A Theory of Corporate Boards with Endogenous Information Collection, Optimal Compensation and Strategic Voting:

When do Independent Boards Dominate Rubberstamping Ones?

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Abstract

This paper presents a model of collective decisionmaking by corporate boards. Each director expends costly effort to collect information about major decisions facing the firm and votes to accept or reject. We derive optimal compensation contracts that maximize shareholder value and condition on directors' tendencies to free-ride on each others' effort (ex ante) and votes (ex post). We identify fairly general conditions under which rubber-stamping/captive boards achieve higher shareholder value than independent boards. The conditions emerge from frictions between information collection and information sharing and between board accountability and board independence. Optimally compensated independent boards can add value but only if board diversity, expertise and/or CEO private benefits are substantial. We analyze board decisions in the context of majority, supermajority or unanimity voting rules and when balloting is open or secret. We demonstrate that optimal compensation contracts and corporate governance rules are interdependent and show how compensation contracts vary with the governance structures of corporations.

Keywords: corporate boards, corporate governance, collective decision making, executive compensation, strategic voting, majority voting, unanimity voting, board independence

JEL Classification: G34, L22

1 Introduction

Following the corporate scandals engulfing Enron, Arthur Andersen, Worldcom, etc. the board of directors was identified as one of the weak links. NYSE and Nasdaq adopted new standards and Sarbanes-Oxley was passed in 2002 to make corporate boards more independent and accountable.[1] However, empirical evidence about the impact of board composition, board compensation and committee structures on board effectiveness is at best mixed[2] raising some fundamental questions about the ability of boards to meet these higher expectations. This skepticism is particularly apparent in the aftermath of the current financial crisis. While CEOs of many troubled financial institutions have been dismissed, boards themselves have mostly avoided the blame and remained intact.[3] Does this suggest a growing realization that boards are inherently unsuited to provide the monitoring and oversight required of them? Or, is it still reasonable to expect that changes in board independence, incentive compensation, expertise and diversity will lead to improved board performance?

In an attempt to answer these questions, we develop a model to capture the interdependence of board characteristics, board compensation and board decision making. The mandate of a corporate board in practice is to approve major strategic decisions of the firm and we model the board accordingly. In our model each director possesses and/or collects information and contributes to collective decision making by either voting for or against the issue under consideration. The quality of information is related to the expertise of the director and the effort expended on its collection. This effort in turn is determined by the incentives a director faces. Decisions are made jointly by the board on the basis of pre-determined voting rules which stipulate whether voting is done through an open or secret ballot and whether the outcome is determined by a simple majority or requires unanimity. Following US corporate practice, the CEO is a voting member of the board.[4]

We find that neither board independence, nor optimal board compensation, nor the combination of the two necessarily results in higher shareholder value. Regardless of optimal compensation contracts free-riding persists in board decision making. If a board member believes that her information is of inferior quality, she is likely to ignore it and vote along with other directors. Even though this free-riding on votes can be *beneficial* ex post, it creates problems ex ante. When a director anticipates that she will not always rely on her own information when voting, she collects less information ex ante. This is *detrimental* to collective decision making: if the board is expecting an informed vote, it causes a decline in decision quality.[5]

[1] These regulatory steps include separation of chairman and CEO, increasing the percentage of independent directors; SEC recent rule changes for mutual funds to increase independent directors to at least 75 percent.

[2] For an excellent survey of the empirical literature on corporate boards see Hermalin and Weisbach (2003).

[3] See "Wall Street Housecleaning May Bypass Boardroom", WSJ April 2, 2008.

[4] In practice, board decisions are made collectively with the CEO being a voting member of the board and board monitoring occurs as informed board members cast their votes with or against the CEO.

[5] The fundamental tradeoff between inducing agents to tell the truth and inducing them to undertake effort is originally investigated in Pendergast(1993). There it occurs as workers are rewarded on a subjective basis which results in conformity. In our model conformity occurs even though directors are compensated on

We find that for a wide range of parameter values, the ex ante effect dominates.[6] Hence, a company may significantly underperform despite an optimally compensated independent and/or expert board[7] but do better with a rubberstamping board. This occurs regardless of majority or unanimity rules[8] and whether or not information quality is uniform across board members. Replacing majority voting with supermajority or unanimity or adopting rules that encourage communication among board members (before voting) only serves to exacerbate free-riding.[9] Supermajority rules as well as pre-vote discussions are detrimental because they induce greater information sharing allowing for more free-riding ex post and less information collection ex ante.

For a wide range of parameter values, we find that gross firm value is lower under an optimally compensated independent board than under an optimally compensated rubberstamping board.[10] However, lower firm value does not necessarily imply that shareholder surplus is also lower. Independent or active boards may still result in higher shareholder surplus if their aggregate compensation package is less costly so that the reduction in compensation offsets the reduction in firm value. Interestingly, we *do* find that aggregate compensation under independent boards is *lower*. However, we also find that the difference in compensation is not large enough to offset the reduction in firm value. Note that this result is novel, since earlier papers in the corporate governance literature proposing incentive pay for directors did not explicitly analyze the impact of such compensation, nor did they deduct it from gross value to identify shareholder surplus.

We derive optimal compensation contracts under different voting rules and demonstrate that when it comes to compensation contracts there is no "one size fits all". Since voting rules

objective and verifiable basis.

[6]Higher marginal cost of effort results in even lower quality decisions in our model consistent with the finding of Fich and Shivdasani (2006) that directors' busyness is negatively related to firm value. Since the marginal cost of effort is likely to be higher for directors tied up in other activities, such directors are even more inclined to free-ride on the information of fellow board members resulting in lower quality decisions.

[7]On this issue our paper is related to Burkart, Gromb and Panunzi (1997). In BGP's article too much monitoring can destroy firm value. While monitoring increases the value of investments, it reduces the manager's incentives to seek out new projects. Hence, shareholders optimally choose lower level of monitoring to trade off these two effects. In our paper even when monitoring increases firm value, the cost of incentivizing a board to become active is ultimately borne by shareholders. Hence, shareholders set the level of board oversight to equate the marginal benefits of monitoring to its marginal costs.

[8]The role of strategic voting in political elections and jury decisions have been analyzed in Austen-Smith and Banks (1996), Federsen and Pesendorfer (1996), (1997), (1998), McLennan (1998), Dekel and Piccione (2000), Coughlan (2000) and Fey and Kim (2002) among others. In these papers agents are endowed costlessly with private information and strategic voting can lead to beneficial information aggregation. In our paper we study strategic voting among optimally incentivized corporate directors who exert costly effort to collect information. In this setting we show that strategic voting can be detrimental.

[9]This result, also present in Pendergast (1993) is interesting as information sharing is usually viewed as value enhancing and as such drives the results in recent papers on boards by Adams and Ferreira (2007), Harris and Raviv(2008); as well as some of the earlier papers on teams like Lazear (1989), Itoh (1991), and on strategic voting like Federsen and Pesendorfer (1998) and Coughlan (2000).

[10]If each director acts as if she was the sole decisionmaker, the reverse would hold true.

impact ex-ante incentives, optimal contracts are voting-rule-specific and the set of optimal compensation contracts varies with the governance structure of the corporation. Hence our theory implies that optimal compensation contracts in practice must be designed differently when voting is conducted under majority or unanimity rule, or through open or secret ballot.[11] Note that this implication is in line with Coles, Daniel and Naveen (2004) and Easterwood and Raheja (2006) who argue that board structures and board characteristics should reflect firm characteristics and managerial requirements for each firm.

When the CEO has informational advantage, other directors optimally choose to exert minimal effort and shareholders are better off providing steep incentives only for the CEO. This is true regardless of independence, compensation structure or governance rules. On the other hand, shareholder surplus may be increased by adding expert directors to the board, provided they do not attempt to extract rents, bring a sufficiently high level of expertise and are not held accountable for the quality of the decision. Our prediction that monitoring by experts can be value increasing under certain conditions is consistent with the empirical finding of Landier, Sraer and Thesmar (2006) that shareholder returns are higher in companies where a substantial fraction of top executives have stayed with the company longer than the CEO. Similarly, Easterbrook and Raheja (2007) reports that adding experts to boards following a corporate crisis increases firm value whereas other changes in board structure or composition do not. However, since the ability of the CEO to depend on experts can reduce his incentive to collect information, we also identify conditions under which the addition of expert directors may lead to inferior decisions, as in Burkart, Gromb and Panunzi (1997) and Almazan and Suarez (2003).

