investment or sales) adds explanatory power, but the spurious relation between Q and managerial ownership typically remains. In this setting, standard approaches to the endogeneity problem fail to provide a solution. The endogeneity problem, in this empirical context, is substantial and it is difficult to correct using control variables and fixed effects.

Accordingly, our analysis demonstrates: (1) the importance of specifying and estimating a structural model of the firm; and (2) how a structural model of the firm can be applied to isolate the important aspects of governance and quantify the economic significance of incentive mechanisms.

Corporate finance, broadly defined, is concerned with a wide spectrum of organizational features and aspects of firm performance. Dimensions of particular interest include managerial compensation, board structure, 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. To this point, the literature has accumulated an impressive array of suggestive empirical facts. One benefit of this research is that it appears to sensitize investors, academics, policy-makers, and the general public to the importance of corporate governance.

Nevertheless, there are good reasons for concern about the integrity of the empirical groundwork in corporate finance. Most observations and associated inferences/interpretations are based on estimated coefficients from reduced-form regressions of either performance on structure or structure on other structure variables. Despite early mention of the issue (e.g., Koopmans and Hood (1953) and Demsetz (1983)) and general awareness of the problem, relatively few studies go beyond a simple mention of the empirical difficulties associated with endogeneity, much less specify and test a structural model of the firm. If organization structure in equilibrium is endogenously-determined, then there is a legitimate possibility that any understanding of both the relations among organizational features and the connection of structure to performance is based on spurious results from misspecified experiments.

To be more specific, consider the case in which all dimensions of the firm's governance structure, including CEO pay-performance sensitivity, ownership structure, board composition, leadership structure, and antitakeover devices, are chosen jointly as a value-maximizing package. Relatively exogenous or predetermined variables, such as legal rules and institutions, growth opportunities, the nature of the product markets, and the market for corporate control, determine the optimal combination of governance features. Under this scenario, one would not necessarily expect to observe (in equilibrium) a relation between performance, such as Q, and a governance device, such as managerial ownership or pay-performance sensitivity, along the value-maximizing envelope of optimal organization forms. If OLS regressions, for example, detect such a relation in the data, then it is reasonable to suspect that the result is due to omission of some important aspect of the environment that drives both performance and ownership (or the structure of compensation) together. Restated, "performance-structure" regressions, such as Q on managerial ownership, reveal little about causation and more about equilibrium Q and ownership. This concern applies with equal force to regressions of performance on other governance features or of one governance feature on another. See Himmelberg (2002) for a clear and persuasive discussion of this textbook complaint.

The above-mentioned example, analysis of the relation between performance and managerial ownership, comprises a nontrivial segment of the empirical corporate finance literature. The highly-influential paper of Morck, Shleifer, and Vishny (1988), hereafter MSV, documents a nonmonotonic relation between Tobin's Q and managerial stock ownership.[1] McConnell and Servaes (1990), hereafter MS, using different data, report an "inverted-U" or "hump-backed" relation between Q and managerial ownership. While these authors were reluctant to attribute causation, others were not. Certainly it is possible to construct an intuitively-appealing explanation for the MS relation. For example, one interpretation is that incentive alignment effects dominate at first for low inside ownership, but then, 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.[2] Taken to the extreme, firm value is maximized if shareholders (or regulators, perhaps) can coerce managers into owning precisely the amount of stock

associated with the peak of the estimated relation between Q and inside ownership. For example, based on McConnell and Servaes (1990, Table 1, Panel (B), regression (1), 1986 data), maximum Q

[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 Stulz (1988) for a theoretical presentation of these offsetting costs and benefits of managerial ownership.

requires about 37.5 percent inside ownership. But if 37.5 percent managerial ownership maximizes value, why would other combinations of ownership and Q even appear in the data? One possibility is that empiricists have identified an out-of-equilibrium phenomenon. On the other hand, given that it is standard to use models of optimization and equilibrium as heuristics to explain the data, an alternative is that the inverted-U pattern is an equilibrium relation.[3] The challenge for those who operate in the equilibrium paradigm, in this particular empirical context or any other, is to address the endogeneity problem either by specifying and estimating a structural model of the firm or by implementing suitable econometric remedies.[4]

While other empirical agendas would be equally suitable, the performance-ownership literature is a natural context in which to take up this challenge. There are numerous other articles, following MSV (1988) and MS (1990), that examine the relation between Q and inside ownership.[5] Several recent papers explicitly address the endogeneity problem in the performance-ownership relation by using potentially more appropriate econometric techniques. Of interest in this regard are Agrawal and Knoeber (1996, simultaneous equations), Loderer and Martin (1997, simultaneous equations), Cho (1998, simultaneous equations), Himmelberg, Hubbard, and Palia (1999, firm fixed effects and controls for firm heterogeneity), and Palia (2001, two-stage least squares with instrumental variables). In the end, the econometric fixes, while enhancing the integrity of the empirical analysis, have produced varying results and, therefore, no consensus on the relation between managerial

[3] Hermalin and Weisbach (1998) comment on the difficulties of distinguishing empirically between equilibrium and out-of-equilibrium phenomena.

[4] An intermediate possibility is that ownership and Q are determined by value-maximization in the presence of transactions costs, so that observed combinations of Q and ownership depart from the zero-transaction-cost optimum. In this case, based on departures from the benchmark provided by the Coase Theorem, to explore the observed combination of Q and ownership one would include control variables precisely in order to account for the relevant transaction costs.

[5] A small selection includes Demsetz and Lehn (1985), Mehran (1995), Hermalin and Weisbach (1991), Holderness, Kroszner, and Sheehan (1999), Aggarwal and Samwick (1999), La Porta, Lopez de Silanes, Shleifer, and Vishny (2002), and Claessens, Djankov, Fan, and Lang (2002). One indicator of the influence of MSV (1988) and MS (1990) is that a large number of papers seek to test for the MSV and MS effects in data from countries other than the U.S. For recent examples, see Renneboog and Trojanowski (2002) for the UK, Seifert, Gonenc, and Wright (2002) for the UK, Germany, and Japan, Bohren and Odegaard (2001) for Norway, and Alves and Mendes (2002) for Portugal, and Lins (2003) for numerous countries.

ownership and firm performance.[6]

This paper makes three contributions to the literature. First, we specify a structural model of the firm and then use that model to conduct empirical work on the connection between performance and ownership. We employ the principal-agent model of Holmström (1979) and Holmström and Milgrom (1987), but augment that model with an investment decision. Exogenous parameters specify managerial risk aversion, standard deviation of returns, profit margin, how cash flow volatility depends on scale, productivity of managerial effort, and productivity of investment. The shareholders choose investment (assets) and ownership/compensation of the manager, and the manager chooses effort, which is not observable to the principal. This specific model has substantial appeal, because, since the early papers of Holmström (1979) and others, much of our intuition about the role of ownership (or sensitivity of CEO wealth to performance) arises from the basic principal-agent problem.

