The Joint Determinants of Managerial Ownership, Board Independence, and Firm Performance

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First Draft: February 28, 2005
This Version: July 11, 2008

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Abstract

We specify a simple structural model to isolate the economic determinants of managerial ownership and board structure in a value-maximizing contracting environment. The optimal firm size, level of managerial ownership, and the proportion of outsiders on the board is jointly determined by the relative importance of the three productivity parameters of physical assets, managerial/insider effort and outside director's advising/monitoring role in the firm production process. Our model provides an equilibrium explanation for the cross-sectional relationships between managerial ownership, board structure, and firm performance that is consistent with existing evidence. We use the model to provide an alternative explanation for the observed changes in compensation structure arising from new rules mandating changes in board independence following the Sarbanes Oxley act in 2002.

JEL classification code: G32, G34, L29

Key words: Corporate Governance; Board Composition; Managerial Ownership; Structural Model

I. Introduction

Our paper presents a structural model for the joint determinants of firm scale, board structure, firm performance, and the managerial compensation contract. The economic decisions represented in the model are related to the advising and monitoring role of outside directors, the provision of firm- and industry-specific expertise by inside directors, a contractual solution to the standard moral hazard problem for managerial effort, and definition of the boundaries of the firm as defined by the level of investment in physical assets. Using observed data on firm size, managerial pay-for-performance sensitivity, and board independence, we calibrate the model to estimate exogenous parameters that capture the productivity of physical assets, managerial effort, inside director expertise, and outside director advising and monitoring. Variation of these productivity parameters across firms and over time, and the corresponding variation in optimal firm size and internal governance structure as represented in the model, all serve to identify the underlying economic forces that drive the estimated empirical relations among Tobin's Q, board independence, managerial ownership, and firm size.

We develop and implement our structural model with three goals in mind. One is to attempt to isolate some of the underlying exogenous joint determinants of firm performance and value-maximizing organization form. The second is to attempt to reconcile widely varying empirical results and, ideally, to identify how parameters of the contracting environment interact to determine firm structure. Finally, we wish to assess the effects of recent regulatory reforms regarding board structure within an equilibrium framework.

To further frame these objectives, corporate finance, broadly defined, is concerned with a wide spectrum of organizational features, called "structure" and aspects of firm performance. Dimensions of structure of particular interest include managerial compensation, board and ownership structure, debt policy, investment policy, dividend policy, leadership structure, anti-takeover protections, and product market strategy. Performance measures include accounting profit, stock returns, debt returns, and Tobin's Q. Regression experiments typically specify either (1) performance as a function of structure or, (2) structure as a function of structure.

In the case of performance on structure, for example, various papers examine the association between firm performance and managerial ownership. The empirical results are mixed. Choosing the kink points to best fit the data, Morck, Shleifer, and Vishny (1988) find a three-segment relation between Q and inside ownership. McConnell and Servaes (1990) report an "inverted-U" or "hump-shaped" relation between Q and managerial ownership. Over 100 successors investigate the ownership-performance relation using different data, various measures of performance and managerial ownership, and alternative empirical methods.[1] Based on the large variation in results, Demsetz and Villalonga (2001, figure 1) express serious doubt as to whether there is any significant relation between performance and managerial ownership. The same style of regression has been employed to examine the relation between performance and board independence but, again, with varying results.[2]

If we view the firm as an incentive system (Holmstrom and Milgrom 1991), it is logical to employ the second type of empirical specification and regress structure on structure. Are two different mechanisms, managerial compensation and board composition, for example, substitutes or complements in "production"? Restated, if a relatively independent board fulfills the monitoring function, is it necessary to expose the management team to high pay-performance sensitivity? Again, the empirical evidence is mixed. Denis and Sarin (1999), Shivdasani and Yermack (1999), and Coles, Daniel, and Naveen (2008) estimate a negative relation between managerial ownership and the proportion of outsiders on the board, suggesting that they are substitutes. In contrast, Ryan and Wiggins (2004) and Davila and Penalva (2004) find a positive relation between insider ownership and the proportion of outsiders on the board.

There are several potential reasons for the wide variation across studies in results and conclusions. First, different papers rely on different samples that vary by time period, sample size, industry composition, firm size, and data sources. Second, when examining the relationship between firm performance and structure, papers vary in the choice of

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[1] .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.

[2] See next section for detailed review.

control variables, instruments, and functional form. Model specification varies substantially across studies. Third, there may be no relation but different studies, relying on different but inappropriate instruments, deliver spurious (and contrasting) results. Endogeneity and causation problems can lead the researcher to detect a relation when there is none present (Demsetz and Lehn 1995, Himmelberg, Hubbard and Palia 1999, Larker, Richardson and Tuna, 2004, Coles, Lemmon, and Meschke, 2006). Or, instead, omission of underlying joint determinants of the dependent and independent variables can reduce the ability to detect the true relationships among the variables. Related to several of these difficulties, a number of existing studies focus on one aspect of governance and/or performance without controlling for potentially related governance choices.

In order to address some of these difficulties and isolate exogenous determinants of performance, board independence, and managerial compensation structure, we follow the approach of Coles, Lemmon and Meschke (2006, hereafter CLM). We specify a simple structural model of the firm and calibrate the model to data to obtain estimates of three exogenous productivity parameters: the productivity of physical assets; the productivity of managerial/insider effort; and the productivity of outside directors on the board. In particular, we employ the principal-agent model of Holmstrom (1979) and Holmstrom and Milgrom (1987), but augment that model with investment and board structure decisions. We estimate the productivity parameters that would give rise to the observed levels of ownership, the proportion of outsiders on the board, and investment as optimal choices in our model.

Comparative static analysis of our model shows that, based on the industry median estimates of the model parameters, a 10% increase in the productivity of physical assets has a large positive impact on investment in physical assets, yet relatively little effect on managerial ownership and virtually no effect on board composition. However, a 10% increase in the productivity of managerial effort is associated with a nearly 5% increase in CEO ownership, while a 10% increase in the productivity of advising/monitoring by outside directors causes a 1.5% increase in the proportion of outsiders on the board. On the other hand, firm performance measured by Tobin's Q responds strongly to a change in the productivity of physical assets, but only weakly to the other two productivity parameters that are related to human capital.

Our estimates of the productivity parameters vary as might be expected across industries. For example, firms in the Metals and Mining, Utility, Gas, and Manufacturing industries have the highest productivity of physical assets relative to the productivity of human capital, while those in Apparel, Personal Business Services and Retail industries have the lowest.

Having estimated the structural parameters from the data, we then go outside the model to examine whether our estimates of the exogenous productivity parameters have power to explain the various relations of managerial ownership, board composition, and firm performance in the data. Using model-generated Tobin's Q, the familiar (McConnell and Servaes, 1990) hump-shaped relation between managerial ownership and firm performance is generated by the model. Consistent with our view that corporate governance and firm performance are endogenously determined, neither ownership nor the proportion of outsiders on the board has any explanatory power for firm performance as measured by Tobin's Q after including simple functional forms of the three exogenous productivity parameters that describe the contracting environment. Approximately 17% of the variation in the actual Tobin's Q can be explained by these productivity parameters alone.

Our model also provides an explanation for why firms in different sectors or industries employ different combinations of managerial ownership and board independence. The estimated parameters governing the productivity of managerial/insider effort, as well as the productivity of outside director advising and monitoring are correlated in such a way that their effects on board independence and managerial ownership give rise to the negative relationship between CEO ownership and the proportion of outsiders on the board that is observed in our data. The evidence suggests that some simple function forms of the three exogenous productivity parameters can explain 89% and 24% of the variation in CEO ownership and board independence, respectively. These results, and those on the relationship between performance and structure, suggest that the productivity parameters specified in our model indeed capture some of the joint economic determinants of managerial ownership, board composition, and Tobin's Q.

In the last part of the paper, we use our structural model to evaluate the effects of rules mandating changes in board independence that were imposed on firms following the Sarbanes Oxley act in 2002. Within the value maximizing equilibrium framework of our model, firms that are forced to change their board structures in order to comply with the rules readjust their compensation policy and firm scale in response to the exogenous change in board structure. We show that the equilibrium response of compensation generated by our model can replicate the observed changes in compensation documented by Chhaochharia and Grinstein (2008). In our framework, however, the one-size fits all regulatory change forces some firms away from their optimal governance structure and actually reduces firm value. The use of our structural model in this setting highlights the potential unintended consequences of regulation and serves as a benchmark for further evaluating these policy reforms.

Despite the empirical success of our approach, we doubt that our model encompasses all of the relevant economic determinants for managerial ownership and board structure. Nonetheless, our augmented principal-agent model does provide one possible equilibrium explanation for the relation between performance and various internal governance structures, as well as the interaction among these internal governance structures. Such equilibrium arises from endogenous value-maximizing choices of optimal organizational form, rather than from transaction costs or other market frictions.

Our paper contributes in two main ways to the current literature. First, the construction of our model and its application to data provides an example of how a structural model of the firm can isolate important aspects of governance and quantify the economic significance of various incentive mechanisms. Our approach is consistent with recent calls by Zingales (2000), Hermalin and Weisbach (2003), 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. Second, our paper is among the few that examine explicitly how multiple corporate governance mechanisms jointly influence firm performance. Also, there are relatively few papers that explicitly examine the structure on structure relation. We ask, specifically in this paper, whether managerial ownership and the proportion of outsiders on the board, both used to align managerial incentives, are substitutes or complements. Strictly speaking, they are complements in production. Nonetheless, because of how the productivity parameters are correlated in the cross-section, the observed empirical relation between board composition and managerial ownership is negative (Hermalin 2005).

The reminder of our paper is organized as follows. Section II reviews the literature and hypotheses. We present and analyze the model and in Section III. Section IV describes our sample. Section V presents results on the estimated productivity parameters, evaluates variation of the estimates across industries, and provides comparative statics results. Section VI provides empirical evidence on board composition and managerial ownership as determinants of Q. Section VII discusses the association between board composition and managerial ownership. In Section VIII, we employ our model as a vehicle to examine the economic consequences of recent board reforms in an equilibrium setting. Section IX concludes.