When the CEO's private benefits are high, a corporate board can become an effective monitor if directors correctly assess the degree of the agency conflict between management and shareholders. When the CEO enjoys substantial private benefits, the information he provides is less indicative of the quality of investment opportunity, and an active board can add value even with otherwise inferior information. This implication is supported by Gilette, Noe and Rebello (2003) who show that when insiders' agency problems are severe, any independent director can add value by preventing obviously wrong decisions. Similarly, at times when stock prices are very informative, rubberstamping boards can turn into active boards as directors become well informed without expending costly effort. This prediction is consistent with the empirical findings of Ferreira, Ferreira and Rapuso (2008) who document a positive correlation between price informativeness and board independence for firms where board monitoring is valuable.[12] Note also that our theory is not inconsistent with Fich and Shivdasani (2005) that introducing equity-based incentive compensation for directors triggers a positive market

[11] An important insight of our paper is that with optimal incentive contracts, voting rules become irrelevant. However, since voting rules impact ex-ante incentives and the amount of free-riding, optimal compensation contracts are voting-rule-specific. This extends the insights of Persico (2004) by including optimal contracting and strategic voting.

[12] Ferreira, Ferreira and Rapuso (2008) also finds a negative correlation between price informativeness and board independence for companies that face an active market for corporate control.

response at least in some firms. In our model we assume that optimal contracting with a CEO is always possible. However, when this is not the case (see for example Bebchuk et al (2002)), then giving incentives to directors to collect even a little information could add value.

We also find that if directors are sufficiently diverse so that information-sharing significantly improves the quality of the collective information, active boards may increase shareholder surplus. However, such expert boards increase shareholder value only if the value created through discussion exceeds the negative externality of this type of information sharing on ex-ante information collection. This prediction is consistent with the empirical findings of Adams and Ferreira (2008) that diversity of directors increases firm value in companies where active board monitoring is needed to enhance firm performance. The more severe is the agency problem, the more likely that the value created through board discussion exceeds the negative externality of ex post information sharing on ex ante information collection.

Like the model in Hermalin and Weisbach (1998), we show a strong connection between the rules governing the operation of the board and the quality of monitoring by directors. The two models differ in the aspects they focus on. Central to HW's model is the bargaining process between the board and the CEO. In contrast, the core of our paper is the voting process by which directors approve the firm's future investments. In HW firm value is shared between the board and the CEO. In our model directors are compensated only to the extent of their effort and the shareholders get the rest. In HW linking directors' pay to stock performance results in more monitoring and higher firm value. In our model, stock based board compensation reduces both firm and shareholder value.

Our paper is also related to the small but growing theoretical literature on corporate boards such as Bainbridge (2001), Adams and Ferreira (2007), Raheja (2005), Aggarwal and Nanda (2005) and Harris and Raviv (2008). Based on cognitive psychology Bainbridge (2001) argues that groups are more effective decision makers than individuals in settings analogous to those in which boards operate. Adams and Ferreira (2007) present a model where friendly boards can dominate because of their dual role of monitoring and advising management and provide a rational for one-tier and two-tier boards. Raheja (2005) and Harris and Raviv (2008) develop novel theories about the optimal composition of boards between insiders and outsiders, and optimal board size.[13] In Raheja (2005) insiders share their information with outsiders after a negative shock to firm performance because they wish to position themselves in case of CEO turnover. In Harris and Raviv, insider controlled boards can be optimal if insiders' information is critical for the investment decision of the firm.[14] Aggarwal and Nanda (2005) investigate

[13]In our model monitoring is done through voting. When voting takes place after directors have communicated with each other, it also subsumes the advisory role of boards. Whereas in Adams and Ferreira (2007) and others, advising improves firm value, in our model pre-communication makes free-riding worse and results in less information collection ex ante leading to inferior decisions.

[14]While one of our conclusions also favors friendly boards, the reason is quite different. In Adams and Ferreira (2007) and Harris and Raviv (2008) friendly boards allow for better information sharing. In our model friendly boards emerge endogenously when the CEO is known to have less costly search technology. It is then optimal for only the CEO to search and for other board members to rubberstamp his recommendation.

the impact of the size of a firm's board of directors on managerial incentives. In their model each director owns a specific asset or skill and differ in their objectives. They find that the manager's incentives weaken as board size increases and the number of social objectives that a firm pursues is positively related to board size. None of these studies explore the friction between information collection and information sharing, optimal incentive contracts and their impact on board independence, or the impact of board compensation on firm and shareholder value which are the main focus of our paper.

Like Kumar and Sivaramakrishnan (2008) we find that director independence and equity-based board compensation do not necessarily increase shareholder value. Their model compares monitoring and contracting with the CEO by a one-member board compensated through an equity contract, to direct shareholder monitoring and contracting with the CEO. Our model differs from KS as we study a multi-member board. This allows us to highlight the role of free-riding in board decision making: in ex ante information collection and in ex post voting and to show how optimal board compensation depends on the governance rules of the corporation. We also demonstrate that in equilibrium independent directors do not necessarily act independently but they endogenously decide whether to become active monitors or to rubberstamp.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 describes the optimal contracting between shareholders and the CEO. Section 4 derives the optimal board compensation in the case of majority voting. Section 5 and 6 study the impact of board monitoring on firm value, executive compensation and shareholder value. Section 7 derives optimal compensation for directors when decisions require unanimous board approval. In Section 8 we present conditions under which any independent board turns into a rubber-stamping board. Section 9.1 focuses on expert directors; Section 9.2. studies the case when the CEO enjoys substantial private benefits from his position; and Section 9.3 when information sharing (discussion) among independent directors improves the precision of the collective information. Section 10 concludes.

2 The Model

We consider a firm that is facing an investment decision.[15] The firm's investment opportunity θ can be H or L with equal probability. Gross profit is 1 if H is realized, and 0 if L is realized. The cost of investing is $c > 0.5$, so investing without information about which state is more likely makes the project negative NPV. For convenience, assume the discount rate is zero.

The objective of the firm's shareholders is to maximize the expected value of their equity. Shareholders elect a board of directors to decide by vote whether to invest. In line with common corporate practice, we assume that the CEO is a member of the board and the board makes its decision by applying the majority rule. (In later sections we will also study voting

[15] We refer to the decision as an investment choice. However, our results apply to any strategic decision where resolution of uncertainty about the future is valuable.

by supermajority and unanimity.) We further assume that shareholders and board members (including the CEO) are risk-neutral.

By exerting effort, each board member including the CEO, can obtain a signal about the quality of the firm's investment opportunity. The precision of the signal depends on the amount of effort exerted. If a board member exerts effort, $q \in [0.5, 1]$, then she will receive a signal with precision q. The higher q is, the better forecast the board member obtains. If a board member exerts effort q and observes a signal H, then with probability $q \geq 0.5$ the investment opportunity is H, and with probability $(1 - q)$ the investment opportunity is L. If the signal is L, then the investment opportunity is L with probability q and H with probability $(1 - q)$. The expected gross profit of the firm $E(\pi) = \frac{1}{2}(q - c)$ is a function of directors' monitoring efforts, q.

Following previous literature, we assume a quadratic effort cost function, $\alpha(q - .5)^2$ where α denotes a board member's marginal cost of effort. The cost of effort depends on the amount of effort exerted and the marginal cost of effort and is increasing and convex in the amount of effort exerted. We initially assume that board members are identical in their marginal cost of effort and productivity, so we omit the subscript on α and q. In later sections we will extend the analysis to boards with heterogenous members and will also study the limiting case when directors are endowed with free information.[16]

Shareholders incentivize the board to maximize shareholder value. They write an optimal compensation contract to induce board members to exert optimal effort. Following Holmström (1982) and Khanna (1998), the optimal contract shareholders offer each board member is a combination of a "carrot" (incentive payment) and a "stick" (penalty)[17] and it takes the form

$$w = \omega + \lambda\pi(q) - \gamma I \tag{1}$$

where π is the realized gross profit of the firm; ω is the director's fixed wage, λ is the director's stake in the firm, γ is the amount of penalty for making the wrong recommendation and I is an indicator variable that equals zero if the board member's vote turns out to be correct ex post and one otherwise. The term, $\lambda\pi$ constitutes the incentive payment or "carrot" if π is positive and reflects the pay for performance component or equivalently a stake in the

[16] If information is perfectly divisible, then this case is equivalent to a board with infinitely many members searching for infinitesimal information where information costs are flat.