We then calibrate the model to data by matching model-generated, value-maximizing managerial ownership and investment to actual firm data from Execucomp and Compustat. In particular, for each firm-year observation, we calculate the productivity parameters for effort and investment that would give rise to observed ownership and investment as optimal choices in our model. This allows us to assess the economic importance for the structure of the firm of the structural productivity parameters. Based on the model, increasing the effort productivity parameter has a strong positive effect on the slope of the optimal contract but very little effect on firm scale and Q. On the other hand, the investment productivity parameter has a substantial positive effect on optimal firm scale and a strong negative effect on the slope of the compensation contract and Q.

Having fitted the model to the data, we then go outside the model to examine the performance-ownership relation. In particular, our tests show that our model is consistent with the hump-shaped relation between Q and managerial ownership documented by MS (1990) and many others.

[6] Demsetz and Villalonga (2001, Figure 1) illustrate the extent to which various studies, using different data and estimation techniques, generate a wide range of results.

Moreover, the ratio of the estimated parameter on managerial ownership to that on managerial ownership squared is similar to what we obtain when we estimate the McConnell and Servaes (1990) model using our Execucomp and Compustat data. Of course, in our model this relation is generated endogenously through variation in the structural productivity parameters. Thus, our augmented principal-agent model can explain the empirical relation between performance and managerial ownership. No additional factors, such as managerial entrenchment swamping incentive alignment at high ownership levels, are required. Nonetheless, we do not provide a formal test of our model versus the entrenchment model.

Our second contribution is to evaluate the statistical and economic relevance of the endogeneity problem and whether standard econometric approaches to endogeneity are effective. The opportunity to do so arises because, as described above, 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. We then turn the model around: we assume the calibrated model is correct and then use the model to generate the data, specifically endogenously-determined Q. In essence, by this calibration and with the addition of simulated disturbance terms (with a distribution specified in the original underlying agency problem), we create a data panel for which we *know* the underlying structural model and appropriate empirical specification. It is no surprise that we find that regressions with no specification error explain essentially all variation in model-generated Q and that the correctly-specified structural variables remove all explanatory power from endogenously-determined ownership and ownership squared. Misspecified regression models, however, continue to yield a relation between performance and ownership that is similar to that documented in McConnell and Servaes (1990). Moreover, controls for firm size (assets, sales), leverage, R&D expense, advertising expense, and industry add explanatory power, but the spurious relation between Q and managerial ownership typically remains. The same statement applies to the addition of firm fixed effects. Thus, in our simple empirical setting, the conclusion is that endogeneity can be a severe problem and standard empirical approaches to endogeneity often fail to provide a solution.

Our third contribution, while closely-related to the first, has broader implications. Essentially, the construction of our model and its application to data provide an illustration of how quantitative structural models can be applied to a spectrum of empirical questions in corporate finance. While the bad news is that the endogeneity problem is substantial and it is difficult to correct using control variables and fixed effects, 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. 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.

Section I presents and analyzes a principal-agent model augmented by an investment/scale choice. Section II describes our sample. Section III calibrates the model to data on managerial ownership and total assets and assesses the economic importance of changes in the structural parameters for investment and ownership. Section IV shows that the fitted model generates the hump-shaped relation between Tobin's Q and managerial ownership. Section V examines the severity of the endogeneity problem and assesses the effectiveness of standard econometric solutions. Section VI examines the same issues in a different branch of the literature. In particular, when we consider regressions of managerial ownership on Q, where Q is interpreted as a measure of intangible assets and/or growth opportunities, our general conclusions are much the same as for the specification of Q on ownership. Section VII concludes.

I. Optimizing Choice of Ownership and Investment

Our model specifies 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 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, gross of initial investment, 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 effort. Assets (I) can include property, plant, and equipment as well as other intangible assets. Effort and investment interact in the production function, $I^y g^z$, with parameters $y \in (0,1)$ and $z \in (0,1)$, which determine the productivity of assets and managerial effort, respectively. Production is scaled by $p > 1$, which 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, $\tilde{\varepsilon} \sim N(0, \sigma^2)$ is idiosyncratic firm risk, perhaps from a technology shock, and is scaled by a function of investment, I^x, where $x > 0$. We scale $\tilde{\varepsilon}$ because it is reasonable to assume that an additive cash flow shock depends on firm size.

The manager's utility function is

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

where $\tilde{w}$ is the uncertain wage, $C(g)$ is the money equivalent cost of effort, and r is a parameter determining the degree of risk aversion. For algebraic convenience, let the cost of effort be linear, $C(g) = g$, and define the manager's reservation utility constraint as $E[U] \geq -e^{-r(0)} = -1$. Expected utility is

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

Following Holmström and Milgrom (1987) 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

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

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

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

which is increasing in ownership (or slope of the compensation scheme, $\phi'(\tilde{f})$), δ, margin, p, investment, I, and parameters that determine the marginal productivity of effort, z, and investment, y.[7] Shareholders maximize expected total surplus

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

subject to the reservation utility constraint that

$$\alpha + \delta E[\tilde{f}] - \frac{r}{2}\delta^2 I^{2x}\sigma^2 - g = \alpha + \delta p I^y g^z - \frac{r}{2}\delta^2 I^{2x}\sigma^2 - g \geq 0 \tag{7}$$

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

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

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

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

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

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

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

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

Exogenous parameters are z (or n), y, x, r, σ^2, and p. Optimal ownership and investment, denoted by δ^* and I^*, arise from solving (9) and (10), and optimal α, denoted by α^*, is given by substitution in the reservation utility constraint.