II. Literature review and hypotheses

A. Performance on structure

Morck, Shleifer, and Vishny (1988), hereafter MSV, document a non-monotonic relation between Tobin's Q and managerial stock ownership. McConnell and Servaes (1990), hereafter MS, reports an “inverted-U” or “hump-shaped” relation between Q and managerial ownership. 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. But then 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 at the top of the function is large will the benefits to shareholders of realigning ownership structure to the optimum exceed the transaction costs of doing so.

An alternative interpretation is that the inverted-U pattern represents a value-maximizing relationship between two endogenous variables. In this framework, 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 association 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. Along these lines, in contrast to studies that view equity incentives as being too low, Demsetz and Lehn (1985), and Himmelberg, Hubbard, and Palia (1999) conjecture that managerial ownership levels are set, on average, at the optimal value-maximizing level.

A similar style of argument can be made for the relationship between Tobin's Q and board composition. As with managerial ownership, the results vary. Weisbach (1988), Borokhovich, Parrino, and Trapani (1996), Brickley, Coles, and Terry (1994), Byrd and Hickman (1992), and Cotter, Shivdasani, and Zenner (1997) find that more-independent boards add value in some circumstances. Baysinger and Butler (1985), Hermalin and Weisbach (1991), and Bhagat and Black (2001), find no relation between the fraction of outside directors on the board and Tobin's Q. Yermack (1996) and Agrawal and Knoeber (1996) find a negative association between the fraction of outside directors and Tobin's Q, while Rosenstein and Wyatt (1997) and Klein (1998) find that insiders add value. Coles, Daniel, and Naveen (2008) find that the relationship between Q and board independence depends on R&D intensity. But even if there were agreement about the shape of the association, there would be disagreement over interpretation. What we believe, and provide some evidence for in this paper, is that the empirical association represents the locus of maxima of value-maximizing board structures, where the individual firm maxima vary in location according to exogenous factors, including technology and the nature of the product market.

B. Structure on Structure

A natural question to ask from the perspective of shareholders when designing the structure of corporate governance is whether to give CEOs more pay-for-performance sensitivity when the firm already has an effective, independent board. Viewing the firm as an incentive system, Holmstrom and Milgrom (1991) suggest that ownership of assets and worker freedom from direct control are complementary instruments for motivating workers. The bargaining framework in Hermalin and Weisbach (1998) argues that a risk-averse and successful CEO can bargain for both less board scrutiny and less pay-for-performance sensitivity. In general, the board of directors performs both advisory and monitoring functions. In the standard principal-agent framework, monitoring can both directly affect the firm's cash flows and also reduce the noise in the signal used to evaluate the effort choice of the CEO, while advisory functions may provide valuable and relevant knowledge that improves the productivity of CEO effort. A natural assumption is that inside directors, who have valuable firm and industry specific knowledge, have a comparative advantage in enhancing the productivity of CEO effort, while outside directors have a comparative advantage in monitoring. The interaction between these forces suggests a potentially complex relation between board structure and the incentives provided to the CEO.

A negative relationship between CEO ownership and board independence has been documented in several papers, including Denis and Sarin (1999), Baker and Gompers (2003), Shivadani and Yermack (1999) and Coles, Daniel and Naveen (2008). In contrast, Core, Holthausen and Larcker (1999) find that the proportion of outside directors is significantly positively related to a measure of the amount of performance-based pay given to the CEO.

C. The economic determinants of managerial ownership and board independence

What ingredients would a model of board structure, managerial compensation, and firm performance contain? The prior literature provides some guidance. Many studies focus on the information asymmetry between insiders and outsiders. Demsetz and Lehn (1985) suggest that required levels of managerial equity ownership are related to firm size and monitoring difficulty. They argue that there is an optimal firm size and optimal level of managerial ownership given the firm's factor input and product markets. Harris and Raviv (2004) present a model for optimal board control, in which decision delegation, the optimal number of outsiders, and resulting profits are functions of the importance of insiders' and outsiders' information and the extent of agency problems. Their model assumes that outside directors are monitors and inside directors are information providers. Hermalin (2005) explains a number of trends in corporate governance with the proposition that the intensity with which the board monitors management is increasing in board independence. In particular, his model predicts that board independence and CEO compensation should co-vary inversely in the cross-section but positively in time-series data. Adams and Ferreira (2005) show that when it is important for the CEO to share information with the board of directors, shareholders may optimally choose a less independent or friendlier board. Raheja (2005) argues that optimal board size and composition are functions of the directors' and firm characteristics when the board is responsible for monitoring projects and making CEO succession decisions. In her model, the optimal board structure is determined by the tradeoff between maximizing the incentive for insiders to reveal their private information and minimizing the costs of outsiders to verify and reject inferior projects. Empirically, Boone et al. (2004) suggest that board size and independence reflect a trade-off between the firm-specific benefits of monitoring and the costs of such monitoring.

Based on the prior literature and our focus, we include in our model what we think of as three natural components. One is the standard agency problem, from which arises strong intuition about the conditions under which the agent's (manager's) compensation should be exposed to firm performance through ownership and the managerial compensation contract. Second, we include the investment decision. Firm size is a crude representation of boundaries of the firm. Moreover, firm size affects the contracting problem insofar as managerial input is combined with fixed assets. In addition, firm size affects the sharing of risk among shareholders and managers. Third, our model recognizes the dual role of the board of directors in providing both advisory and monitoring services and the natural advantages that inside and independent directors have in providing these services. In the next section, we present a structural model of the firm that is based on these features.

III. Model

Our model is based on the standard principal-agent problem (see Holmstrom 1979 and Shavell 1979, for example). In particular, the principal chooses the size of the firm as well as the internal corporate governance structure, that includes the equity ownership (compensation scheme) of the manager and the fraction of outsiders on the board (advising/monitoring scheme).

In our model, shareholders choose the composition of the board, as well as the manager's compensation contract and the optimal scale of the firm to maximize firm value. By choosing board composition and managerial compensation *ex ante*, shareholders pre-commit to the internal governance structure. While it is standard to think of shareholders choosing the internal corporate control mechanisms, 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 generated by the following production function:

$$\tilde{f} = pI^{y}((1-m)g)^{z}m^{t} + I^{x}(\tilde{\varepsilon} + \tilde{v}) \qquad (1)$$

where I is the level of investment or assets, g is the manager's effort and m is the proportion of outsiders on the board (so $(1-m)$ is the proportion of insiders). Assets I can include property, plant, and equipment as well as physical assets. Managerial effort, board of director monitoring/advising and firm investment interact in the Cobb-Douglas production function, $I^{y}((1-m)g)^{z}m^{t}$. The productivity parameter $y \in (0,1)$ determines the productivity of physical assets. Parameter $z \in (0,1)$ determines the productivity of managerial effort (g) and is combined with inside directors' firm- and industry- specific expertise given the common practice that most insiders are also members of the management team. Finally, $t \in (0,1)$ determines the productivity of outside director advising/monitoring that will contribute directly to the total cash flows. Production is scaled by $p > 1$, which can be interpreted as the standard Cobb-Douglas scale parameter times a profit margin (net of all input costs other than managerial compensation and the cost of initial investment). For simplicity, we do not include an explicit adjustment for board costs.

The disturbance term has two independent components. $\varepsilon \sim N(0,\sigma^2)$ is idiosyncratic firm risk, perhaps from a technology shock. $\nu \sim N(0,(1-m)^2)$ represents other cash flow variability. This term can also be interpreted as the information gap between insiders and outsiders (Harris and Raviv 2004). Costly monitoring by outsiders on the board can reduce this variability, in part through cooperation between insiders and outsiders (Holmstrom and Tirole 1993). Cash flow risk is scaled by a function of investment, I^x, where $x > 0$, because it is reasonable to assume that an additive cash flow shock depends on the size of the asset base (firm size).

In this formulation it is clear that there is a tradeoff between the advising and monitoring provided by outside directors and the firm-specific human capital of inside directors. Inside directors make managerial effort (g) more productive. On the other hand, outside directors have broader knowledge (i.e. about financing or legal issues) relevant to firm decisions and they are also effective monitors.

Note that the expected cash flow $E(f)$ is not always an increasing function of the proportion of outside directors (m). The ultimate sign of $\frac{\partial E(f)}{\partial m}$ depends on the relative importance of insiders' firm-specific information and outsiders' non-firm-specific expertise ($\frac{\partial E(f)}{\partial m} > 0$ if and only if $\frac{z}{t} > \frac{1-m}{m}$). Of course, optimal board independence (m) will exceed that which maximizes $E(f)$. The reason is that more outsiders also implies more intense monitoring, which leads to lower cash flow variability ($\text{var}(\tilde{f}) = I^{2x}(\sigma^2 + (1-m)^2)$, with $\frac{\partial \text{var}(\tilde{f})}{\partial m} < 0$) and better inference and risk-sharing in the contracting problem.

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.[3] For convenience, we let the cost of

[3] Generally, we focus on the case in which the manager has CARA, that is r(w)=r(constant). Nonetheless, our model can be implemented using an approximation of CRRA similar to that employed by CLM (2006). CLM (2006) specify $r(w_o) = r/w_o\gamma$, where w_o represents accumulated wealth of the manager.

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:

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

Following Holmstrom and Milgrom (1987) (also see Hellwig and Schmidt 2002), the optimal contract that specifies the manager's claim is linear in the observable outcome and is given by:

$$\phi(f) = \widetilde{w} = \alpha + \delta\widetilde{f} \tag{4}$$

Thus, maximizing expected managerial utility is equivalent to maximizing the certainty equivalent of the manager given by:

$$\alpha + \delta p I^y ((1-m)g)^z m^t - \frac{r}{2}\delta^2 I^{2x}(\sigma^2 + (1-m)^2) - g \tag{5}$$

Solving the first-order condition for the optimal effort level, g, yields:

$$g^* = ((1-m)^z m^t z \delta p I^y)^{\frac{1}{1-z}} \tag{6}$$

which is increasing in ownership (or slope of the compensation scheme $\phi'(\widetilde{f})$=δ), scaled margin(p), investment(I), and parameters that determine the marginal productivity of managerial effort (z), outside director input (t), and investment (y). Given the tradeoffs between the costs and benefits of outside versus inside directors, optimal effort is not monotonic in the proportion of outsiders on the board.