[17] In group decisions preventing free-riding is difficult as the cost of information collection is borne by individual directors while the benefits accrue to the group. To prevent free-riding on effort, Holmström (1982) derives a uniform penalty for each member if the targeted group output is not achieved. This solution, however, often results in contracts that are infeasible to implement. If one also observes how individual directors vote, the set of feasible contracts can be enlarged by specifying both the portion of output a director gets and a penalty for being wrong ex-post. (See, for instance, Khanna (1998).) While this increases the set of optimal contracts, basing penalty on a wrong vote can induce a director to ignore her own information and free ride on other directors' vote if doing so reduces her probability of being wrong. Khanna and Slezak (2000) studied optimal contracting in the context of team decisionmaking with risk averse parties and showed that optimal contracts with risk-averse parties exhibit similar properties.

firm.[18] The term γI represents the individual penalty or "stick"that is based on whether the board member's vote turned out to be wrong ex-post. For the rest of the paper we assume that directors are wealth constrained and feasible contracts are those with non-negative pay in expectation, that is,[19]

$$\hat{w} \geq 0 \qquad\qquad \forall \lambda,\ \gamma. \tag{2}$$

First we study the case of a rubberstamping or captive board, then the case of an independent or active board.

3 The Rubberstamping or Captive Board

For tractability, we start with the base case where the CEO holds full control over the board. Such a board is frequently labelled in the literature as a rubberstamping or captive board. In Section 8 we identify fairly general conditions under which independent boards endogenously act as rubberstamping boards despite optimal incentive compensation for directors. Under these conditions giving equity or option based compensation for non-CEO directors does not enhance shareholder value. It needs only the CEO to be given a performance based contract while other directors receive token compensation.

When the CEO has a rubberstamping board[20], his compensation contract determines his effort and the precision of the signal he bases his decision on. The objective of shareholders is to identify a contract $(\omega,\ \lambda,\ \gamma)$ that induces the CEO to incur effort level that maximizes shareholder surplus (expected gross firm value less expected CEO compensation) subject to the CEO's participation constraint. Formally,

$$\max_{q\in[.5,1]} E[\pi(q) - \omega - \lambda\pi(q) + \gamma I] \tag{3}$$
$$\text{subject to } E(\omega + \lambda\pi(q) - \gamma I) \geq \alpha(q - .5)^2.$$

The CEO's objective is to maximize his pay minus the cost of his effort. Formally,

$$\max_{q\in[0.5,1]} E[\omega + \lambda\pi(q) - \gamma I] - \alpha(q - .5)^2 \tag{4}$$

Assuming a competitive market for executives, shareholders set the terms of the compensation contract, $\omega \geq 0$, $\lambda \in [0,1]$ and $\gamma \geq 0$ to induce the CEO to select the q that maximizes (3) at

[18]Since we do not impose limited liability, this portion can be negative ex-post, and represent a penalty that is uniform across all directors. This is distinct from individual penalties based on whether the individual's vote turned out to be wrong ex-post.

[19]This assumption rules out extreme contracts in which shareholders sell the firm to the directors in exchange of payments.

[20]For the remaining discussion we ignore the token compensation of the non-CEO directors.

the least possible cost to the firm. That is, they equate CEO's expected compensation to his effort cost making his participation constraint binding,

$$E[\omega + \lambda\pi - \gamma I] = \alpha(q - 0.5)^2 \quad q \in [0.5, 1] \tag{5}$$

and expression (3) becomes

$$\max_{q\in[0.5,1]} E[\pi] - \alpha(q - 0.5)^2 \tag{6}$$

For a given signal precision q, a rational CEO will decide to invest if he observes a signal H, and to not invest otherwise. Since the unconditional probability of the investment opportunity being good is 1/2, $E[\pi(q)] = 0.5[q * 1 + (1 - q) * 0 - c]$. Investment will occur with probability 1/2, out of which the H signal will correctly predict the H state with probability q. Thus, expected firm value can be written as a function of signal precision as

$$E[\pi(q)] = 0.5(q - c) \tag{7}$$

and shareholders will maximize

$$\max_{q\in[0.5,1]} 0.5(q - c) - \alpha(q - 0.5)^2 \tag{8}$$

Taking the first-order condition for $q \in [0.5, 1]$ when $\alpha > 0$ yields

$$0.5 - 2\alpha(q - 0.5) = 0 \tag{9}$$

The choice of effort and signal precision that maximizes shareholder value obtains as

$$q^* = \begin{cases} \frac{\alpha+0.5}{2\alpha} & \text{if } \alpha > 0.5 \\ \\ 1 & \text{otherwise} \end{cases} \tag{10}$$

Given his compensation contract, the CEO will exert effort to

$$\max_{q\in[0.5,1]} \omega + 0.5\lambda(q - c) - \gamma(1 - q) - \alpha(q - 0.5)^2 \tag{11}$$

The first-order condition for $q \in [0.5, 1]$ takes the form of

$$0.5\lambda + \gamma - 2\alpha(q - 0.5) = 0 \tag{12}$$

and yields the CEO's choice of effort and signal precision as

$$q^M = \frac{0.5\lambda + \gamma + \alpha}{2\alpha} \tag{13}$$

Shareholders will choose the terms of the incentive compensation contract, $(\omega,\ \lambda, \gamma)$ to induce the CEO to maximize shareholder value by choosing his effort level q^M equal to the the effort level desired by the shareholders q^*. Formally,

$$\frac{0.5\lambda + \gamma + \alpha}{2\alpha} = \begin{cases} \frac{\alpha+0.5}{2\alpha} & \text{if } \alpha > 0.5 \\ \\ 1 & \text{otherwise} \end{cases} \tag{14}$$

Hence, when the CEO faces a rubberstamping or captive board, the incentive compensation contract for the CEO has the following property.

Proposition 1 *For any α, a compensation contract will induce the CEO to maximize shareholder value if and only if the terms of the contract satisfy (2) and*

$$\lambda + 2\gamma = \begin{cases} 1 & \textit{if } \alpha > 0.5 \\ \\ \alpha & \textit{otherwise.} \end{cases} \tag{15}$$

Given the optimal effort induced by the incentive compensation contract of the CEO, the expected gross (pre-compensation) firm value will be

$$\pi^* = \begin{cases} \frac{\alpha+0.5}{4\alpha} - 0.5c & \text{if } \alpha > 0.5 \\ \\ \frac{1-c}{2} & \text{otherwise.} \end{cases} \tag{16}$$

Net firm value or shareholder value is computed by subtracting the value of the compensation contract from gross firm value. Formally,

$$S^* = \begin{cases} \frac{1}{4} + \frac{1}{16\alpha} - \frac{c}{2} & \text{if } \alpha > 0.5 \\ \\ \frac{1-c}{2} - \frac{\alpha}{4} & \text{otherwise.} \end{cases} \tag{17}$$

The alternative to the rubberstamping board is an independent or active board. To assure that the board actively monitors the firm, shareholders need to offer optimal incentive contracts to the directors. Board monitoring has the potential to increase the accuracy of the investment decisions by improving the quality of the collective information.

4 The Independent or Active Board

In this section we study an independent or active board in which directors make decisions on the basis of a pre-determined voting system. We identify equilibrium information collection and voting strategies for each director under an incentive contract that is optimal for a particular voting system. This allows us to establish the merits and deficiencies of each system and make cross-sectional comparisons to see if any one system dominates. We can then determine whether shareholder surplus is maximized under an optimally incentivized independent or active board, or under an optimally compensated CEO with a rubberstamping board.

For simplicity, we consider a three-member board. In line with corporate practice the CEO is a voting member of the board. We assume that all directors including the CEO have the same marginal cost of effort, α. (Later in the paper we extend the analysis to accommodate heterogenous board members.) Each director monitors the firm by exerting effort and obtaining a signal about the investment opportunity. The precision of each director's signal depends on the effort exerted. Following corporate practice we first assume that the board uses the majority rule to make decisions. In Section 7 we will extend the analysis to unanimity rules.

We consider three different voting procedures. In the first case, board members vote simultanously so no one director votes after observing how others have voted. In the second case, board members vote sequentially with the order of the vote being determined randomly after each director has expended the effort to obtain his private signal.[21] When voting sequentially, each director observes the votes of his colleagues who voted before him but does not observe the vote of members who vote after him. Hence each board member can aggregate the information conveyed by the votes of those who voted before him and can potentially free ride on their monitoring efforts. In the third case, board members can discuss their private signals before voting takes place. In this case each board member can aggregate the information revealed by all the other board members, allowing him to free ride on the monitoring efforts of a larger set.

Shareholders set the terms of the optimal incentive compensation contract for directors to maximize shareholder value under each voting rule. This compensation contract incentivizes directors to choose the signal precision that corresponds to the shareholder value maximizing effort choice. When voting is simultanous, the dominant strategy of each director who received signals indicating that the investment opportunity has high value, i.e. $\theta = H$ is to vote in favor of investing (i.e., there is no free-riding on how others vote). Using the majority rule, the board accepts the investment if at least two board members vote for investing. In all other cases, the board rejects the investment.