Solving the first-order conditions is non-trivial.[8] Accordingly, we use numerical methods to solve (9) and (10) and verify the conditions for a global maximum. For any combination of the

[8] It is possible, however, for certain parameter values. For example, if $z = .5$ (so $n = 1$), then (9) yields solutions of $\delta = 0$ and $\delta = \left(1 + \frac{2r\sigma^2}{p^2 I^{y(2)-2x}}\right)^{-1}$ and the larger solution supports the global maximum. Of course, (10) still needs solving simultaneously with (11). In general, analytical solutions to (9) and (10) are unavailable. For a polynomial of degree q (an integer) > 4 it has been proved that in general it is impossible to provide the algebraic solution. More specifically, it is not possible to find the exact root of every equation of degree q ($q > 4$) (integer exponents) by solving by radicals (performing upon the coefficients a finite number of additions, multiplications, subtractions, divisions, and root extractions). See Conkwright (1941) and Hungerford (1974). We have been unable to do so for most values of z. Exponents that are not integer-valued pose further difficulties. To this point, we can solve (9) for $z = \frac{2}{3}$ (n=1), $z = \frac{3}{4}$ (n=3), $z = \frac{3}{5}$ ($n = \frac{3}{2}$), $z = \frac{1}{3}$ ($n = \frac{1}{2}$), and $z = \frac{2}{5}$ ($n = \frac{2}{3}$).

parameters, we can provide $\delta^* = \delta^*(z, y, x, r, \sigma^2, p)$ and $I^* = I^*(z, y, x, r, \sigma^2, p)$. Moreover, with the assistance of the second order conditions and verification that the maximum is the global maximum, the functions are numerically invertible for restrictions that reduce the dimensionality of the parameter space to two. In our case, we fix x, r, σ^2, and p, and allow z and y to vary in the cross-section so as to fit (δ^*, I^*) to data. In particular, as described below, we take δ^* to be effective CEO ownership and I^* to be total assets, and then infer the combination of z and y that gives rise to observed CEO ownership and firm total assets. In this way, we estimate the parameters z and y for each firm-year observation.

II. Sample Collection and Characteristics

To examine the relation between 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 we include the effects of the CEOs 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 shares granted to total shares outstanding. We compute option deltas separately for new option grants and existing options following Murphy (1999). 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 (1997), and

Bizjak, Bettis, and Lemmon (2002)). 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 five years. The risk-free rate and volatility estimates for each firm year are given in Execucomp. The effective ownership share of the CEO, which corresponds to δ^* in our model, is then computed 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. Research and development expenditures and advertising expenses (both set to zero when missing), both scaled by total assets, measure asset intangibility and growth opportunities. Book leverage is calculated as long-term debt divided by total assets. Finally, in some regression specifications we include firm fixed effects.

Summary statistics for our sample of 8,576 firm-year observations are reported in Table I. The mean effective ownership share of the CEO is 0.033 indicating that the CEO's wealth increases about three and one half 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).[9] Sales average \$4,255 million and range from \$0.394 million to \$206,083 million (Exxon Mobil in 2000). The table also reports statistics for several additional variables that have been used as control variables in other studies of the relation between ownership and firm performance. Leverage averages 0.188, and the mean values of R&D

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

and advertising expense scaled by total assets are 0.031 and 0.011, respectively.[10] Finally, firms in the sample have average values of Tobin's Q of 2.11. The maximum Tobin's Q in the sample is 45.3, and the minimum is 0.30.

III. Calibrating the Model

Using the Execucomp and Compustat data, we calibrate our model to fit the observed ownership shares and book assets in our data, which correspond directly to δ^* and I^* in the model. In calibrating the model we fix the values of p at 40, σ at 0.333, and r at 4.[11] We perform the calibration for several values of x so as to gauge the effect of changing the relation between firm scale and volatility. For each firm-year observation in the sample, we use numerical techniques to find the values of y and z that produce optimal choices of δ^* and I^* from the model that match the ownership shares and book assets values in the data. To do so, given a pair of δ^* and I^* from the data, we numerically solve the first-order conditions (9) and (10) for z and y. Then we check the second order conditions and the objective function to verify that the selected values of z and y give rise to δ^* and I^* at the global maximum.

Figure 1 provides a joint histogram of δ^* and I^* as they appear in the data. Our data contain the previously-documented negative relation between effective ownership (wealth performance sensitivity) and firm size (e.g., Bizjak, Brickley, and Coles (1993), Schaefer (1996), and Baker and Hall (1998)). As Table II indicates, the correlation between ownership and total assets is -0.108 ($p < 0.01$). CEOs in larger firms have smaller ownership shares.

We perform several calibrations for the model based on different values of the parameter x. The purpose is to examine how differences in the way that firm scale affects volatility are manifested in differences in the relations between the optimal values of δ^*, I^*, and corresponding Q in the

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

[11] For our assumption on 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 Execucomp.

model. The values of x we consider are x = 1.0, 0.75, 0.50, and 0.30. The additive shock is given by $I^x\tilde{\varepsilon} \sim N(0, I^{2x}\sigma^2)$. For x = 1.0, standard deviation of the shock increases linearly in total assets and, for x = 0.50, variance increases linearly in scale.

For x = 0.50, Figure 2 depicts the joint distribution of the underlying parameters, z and y, that give rise, at least under our interpretation of the data, to observed surplus-maximizing choices of ownership and total assets. Recall that z and y, in the way that they enter the production function (1), are central determinants of the marginal productivity of effort and physical assets. The correlation between induced z and y is -0.107 ($p < 0.01$). This distribution of underlying parameters z and y gives rise to the observed distribution of effective ownership and total assets depicted in Figure 1.

We use the derived underlying values of y and z and the associated optimizing choices δ^* and I^* to generate a value for Tobin's Q from the model. While we calibrate the model to ownership and total assets, we do not calibrate to Q. Any comparison of model-generated Q to the data is outside of our initial calibration. Instead, Q arises endogenously from the production function, value-maximizing choices of ownership and size, exogenous parameters, and the realization of the random disturbance. We define $Q^*(x)$ as maximized surplus, S^*, plus optimal initial investment, I^*, plus the random shock, all scaled by optimal initial investment, or $\frac{S^*+I+I^{*x}\tilde{\varepsilon}}{I^*}$. To calculate the additive shock, for each firm-year observation we draw a randomly generated value of $\tilde{\varepsilon}$ from $N(0, \sigma^2)$. Expected (ex ante) Q^*, written as EQ^*, is Q^* with the random shock set equal to zero. Again note that this modeled value of Q, Q^*, by definition, is determined endogenously along with the optimal choices of δ and I. Table I provides summary statistics of the modeled values of Tobin's Q for x = 0.50 and x = 0.75. When 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 of the model-generated Tobin's Q is 1.86, with a standard deviation of 0.44.