Expected total surplus is given by:

$$S = E\{[\widetilde{f}] - E[\phi(\widetilde{f})] - I\} + \{E[\phi(\widetilde{f})] - \frac{r}{2}\delta^2 I^{2x}(\sigma^2 + (1-m)^2) - g\} \tag{7}$$

The shareholders' maximization problem is

$$\max_{I,\delta,m}\{S = pI^y((1-m)g)^z m^t - I - \frac{r}{2}\delta^2 I^{2x}(\sigma^2 + (1-m)^2) - g\} \tag{8}$$

$$s.t. \quad g = g^* \tag{9}$$

$$\alpha + \delta p I^y((1-m)g)^z m^t - \frac{r}{2}\delta^2 I^{2x}(\sigma^2 + (1-m)^2) - g \geq 0 \tag{10}$$

Empirically, CLM use m = max{$5,000,000, 6(0.28)(ln(assets))}. As do we, CLM find that the results using CRRA are quite similar to those based on CARA.

$$S \geq 0 \tag{11}$$

Equation (9) is the manager's incentive compatibility constraint (IC), arising from (6). Equations (10) and (11) are the manager's and shareholders' individual rationality constraints (IR), respectively. The corresponding F.O.Cs for the principal's choice of ownership δ, board independence, m, and assets, I, are[4]:

$$\begin{cases} \left.\dfrac{\partial S}{\partial I}\right|_{I=I^*} = 0 \\ \left.\dfrac{\partial S}{\partial \delta}\right|_{\delta=\delta^*} = 0 \\ \left.\dfrac{\partial S}{\partial m}\right|_{m=m^*} = 0 \end{cases} \tag{12}$$

Supposing the inequality constraints hold, 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 (or the Hessian matrix is negative semi-definite). We eliminate all other maxima in favor of the global maximum. Holding x, r, σ^2, and p constant, the input and output of the above system of equations are:

$$(y,z,t) \rightarrow (I^*,\delta^*,m^*) \tag{13}$$

Optimal ownership, board composition, and investment, denoted by δ^*, m^* and I^*, arise from exogenous productivity parameters *y*, *z*, and *t*. Finally, the optimal fixed component of compensation, denoted by α^*, is given by substitution in the manager's reservation utility constraint.

Despite the simplicity of the model, solving for the maximum is nontrivial. Accordingly, we use numerical methods to solve and verify the conditions for a global maximum. For any combination of the parameters, we can provide $\delta^* = \delta^*(z,y,t,x,r,\sigma^2 p)$, $m^* = m^*(z,y,t,x,r,\sigma^2 p)$ and $I^* = I^*(z,y,t,x,r,\sigma^2 p)$. Reversing the calculation, the functions are numerically invertible for restrictions that reduce the dimensionality of the parameter space to three. In our case, based on results in other studies we fix x, r, σ^2, and p, and then allow y, z and t to vary so as to fit (I^*,δ^*,m^*) to data. In particular, we take δ^* to be effective CEO ownership, m^* to be the proportion of outsiders on the board, and I^* to be firm total assets, and then calculate the

[4] Of course, in this problem inequality constraints also apply.

combination of y, z and t that would give rise to observed CEO ownership, board composition, and firm total asset as optimal choices in the model. We also calibrate the rest of the model parameters by simulating some moments of using the actual data. In this way, we estimate the parameters y, z and t for each firm-year observation on the triple (I^*, δ^*, m^*).

Our one period model provides a natural definition for Tobin's Q. Model generated Q^* equals maximized surplus, S^*, plus optimal initial investment, I^*, plus the random shock, all scaled by optimal initial investment, or:

$$Q^* = \frac{S^* + I^* + I^{*x}(\tilde{\varepsilon} + \tilde{v})}{I^*} \tag{14}$$

Model-generated Q^* arises endogenously from the production function, value maximizing choices of corporate governance and firm investment, the exogenous parameters, and the realization of the random disturbance. Define expected (*ex ante*) model generated Q^*, written as EQ^*, as Q^* with the random shock set equal to zero.

IV. Sample Collection and Characteristics

We use the 2003 version of the Execucomp database, covering the years 1993 through 2003. Execucomp provides data on salary, bonus, and total compensation for the top five executives, though we include only those who are identified as CEOs. 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 (δ^*), we include the effects of the CEO's direct stock ownership, restricted stock, and existing and newly granted stock options.[5]

[5] 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 Core and Guay (2002). 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 (2003)). 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 (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.

Board data are generated from the merger of Compact Disclosure for the years 1993-2000 and IRRC for the years 1999-2003. Compact Disclosure gives the name of the company, CUSIP, name, age and designations of both the officers and the directors of the firm. Compact Disclosure obtains these data from the proxy statement filed by the company. If the proxy date is not indicated we cannot align the data, in which case we delete the observation. We cross-check Compact Disclosure information with the proxy statements directly (using LEXIS-NEXIS) for a substantial portion of the data. One problem with Compact Disclosure is that it identifies only whether the director is an officer of the firm and cannot differentiate among the various types of "affiliated" or "gray" directors. IRRC provides more detailed information on affiliation of directors. Ideally, we would like to use the proportion of truly independent outsiders as our proxy for the board's advising/monitoring intensity, since affiliated directors are not generally viewed as effective monitors due to conflicts of interest (Klein 1998; Booth and Deli 1996). Because of the nature of the data, however, we use the proportion of nonexecutive directors as m^* when performing the analysis.[6]

Financial data come from Compustat. We use data on the book value of total assets to represent firm size I^*. 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 also collect a number of other firm characteristics that have been used in other studies as follows. Research and development expenditures and advertising expenses, both scaled by total assets, measure asset intangibility and growth opportunities. Following Bizjak, Brickley and Coles (1993), we set missing values of R&D and advertising expense to zero. Book leverage is calculated as long-term debt divided by total assets. Return on assets is calculated as net income, subtracting interest and depreciation, scaled by book assets. The standard deviation inferred from the Black-Scholes option-pricing model represents firm volatility. Finally, in some regression specifications we include industry dummies based on the Fama-French 30 industry classification.

[6] Fortunately, the correlation between the two datasets during the two overlapping years (1999 and 2000) is 0.9775. We repeat some of our analysis using data only for the two overlapping years (so as to use only the IRRC data on the proportion of independent outside directors). The results are similar.

Summary statistics for our sample of 8,512 firm year observations are reported in Table 1.[7] The mean effective ownership share of the CEO is 2.97% indicating that the CEO's wealth increases about three cents for every dollar increase in shareholder wealth. The standard deviation of the CEO's effective ownership share is 5.67%. Notice that managerial ownership in our sample is comparable to Shivdasani and Yermack (1999), where they use a sample of Fortune 500 firms. CEO age, on average, is 57. CEO tenure, which is defined as the number of years since s/he became the CEO, is 10.6 years (mean) and 9 years (median). If the CEO age is missing, we set it as the median value of 57. If CEO tenure is missing, we replace it by subtracting from 2003 (the latest year in the sample) the year he/she becomes the CEO.

The median board has 10 members, with roughly 2 insiders and 8 outsiders (including affiliated directors). These numbers are similar to other recent studies. For example, Bhagat and Black (2001) report a median board of 11 members with 3 insiders using data for the year 1991. Huson, Parrino, and Starks (2001) find that in their sample, for the period 1989-1994, the median board size is 12, with median insider fraction of 0.21. Yermack (1996) finds that over the period 1984-1991, the median sample firm has 12 board members with an insider fraction of 0.33. Coles, Daniel, and Naveen (2008), based on the period 1992-2001, find medians of 10, 2, and 8 for board size, number of inside directors, and number of outside directors.

Book asset of the firm in the sample is $13,301 million on average with a range from $21 million to $1,264,032 million (Citigroup in year 2003). Sales average $5,963 million and range from $0.099 million to $245,308 million (Exxon Mobil in 2003). Firm age is defined as the number of years since it has been added to Compustat. Average firm age is 31 years. Based on median size (2,323.79 million) and age (32 years) for S&P 500 firms over the same period, many of our sample firms are relatively large and mature. Leverage averages 0.197, and the average ratio of R&D and advertising expense scaled by total assets are 0.024 and 0.011, respectively. Scaled by total assets, on average, free cash flow is 2% and capital expenditures are 6%. Finally, average Tobin's Q for firms in the sample is 1.92. The 90th percentile is 3.32 and the 10th percentile is 1.02.

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[7] We start with 8582 firm-year observations. There are 70 firm-year observations we could not identify as a global maximum, which brings down the actual number of observations used in this paper to 8512.

V. Estimates of the Exogenous Productivity Parameters

To calibrate the model, we fix σ at 0.333 and r at 4.[8] 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 scale parameter, x, we follow the methodology in CLM (2006). In particular, we regress ln(σ^e) on ln(I), where I is total book assets of the firm. For each firm, cash flow volatility (σ^e) is calculated as the standard deviation of the time series of monthly total dollar 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 almost exactly 0.5, and x reliably falls between 0.4 and 0.6. The point estimate of $x = 0.5$ represents decreasing risk, as measured by standard deviation, per unit of firm scale. Perhaps larger firms operate in more lines of business and are more diversified and less risky per dollar invested. p (margin times the Cobb-Douglas scale/unit parameter) is estimated at the Fama-French 30 industry level such that the first and second moments of model-generated Q^* have the smallest squared distance from those of actual Tobin's Q.