There are eight possible signal realizations for the three-director board: (H, H, H); (H, H, L); (H, L, H); (L, H, H); (L, L, H); (L, H, L); (H, L, L); (L, L, L). In the first four cases the

[21] This allows us to treat each director symmetrically. If the order of voting is predetermined, optimal contracts will differ depending on the order.

investment opportunity will be undertaken under a majority rule, in the last four cases the investment will be rejected. When the investment is rejected, firm value will be 0. When the investment is undertaken cost, c is incurred and the expected value of the firm conditional on realized signals yields

$$\begin{aligned} E[\pi|HHH] &= \frac{0.5q^3}{0.5q^3 + 0.5(1-q)^3} - 0.5c \\ E[\pi|HHL] &= E[\pi|HLH] = E[\pi|LHH] = \frac{0.5q^2(1-q)}{0.5q^2(1-q) + 0.5q(1-q)^2} - 0.5c \end{aligned} \tag{18}$$

The unconditional expected value of the firm (before directors recive signals) given that each director will reach her decision independently (i.e. based on her own signal only) and the board accepts investment on the basis of the majority rule becomes

$$\begin{aligned} E[\pi] = 0.5 * [&E[\pi|HHH] * Prob(HHH) + E[\pi|HHL] * Prob(HHL) \\ &+ E[\pi|HLH] * Prob(HLH) + E[\pi|LHH] * Prob(LHH) - c] \end{aligned} \tag{19}$$

Substituting for probabilities and expected values in (19) yields the first term in the bracket as q^3 and the second through the fourth term as $q^2(1-q)$ each. Computing the sum and simplifying the resulting expression obtains the expected gross firm value as

$$E[\pi] = 0.5[3q^2 - 2q^3 - c]. \tag{20}$$

Given this value, shareholders maximize their residual left after the board is compensated for its effort,

$$\max_{q \in [0.5;1]} 0.5[3q^2 - 2q^3 - c] - 3\alpha(q - 0.5)^2 \tag{21}$$

Taking the first-order condition for $q \in [0.5, 1]$ gives

$$q^2 + (2\alpha - 1)q + \alpha = 0 \tag{22}$$

The choice of effort and signal precision that maximizes shareholder value obtains as

$$q^{***} = \frac{1}{2} - \alpha + \sqrt{\frac{1}{4} + \alpha^2} \tag{23}$$

Note that $\frac{1}{2} - \alpha + \sqrt{\frac{1}{4} + \alpha^2} < 1 \ \ \forall \alpha > 0$. For the special case of $\alpha = 0$, $\frac{1}{2} - \alpha + \sqrt{\frac{1}{4} + \alpha^2} = 1$.

Comparing this value maximizing choice of effort by each director to the rubberstamping regime, we obtain as expected, that $q^* \geq q^{***}$. Obviously, the important question is how q^* compares with the aggregation of three q^{***}. We address this question in the next section.

Next we identify optimal contracts that induce this desired effort choice from each director. To do so we use the symmetric Nash equilibrium concept. For that we first compute the optimal effort choice, q of a director who takes the effort choice of his fellow directors to be given as p. We re-derive (20) assuming one director selects q while the other two select p. Each director's maximization problem then takes the form

$$\max_{q\in[0.5,1]} \omega + .5\lambda(p^2q + p^2(1-q) + 2pq(1-p) - c)$$
$$-\gamma[\text{Probability of being wrong}] - \alpha(q-.5)^2 \tag{24}$$

where the first term is the fixed wage, the second term is the board member's share of the expected firm value, and the third term is the expected penalty a board member incurs if his vote turns out to be wrong ex post. The probability of penalty will depend on whether directors free ride. We discuss three cases: simultanous voting with no information leakage and thus, no free riding, sequential voting and voting by secret ballot.

4.1 Optimal contracting when directors decide independently

Here we analyze the case when each director reaches his or her decision only on the basis of his or her signal. Then for each director the probability of being wrong is $1-q$. This is the case, for example, if voting is conducted simultanously and no information is leaked prior to the vote or if voting is conducted sequentially but directors ignore information revealed by others' votes. Since each director arrives at his or her decision independently and the board reaches its decision by majority rule, then each director will exert effort q to

$$\max_{q\in[0.5,1]} \omega + .5\lambda(p^2q + p^2(1-q) + 2pq(1-p) - c)$$
$$-\gamma(1-q) - \alpha(q-.5)^2 \tag{25}$$

This is a rewrite of (24) with probability of being wrong equal to $(1-q)$, as each director depends only on his or her own signal.

Given p, the first-order condition with respect to q is

$$\lambda p(1-p) + \gamma - 2\alpha(q-0.5) = 0 \tag{26}$$

Since all directors are equally skilled and face the same effort costs, we look for the symmetric Nash equilibrium. Thus, substituting q for p yields

$$\lambda q^2 - (\lambda - 2\alpha)q - (\gamma + \alpha) = 0 \tag{27}$$

Solving the first order condition for q determines each directors's signal precision as follows.

$$q^B = \frac{\lambda - 2\alpha + \sqrt{(2\alpha - \lambda)^2 + 4\lambda(\gamma + \alpha)}}{2\lambda} \tag{28}$$

or

$$q^B = \frac{1}{2} - \frac{\alpha}{\lambda} + \sqrt{\frac{1}{4} + \frac{\alpha^2}{\lambda^2} + \frac{\gamma}{\lambda}} \tag{29}$$

To attain the effort level that maximizes shareholder surplus, the incentive compensation contract for directors must set q^B in (29) equals that for q^{***} in (23). Proposition 2 describes the optimal incentive compensation contract. The proof is straightforward from the derivations above and is omitted.

Proposition 2 *When each board member reaches his or her decision independently from each other and the majority rule is used to arrive at the investment decision, then the optimal compensation contract,* $(\omega^B, \lambda^B, \gamma^B)$ *must satisfy*

$$\frac{1}{2} - \alpha + \sqrt{\frac{1}{4} + \alpha^2} = \frac{1}{2} - \frac{\alpha}{\lambda} + \sqrt{\frac{1}{4} + \frac{\alpha^2}{\lambda^2} + \frac{\gamma}{\lambda}} \tag{30}$$

Condition (30) that determines the properties of the optimal incentives compensation contract for board members when each director makes his or her decision independently is plotted on Figure 1 in α, λ, and γ space. As before, α captures directors monitoring skills, λ is their equity stake in the company and γ stands for the penalty imposed on them ex post, for casting the wrong vote.

4.2 Is the optimal contract robust to free-riding on information?

When voting is conducted simultaneously and no information is leaked, directors can only rely on their own monitoring effort to support their decision as in Section 4.1. In practice, however, it is difficult to prevent information sharing since directors typically like to discuss their opinion prior to voting. Simultaneous voting is also difficult to carry out in practice.[22]

[22] Only simultaneous ballots by email or by labelled cards and no information sharing can implement the simultaneous voting case above. Such voting arrangement is rarely done in practice. Note that simultaneous secret ballots would not work in the context of our compensation contract because secret ballots does not identify individual votes which are necessary in the penalty term. For secret ballots compensation contracts must be designed differently.

When assessing whether the optimal contract is robust to information leakage or information sharing by fellow directors two questions arise: (1) When directors observe their fellow board members' signals prior to the final vote would they still vote solely on the basis of their own signal or would they alter their vote based on the votes of others?; and (2) If directors incorporate their fellow board members' information into their own vote, would they be less willing to exert effort ex ante? Note that if directors alter their effort in expectation of observing their fellow directors' recommendations, then proposition 2 no longer applies.

Suppose the director voting third observes the votes of her fellow directors. If she makes her decision independently, based only on her private signal, then as in (25) her probability of being wrong ex post is $(1-q)$. If she blindly follows her fellow directors' recommendations when they both vote in favor of investing, but makes her decision independently when her fellow directors cast conflicting votes, her ex post probability of being wrong becomes $(1-p)^2+2p(1-p)(1-q)$. The first term is the probability of being wrong when both of her fellow directors are in favor of investing and the director goes along with them regardless of her own signal, as the probability of both fellow directors being wrong is $(1-p)^2$. The second term is the probability of being wrong when her fellow directors disagree on the investment decision and she votes solely on the basis of her private signal. Her fellow directors will disagree with probability $2p(1-p)$ and she will be wrong with probability $1-q$. Note that the sum $(1-p)^2+2p(1-p)(1-q)$ can be simplified to $(1-p)(1+p-2pq)$.

The director prefers to vote against her signal, if that can increase her expected compensation. To decide whether or not this is the case, we need to compare (24) with $(1-q)$ to that with $(1-p)(1+p-2pq)$ as the respective probabilities of being wrong. With the latter, (24) becomes:

$$\begin{aligned}\max_{q\in[0.5,1]} \omega + .5\lambda(p^2q + p^2(1-q) + 2pq(1-p) - c)\\ -\gamma(1-p)(1+p-2pq) - \alpha(q-.5)^2 \end{aligned} \tag{31}$$

Proposition 3 establishes that directors will occasionally suppress their own signal and vote with others if they learn their fellow directors' information or observe their vote. We call this phenomenon free-riding on fellow directors' vote.