Table II shows the correlations between the variables generated by our model and variables based on the actual data. The ownership share of the CEO is positively correlated with Tobin's Q from Compustat, indicating that firms with higher ownership shares have higher valuations. Both book assets and sales are negatively correlated with actual Tobin's Q.

In general, the model generates a positive correlation between modeled Q^* and ownership that is somewhat higher than that in the data. Moreover, the model-generated Q^* is positively correlated with actual Q with correlation coefficients of 0.24 ($x = 0.50$, $p < 0.01$) and 0.20 ($x = 0.75$, $p < 0.01$). Similar to actual Q, the model-generated Q^* is negatively correlated with both assets and sales, though the correlations between firm size and the model-generated Q values are somewhat stronger than those observed in the data. Finally, it is interesting to note that the model-generated values of Q^* have correlations with leverage, R&D, and advertising that are of the same sign as those between the actual values of Q and these same variables. This suggests that the fitted structural parameters (productivity of effort and investment) have at least some explanatory power outside of our model.

One significant benefit of fitting a structural model to data is the ability 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 margin (p), risk aversion (r), unscaled standard deviation (σ), and the scale factor for cash flow risk (x). The calibrating parameters governing productivity of effort (z) and assets (y) also are exogenous. Table III presents estimates of the effect of each of these parameters on the optimizing choice of size and effective ownership. Because δ^* and I^* are highly nonlinear in the structural parameters, 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 Q^*. We perturb p, r, σ, x, z, and y by 10 percent relative to the benchmark levels. In all calculations, we use $p = 40$, $r = 4$, $\sigma = 0.33$, and $x = 0.50$ as the benchmark levels of the exogenous parameters that do not vary across firms.

Panel A of Table III presents summary statistics for y and z from the distribution extracted from calibration of the model to actual CEO ownership and firm total assets. The mean value of y is 0.561 and the median value is 0.567. The mean value of z in the data is 0.00120, and the median value is 0.00004. The correlation coefficient between y and z is -0.107 (p-value < 0.01). Panel B uses the median values of y and z as benchmarks in computing the percentage changes in the endogenous parameters of the model, δ^*, I^*, and Q^*. As seen in Panel B, a 10 percent increase in z, which increases the marginal productivity of effort, induces nearly a 5 percent change in the optimal ownership level

of the CEO, all else equal. A 10 percent increase in y, which increases the marginal productivity of investment induces a 4.5 percent decrease in the optimal ownership level of the manager. All else equal, a 10 percent increase in z also induces a small decrease in firm size and has no discernible effect on Tobin's Q. In contrast, a 10 percent increase in the value of y induces a very large change (283 percent) in firm size and a 9 percent decrease in Tobin's Q. The changes in the endogenous variables are roughly similar in magnitude, but are of opposite sign, when the values of y and z are decreased by 10 percent from their benchmark levels. These comparative statics, combined with the fact that y and z are negatively correlated in the data, provide some initial intuition about how the equilibrium values of the endogenous variables will vary in the cross-section.

To conclude, our model is sufficiently flexible, despite its nonlinear structure, to fit perfectly the data on ownership and

total assets. We then confront the model with data on variables outside of the model, specifically Tobin's Q. As it turns out, the calibrated model generates correlations between firm size, ownership, and Tobin's Q (model-generated) that are consistent those observed in the actual data. Moreover, actual Q and model-generated Q^* are positively- and significantly-correlated. In the following sections we examine the implications of these findings. In particular, using actual and model-generated data, we replicate the types of empirical analyses often used in the literature. Of course, in the model ownership and total assets, along with model-generated Q^*, all are jointly determined as value-maximizing choices. Because we already "know" the model, we also know which dimensions of the organization are endogenous. Thus, we can evaluate the extent to which standard empirical approaches detect a relation between endogenous variables (δ^* and Q^*, for example) and whether the standard econometric techniques for addressing the endogeneity problem are effective. Sections IV and V explore Q as a function of ownership, while Section VI examines ownership as a function of Q.

IV. The Relation Between Ownership and Performance

One commonly-reported result reported in the literature is 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)). An established 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. Using our model-generated data, we investigate whether these results could also arise as the outcome of value-maximizing choices of organizational form driven by the underlying features of the contracting environment.

Table IV reports pooled OLS regressions of Tobin's Q from the actual data and from our model on the ownership share of the CEO (δ) and its squared value. The first model in the Table 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-statistic = -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 about 20 percent. The adjusted R-squared of the regression is 1.2 percent, which is essentially the same as that reported by Himmelberg, Hubbard, and Palia (1999, Table 5) for the same regression.

The remaining columns in Table IV present results using Tobin's Q values generated by the model for different values of the volatility scale parameter, x. In models 2 and 3, where x = 1.0 and x = 0.75, the relation between Q and ownership is increasing and convex, which is not consistent with the patterns observed in the data. For x = 0.50 and x = 0.30, however, the relation between Q and ownership becomes hump-shaped. For example, when x = 0.50 (model 4), the coefficient on the ownership share variable is 4.74 (t-statistic = 20.11) and the coefficient on the squared ownership share is -11.11 (t-statistic = -14.18). The ratio of the coefficients on the linear term to that on the squared term is -0.336, which corresponds to a maximum Q at CEO ownership of 16.8 percent. The adjusted R-squared of the regression is 11 percent.

To develop the intuition for why the model and data yield a hump-shaped relation between Q and CEO ownership, Table V provides median values of the exogeneous 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 III suggest, while y, z, optimal ownership, and CEO effort are high, so is investment, and the negative effect on Q of higher y and investment is larger than the positive effect on Q of higher z and managerial effort. 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.