For each firm-year observation in the sample, as described above, we invert the model. That is, we use numerical techniques to find the values of y, z and t that produce optimizing choices of δ^*, m^* and I^* from the model that match effective CEO ownership, board independence, and total assets in the data. Based on the estimated values of y, z and t, observed δ^*, m^* and I^*, as well as x and simulated cash flow shocks, we are able to calculate the value of Q predicted by the model. Recall that model generated Q^* is defined in equation (14). To calculate the additive shock, for each firm year observation we draw a randomly generated value of ε from $N(0,\sigma^2)$ and ν from $N(0,(1-m)^2)$,

[8] The assumption to choose risk aversion of 4 is taken from Haubrich (1994). The assumption that risk aversion does not vary across managers and firms is consistent with the choice to exclude adverse selection from the model. Instead, our modeling strategy focuses on differences in contract form, board structure, and firm size being driven by variation in production opportunities rather than by differences in managerial preferences.

separately, sum the two and scale by the square root of total assets. Recall that EQ^* is Q^* with the random shock set equal to zero.

The bottom panel of Table 1 presents summary statistics for the estimated productivity parameters derived from inverting the model to match the data. The mean value of y is 0.5145, and the median value is 0.5387. The mean value of z is 0.2471×10^{-2} and the median value is 0.0038×10^{-2}. Such values of y and z are very close to the calibration results in CLM (2006). The mean and median values of t are 0.2487×10^{-2} and 0.0088×10^{-2}, respectively.

Our estimates of the productivity of managerial effort, outside director advising and monitoring, and physical assets all appear to vary in a "reasonable" and plausible way across industries. Table 2 reports median values of the estimated structural parameters, y, z and t, endogenous inside ownership, board composition and investment (i.e., δ^*, m^* and I^*), and predicted Q^* (including the random disturbance term), across industries. The parameter y, a measure of the importance of physical capital in the production process, is high in a broad spectrum of industries, ranging from Utilities, Textile, Steel and Manufacturing. Both managerial effort and inside director expertise are most productive in Restaurants and Hotels, Apparel and Transportation. Outside directors are relatively important in Apparel, Transportation and Financials.[9] It is also interesting to point out that industries with a high value for the productivity of physical assets normally carry a low value for the other two parameters measuring the productivity of human capital. Physical assets are most important relative to human capital (the ratio of y over the product of z and t) in Metal and Mining, Utilities and Business Suppliers.

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. Based on the numerical solution of the model, we can measure the relative impact of various exogenous parameters on the design of firm's value-maximizing internal governance structure. Exogenous variables include margin (p), risk aversion (r), unscaled standard deviation (σ), and the scale factor for cash flow risk (x),

[9] See the survey of Murphy (1999) for evidence of similar variation in pay-performance sensitivity across industries.

plus the calibrating parameters governing the productivity of human capital (z and t) and physical capital (y). Table 3 presents comparative static estimates of the effect of each of changing these parameters on the optimizing choice of investment, managerial ownership, and board composition, as well as firm performance. Because δ^*, m^* and I^* are highly nonlinear in the structural parameters, so is EQ^*, we calculate optimal ownership, board composition and firm size for a benchmark level of the parameter plus and minus a perturbation in that parameter and then calculate the percentage changes in δ^*, m^*, I^* and EQ^*.[10] In all calculations, we use the median values of the estimated productivity parameters, z, t and y as the benchmark levels of the exogenous parameters.

Table 3 reports that a 10% increase in z, which increases the marginal productivity of managerial effort, implies an increase of 4.85% in the optimal ownership level of the CEO and a 1.41% decrease in board independence. A 10% increase in t, which increases the marginal productivity of outside director input, implies a increase of 1.53% in the optimal proportion of outsiders on the board. Increasing y by 10%, which increases the marginal productivity of investment, induces a 335.74% increase in the optimal investment scale, a 3.83% decrease in the optimal ownership level of the manager, and a 0.38% decrease on board independence. Neither z nor t has much effect on firm performance EQ^*. In contrast, a 10% increase in the value of y (and corresponding increase in investment) induces a relatively large decrease (8.99%) in EQ^*.

Consistent with the basic predictions of our augmented principal-agent model, an increase in sigma, which is the measure of the volatility of cash flows, reduces the optimal level of both managerial ownership and the proportion of outsiders. An increase in x, which determines the extent to which scale affects cash flow volatility, decreases ownership but has very little effect on EQ^*, investment, and the proportion of outsiders on the board. Increases in managerial risk aversion are negatively related to the optimal level of CEO ownership. An increase in risk aversion, however, has only negligible effects on investment, board composition and expected firm performance. All else equal,

[10] In all calculations, we use the industry median of the estimated productivity parameters, z, t and y as the benchmark levels of the exogenous parameters that vary across firms. Firm size, ownership and board independence are benchmarked in a similar way.

an increase in scaled profit margin (p) increases the optimal size of the firm, but has negligible effects on ownership, board composition and EQ^*. When the values of the parameters are decreased by 10% from their benchmark levels, the changes in the endogenous variables have the opposite signs, yet are somewhat different in magnitude, presumably because of the nonlinearities in the model.

None of these results is a surprise in the qualitative sense. The comparative statics are perfectly consistent with what our underlying model would predict given the structure of the model and the role of the exogenous parameters. What is new is that we provide evidence on the economic significance (the magnitudes) of the changes. These figures go some distance toward satisfying the call by Zingales (2000) and 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.

Table 4 reports Pearson and Spearman correlation coefficients of the estimated productivity parameters and a number of other variables that have been used either as control variables or firm performance measures in other research. The Pearson/Spearman correlation between y and z is -0.07/-0.26 (both significant at 1% level). The negative correlation between y and z is consistent with the previously documented negative relation between effective CEO ownership (wealth to performance sensitivity) and firm size. Indeed, the correlation between ownership and total assets in our data is also negative and significant, indicating that CEOs in larger firms have smaller ownership shares. The Pearson/Spearman correlation between y and t is -0.05/-0.18 (both significant at 1% level). The negative relationship between y and t suggests that larger firms should have a smaller proportion of insiders on the board. This relation is confirmed in our data by the positive correlation between total assets and proportion of outsiders and is also consistent with the results in Coles, Daniel, and Naveen (2008), who argue that larger firms are more complex and will therefore have more independent directors.

The Pearson/Spearman correlation between z and t is 0.71/0.89 (both significant at 1% level). Can this positive relationship between z and t mean that the board will optimally have more outsiders when the CEO has higher effective ownership (higher sensitivity of wealth of performance)? The comparative statics suggest that the positive effect of an increase in z on optimal ownership will complement the same effect of an increase in t, while the negative effect of an increase in z on board independence can more than offset the increase in the optimal proportion of outsiders from an increase in t. It is in this way that the productivity parameters drive the relationship between ownership and board independence to be negative in the data.

It is important to note that it is variation in the exogenous productivity parameters that define the contracting environment that drives the relationship between the two endogenous choices of ownership and board independence. Note that, in some sense, effective ownership and board independence are "complements" in production. To be specific, for $\delta \leq \delta^*$, $m \leq m^*$, and $I \leq I^*$, it can be shown that the second cross-partial derivative of expected surplus in δ and m is positive.[11] Thus, an increase in board independence increases the marginal impact of effective ownership on expected surplus. Holding scale constant, maximizing expected surplus is the same as maximizing firm value, so effective ownership and board independence are complements in production in the conventional sense for usage of those governance mechanisms below the optimal values.

It follows that one could obtain a specified value of expected surplus by trading off, or "substituting," board independence against effective ownership. Nonetheless, it is important to note that it is not this tradeoff, that is, not the shape of the "production function," that drives the relation of these two structures in our model. Indeed, optimizing choices of ownership and board structure will place the firm at the *top* of the objective function. Thus, it is the variation in the location of that maximal point across firms and over time that gives rise to the ultimate relation between ownership and board independence in the data. And it is precisely co-variation in the productivity parameters, specifically the positive correlation between z and t, that drives the negative relation between jointly-determined δ^* and m^* in the cross-section.

The above analysis shows that the model is invertible in the sense that there always exists a triple of productivity parameters for physical assets, managerial effort and

[11] There is no analytical solution for this partial derivative. Again, here we use a numerical approach with actual data plugged in.

outside director monitoring and advising that support the observed firm size, managerial ownership and board independence as part of optimal organizational form. We now use the model to illuminate the standard prior empirical experiments that analyze Tobin's Q, board independence, and managerial ownership.

VI. Results for Performance on Structure

One test of our model is to confront model generated Q^* with the data. 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. On the other hand, if our model captures some of the important determinants of the structure of the firm, then Q^* derived from the productivity parameter estimates, should be consistent with the data.

The mean of actual Tobin's Q in our sample is 1.92 and the mean of model generated Q^* is 2.26. The standard deviation of actual Q (Q^*) is 1.56 (1.20). Actual Q has somewhat larger cross-sectional variation than model-generated Q^*. One reason is that additional or latent factors outside our model are likely to influence realized firm performance. Nonetheless, the Pearson and Spearman correlation coefficients between Q^* and actual Q are 0.30/0.44 (both significant at 1% level).

Additional evidence that model-generated Q^* is a good representation of actual Q is provided in Table 4. Both actual Q and model-generated Q^* are correlated in a similar manner to variables outside of the model. Both are positively related to CEO ownership, R&D expenditure, return on asset, and free cash flows. The correlation between model-generated Q^* and ownership, however, is much higher than that between actual Q and ownership. Both actual Q and model-generated Q^* are negatively related with total assets, sales, leverage, and firm age. The negative relationship between firm performance and physical assets is due to the decreasing returns to scale in the Cobb-Douglas production function we adopt in our model. In terms of board structure, board size is negatively related to both actual Q and model-generated Q^*, which indicates that smaller boards tend to be associated with higher firm valuations (per Yermack, 1996). The proportion of outsiders is also negatively related to both actual Q and model-generated

Q^*. In short, model-generated Q^* has the same relationship with most firm characteristics as actual Q does, suggesting that our model does a good job capturing the primary economic determinants of board independence, CEO ownership, firm size, and firm performance.