Proposition 3 *When a director observes her fellow directors' information or vote, then she prefers to ignore her own signal (if different) and vote with others when those are in agreement and prefers to follow her own information when her fellow directors disagree.*

Proof: in Appendix.

Proposition 3 implies that the optimal contract in (30) is not robust to information leakage or sequential voting. An important consequence of Proposition 3 is that the contract $(\omega^B, \lambda^B, \gamma^B)$ encourages a director who observes the votes of fellow directors to free-ride on fellow board members' information. While free-riding on information or votes may be beneficial ex post, it is value-reducing ex ante. Recognizing that occasionally she will prefer to rely on her fellow directors' information when she is about to vote, the director gains less from her own information collection/monitoring effort and consequently she will reduce these efforts ex ante. We call this free-riding on fellow directors' effort.

Proposition 4 *When a director can potentially rely on the information of her fellow board members at the time of her vote, then the incentive compensation contract* $(\omega^B, \lambda^B, \gamma^B)$ *fails to induce shareholder value maximizing effort ex ante.*

Proof: in Appendix.

Note that while board members benefit from each others' monitoring via their stake in the firm, a director voting third benefits from free-riding on others' votes because doing so reduces his expected penalty for being wrong ex post (the γI term in the optimal compensation contract). This tendency to free-ride on others' votes has been shown to be potentially value-increasing in models in the strategic voting literature (see footnote 8 on Page 4) but it is not actually value-increasing in our model. In our model only the director voting third will ignore his own signal and only when he is in the minority. Since his vote is not pivotal then, his doing so has no direct effect on the quality of the collective decision. However, it has an indirect effect. When a director anticipates that she will not always rely on her own information when voting, she collects less information ex ante. This effect is detrimental to collective decision making causing a decline in decision quality. Thus, the interplay between ex post strategic voting and ex ante effort incentives for information collection leads to lower profits and firm value.

The optimal incentive compensation contract must either countweigh directors' tendencies to free ride on fellow board members' efforts and votes or, if that is too expensive or even infeasible, condition on the possibility of free-riding. In the next section we derive such contracts.

4.3 Optimal contracting with free-riding directors

Without loss of generality, we assume that voting is sequential and the order of the vote is determined randomly after board members have gathered their own private signals. When voting sequentially, each board member observes the votes of those who vote before him but does not observe the vote of fellow board members who vote later. Hence each director can aggregate the information inferred from the votes of those who voted before him and potentially free ride on it. Using fellow board members' information to reduce the probability of being wrong ex post, each director can increase his or her expected payoff.

To derive the optimal contract that conditions on potential free-riding by directors, we proceed by backward induction focusing first on the third board member's decision whether to approve or reject the investment. Note that if the rest of the board is in agreement, then the third board member's decision will have no impact on the investment choice under a majority rule. It follows from Proposition 3 that the director who votes third and observes the votes of the other two directors will suppress his signal (if different) and follow his fellow directors when they agree and follow his own signal otherwise. Therefore, the third director's problem takes the following form:

$$\max_q \omega + .5\lambda(p^2q + p^2(1-q) + 2pq(1-p) - c)$$
$$-\gamma(1-p)(1+p-2pq) - \alpha(q-.5)^2 \tag{32}$$

where $(1-p)(1+p-2pq)$ is the probability of a director being wrong when he votes with his fellow directors if they agree and pursues his own signal if they disagree.

It follows from Proposition 4 if a a director can condition on others' information, he will reduce his effort ex ante. Therefore, when each director has equal probability to go third (i.e. their voting order is expected to be random), each reduces his effort.

In contrast to the director who votes third, the second director does not gain by ignoring his own signal and voting with the first director, since the probability of being wrong is the same for both strategies. Therefore, the second director's problem will be the same as in (25).

Each director recognizes ex ante that if he is called upon to vote third (which has a one-third probability) and the other two board members before him agree, he may suppress his signal. Hence each director's problem becomes

$$\max_q \omega + .5\lambda(p^2q + p^2(1-q) + 2pq(1-p) - c)$$
$$-\gamma[\frac{2}{3}(1-q) + \frac{1}{3}(1-p^2-2pq+2p^2q)] - \alpha(q-.5)^2 \tag{33}$$

This objective function takes into account that directors will vote independently when they are called upon to vote first or second (which happens with probability two-third) but they will follow others when they are called upon to vote third and the ones voting first and second vote the same way.

The first-order condition of (33) in q yields

$$-p^2(3\lambda+2\gamma) + p(3\lambda+2\gamma) + (3\lambda+2\gamma) - 2\alpha q = 0 \tag{34}$$

Substituting back for $p = q$ in the first-order condition as

$$q^2(3\lambda+2\gamma) + q(6\alpha-3\lambda-2\gamma) - (3\alpha+2\gamma) = 0 \tag{35}$$

yields the director's effort choice as

$$q^{BC} = \frac{-(6\alpha - 3\lambda - 2\gamma) + \sqrt{(6\alpha - 3\lambda - 2\gamma)^2 + 4(3\lambda + 2\gamma)(2\gamma + 3\alpha)}}{6\lambda + 4\gamma} \tag{36}$$

Simplifying expression (36) gives

$$q^{BC} = \frac{1}{2} - \frac{\alpha}{\lambda + \frac{2}{3}\gamma} + \frac{\sqrt{4(\alpha + \frac{2}{3}\gamma)^2 - \frac{8}{3}\alpha\gamma + (\lambda + \frac{2}{3}\gamma)^2}}{2(\lambda + \frac{2}{3}\gamma)} \tag{37}$$

The optimal contract equates q^{BC} and q^{***} and induces directors who tend to free ride on each others' effort and vote to exert the effort shareholders desire. Proposition 5 below characterizes the terms of the optimal incentive compensation contract for free-riding directors.

Proposition 5 *When directors potentially free ride on each other's effort and vote, a compensation contract will induce these directors to maximize shareholder value if and only if the terms of the contract, ω, λ and γ satisfy (2) and*

$$\frac{1}{2} - \alpha + \sqrt{\frac{1}{4} + \alpha^2} = \frac{1}{2} - \frac{\alpha}{\lambda + \frac{2}{3}\gamma} + \frac{\sqrt{4(\alpha + \frac{2}{3}\gamma)^2 - \frac{8}{3}\alpha\gamma + (\lambda + \frac{2}{3}\gamma)^2}}{2(\lambda + \frac{2}{3}\gamma)} \tag{38}$$

The proof is straightforward from the formal arguments above and is therefore omitted.

Note this contract sets q^{BC} equal to q^{***}, the shareholder value maximizing effort choice given an active or independent board. Notice that the q^{***} is the same shareholder value maximizing effort choice as before. However the contract that implements it requires more powerful incentives when directors can potentially free ride on each others' information ex post and effort ex ante.

Obviously, joint effort $(q^{***}, q^{***}, q^{***})$ may result in higher shareholder value depending on the difference between q^* and q^{***} and the costs of implementing the respective contracts. Since fellow board members' monitoring represents a positive externality for all directors, mitigating the directors' free riding incentives imposes additional costs on shareholders.

As Proposition 6 below states that the terms of the optimal contract in the case of an independent or active board will vary with α. This contrasts with the rubberstamping board case where the optimal contract is independent of α. Note also that the optimal contract for a CEO with a captive board is not an optimal contract for an independent or active board.

Proposition 6 *There does not exist any optimal contract that would induce board members to exert value maximizing effort independent of α.*

Proof: in Appendix.

Expression (38) yields $\lambda = 1$ and $\gamma = 0$ as the only optimal contract that induces shareholder value maximizing effort independent of α. This contract is of course impossible, since shareholders cannot give the whole firm to each of the directors. Setting $\gamma = 0$ would take away all the incentives of directors to free-ride on each other's effort but it would be prohibitively costly to implement. The remaining α-dependent contracts characterized by $\gamma > 0$ induce the directors to exert more effort ex ante but at the expense of potential free-riding when voting in the third position. Figure 2 plots the set of all contracts that induce free-riding directors to exert shareholder value maximizing effort. Note that for a given α, these contracts exhibit higher λs and γs than in the independent voting case.