The empirical results are remarkable in that they clearly demonstrate that a simple model of optimal contracting can generate many of the relations between ownership and firm performance that have been documented in the literature. Of greatest interest perhaps is the ability to explain nonlinear relations between ownership and performance as endogenous value-maximizing choices of organizational form, rather than as arising from additional frictions, such as entrenchment and perquisite taking. This is not to suggest that these alternative forces are unimportant - there is plenty of other evidence to suggest they are. Moreover, 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 inclusion of entrenchment in the model. But our analysis does illustrate the difficulty of discriminating among alternative interpretations in the absence of a well-specified model of firm behavior. In the next section, we turn our attention toward examining how controlling for the potential endogeneity between Q and ownership affects our interpretations and conclusions.

V. Econometric Approaches to the Endogeneity Problem

The simple regressions in the previous section illustrate the potential for endogeneity issues to cloud the interpretations of results gathered from reduced form regressions of firm performance measures on features of the organization. The potential for endogeneity is generally acknowledged in the literature, and is dealt with in a variety of ways, the most common being the addition of potentially-omitted control variables. Other methods for dealing with endogeneity include using fixed effects, two-stage least squares, and instrumental variables. In this section we attempt to assess the validity of some of the methods for dealing with 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. To do so, we use expected (model-generated) Q, EQ^*, on the right-hand side. Expected Q^* embeds the optimal choices of ownership and size, δ^* and I^*, in the functional form of surplus to get maximized surplus, which is scaled by optimal investment. Because the optimizing choices depend on the production and utility functions, the relevant six exogenous parameters and the appropriate functional forms by definition are contained in EQ^*.

Model 4 of Table VI regresses model-generated Q^*, which includes the scaled additive technology shock, on EQ^*. The fit is nearly perfect. Model 5 also includes δ^* and δ^{*2} as independent variables. As expected, both estimated coefficients are insignificant, the variables combined add no explanatory power, and the inference that the structural parameters and model explain the "data" is unaffected. Of course, it is possible that the researcher does not know the exact functional form to use for the exogenous parameters, such as z and y (or that these parameters are unobservable). Thus, model 6 uses a relatively parsimonious set of nonlinear functions of z and y to control for the structural determinants of Q^* (and δ^* and I^*). The approximation does a 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.

Models 1-3 use actual Q as the dependent variable. Because actual Q is outside the model, it is likely to be measured with errors that are correlated with endogenous variables. In addition, actual Q could arise from a different functional form for utility, production, or volatility. Moreover, actual Q could be affected by other factors (besides z and y) that are correlated with optimal choices of ownership and size. Models 1 and 2 of Table VI confirm the validity of these concerns. EQ^* alone provides modest explanatory power on its own (model 1). Note, that the intercept is statistically indistinguishable from zero and the slope coefficient is close to one, indicating that EQ^* does a reasonable job of tracking the cross-sectional variation in actual Q values. When EQ^* is included as a regressor, as in model 2, both δ^* and δ^{*2} are significant and continue to imply the MS (1990) hump-shaped relation. Note however, that the magnitudes of the coefficients on the ownership variables are about three to four times smaller compared to those in the simple regressions in Table IV. Because the fit of model 2 is so poor, it is reasonable to suppose that the problem is the wrong functional form. Accordingly, in model 3 we replace EQ^* with a relatively parsimonious set of nonlinear functions of z and y. The fit from the structural variables is improved somewhat. Moreover, the parameter estimates on ownership and ownership squared are insignificant and together the ownership variables provide insignificant explanatory power.

These results, in one way, constitute a test of our model. The estimated coefficients on δ^* and δ^{*2}, as well as the explanatory power of effective ownership, both using model-generated Q and actual Q, are reduced substantially by the inclusion of variables suggested by our model. For modeled Q, this is illustrated by the comparison of model 4 with models 5 and 6 from Table V. For actual Q, the comparison of model 2 of Table V with the first model in Table IV shows how variables from our model undercut the explanatory power of the ownership variables.

The primary conclusion to carry forward is that when we include the right variables in the correct functional form then, even with noise (the additive shock)in the model, regression analysis does not produce spurious empirical relations between endogenous variables. This can hardly be a surprise. We make the observation so as to provide a benchmark for the following two subsections. In particular, we now set aside what we know about the "true" model and examine whether standard econometric solutions to the endogeneity problem are effective.

B. **Omitted Control Variables**

Once again, in our model setting, Q is determined endogenously along with the CEO's ownership share and with the scale of the firm (book assets). The relations among these variables are driven by the exogenous parameters of the contracting environment. Parameters p, r, σ, and x are fixed in our model. In contrast, parameters z and y, which correspond to the productivity of managerial effort and physical capital, respectively, vary across firms. Calibrating the model, as in section III, yields estimates of both z and y for each firm-year observation in the sample. But, in general, y and z (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 the corresponding Q^*.

The prevalent approach to this omitted variable problem is to add additional control variables that should jointly influence both Q

and δ. 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 VII presents results from misspecified (excluding z and y) 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. 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 examine 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 SIC code in the sample.

As seen in Table VII, when firm size measured using book assets is added to the regressions using actual Q as the dependent variable (model 1), the coefficients on both CEO ownership and the squared ownership variable are reduced in absolute magnitude compared to the first regression in Table IV. The linear term remains statistically significant at the 10 percent level and the squared term is significant at 5 percent. 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 in the basic regressions in Table IV. 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 economically-meaningful and statistically-significant at the 1 percent level.

The last three models in the table use the modeled value of Tobin's Q (with x = 0.50) as the dependent variable. When book assets is used to measure firm size, the coefficients on the ownership variables change sign from their values in several of the regressions reported in Table IV. The coefficient on CEO ownership becomes negative and 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.[12] In particular, the results suggest that the relations between the endogenous variables are non-linear. In contrast, when sales is used to measure firm size, the coefficients on CEO ownership and squared ownership retain their signs from the regressions in Table IV, although the absolute magnitudes of the coefficient estimates are reduced by about half. Moreover, the coefficient estimates on both variables remain statistically significant at the 1 percent level. Finally, model 6 shows that adding additional control variables does not drive out the explanatory power of the ownership variables, both of which remain 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 (e.g., sales, R&D, etc.) is unlikely to eliminate serious specification problems in the absence of a structural model relating firm performance to ownership, size, and other structural variables associated with the contracting

[12] 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).

environment.