Table 5 examines the relationship between firm performance and governance structure in a regression framework. When we regress actual Q on ownership and the square of ownership (Model 1), we see the commonly reported result of an "inverted-U" or "hump-shaped" association between ownership and Tobin's Q (e.g., McConnell and Servaes, 1990). The coefficient estimate on the CEO's ownership share is 3.769 (p-value<0.001), and the coefficient estimate on the squared ownership of the CEO is -7.705 (p-value<0.001). The ratio of the coefficient estimates of the linear term to that of the squared term is 0.49, which corresponds to a maximum Q at CEO ownership of about 24.5%.[12] We replace actual Q with model-generated Q^* in Model 4. The hump shape persists, with the maximum occurring at a similar level. One 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 (Stulz 1988). An alternative interpretation, consistent with the model herein (and CLM, 2006), is that these results could also arise as the outcome of value maximizing choices of organizational form driven by the underlying features of the contracting environment.

Model 2 regresses actual Q on the level of board independence and shows that Q is inversely related to board independence similar to results reported in Yermack (1996) and Agrawal and Knoeber (1996). This result is somewhat counterintuitive relative to the conventional wisdom which suggests that independent directors provide better monitoring compared to inside directors, but can be explained within the context of our model by the fact that firms with high productivity of CEO effort (and therefore high values of Tobin's Q) optimally choose less independent boards. Model 5 shows that similar results hold when actual Q is replaced with model-generated Q^*. Finally, Models

[12] CLM (2006) report a figure of 20% CEO effective ownership to reach maximum Q. The maximum based on the result in McConnell and Servaes (1990) is at about 37.5% ownership for the larger group of officers and directors.

3 and 6 show that both ownership and board independence remain statistically significantly associated with firm performance when both are included in the regression.

These simple specifications with no control variables essentially ignore what we know from the model, and the structural model provides a convenient way to evaluate the above results. Within the model, optimal ownership, board structure and firm performance are all endogenously determined as value-maximizing choices by the exogenous productivity parameters *z*, *y*, and *t*, that define the contracting environment. In the context of our model, a properly specified empirical test should not detect any significant relationship between Q and the corporate governance variables once the exogenous parameters are adequately controlled for. To explore these issues, Table 6 reports regressions that include a relatively parsimonious set of nonlinear functions of *z*, *t* and *y* to control for the structural determinants of Q^*. Note that we do not know the exact functional form to use because the model is not solvable in closed form.

Model 1 shows that a simple regression using the estimated productivity parameters has significant explanatory power for actual Tobin's Q. The adjusted R^2 from Model 1 is equal to 17%. We then add ownership and board independence in Model 2. The estimated parameters on δ^* and m^* are insignificant and small, and the adjusted R^2 remains almost unchanged. However, the coefficient estimate on the squared ownership term remains significantly different from zero at the 10% level. Of course, actual Q is likely to be measured with errors that are correlated with other forces outside the model.[13] Models 3 and 4 use model-generated Q^* as the dependent variable. As expected the R^2 of the regressions in both models are very high because *z*, *y*, and *t* are by definition the correct explanatory variables. Also as expected within our equilibrium context, adding *z*, *y*, and *t* to the regressions drives out the effects of ownership and board independence in explaining firm performance.

The evidence in this section suggests that the model does a reasonable job explaining performance, board independence, and ownership. The explanatory power of effective ownership and board independence, using either model generated Q^* or actual

[13] 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, t and y) that are correlated with optimal choices of ownership and board's independence.

Q, are either eliminated or reduced substantially by the inclusion of the exogenous variables provided by our structural model[14].

VII. Results for Structure on Structure

While the relation between CEO compensation level and board independence has been examined both theoretically (Hermalin, 2004) and empirically (Core et. al., 1999), the evidence on the relation between CEO pay-for-performance sensitivity and board independence is mixed. Denis and Sarin (1999), Shivdasani and Yermack (1999), and Coles, Daniel, and Naveen (2008) estimate a negative relationship between managerial ownership and the proportion of outsiders on the board, suggesting that they are substitutes. In contrast, Ryan and Wiggins (2004) and Davila and Penalva (2004) find a positive correlation between insider ownership and the proportion of outsiders on the board. Our model suggests that CEO ownership and board independence are determined by the exogenous productivity parameters. Variation across firms and over time in these parameters could lead to either a positive or negative relationship between CEO ownership and board independence.

To illustrate, an increase in the productivity of outside director advising/monitoring (t), as Table 3 indicates, implies an increase in ownership and an increase in board independence. Thus, holding the other two productivity parameters, y and z, constant, there will be a positive relation between ownership and board independence. Ownership and board independence will, however, move in the opposite direction if we hold y and t constant and let z vary across the firms. In contrast, if the productivity of physical assets (y) increases while t and z are held constant, there is a decrease in both ownership and board independence. In other words, the model can generate some mixed results for the relation between ownership and board independence, depending on how the three productivity parameters move across firms and industries. If parameter z moves to a larger extent in the cross section than parameter t, or if parameter y moves in the opposite direction from z or t, then we would expect ownership to be negatively related to board

[14] We do not suggest that other forces are unimportant. It is quite likely that factors other that z, y and t also affect investment, managerial ownership and board structure. Such variables may include takeover and anti-takeover provisions, exchange rates, monetary and fiscal policy, government regulation, taxes etc. 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.

independence. Indeed, as indicated in Table 4, both *z* and *t* are negatively correlated with *y* and correspondingly, board independence and ownership are negatively correlated in the data.

Table 7 reports regressions similar to those reported in Table 6 that examine whether simple functional forms of the three productivity parameters can explain the negative relationship between ownership and board independence is structure-on-structure regressions. The dependent variable is ownership in Model 1 and board independence in Model 3. It turns out that using the same simple function forms of three productivity parameters can explain 89% and 24% variation in ownership and board independence, respectively. Notice that the lower R^2 in Model 3 partially reflects the fact that board independence does not vary too much in the sample. The null hypothesis arising from our model is that once we control for the productivity parameters, variation in ownership should not be associated with variation in board independence. The evidence in Models 2 and 4 supports this hypothesis. When ownership is the dependent variable in Model 2, the coefficient on board independence is negative but insignificant. We obtain a similar result when we regress board independence on ownership in Model 4. The productivity parameters extracted from the contracting model have power to explain the joint determination of optimal board independence and CEO ownership.

The results in Section VI and Section VII warrant a few comments. First, in actual data the econometrician does not observe the exogenous productivity parameters. Instead, existing studies employ numerous proxy variables, such as industry, R&D, etc. to control for differences in the underlying contracting environment. Nevertheless, model specification issues arise both from the unobservability of the underlying exogenous parameters and from the fact that the relation between ownership and board independence is a nonlinear function of these exogenous variables. Absent a properly specified model it is easy to generate spurious relationships between various governance and performance variables that are not causal. By specifying a structural model and estimates of the underlying exogenous parameters we are potentially able to avoid some of these issues and identify some of the primary economic determinants of corporate governance structure.

VIII. Policy Analysis—The Case of Board Reforms

In response to the corporate scandals in the United States in 2001 and 2002, the Sarbanes-Oxley Act and the new rules of the major exchanges established new restrictions on the structure and operations of boards. The purpose of these rules was to "… strengthen corporate governance practices of listed companies." One of the main provisions of these rules was to require that a majority of board members on a single board be independent. Chhaochharia and Grinstein (2008) examine the effects of these reforms on the setting of executive compensation and, using a difference-in-difference approach, find a significant decrease in CEO compensation for firms that were more affected by these requirements, compared with firms that were less affected. The effect is economically large. According to their estimates, CEO compensation in the affected firms declines by around 17% following the reforms. Based on this result, they argue that the reforms appear to have changed the way that firms make compensation decisions in a manner consistent with the intent of the rule changes.

In this section we use our model to provide an alternative perspective on these conclusions and to highlight an advantage of our structural approach to analyzing corporate governance. In the context of our model, some firms should optimally choose insider dominated boards. A one-size-fits-all regulatory reform forces these firms away from their preferred board structure and causes them to readjust the usage of other governance mechanisms (i.e., compensation in this case) in response. We use our model to assess the whether the changes in compensation that would be generated within an equilibrium value-maximizing framework are consistent with those documented by Chhaochharia and Grinstein (2008, hereafter, CG).

To be comparable to the analysis in CG, we use the compensation data and director information in year 2000 and 2001 as the pre-SOX period, and data for years 2004 and 2005 as the post-SOX period. We include in the analysis only firms that existed in both periods to avoid any structural changes in the sample composition due to entries and exits. In each year, we calculate the firm total assets, CEO ownership (including options) and proportion of insiders on the board, as defined in IRRC. Firm-year observations are then averaged at the firm level in both pre- and post-SOX periods. Our final sample contains 1,136 firms.

To evaluate the effect of the reforms we follow a two step procedure. The first step is to estimate the productivity parameters (y, z, t) using pre-SOX firm size, CEO ownership and board independence as inputs in our model. The estimation is the same as described in Section 2. The model estimates of the productivity parameters are then assigned to the same firm in the post-SOX period. The second step is to generate the post-SOX firm size and CEO ownership from the model that are consistent with the new board structure. We generate the post-SOX ownership and firm size by inversely solving the model given the pre-determined model parameters, plus the observed post-SOX proportion of insiders on the board. More specifically, in the second step, optimal firm size and CEO ownership are obtained by maximizing the total surplus in Eq. (7) with respect to I and δ, given the productivity parameters and the observed level of board independence.

In the subsequent analysis, firms are categorized into two groups: compliant firms and non-compliant firms. Following CG, firms that do not have a majority of independent directors on the board in year 2002 are assigned to the non-compliant group. There are 938 compliant firms and 198 non-compliant firms. The proportion of non-compliant firms is 17%, the same as reported in CG's paper. Table 8 presents summary statistics from our simulation. Given the linear contract in our model, the total compensation is the sum of base salary and performance-based compensation. Base salary is backed out from the model by assuming that the participation constraint is binding and solving for the manager’s reservation utility. The expected value of the performance-based compensation is the level of CEO ownership multiplied by expected firm cashflows from Eq. (1). The risk premium and managerial effort are also calculated based on Eq. (5) and Eq. (6), respectively. Notice that firm size and CEO ownership in the Pre-SOX period are taken from Execucomp. Board independence in both the pre- and post-SOX periods are taken from the IRRC. However, the post-SOX values of compensation, ownership and firm size are simulated as value maximizing choices from the model.