There are alternative cases to consider. These include the case when the order of voting is fixed and the case when directors vote by secret ballot with no prior information sharing. We discuss these in turn. First, note that fixed order of voting is not a special case of random voting order. When the order of vote is fixed, then directors will exert different effort depending on their predetermined order of vote. The directors who know that they will vote first or second will vote independently by maximizing (25) but the director who votes third will maximize (24). In this case directors' compensations will differ based on the correctly anticipated sequence of voting. In case of secret ballot voting with no prior information sharing, voting is simultaneous. However, the optimal contract cannot penalize individual directors for making the wrong decision because secret ballots cannot identify which way a director voted. Thus, the penalty cannot be contingent on individual decisions, only on the board's joint decision. While the λ term does impose a collective penalty on each director when the board makes the wrong decision regardless of whether a particular director voted with the majority or opposed it, the γ term is no longer useful because balloting is secret. This inability to rely on the additional penalty term to incentivize board members, results in a higher λ in the optimal contract. As this is now similar to Milgrom (1982), the optimal contracts become prohitively expensive and potentially not even feasible. Shareholders are worse off under secret balloting than with open voting.

5 The impact of board monitoring on firm value

In this section we investigate the impact of board monitoring on firm value. For now we ignore the impact of compensation costs and only consider the benefits of board monitoring. We proceed in two steps. First, we compare gross profits/gross firm values between a rubber-stamping board with optimal effort q^* by only the CEO, to that of an independent 3-person board where each director exerts the same effort q^*. Second, we compare firm values under a captive board to that under an optimally incentivized active board.

If a director thinks that he is the sole decision-maker, then he would exert effort q^* in (10). If all directors think the same, they would work equally hard and as Lemma 1 states, monitoring by such a board would increase gross firm value relative to the case of CEO control. Even though there is duplication of effort among directors, independent or active board monitoring nevertheless adds value.

Lemma 1 *If all three directors exert monitoring effort q^*, then independent or active boards would improve firm value.*

Proof: To see this, let us substitute q^* into (20) the firm value expression for the case of an independent board and compare it with the firm value/gross profit expression of the case of CEO control in (16). For the same effort, board monitoring would improve firm value if

$$3q^* - 2q^{*2} > 1 \tag{39}$$

holds. Solving the quadratic equation yields roots of 1/2 and 1 and minimum value of -1/8. Hence, (39) is satisfied for any $q \in [0.5, 1]$, that is, for the same level of effort, board monitoring by independent-minded directors add value. **Qed**

However, as shown in Section 4, when directors decide jointly, shareholders induce them to exert less effort, q^{***}. The profit function with q^{***} yields

$$\pi^{***} = \left[\frac{1}{2} + 2\alpha^2 - \alpha + (1-2\alpha)\sqrt{\frac{1}{4} + \alpha^2}\right] * (1 + \alpha - \sqrt{\frac{1}{4} + \alpha^2}) - 0.5c \tag{40}$$

or

$$\pi^{***} = 1/4 + 4\alpha^3 + (1/2 - 4\alpha^2)\sqrt{\frac{1}{4} + \alpha^2} - 0.5c \tag{41}$$

As Proposition 7 demonstrates, π^{***} compares unfavorably with π^* from (16), the expected firm value under CEO control. Directors' willingness to internalize the positive externality from fellow directors' monitoring ultimately reduces gross profits/firm value because the marginal benefits from additional monitoring effort is less than the marginal cost of inducing such effort and thus shareholders settle for lower effort choice and lower gross profits/ firm value. Whether lower gross profit/firm value also translates into lower shareholder value will be the subject of our analysis in Section 6.

Proposition 7 *Independent or active boards reduce gross firm value relative to rubberstamping or captive boards.*

Proof: in Appendix.

The difference in firm values between the active and the rubberstamping boards is illustrated on Figure 3. This difference takes the form of

$$DFV = \begin{cases} 32\alpha^4 - 32\alpha^3\sqrt{\alpha^2 + 1/4} + 4\alpha\sqrt{\alpha^2 + 1/4} - 1 & \text{if } \alpha > 0.5 \\ \\ 4\alpha^3 + (\frac{1}{2} - 4\alpha^2)\sqrt{\frac{1}{4} + \alpha^2} - \frac{1}{4} & \text{otherwise.} \end{cases} \tag{42}$$

We plot this difference against α, the parameter capturing the cost of individual effort. Figure 3 shows that for any $\alpha > 0$ the difference between firm values is always negative and asymptotes to zero from below. At $\alpha = 0$ the difference in firm value is zero, because when effort is costless, independent and rubberstamping boards are equivalent. For $\alpha > 0$ Figure 3 demonstrates that active boards decrease firm value.

Our finding that active board monitoring results in lower firm value is robust to changes in the model setup. For example, even if the CEO were more informed than the rest of the board and directors could receive differential pay, firm value is still higher in the rubberstamping board case. (We will prove this formally in Section 8.) Alternatively, if different directors have different monitoring skills or expertise and are paid accordingly, then firm value may be higher but shareholder value will be again lower.

6 The impact of board monitoring on shareholder value

While firm value is an important measure, what shareholders ultimately care about is shareholder value. Shareholder value is the residual value that accrues to shareholders and, in our model it is gross firm value net of compensation.

Note that lower firm value (gross profit) does not necessarily imply lower shareholder value. That depends also on the amount of compensation executives receive. For example, if executive compensation (the sum of the CEO's and the board compensation) was lower for rubberstamping boards, then independent boards would unambigously decrease shareholder value because they lead to lower gross firm value. Otherwise, independent or active boards may increase or reduce shareholder value depending on the interplay between executive compensation and gross firm value.

The natural first step for the comparison of shareholder values is a comparison of executive compensation payments. From Section 3, executive compensation in the controlling CEO case is $\alpha(q^* - .5)^2$. From Section 4, executive compensation for the independent or active board totals $3\alpha(q^{***} - .5)^2$. We substitute for q^{BC} from (23) and for q^{CEO} from (10) to obtain the optimal executive compensation payments in the two cases. Proposition 8 compares the optimal executive compensation payments with and without active board monitoring.

Proposition 8 *Optimal executive compensation is higher under a rubberstamping board than under an independent board.*

Proof: in Appendix.

Thus, active or independent boards are associated with lower firm value and lower (but steeper) optimal compensation payments than rubberstamping boards. Hence, the comparison of shareholder values depends on whether the decline in gross firm value is fully or partially offset by the reduction in executive compensation.

The sign of the difference in shareholder value decides the comparison of shareholder values. For the rubberstamping board case, shareholder value takes the form of

$$0.5(q^* - c) - \alpha(q^* - 0.5)^2 \tag{43}$$

and for the independent board case, shareholder value becomes

$$0.5(q^{***})^2(3 - 2q^{***}) - 0.5c - 3\alpha(q^{***} - 0.5)^2 \tag{44}$$

Substituting into (43) for q^* from (10) shareholder value under a captive board becomes

$$S^* = \begin{cases} \frac{1}{4} + \frac{1}{16\alpha} - \frac{c}{2} & \text{if } \alpha > 0.5 \\ \\ 0.5(1-c) - 0.25\alpha & \text{otherwise.} \end{cases} \tag{45}$$

Substituting into (44) for q^{***} from (23) shareholder value under an independent board becomes

$$\begin{aligned} S^{***} = & \left[\frac{1}{2} + 2\alpha^2 - \alpha + (1-2\alpha)\sqrt{\frac{1}{4} + \alpha^2}\right] * (1 + \alpha - \sqrt{\frac{1}{4} + \alpha^2}) \\ & -0.5c - 3\alpha\left[\sqrt{\frac{1}{4} + \alpha^2} - \alpha\right]^2 \end{aligned} \tag{46}$$

or after simplifying

$$-2\alpha^3 + \left(2\alpha^2 + \frac{1}{2}\right)\sqrt{\frac{1}{4} + \alpha^2} - \frac{3\alpha}{4} + \frac{1}{4} - 0.5c \tag{47}$$

The difference in shareholder value (DS) between independent and rubberstamping boards becomes

$$DS = \begin{cases} -\frac{1}{16\alpha} - 2\alpha^3 + (2\alpha^2 + \frac{1}{2})\sqrt{\alpha^2 + \frac{1}{4}} - \frac{3\alpha}{4} & \text{if } \alpha > 0.5. \\ \\ -\frac{1}{4} - \frac{\alpha}{2} - 2\alpha^3 + (2\alpha^2 + \frac{1}{2})\sqrt{\alpha^2 + \frac{1}{4}} & \text{otherwise} \end{cases} \tag{48}$$

Interestingly, for any $\alpha > 0$ this difference is always negative. In the special case of $\alpha = 0$ the shareholder value difference is zero, because when effort is costless, the two organizational structures are equivalent.

Proposition 9 *Active or independent boards are associated with lower shareholder value than rubberstamping ones for all* $\alpha > 0$.

Proof: in Appendix.