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 (like y and z in our model). This procedure relies on time-series variation 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 calibrate to observed values of ownership and book assets in each firm 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. The first four regressions in Table VIII report the results from fixed-effect regressions using actual Q as the dependent variable. When only CEO ownership and its squared term are included in the regression (model 1), the coefficient on CEO ownership is positive but not statistically significant. The coefficient on the squared ownership term also is not 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. 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. 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.

The last four columns in Table VIII, which use modeled Q as the dependent variable, suggest that the test-power issues cannot be easily dismissed. Model 5 includes fixed effects only. Although the magnitudes of the regression coefficients on the ownership variables are reduced relative to those in Table IV (model 4), both remain statistically significant at the 1 percent level. Fixed-effects seem to help. But 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 in Table IV (model 4), and 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. CEO ownership is positive, and remains statistically 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. The results of model 8, which also includes additional control variables, do not alter our conclusions.

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. In general, these results serve to highlight the necessity of having a well-specified structural model of organizational form for discriminating among competing hypotheses regarding the relations between firm performance and organizational structure.

VI. Ownership as a Function of Tobin's Q

Paralleling the work that explores the relation between Tobin's Q as the dependent variable and uses ownership structure as an independent variable is another branch of the literature that examines measures of managerial ownership or compensation as dependent variables and uses Tobin's Q as a measure of the investment opportunity set. Early contributions include Clinch (1991), Smith and Watts (1992), Bizjak, Brickley, and Coles (1993), Mehran (1995), and Gaver and Gaver (1993). Other papers, such as Cho (1998) and Demsetz and Villalonga (2001), address the issue through a simultaneous equations approach to the Q on ownership question. 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.

A common rationale given for ownership as a function of Q is that firms with more growth opportunities, as measured by Q, need to provide more incentive compensation to managers. Q could represent the ability of the manager to shift the distribution of outcomes (e.g., profits or returns) to the right.

Table IX reports pooled OLS regressions of the fractional ownership of the CEO on actual and modeled values of Tobin's Q. In some specifications, we also include the squared value of Tobin's Q. Ownership squared has explanatory power in the mirror-image specification, so we include the square of Q. Models 1 and 2 report the results using actual Tobins' Q. In both models, the coefficient estimates on Tobin's Q are positive and statistically significant at the 1 percent level indicating that CEOs have a higher fractional ownership in firms with high values of Tobin's Q. In model 2, the coefficient on the squared value of Q is negative and statistically significant at the 1 percent level, indicating that CEO ownership is increasing in Q, but at a decreasing rate. This is consistent with the notion that higher Q is associated with higher risk, which would imply lower ownership, as well as higher marginal productivity of managerial effort.

Models 3 and 4 in the table repeat these regressions, but replace actual Q with the modeled value of Tobin's Q as generated by our calibrations. The results are similar to those reported above using actual Q. In both models, the coefficient estimates on the modeled value of Tobin's Q are positive and statistically significant at the 1 percent level, although the coefficient estimates are more than an order of magnitude larger compared to those in models 1 and 2. In model 4, the coefficient estimate associated with the square of the modeled value of Tobin's Q is negative and statistically significant, but again is more than an order of magnitude larger than the corresponding coefficient estimate in model 2.

Table X reports results from pooled OLS regressions of ownership on Tobin's Q, but that include additional control variables. We use the same control variables employed in Table VII. In models 1 through 3, the actual value of Tobin's Q is used along with various additional explanatory variables. In model 1, when the log of total assets and its squared value are used as control variables the coefficient estimate on Tobin's Q becomes statistically insignificant. Recall, however, that at least in our model, total assets or firm size is also endogenously determined. For comparison, model 4 shows that when the modeled value of Tobin's Q is used, the coefficient estimate on Q^* becomes negative and is significant at the 10 percent level. When sales is used to measure firm size and when additional control variables are added, the results in models 2 and 3 show that Tobin's Q remains significantly positively related to CEO ownership at better than the 10 percent level. Similar inferences are obtained in models 5 and 6, when actual Q is replaced with model-generated Q^*.

VII. Conclusion

This paper specifies a structural model of the firm and then uses that model to conduct empirical work on the connection between performance and ownership. The specific model we use, the Holmström and Milgrom (1987) model augmented with an initial investment decision, has substantial appeal, because much of our intuition about the role of ownership (or sensitivity of CEO wealth to performance) arises from the principal-agent framework. Exogenous parameters specify managerial risk aversion, standard deviation of returns, profit margin, how cash flow volatility depends on scale, marginal productivity of managerial effort, and marginal productivity of investment. The shareholders choose investment (assets) and ownership/compensation of the manager, and the manager chooses effort, which is not observable to the principal.

To fit the model to actual firm data from Execucomp and Compustat, we allow two model parameters, productivity of effort and investment, to vary. This is sufficient to fit the model exactly to data on managerial ownership and initial investment in productive assets. In particular, for each firm-year observation, we calculate the productivity parameters for effort and investment that would give rise to observed ownership and investment as optimal choices in our model. This allows us to assess the economic importance for the structure of the firm of the structural productivity parameters. Increasing the productivity parameter for effort has a strong positive effect on the slope of the optimal contract but very little effect on firm scale and Q. On the other hand, the investment productivity parameter has a substantial positive effect on optimal firm scale and a strong negative effect on the slope of the compensation contract and Q.

Having fitted the model to the data, we then go outside the model to examine the performance-ownership relation. By the calibration, we create a data panel for which we know the underlying structural model and appropriate empirical specification. We then calculate Tobin's Q from the model and examine whether Q and managerial ownership exhibit the patterns documented previously. As it turns out, for a reasonable range of parameter values, the relation between performance and ownership is similar to that documented in McConnell and Servaes (1990). The relation is hump-shaped, and the ratio of the estimated parameter on managerial ownership to that on managerial ownership squared is similar to what we obtain when we estimate the McConnell and Servaes (1990) model using our Execucomp and Compustat data. Thus, our augmented principal-agent model can explain the empirical relation between performance and managerial ownership. No additional factors, such as managerial entrenchment swamping incentive alignment at high ownership levels, are required. Instead, Q and δ (ownership) vary together endogenously, as their underlying determinants, marginal productivity of investment and effort, vary in the cross-section and through time.