Panel A is the summary statistics for the entire sample. Average total compensation decreased from \$8.742 million in the pre-SOX period to \$7.47 million in the post-SOX period. The average base salary decreases from an average of \$2.545 million to \$2.318 million, a drop of \$0.227 million. Most of the drop is attributed to the drop in the value of performance-based compensation. The value of performance-based compensation decreases from an average of $6.197 million to $5.152 million, a drop of $1.045 million. Consistent with the mandates of the reforms, board independence increases from 64% to 71%.

Panel B divides the firms into compliant and non-compliant groups. The decline in total compensation, as well as the drop in the value of performance-based compensation is only found in the non-compliant group. For non-compliant firms, the total compensation decreases from $20.352 million to $9.398 million, and performance based compensation drops from $15.291 million to $6.634 million. Actual board independence is increased from 37.1% to 52.8%. However, our simulation results show that both managerial effort and the risk premium decrease in response to the change in board independence. This effect is intuitive within our model. The ratio of managerial productivity (z) to outsider director productivity (t) for non-complaint firms is three times higher than the ratio for compliant firms. Hence, for non-compliant firms, inside director expertise is much more important to firm production than outside director advising and monitoring. As these firms are forced away from their preferred board structures by the regulation they decrease the pay-performance sensitivity of the manager's contract. The model also predicts that firm output, which is the expected cashflow, declines from $389 million to $368 million, approximately a 5% loss in value to shareholders.

Panel A of Table 9 presents the univariate analysis for the change in the natural log of total compensation from pre–SOX period to the post-SOX period for both compliant and non-compliant firms. The last row of the table reports the t-statistics and Wilcoxon rank sum tests for the differences in means and medians, respectively. Similar to results documented in CG, both tests suggest that the decline in total compensation from the pre-SOX period to the post-SOX period is significantly more negative for non-complaint firms compared to compliant firms.

Panel B in the table presents the results from the following regression specification over the balanced panel of 1136 firms. The regression is similar to the one presented in CG as our main purpose is to see if our simulated data can replicate their results.

Log(total compensation) = Post-SOX + Non-compliant + Post-SOX*Non-Compliant + Sales*Pre-SOX + Sales*Post-SOX + ROA*Pre-SOX + ROA*Post-SOX + Returns*Pre-SOX + Returns*Post-SOX + Tenure

Post-SOX is a dummy variable that equals to one if the observation is from the years 2004 or 2005 and zero otherwise. Pre-SOX is a dummy variable that equals to one if the observation is from the years 2000 or 2001 and zero otherwise. Non-compliant is a dummy variable that equals to one if the firm did not have a majority of independent directors on the board in the year 2002 and zero otherwise. To account for other firm characteristics related to compensation, we also include the following control variables as in CG. Sales is the natural log of company sales. ROA is the natural log of one plus the return on assets. Returns is the natural log of the annual gross stock return (dividend reinvested). Tenure is the number of years in which the CEO served in the firm. The numbers in parentheses are robust standard errors, clustered at the firm-period level.

Model 1 in the table shows that the coefficient of the interaction dummy Post-SOX and Non-compliant is negative and significant, with a magnitude of -0.135. The magnitude of the coefficient suggests a drop in the compensation of firms not complying with the rules on the order of 13.5%, relative to complying firms. After we include the control variables in Model 2, the coefficient estimate for the interaction term is still negative and significant. Essentially, we are able to replicate CG's main results by simulating data from our model. Note, however, that in our framework, the regulatory reforms represent a net cost to shareholders as they push firms away from their optimal governance structures. The main conclusion from our analysis is that observing a decline in compensation following the reforms cannot be taken as evidence that the reforms improved corporate governance and managerial oversight, and our analysis highlights the difficulties of assessing the costs and benefits associated with regulatory reform and provides a benchmark for assessing the efficacy of these policy changes.

IX. Conclusion

We specify a simple structural model of the firm and calibrate the model to data to obtain estimates of three exogenous productivity parameters: the productivity of physical assets; the productivity of managerial/insider effort; and the productivity of outside directors advising/monitoring. In particular, we employ the principal-agent model of Holmstrom (1979) and Holmstrom and Milgrom (1987), but augment that model with investment, managerial ownership and board structure decisions. We estimate the productivity parameters that would give rise to the observed levels of ownership, the proportion of outsiders on the board, and investment as optimal choices in our model.

Our estimates of the productivity parameters vary as might be expected across industries. Physical assets and human capital play different roles in different industries, which lead to various designs of CEO compensation and board structure in practice. Furthermore, we provide comparative static results based on the model which allows us to gauge the economic significance of the underlying structural parameters as determinants of the organization form.

Having estimated the structural parameters from the data, we test whether our estimates of the exogenous productivity parameters have power to explain managerial ownership, board composition, and firm performance. Using model-generated Tobin's Q, the familiar (McConnell and Servaes, 1990) hump-shaped relation between managerial ownership and firm performance is generated by the model. When including simple functional forms of our three productivity parameters, neither ownership nor the proportion of outsiders on the board has any explanatory power for firm performance.

Our model also explains the negative relation between managerial ownership and board independence that often appears in the data. The estimated parameters governing the productivity of managerial effort and outside director advising are correlated in such a way that their effects on board independence and managerial ownership give rise to the negative relation between ownership and board independence that is reported in various studies. This result, and those on performance and structure, suggest that the productivity parameters specified by our model represent some of the joint economic determinants of managerial ownership, board composition, and Tobin's Q.

At the center of our analysis, we examine the extent to which changes in the productivity of physical assets, managerial input, inside director expertise, and outside director monitoring and advising affect optimal managerial ownership and board independence, as well as firm performance. That is, our model represents part of 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. Despite the empirical success of our approach, however, we doubt that our model encompasses all of the relevant economic determinants for managerial ownership and structure of board. Nonetheless, our augmented principal-agent model does provide one possible equilibrium explanation for the relation between performance and various internal governance structures, as well as the interaction among these internal governance structures. Such equilibrium arises from endogenous value-maximizing choices of optimal organizational form, rather than from transaction costs or other market frictions.

Finally, we apply our model to analyze the effects of recent board reforms on compensation policy. Our model replicates the observed drop in compensation associated with changes in board structure but suggests a different interpretation from that espoused by corporate governance activists. Our analysis points out the potential costs of one-size-fits-all regulation.

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Table 1: Summary Statistics

The total sample consists of 8512 firm-year observations from 1993-2003. Ownership is computed as the fractional direct stock ownership of the CEO plus the effective fractional ownership arising from the CEO's stock option holdings. Firm age is calculated as the years since the firm has been added to Compustat. Leverage is the ratio of long-term debt to total book assets. R&D, advertising expenses and capital expenditure are all scaled by total book assets. Missing values of R&D and advertising expenses are set to zero. Free cash flow is calculated as net income subtracting interest and depreciation, scaled by total book assets. The standard deviation inferred from the BS option-pricing model is volatility. Missing values of CEO age are replaced with the median value of the sample. CEO tenure is defined as the number of years since s/he becomes the CEO and, if the value is missing, we assume the CEO is still in the position. 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. Board data are from Compact Disclosure and IRRC. Board size is the number of directors on the board. Outsiders on the board are defined as the directors who are not the employees of the firm. Panel B presents the parameter calibration results from the model in Section III. y governs the productivity of physical assets, z governs the productivity of managerial effort, and t is the governs productivity of outside director input. Q* is the model generated Tobin's Q using (14).

Variable	Mean	Median	Std Dev	10 Percentile	90 Percentile
Panel A (firm characteristic) :					
Ownership	0.0297	0.0107	0.0567	0.0021	0.0736
Assets ($millions)	13301.24	2323.79	50020.15	391.1	26220
Sales ($millions)	5838.68	1903.61	13601.32	386.344	13544
Leverage	0.1971	0.1860	0.1526	0.0029	0.3878
Firm age (years)	31.2550	32	15.8738	11	53
R&D	0.0244	0	0.0531	0	0.0846
Free cash flow	0.0213	0.0255	0.0742	-0.0435	0.0877
Volatility	0.3810	0.341	0.1700	0.207	0.613
ROA	0.1353	0.1323	0.0979	0.0313	0.2387
Advertising	0.0111	0	0.0333	0	0.0382
Capital Expenditure	0.0611	0.0494	0.0510	0.0142	0.1190
Tobin's Q	1.9200	1.4262	1.5606	1.0200	3.3210
Board size	10.3005	10	3.1176	7	14
Factions of outsiders	0.7361	0.7778	0.1536	0.5	0.9
CEO age (years)	57.0150	57	5.1927	51	63
CEO tenure (years)	10.5732	9	7.1950	4	20
Panel B (model estimates):					
y	0.5145	0.5387	0.1669	0.2818	0.7028
z ($\times 10^2$)	0.2471	0.0038	1.3493	0.0001	0.2293
t ($\times 10^2$)	0.2487	0.0088	1.4298	0.0004	0.2705
Q*	2.2643	1.8539	1.1960	1.4236	3.5518

Table 2: Summary Statistics by Industry

This table presents summary statistics for estimated parameters by industry. The 30 industry definition is based on Ken French's classification available at his homepage. N is the number of firms in each industry. P is the profit margin or unit cost and is fixed for all firms in the same industry. Median value is reported for each parameter within the industry. z and t are scaled by 10^2. Q and Q* are actual and model generated Tobin's Q, respectively. Ownership and investment are the median value of CEO effective ownership and total book assets in each industry. The standard deviation of each parameter is all calculated within each of the 30 industry groups.