Figure 4 depicts the difference in shareholder value as a function of α. For any $\alpha > 0$, this difference is always negative. Both firm value and executive compensation is lower in the independent board case, and so is shareholder value. While independent boards reduce executive compensation, they also destroy shareholder value.

Note also in Proposition 9 that if the investment outlay is close to 0.5, then both organizational structures yield positive shareholder value. However, as c becomes higher, independent boards may represent a negative net present value investment for shareholders while captive boards still produce positive net present value for shareholders. This suggests that in capital intensive industries or in industries where more substantial investment is needed, independent boards are not only suboptimal but may be infeasible. This result is consistent with Coles, Daniel and Naveen (2004) and Easterwood and Raheja (2006) that there is no one size fits all in corporate boards.

7 Voting under the unanimity rule

In this section we analyze board decisions if a unanimous vote is required to accept an investment. We investigate whether unanimity voting provides more intense scrutiny than majority voting and if so would such increased scrutiny translate into increased shareholder value.

Unlike majority voting, the unanimity rule comes with three possible outcomes: the investment is unanimously accepted, unanimously rejected, or no decision is reached. The third outcome is specific only to the unanimity rule since for an odd number of board members it would never arise under majority rule. In line with corporate practice, we assume that if no decision is reached, the board takes a new round of votes. (The same practice is common in jury voting.)

It follows from Proposition 3 and our follow up discussion in Section 4.3 that under majority rule only the third member will find it beneficial to ignore his information and vote along with the other two board members if they vote the same way. If voting order is random, this occurs with probability 1/3. So he expects to free ride 1/3d of the time. However, under the unanimity rule because of the potential for a second round voting in case of disagreement, even directors who voted first and second get to free ride on the third director's vote. This increases the opportunity to free ride and reduces directors' ex-ante efforts accordingly.

Note that while under majority voting a board member's probability of being wrong is $[\frac{2}{3}(1-q)+\frac{1}{3}(1-p^2-2pq+2p^2q)]$, under unanimity voting it is $(1-p)(1+p-2pq)$. This is so because each director observes other directors' vote prior to a potential second round of voting.

After taking the first-order condition of (31) in q, we get

$$\lambda p(1-p)+2\gamma(1-p)p-2\alpha(q-.5)=0 \tag{49}$$

Note that given p, a board member will choose lower ex ante effort under unanimity since the q that solves (49) is lower than the q that solves (34).

Since directors have the same skills and effort costs, we look for the symmetric Nash equilibrium. Substituting q for p and simplifying expression (49) yields

$$(\lambda+2\gamma)q^2-(\lambda+2\gamma-2\alpha)q-\alpha=0 \tag{50}$$

Thus, if the board applies the unanimity rule, each board member would choose effort to attain signals of quality

$$q^{AC}=\frac{\lambda+2\gamma-2\alpha+\sqrt{(\lambda+2\gamma-2\alpha)^2+4(\lambda+2\gamma)\alpha}}{2(\lambda+2\gamma)} \tag{51}$$

Simplifying expression (51) gives

$$q^{AC}=\frac{1}{2}-\frac{\alpha}{\lambda+2\gamma}+\sqrt{\frac{1}{4}+\frac{\alpha^2}{(\lambda+2\gamma)^2}} \tag{52}$$

Shareholders will choose the optimal compensation contract to induce the board members to exert value maximizing effort. That is, shareholders will choose λ and γ by setting $q^{***}=q^{AC}$ which yields

$$-\alpha+\sqrt{\frac{1}{4}+\alpha^2}=-\frac{\alpha}{\lambda+2\gamma}+\sqrt{\frac{1}{4}+\frac{\alpha^2}{(\lambda+2\gamma)^2}} \tag{53}$$

It is straightforward to show that for every α there exists an optimal contract with the following property.

Proposition 10 *If $\lambda+2\gamma=1$, then $q^{***}=q^{AC}$ is attained.*

Note that when voting requires unanimity, the optimal contract for independent boards exhibit the same λ and γ as the optimal contract for a controlling CEO with a captive board for any $\alpha\geq 1/2$. Note that for specific αs other optimal contracts also exist. For the special case of $\alpha=0$ any λ and γ satisfy.

Substituting $\gamma=\frac{1-\lambda}{2}$ into (52), the expected firm value

$$E[\pi(q^{BC})]=E[\pi(q^{AC})]=\frac{1}{4}+4\alpha^3+(\frac{1}{2}-4\alpha^2)\sqrt{\frac{1}{4}+\alpha^2}-.5c \tag{54}$$

is the same under the unanimity and the majority rules. However, the compensation contracts are different. Proposition 11 states this result. The proof is straightforward from above and is omitted.

Proposition 11 *The optimal executive compensation contract depends on the governance structure of the corporation. A contract that induces shareholder value maximization in a corporation whose board applies the majority rule is strictly suboptimal for a corporation whose board applies the unanimity rule.*

In our model the supermajority rule coincides with the unanimity rule. If instead a board had five members, then the majority rule would require three votes and the supermajority would require four. While there will be more free-riding on fellow board members' information under supermajority voting than under majority voting, there will be even more free-riding under unanimity voting than under supermajority voting. The more likely a second round of voting is needed to reach a decision by the board, the more likely that directors can rely on fellow directors' information and the more they will reduce effort ex ante.

8 Endogenous emergence of the rubber-stamping board

It has been emphasized in the corporate finance literature how important an independent/active board is. We have studied a rubberstamping board in Section 2 and an active or independent board in Section 3 and compared the two organizational structures in Section 5 and 6. Now we derive conditions under which a rubberstamping board arises endogenously regardless of board independence and compensation.

Consider the case when the CEO has lower information costs than other board members, he volunteers to vote first and this is known ex-ante.[23] Denote by $q > p$ the information precision of the CEO and by p the information precision of the rest of the board members.[24] We next show that in this case non-CEO directors prefer to ignore their own signal and free-ride on the CEO's vote regardless of their compensation structure.

Suppose first that the CEO receives a signal L and recommends not to invest. Suppose furthermore that the second director receives a signal H. What will the second director vote? Note that Proposition 3 still applies, i.e. the third director will go with the recommendation of the first two if they agree.

The second director after seeing his own signal H can either go with his signal and accept the project, or ignore his signal and reject the project. If the second director rejects the project, then by Proposition 3 so will the third director. If the second director accepts the project, the third director may vote accept or reject depending on his own signal and the ratio of p to q.

[23] In some organizations members speak in a set order. In some of these organizations the most junior, in others the most senior member speaks first. This order is not critical in our analysis. In most organizations there is no set order for discussion.

[24] It can be shown that if the CEO's information is superior, the optimal contract will require him to go first under the majority rule, but his order of voting will be irrelevant if decisions require unanimity. In that case everyone will copy his vote either in the first round or in the second round (if there is disagreement in the first round and voting proceeds to a second round). This is effectively identical to his going first.

Given that the first director recommended rejecting the project, and assuming that the third director will follow his own signal if the two directors voting before him disagree, the second director will be wrong if he recommends accepting the project based on his own signal if either the signal sequence is LHH, the majority accepts and $\theta = L$, or the signal sequence is LHL, the majority rejects and $\theta = L$. Hence, the probability of the second director being wrong if he rejects the project given his signal H is :

$$\begin{aligned} Pr(\theta = L|LHH) * Pr(LHH) &\quad + \quad Prob(\theta = L|LHL) * Pr(LHL) \\ = \; 0.5q(1-p)^2 + 0.5q(1-p)p &\quad = \quad .5q(1-p) \end{aligned} \tag{55}$$

If the second director ignores his own signal and recommends rejecting the project, his probability of being wrong is

$$\begin{aligned} Prob(\theta = H|LHH) * Prob(LHH) &\quad + \quad Prob(\theta = H|LHL) * Prob(LHL) \\ = \; 0.5p^2(1-q) + .5p(1-q)p &\quad = \quad 0.5p(1-q) \end{aligned} \tag{56}$$

A comparison of these probabilities reveals that

$$.5q(1-p) > .5p(1-q) \qquad\qquad \text{for all } q > p, \tag{57}$$

that is, the second director is better off ignoring his own signal and free-riding on the recommendation of the first director. From Lemma 1, the third director will also free-ride. Since each board member is better off by free riding on the CEO, other board members will exert no effort in generating signal precision, that is $p = .5$.