We use these results to examine the importance of specification error and endogeneity in empirical work. Including firm fixed effects or additional control variables adds explanatory power, but the spurious relation between Q and managerial ownership typically remains. In this setting, standard approaches to the endogeneity problem fail to provide a solution. The bottom line is that the endogeneity problem is substantial and it is difficult to correct using control variables and fixed effects. This work remains incomplete. It would be interesting to assess the usefulness of simultaneous equations (e.g., 2SLS), instrumental variables, and tests for direction of causation.

Our procedure illustrates how a structural model of the firm can isolate the important aspects of governance and quantify the economic significance of incentive mechanisms. In particular, we show how the relation observed in the data between performance and managerial ownership arises in a specific structural model. In general, this sort of approach, confronting a structural model of the firm with the usual data, may be what is required to isolate the role of various governance mechanisms and quantify the economic importance of those mechanisms for firm value.

Two points deserve mention. First, this paper does not provide tests of our model versus competing models. Our model generates the MS (1990) inverted-U relation without relying other factors, such as entrenchment. But entrenchment could be an important force as well. Certainly the regression specifications in Table VI (models 1-3) do not provide a perfect fit. A formal test of the importance of other factors would require a model that includes such factors as either jointly-determined or exogenous, as appropriate. Aside from the modeling difficulties, an additional part of the challenge is to embed entrenchment forces in a model so that entrenchment or the effects of entrenchment are measurable and can be tested in data.

Second, while our model is one example of analysis of a performance-structure relation, the Q-ownership literature suffers no more and no less from endogeneity and specification problems than other branches of the literature. We chose the Q-ownership relation because it continues to attract significant attention and resources from researchers. Nonetheless, other empirical experiments are amenable to our approach and we believe there are many opportunities for additional work. Empirical work has used Q, accounting return, and market return as performance measures. 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 U-form or M-form, diversification strategy, and product market strategy. The literature has provided reduced-form empirical analysis of almost every possible combination of performance and structure. In addition, there has been substantial work on the structure-structure relation. Pick any pair of the organization features listed above and there is a high probability that empiricists have examined the connection. Our model, for jointly-determined Q^*, δ^*, and I^*, illuminates the connection between Tobin's Q and managerial ownership, as an endogenous performance-structure relation, and managerial ownership and firm size, as an endogenous structure-structure relation. In this empirical context, we illustrate three benefits of using a structural model. One is that we can treat explicitly the endogeneity problem with a correctly-specified model. Another benefit is the ability to estimate the economic effect of changes in structural variables, such as productivity of investment and managerial effort. Finally, though we have not done so in our model, use of a structural model presents the opportunity for conducting analysis of economic policies aimed at changing exogenous aspects of the underlying contracting environment.

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Table I: **Summary Statistics of Effective CEO Ownership and Firm Characteristics**

This table shows summary statistics of effective CEO ownership and characteristics for our sample firms. Data are obtained from the Execucomp and Compustat databases 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. The modeled values of Tobin's Q^* arise from a calibration of the model described in Section III.

	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
Modeled Tobin's Q^* (x=0.5)	1.8303	0.3643	1.3300	8.2828
Modeled Tobin's Q^* (x=0.75)	1.8647	0.4383	1.3247	8.4258

Table II: **Correlation Matrix**

Correlation matrix of Ownership share of the CEO (δ), Book Assets (I), Sales, leverage, R&D, advertising, Tobin's Q, and Tobin's Q* values generated from calibrations of the model described in Section III. 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. Unless otherwise specified, all correlations are significant at the 1% level. Superscripts a, b, and ns indicate levels of significance of 10%, 5%, and not significant, respectively.

	Ownership Share	Book Assets	Sales	Debt Ratio	R&D	Adver-tising	Actual Q	Mod. Q (x=0.5)	Mod. Q (x=0.75)
Ownership Share of CEO (δ)	1								
Book Assets (I)($Mill)	-0.1076	1							
Sales ($Mill)	-0.1297	0.5784	1						
Leverage (Debt) Ratio	-0.0221^b	-0.0355	0.0103^{ns}	1					
R&D / Assets ($Mill)	0.0114^{ns}	-0.0797	-0.0619	-0.2129	1				
Advertising / Assets ($Mill)	0.0390	-0.0438	0.0202^a	-0.0433	-0.0065^{ns}	1			
Actual Tobin's Q	0.0677	-0.0858	-0.0374	-0.2187	0.3314	0.0673	1		
Modeled Tobin's Q* (x=0.5)	0.2405	-0.2758	-0.3063	-0.1834	0.4858	0.0403	0.2411	1	
Modeled Tobin's Q* (x=0.75)	0.5957	-0.2403	-0.2665	-0.1386	0.3797	0.0388	0.2022	0.8229	1

Table III: **Comparative Statics for Endogenous Parameters**

This table presents comparative statics for endogenous parameters of the model, δ, investment, and Q^* as functions of the exogenous parameters z, y, p, r, σ and x.

Panel A: Summary Statistics for z and y

	Mean	Median	Std. Dev.	Min.	Max.
y	0.56133	0.56760	0.08475	0.11907	0.75179
z	0.00120	0.00004	0.00622	0.00000	0.14501

Panel B: Benchmark parameter values are median z and y, p=40, r=4, σ=0.333, x=0.5

Percent Changes for a 10% increase in parameter

	baseline	z	y	p	r	σ	x
δ	0.0125	4.849	-4.626	0.000	-4.626	-9.129	-30.171
Investment	1367.59	-0.005	283.797	24.663	0.000	-0.001	-0.004
Q^*	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
δ	0.0125	-5.101	5.374	0.000	5.373	10.923	43.090
Investment	1367.59	0.005	-65.123	-21.627	0.000	0.001	0.004
Q^*	1.7618	0.000	11.112	0.000	0.000	0.000	0.000

Table IV: **Pooled OLS Regression for Actual Q and Various Modeled Q*s**

Pooled OLS regression of Q on the ownership share of the CEO(δ) and the squared ownership share of the CEO (δ^2)for actual Q and for Q^* values calibrated from the model described in Section III. 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 (White (1980)). Superscripts a, b, and c indicate levels of significance of 10%, 5%, and 1%, respectively.