Industry name	n	p	Inv	y	Ownership	z(×10^2)	Independence	t(×10^2)	Q	Q*	std(Q)	std(Q*)
Precious Metals and Metal Mining	52	46	2619.87	0.5576	0.011	0.0111	0.82	0.0202	1.69	1.81	1.55	0.89
Utilities	529	6	10342.69	0.8134	0.007	0.054	0.81	0.0252	1.19	1.23	2.35	0.44
Business Supplies and containers	268	27	5338.7	0.6307	0.014	0.0288	0.77	0.0487	1.47	1.60	0.86	0.24
Others	100	69	31739.15	0.5563	0.015	0.0215	0.81	0.0666	1.70	1.83	1.21	0.63
Perroleum and Natural Gas	349	33	11731.2	0.6278	0.016	0.0637	0.74	0.0641	1.52	1.61	0.98	0.23
Products and Machinery	349	61	3430.56	0.5199	0.019	0.0477	0.79	0.0786	1.74	1.96	2.36	2.11
Electrical Equipment	109	150	2594.66	0.4171	0.026	0.0757	0.74	0.0924	1.90	2.50	0.60	0.19
Chemicals	316	49	4837.1	0.563	0.018	0.1037	0.78	0.1723	1.66	1.79	0.39	0.03
Communications	179	222	30791.17	0.4958	0.017	0.1225	0.73	0.1316	1.85	2.06	0.69	0.15
Healthcare	576	463	5213.56	0.3142	0.030	0.1158	0.73	0.1109	3.36	3.74	0.57	0.08
Wholesale	333	22	3010.08	0.6331	0.028	0.1527	0.73	0.2778	1.45	1.58	0.88	0.27
Business Equipment	815	532	4403.17	0.2972	0.031	0.1732	0.73	0.151	2.73	3.74	1.54	0.70
Financials	1194	58	53118.23	0.6212	0.026	0.2068	0.75	0.3158	1.34	1.62	0.67	0.17
Consumer Goods	182	181	4488.21	0.4078	0.034	0.2922	0.73	0.1512	2.24	2.58	0.45	0.15
Textiles	60	4	1232.97	0.8272	0.030	0.3866	0.66	0.2489	1.22	1.20	0.71	0.18
Automobiles and Trucks	214	31	22070.66	0.6156	0.029	0.3327	0.74	0.2156	1.46	1.64	0.43	0.16
Recreation	108	255	4864.1	0.3939	0.042	0.1979	0.69	0.2428	1.91	2.61	0.15	0.04
Printing and Publishing	174	108	2760.84	0.4722	0.034	0.2157	0.76	0.2682	1.93	2.14	0.78	0.31
Aircraft, ships and Railroad	87	45	11316.54	0.6084	0.029	0.3624	0.77	0.2447	1.54	1.65	2.19	1.40
Restaurants, Hotels and Motels	152	64	2707.62	0.494	0.044	0.4207	0.64	0.2109	1.87	2.06	2.69	1.35
Steel Works	238	13	3103.21	0.6965	0.026	0.383	0.75	0.3646	1.31	1.44	0.59	0.15
Food, Beer, Liquor and Tobacco Product	287	403	8642.8	0.3721	0.042	0.3252	0.71	0.2807	2.39	2.88	0.66	0.14
Construction	299	32	2811.04	0.5902	0.039	0.4054	0.73	0.4662	1.54	1.70	0.68	0.12
Retails	578	171	5185.08	0.4246	0.042	0.3767	0.68	0.3782	2.06	2.43	1.26	0.45
Personal and Business Services	588	384	4317.91	0.3111	0.046	0.3434	0.68	0.3536	2.77	3.53	0.83	0.29
Transportation	246	27	6528.71	0.6242	0.051	1.1504	0.74	0.9413	1.46	1.60	0.91	0.18
Apparel	52	46	2619.87	0.5576	0.011	0.0111	0.82	0.0202	1.69	1.81	1.55	0.89

Table 3: Comparative Static

This table presents the comparative static results for ownership (δ), investment (I), board independence (m) and expected model generated Tobin's Q (EQ*). The benchmark values for the exogenous parameters, as well as the three choice variables, are the median values in each industry. The number in the table is the percentage change based on the 10% increase or decrease in one of the exogenous parameters. The reported results are averaged across all industries. Changes based on one parameter perturbation keep the other parameters constant.

Percent changes for a 10% increases in parameter

	baseline	z	y	t	x	r	p	σ
Investment (I)	3307.61	-0.85	335.74	-0.84	-0.85	-0.84	25.55	-0.84
Ownership (δ)	0.01144	4.85	-3.83	3.18	-30.56	-3.09	1.61	-5.70
Independence (m)	0.76889	-1.41	-0.38	1.53	0.11	0.08	0.08	-0.87
EQ*	1.99815	0.11	-8.99	0.11	0.11	0.11	0.11	0.11

Percent changes for a 10% decreases in parameter

	baseline	z	y	t	x	r	p	σ
Investment (I)	3307.61	-0.83	-63.56	-0.84	-0.84	-0.84	-22.78	-0.84
Ownership (δ)	0.01144	-1.92	7.07	-0.17	48.77	7.06	1.61	10.20
Independence (m)	0.76889	1.69	0.07	-1.57	0.03	0.07	0.08	1.15
EQ*	1.99815	0.11	11.24	0.11	0.11	0.11	0.11	0.11

Table 4: Pearson/Spearman Correlation Matrix

The definitions of the all variables in this table can be obtained in Table 1. The ownership is computed as the fractional direct stock ownership of the CEO plus the effective factional ownership arising from the CEO's stock option holdings. Pearson correlations are above the diagonal and Spearman rank-correlation are below the diagonal. Unless otherwise specified (italic), all correlations are significant at the 10% level.

	Ownership	Assets	Sales	Leverage	Firm age	R&D	ROA	FCF	Actual Q	Board size	Outsiders	Q*	y	z	t
Ownership		-0.091	-0.123	-0.072	-0.221	-0.012	0.013	0.035	0.051	-0.238	-0.296	0.192	-0.224	0.802	0.714
Assets	-0.511		0.529	-0.044	0.073	-0.076	-0.138	-0.036	-0.077	0.295	0.054	-0.152	0.222	-0.037	-0.033
Sales	-0.475	0.820		-0.003	0.231	-0.049	0.007	-0.032	-0.001	0.286	0.077	-0.182	0.221	-0.046	-0.042
Leverage	-0.075	0.113	0.123		0.130	-0.189	-0.062	-0.217	-0.208	0.012	0.068	-0.201	0.228	-0.033	-0.017
Firm age	-0.422	0.364	0.446	0.176		-0.142	0.060	-0.058	-0.132	0.361	0.265	-0.327	0.391	-0.083	-0.064
R&D	-0.014	-0.176	-0.102	-0.197	0.041		-0.158	-0.099	0.360	-0.219	0.001	0.564	-0.456	-0.038	-0.046
ROA	-0.010	-0.240	0.043	-0.055	0.058	0.150		0.659	0.374	-0.078	-0.047	-0.068	-0.152	0.016	-0.003
FCF	0.126	-0.168	-0.042	-0.249	-0.121	0.203	0.566		0.240	-0.031	-0.061	-0.007	-0.159	0.008	0.002
Actual Q	0.004	-0.180	-0.022	-0.243	-0.071	0.384	0.625	0.414		-0.147	-0.065	0.297	-0.353	0.011	0.001
Board size	-0.446	0.600	0.517	0.086	0.419	-0.194	-0.089	-0.135	-0.134		0.213	-0.383	0.423	-0.106	-0.090
Outsiders	-0.297	0.236	0.204	0.094	0.261	0.047	-0.054	-0.105	-0.087	0.236		-0.163	0.214	-0.250	-0.045
Q*	0.358	-0.582	-0.458	-0.259	-0.359	0.409	0.280	0.327	0.442	-0.440	-0.212		-0.833	0.044	0.018
y	-0.368	0.585	0.459	0.259	0.362	-0.407	-0.280	-0.327	-0.442	0.442	0.219	-0.999		-0.070	-0.046
z	0.981	-0.457	-0.432	-0.049	-0.406	-0.087	-0.027	0.105	-0.040	-0.411	-0.401	0.255	-0.264		0.706
t	0.929	-0.380	-0.365	-0.011	-0.312	-0.069	-0.052	0.062	-0.084	-0.332	0.009	0.175	-0.183	0.891	

Table 5: Pooled OLS Regression for Actual Q and Modeled Q

This table contains pooled OLS regressions of Q on the ownership share of CEO, the squared ownership share of CEO, the board independence. Ownership (δ) is computed as the fractional direct stock ownership of the CEO plus the effective factional ownership arising from the CEO's stock option holdings. Board Independence (m) is measured by the fractions of outsiders on the board. In model 1-3, the dependent variable is the actual Tobin's Q. In model 4-6, the dependent variable is the model-generated Q^*. Robust standard errors are given in parentheses (White 1980). *, ** and *** indicate the level of significance at 10%, 5% and 1%, respectively.

Dependent Variable:	Actual Q			Modeled Q*		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	1.840***	2.408***	2.225***	2.087***	3.201***	2.719***
	(0.021)	(0.087)	(0.097)	(0.004)	(0.065)	(0.075)
Ownership (δ)	3.769***		3.007***	7.546***		6.283***
	(0.872)		(0.901)	(1.030)		(1.019)
δ^2	-7.705***		-6.521***	-11.378***		-9.401**
	(2.369)		(2.337)	(3.924)		(3.767)
Independence (m)		-0.663***	-0.499***		-1.272***	-0.819***
		(0.114)	(0.121)		(0.084)	(0.089)
Adjusted R^2	0.005	0.004	0.007	0.045	0.027	0.054

Table 6: Non-linear OLS Regression for Performance on Structure

This table contains non-linear OLS regression of actual Q and model-generated Q^* on CEO ownership and board independence with exogenous parameters. Robust standard errors are given in parentheses (White 1980). *, ** and *** indicate the level of significance at 10%, 5% and 1%, respectively.