	Actual Q	**Modeled Q***			
		(x=1.0)	(x=0.75)	(x=0.5)	(x=0.3)
	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	1.9112	1.7372	1.7347	1.7224	1.7215
	(76.17^c)	(6.79^c)	(298.62^c)	(361.07^c)	(361.54^c)
$\delta = \delta^*$	8.6069	14.9988	3.4267	4.7399	4.8329
	(9.00^c)	(0.83)	(10.71^c)	(20.11^c)	(20.54^c)
$\delta^2 = (\delta^*)^2$	-21.4634	384.8692	4.1451	-11.11386	-11.4167
	(-8.38^c)	(4.36^c)	(3.01^c)	(-14.18^c)	(-14.75^c)
R^2	0.0116	0.3728	0.3605	0.1166	0.1192

Table V: **Productivity Parameters and Endogenous Variables by Ownership Decile**

This table ranks δ into deciles and reports the median values of investment (inv), and various parameters for every decile. Data are obtained from the Execucomp and Compustat databases and consist of 8576 firm-year observations from 1993 to 2000. Optimal effort level, g^*, modeled Q^*, and the parameters z and y are generated from calibrations of the model described in Section III.

Decile	δ^*	**Investment (Mill$)**	$\mathbf{g}^*$	$\mathbf{Q}^*$	**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 VI: **Nonlinear OLS Regression for Actual Q and Modeled Q***

Correctly-Specified nonlinear OLS regression of actual Q and Modeled Q* on the ownership share of the CEO (δ) and the squared ownership share of the CEO (δ^2) 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 (White (1980)). 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)
R^2	0.0575	0.0584	0.0672	0.9982	0.9982	0.9982

Table VII: **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. Model 1 regresses actual Q on the ownership share of the CEO (δ) and the squared ownership share of the CEO (δ)and adds the natural logarithm of assets and its squared value as control variables. Model 2 uses the natural logarithm of sales and its squared value as control variables instead, and Model 3 adds leverage ratio, research and development (R&D) and advertising expenditures (both scaled by book value of assets). To control for industry effects, Model 3 also includes unreported dummy variables for the 2-digit SIC codes. Robust t-statistics are given in parentheses (White (1980)). 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)		
$\ln(\text{Assets})^2$	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)
$\ln(\text{Sales})^2$		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
R^2	0.0574	0.0579	0.2085	0.8675	0.6722	0.7625

Table VIII: **Fixed Effects Regression of Tobin's Q on CEO Ownership**

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. Model 1 regresses Q on the ownership share of the CEO and the squared ownership share of the CEO. Model 2 adds the natural logarithm of investment and its squared value as control variables. Model 3 uses the natural logarithm of sales and its squared value as control variables, and Model 4 adds leverage ratio, research and development (R&D) and advertising expenditures (both scaled by book value of assets). Robust t-statistics are given in parentheses (White (1980)). 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
δ	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)
δ^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 IX: **Pooled OLS Regressions of CEO Ownership on Actual and Modeled Q**

Pooled OLS regressions of the ownership share of the CEO (δ) on both actual Q and the squared value of actual Q, and on Modeled Q^* and the squared value of Modeled Q^* (x = 0.5). 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 (White (1980)). Model 1 regresses CEO ownership on actual Q, and Model 2 adds the squared value of actual Q as control variable. Model 3 regresses CEO ownership on Modeled Q^*, and Model 4 adds the squared value of Modeled Q^* as control variable. Superscripts a, b, and c indicate levels of significance of 10%, 5%, and 1%, respectively.

	Model 1	Model 2	Model 3	Model 4
Intercept	0.0288	0.0267	-0.0355	-0.0899013
	(31.08)^c	(23.19)^c	(-7.09)^c	(-12.14)^c
Actual Q	0.0019	0.0032		
	(5.41)^c	(5.73)^c		
(Actual Q)^2		-0.0001		
		(-2.84)^c		
Modeled Q^*			0.0373	0.0835
			(13.32)^c	(12.85)^c
(Modeled Q^*)^2				-0.0086
				(-6.44)^c
R^2	0.0046	0.0057	0.0578	0.0720

Table X: **Pooled OLS Regressions of CEO Ownership on Actual and Modeled Q**

Misspecified pooled OLS regressions of the ownership share of the CEO (δ) on both actual Q and Modeled Q^* (x = 0.5) and control variables. Data are obtained from the Execucomp and Compustat databases and consist of 8576 firm-year observations from 1993 to 2000. Model 1 regresses CEO Ownership on the actual value of Q, and adds the natural logarithm of assets and its squared value as control variables. Model 2 uses the natural logarithm of sales and its squared value as control variables instead, and Model 3 adds leverage ratio, research and development (R&D) and advertising expenditures (both scaled by book value of assets). Model 4 regresses CEO Ownership on modeled Q^*, and adds the natural logarithm of assets and its squared value as control variables. Model 5 uses the natural logarithm of sales and its squared value as control variables instead, and Model 6 adds 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 includes unreported dummy variables for 2-digit SIC codes. Robust t-statistics are given in parentheses (White (1980)). Superscripts a, b, and c indicate levels of significance of 10%, 5%, and 1%, respectively.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	0.1401	0.0753	N/A	0.1994	-0.0316722	N/A
	$(15.38)^c$	$(10.57)^c$		$(6.45)^c$	$(-1.86)^a$	
Actual Q	0.0001	0.0007	0.0008			
	(0.26)	$(2.14)^b$	$(1.96)^a$			
Modeled Q^*				-0.0113	0.027736	0.0234
				$(-1.85)^a$	$(6.20)^c$	$(4.88)^c$
ln(Assets)	-0.0205			-0.0290		
	$(-9.45)^c$			$(-6.46)^c$		
$\ln(\text{Assets})^2$	0.0008			0.0012		
	$(6.04)^c$			$(5.29)^c$		
ln(Sales)		-0.0038	-0.0129		0.0083558	-0.0038
		$(-2.10)^b$	$(-6.16)^c$		$(3.65)^c$	(-1.57)
$\ln(\text{Sales})^2$		-0.0003	0.0002		-0.00086	-0.0002
		$(-2.64)^c$	$(1.72)^b$		$(-6.76)^c$	(-1.14)
Leverage			0.0094			0.0120
			(1.77)			$(2.27)^b$
R&D/Assets			-0.0656			-0.0785
			$(-3.63)^c$			$(-5.93)^c$
Advertising/Assets			0.0219			0.0175
			(0.93)			(0.74)
Industry Dummies	no	no	yes	no	no	yes
R^2	0.0778	0.0591	0.1400	0.0784	0.0691	0.1448