Dependent	Actual Q		Modeled Q^*	
	Model 1	Model 2	Model 3	Model 4
Intercept	0.801	0.323	-0.061	0.025
	(1.609)	(1.614)	(0.074)	(0.055)
Ownership (δ)		1.274		-0.073
		(1.175)		(0.057)
δ^2		-19.787*		3.597
		(11.431)		(2.581)
Independence (m)		-0.052		-0.004
		(0.117)		(0.003)
y	5.673	6.622*	0.109	-0.044
	(3.687)	(3.712)	(0.161)	(0.117)
z	-3.895	29.662	2.787***	-0.428***
	(9.939)	(29.164)	(0.644)	(0.855)
t	5.348	25.019	-1.101***	-5.097***
	(10.761)	(14.601)	(0.425)	(0.804)
y^2	-6.359**	-6.807***	-0.053	0.031
	(2.623)	(2.631)	(0.111)	(0.082)
z^2	7.011	-23.327	-4.199**	3.981***
	(21.408)	(37.685)	(1.943)	(1.363)
t^2	-0.185	-13.549	0.531	3.579***
	(10.641)	(7.681)	(0.509)	(0.682)
1/y	0.034	0.117	1.011***	0.995***
	(0.248)	(0.249)	(0.013)	(0.009)
1/z	0.001	0.001	0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
1/t	0.001	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
$1/y^2$	0.008	0.004	-0.001	0.001
	(0.011)	(0.011)	(0.001)	(0.001)
$1/z^2$	-0.001	-0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
$1/t^2$	-0.001	-0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
yz	10.937	-26.258	-6.366***	0.811
	(12.119)	(28.524)	(1.114)	(0.921)
yt	-8.591	-29.608	1.954**	6.032***
	(14.999)	(19.013)	(0.807)	(1.046)
zt	-19.234	10.036	-2.282	-7.759***
	(32.626)	(22.137)	(2.172)	(2.236)
1/yz	0.001	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
1/yt	0.001	0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
1/zt	0.001	0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Industry Dummy	yes	yes	yes	yes
Adjusted R^2	0.171	0.172	0.999	0.999

Table 7: Non-linear OLS Regression for Structure on Structure

This table contains non-linear OLS regression of CEO ownership on board independence or vice versa, both with control variables and exogenous parameters. Robust standard errors are given in parentheses (White 1980). *, ** and *** indicate the level of significance at 10%, 5% and 1%, respectively.

Dependent	Ownership	Ownership	Independence	Independence
	Model 1	Model 2	Model 3	Model 4
Intercept	0.059***	0.075***	0.679***	-0.743***
	(0.019)	(0.019)	(0.109)	(0.108)
Ownership (δ)				-1.067
				(0.751)
Independence (m)		-0.022		
		(0.017)		
y	-0.112***	-0.112***	-0.008	-0.127
	(0.042)	(0.042)	(0.254)	(0.251)
z	5.435***	5.187***	-11.178***	-5.379***
	(0.353)	(0.358)	(0.807)	(0.822)
t	3.098**	3.257**	7.175***	10.482***
	(0.426)	(0.441)	(0.933)	(1.355)
y^2	0.018	0.027	0.403**	0.423**
	(0.031)	(0.030)	(0.191)	(0.189)
z^2	-13.763***	-12.825***	42.409***	27.722***
	(1.586)	(1.542)	(3.863)	(2.936)
t^2	-4.141***	-4.293***	-6.901***	-11.319***
	(0.781)	(0.789)	(1.381)	(1.807)
1/y	0.003	0.003	-0.009**	-0.005
	(0.003)	(0.003)	(0.017)	(0.016)
1/z	-0.001**	-0.001*	0.001**	0.001**
	(0.001)	(0.001)	(0.001)	(0.001)
1/t	0.001*	0.001	-0.001***	-0.001***
	(0.001)	(0.001)	(0.001)	(0.001)
$1/y^2$	-0.001	-0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
$1/z^2$	0.001***	0.001***	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
$1/t^2$	0.001***	0.001***	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
yz	-2.656***	-2.648***	0.347	-2.487
	(0.589)	(0.591)	(1.567)	(1.683)
yt	-1.633**	-1.647**	-0.604	-2.347
	(0.813)	(0.836)	(1.837)	(2.453)
tz	-1.047	-1.474	-19.339***	-20.457***
	(3.269)	(3.204)	(4.743)	(3.817)
1/yz	-0.001	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
1/yt	-0.001**	-0.001	0.001***	0.001***
	(0.001)	(0.001)	(0.001)	(0.001)
1/tz	-0.001	-0.001***	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Industry Dummy	yes	yes	yes	yes
R^2	0.885	0.887	0.242	0.259

Table 8: Summary Statistics for SOX Analysis

This table shows simulated CEO compensation for the post-SOX period using model parameters estimated in the pre-SOX period. The sample consist of 1136 firms exist in both pre-SOX period, which is year 2000 and 2001 and post-SOX period, which is year 2004 and 2005. In panel A, summary statistics are given for sample firms in both pre-SOX and post-SOX period. Base salary (α^*) is the optimal fixed component of compensation by setting the manager's reservation utility constraint binding. Option-based compensation is CEO ownership (δ) multiplied by expected cashflows in Eq (1). Total compensation is the sum of base salary and option-based compensation according to Eq. (4). CEO risk premium and effort (g*) is given by Eq. (5) and Eq. (6), respectively. Panel B separates the firms into compliant group and non-compliant group. A firm is in the no-complaint group is the firm did not have a majority of independent directors on the board in the year 2002. Numbers without parentheses are means and with parentheses are medians.

Panel A: Summary Statistics

	Pre-SOX (2000-2001)	Post-SOX (2004-2005)
Base Salary ($MM)	2.545	2.318
	(0.479)	(0.496)
Option-based Compensation ($MM)	6.197	5.152
	(0.480)	(0.502)
Total Compensation ($MM)	8.742	7.470
	(1.128)	(1.152)
Board Independence (m)	0.640	0.701
	(0.667)	(0.721)
CEO ownership (delta)	0.034	0.035
	(0.013)	(0.013)
Expected Cashflows ($MM)	458.916	455.920
	(36.708)	(36.690)
Risk Premium	0.295	0.067
	(0.001)	(0.001)
Managerial Effort (g*)	23.608	4.389
	(0.003)	(0.003)

Panel B: Summary Statistics by Compliant and Non-Compliant firms

	Compliance Firms		Non-Compliance Firms	
	Pre-SOX	Post-SOX	Pre-SOX	Post-SOX
Base Salary ($MM)	2.014	2.224	5.061	2.763
	(0.443)	(0.481)	(0.715)	(0.705)
Option-based Compensation ($MM)	4.277	4.842	15.291	6.634
	(0.458)	(0.481)	(0.572)	(0.536)
Total Compensation ($MM)	6.291	7.066	20.352	9.398
	(1.024)	(1.078)	(1.628)	(1.579)
Board Independence (m)	0.696	0.737	0.371	0.528
	(0.697)	(0.750)	(0.385)	(0.536)
CEO ownership (delta)	0.028	0.031	0.060	0.055
	(0.011)	(0.012)	(0.023)	(0.025)
Expected Cashflows ($MM)	473.682	474.353	388.964	367.891
	(42.444)	(42.532)	(20.565)	(20.451)
Risk Premium	0.052	0.052	1.468	0.140
	(0.001)	(0.001)	(0.007)	(0.005)
Managerial Effort (g*)	2.094	2.267	125.527	14.523
	(0.002)	(0.002)	(0.038)	(0.036)
y	0.564		0.519	
	(0.579)		(0.530)	
z ($*10^2$)	0.243		1.356	
	(0.006)		(0.055)	
t ($*10^2$)	0.224		0.327	
	(0.008)		(0.007)	

Table 9: Regression Result for SOX Analysis

This sample consists of a balanced panel of 1136 firms that exist in both pre-SOX and post-SOX period. Post-SOX is a dummy variable that equals to one if the observation is in year 2004 and 2005 and zero otherwise. Pre-SOX is a dummy variable that equals to one if the observation is in year 2000 and 2001 and zero otherwise. Non-compliant is a dummy variable that equals to one if the firm did not have a majority of independent directors on the board in the year 2002 and zero otherwise. Sales is the natural log of company sales. ROA is the natural log of one plus the return on assets. Returns is the natural log of the annual gross stock return (dividend reinvested). Tenure is the number of years in which the CEO served in the firm. Panel A shows the univariate analysis for change in natural log of total compensation from post –SOX period to pre-SOX period for both complaint firms and non-compliant firms. The last row reports the t-statistics for parametric test for the difference in mean and z-score for Wilcoxon rank sum test for the difference in median. Panel B shows the panel regression. The dependent variable is the natural log of total compensation. The numbers in parentheses are robust standard errors, clustered at the firm-period level. *,**,*** indicates significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Univariate Test

	Mean	Median
Change in Log(total compensation) for Compliant Firms	0.057	0.045
Change in Log(total compensation) for Non-Compliant Firms	-0.015	-0.035
Difference in Difference (Non-Compliant - Complaint)	-0.072	-0.080
T-stats (Z-score)	-4.96	-5.58

Panel B: Multivariate Regression

	Model 1	Model 2
Intercept	0.213***	4.389***
	(0.053)	(0.241)
Post-SOX	0.061***	0.251
	(0.006)	(0.163)
Non-Compliant	0.248*	0.205
	(0.142)	(0.126)
Post-SOX*Non-Compliant	-0.135***	-0.033**
	(0.046)	(0.015)
Sales*Pre-SOX		0.530***
		(0.031)
Sales*Post-SOX		0.507***
		(0.036)
ROA*Pre-SOX		-0.539
		(0.338)
ROA*Post-SOX		1.455**
		(0.544)
Returns*Pre-SOX		0.088
		(0.144)
Returns*Post-SOX		0.281**
		(0.122)
Tenure		0.060***
		(0.006)
N	2272	2272
Adjusted R^2	0.002	0.268