Shareholders recognize that only one board member will exert effort and set the compensation contract accordingly. The CEO gets an incentive based contract that induces him to exert the effort that maximizes shareholder wealth, given the other directors get only a nominal payment and do not exert any effort. With $q > p$ and under the majority rule, the project will be accepted when signal sequence HHL, HLH, HHH, or HLL is observed. The expected firm value given a particular signal sequence is as follows:

$$\begin{aligned} E[\pi|HHL] &= E[\pi|HLH] = 0.5qp(1-p) \\ E[\pi|HHH] &= 0.5qp^2 \\ E[\pi|HLL] &= 0.5q(1-p)^2 \end{aligned} \tag{58}$$

Hence,

$$E[\pi|s_1, s_2, s_3] = .5[2qp(1-p) + qp^2 + q(1-p)^2 - c] = .5[q-c] \tag{59}$$

Substituting this in the shareholders' optimization problem yields:

$$q^{RS} = \begin{cases} \frac{0.5+\alpha}{2\alpha} & \text{if } \alpha > 0.5. \\ \\ 1 & \text{otherwise} \end{cases} \tag{60}$$

Notice that $q^{RS} = q^*$ where q^* is the optimal signal precision as in the rubberstamping board case in Section 3. Thus, from Proposition 1, for any α the optimal compensation contract for the CEO must satisfy

$$0.5 = 0.5\lambda + \gamma \tag{61}$$

and

$$\omega \geq 0. \tag{62}$$

Given that the rest of the board will rubberstamp the CEO's choice a symbolic attendance fee equal to the opportunity cost of attending the meeting, $\omega = \omega_1$ will suffice. Attendance based compensations has been common practice for boards until recently when corporate governance activists started to lobby for equity-based incentive compensations for directors.

9 When do Independent Boards Dominate?

In this section we derive conditions under which independent boards dominate rubberstamping ones. We identify three different scenarios. In the first we consider the case when other directors are endowed with certain expertise while the CEO needs to incur costly effort to improve the quality of his information. This case is shown in Section 9.1. In the second we see whether independent directors are important when the CEO enjoys private benefits of control. This case is discussed in Section 9.2. In the third we investigate the value of independent boards in a setting where communication among independent directors increases the precision of their collective information. This case is presented in Section 9.3.

9.1 When non-CEO directors are endowed with expertise

Suppose that each non-CEO director is *endowed* with information of precision $\hat{p}$. The CEO, in contrast faces the same cost function for information collection as before, i.e. $\alpha(q^* - 0.5)^2$ for information of precision q^*. The information precision of the CEO, q^*, will depend on $\hat{p}$ and α.

First consider the case when the CEO's signal is H and the other two directors' signals are low. Whose party's recommendation will be adopted then? If the expected firm value from the investment is positive when the CEO's signal is H and the other two directors' signal is low, then the directors should ignore their own information and rubberstamp the CEO's recommendation. Otherwise, the directors should vote independently based on their individual expertise and override the CEO's recommendation.

Formally,

$$E(\pi|HLL) = Pr(\theta = H|HLL) * 1 + Pr(\theta = L|HLL) * 0 - c \tag{63}$$

or

$$E(\pi|HLL) = \frac{q(1-\hat{p})^2}{q(1-\hat{p})^2 + (1-\hat{p})q^2} - c \tag{64}$$

It is straightforward to see that if

$$\frac{q(1-\hat{p})^2}{q(1-\hat{p})^2 + (1-\hat{p})q^2} \geq c$$

then shareholders are better off if the CEO's recommendation is accepted. This is the case when

$$q \geq \frac{\hat{p}^2 c}{(1-\hat{p})^2(1-c) + \hat{p}^2 c}$$

or the quality of the CEO's information dominates the aggregate quality of the two outside directors' signals put together. In this case shareholders would prefer the independent directors to rubberstamp and contract with the CEO as in the rubberstamping board case (Section 3). The CEO will choose q^* as in (10).

If instead $q < \frac{\hat{p}^2 c}{(1-\hat{p})^2(1-c)+\hat{p}^2 c}$ holds, then the quality of the CEO's signal no longer dominates the quality of the fellow directors' aggregate signal. Now shareholders prefer the project to be accepted or rejected on the basis of the majority vote. Thus shareholders will induce the CEO to select q^* that maximizes

$$E(\pi|q,\hat{p},\hat{p}) - \alpha(q-0.5)^2 = .5(\hat{p}^2 q + \hat{p}^2(1-q) + 2\hat{p}q(1-\hat{p}) - c) - \alpha(q-0.5)^2 \tag{65}$$

The CEO's optimal choice of effort will become

$$q^* = \frac{\hat{p}(1-\hat{p}) + \alpha}{2\alpha} \tag{66}$$

provided that

$$\frac{\hat{p}(1-\hat{p}) + \alpha}{2\alpha} < \frac{\hat{p}^2 c}{(1-\hat{p})^2(1-c) + \hat{p}^2 c} \tag{67}$$

which holds when

$$\alpha \geq \frac{\hat{p} - 3\hat{p}^2 + 4\hat{p}^3 - 2\hat{p}^4}{2\hat{p} - 1}. \tag{68}$$

Thus, when α, the marginal cost of effort for the CEO exceeds $\frac{\hat{p}-3\hat{p}^2+4\hat{p}^3-2\hat{p}^4}{2\hat{p}-1}$, then an independent or active board in which expert outside directors vote according to their endowed information will add value relative to a rubberstamping board. For more productive CEOs a rubberstamping or captive board will dominate an independent board.

We formally state this result in the proposition below. The formal steps of the proof are shown in the discussion above.

Proposition 12 *Consider an independent board with expert outside directors who are endowed with information of precision $\hat{p}$. When the marginal cost of effort for the CEO exceeds $\frac{\hat{p}-3\hat{p}^2+4\hat{p}^3-2\hat{p}^4}{2\hat{p}-1}$, then such a board will add value relative to a rubberstamping board. However, when the marginal cost of effort for the CEO falls below $\frac{\hat{p}-3\hat{p}^2+4\hat{p}^3-2\hat{p}^4}{2\hat{p}-1}$, then the independent board will be dominated by the rubberstamping board.*

Thus, active board intervention is potentially value-reducing when the CEO has sufficiently superior skills. It can nevertheless be value-increasing when the CEO has poor information, consistent with the empirical findings of Easterbrook and Raheja (2007) and the experimental evidence in Gilette et al. (2003)). Both implications are in line with Burkart, Gromb and Panunzi's (1997) that highlights the benefits and costs of shareholder intervention on managerial effort and firm value.

9.2 When the CEO has significant private benefits of control

Suppose that the CEO derives some private benefits from certain investment opportunities and no private benefits from others. The investment may be of four types: (H;H) ; (H;L) ; (L;H) and (L;L), where the first parameter denotes the profits of the projects and the second parameter the private benfits of the CEO. Depending on the size of the private benfits and the degree of the agency problem, the CEO may be inclined to recommend adopting the project when (L;H). Suppose that the shareholders and the rest of the directors are aware of the CEO's conflict of interest but cannot distinguish projects on the basis of their potential private benefits. From the shareholders' and fellow directors' point of view, the CEO's information and resulting vote is less reliable in predicting the shareholder value maximizing investment choice.

If the third director is not the CEO, he will follow the same strategy as in our basic model (i.e. he will suppress his own signal and follow the other two directors if they agree and follow his own signal if the other two disagree). However, the directors voting first and second directors will more frequently disagree when the CEO's recommendation is compromised due to his agency conflict. Hence, the third director will have to rely on his own signal more often. Furthermore, since any non-CEO director voting third will rely more on his own signal now than in the basic model, he or she will be inclined to increase the quality of his or her private signal by exerting more effort ex ante. Thus, this case is equivalent to a scenario in which fellow directors have better skills and lower effort costs than the CEO.

Let α denote the marginal cost of effort for non-CEO directors and α' for the CEO with private benefits and conflict of interest. The shareholders' problem now becomes

$$\max_{q,p} .5(p^2q + p^2(1-q) + 2pq(1-p) - c) - \alpha'(q^* - 0.5)^2 - 2\alpha(p - 0.5)^2 \tag{69}$$

This problem is the mirror image of that of Section 8 in which the CEO had superior information generating ability or more reliable information than the rest of the board. In that section we showed that shareholders will provide more powerful incentives for the CEO and lesser incentives for outside directors. A straightforward (reverse) application of the analysis in Section 8 yields that when the CEO has private benefits and faces a conflict of interest such that his recommendation is potentially less reliable than his fellow directors, then shareholders will provide more powerful incentives to outside directors and lesser incentives for the inside director, the CEO. The resulting independent board will improve shareholder value relative to a rubberstamping or captive board. Proposition 13 summarizes our finding. The proof is straightforward and is omitted.

Proposition 13 *An optimally incentivized indendent board dominate an optimally compensated rubberstamping board if the marginal return from incentivizing the board is higher than the marginal return from incentivizing the CEO.*

Whether or not an optimally compensated independent board dominates an optimally incentivized CEO with a rubberstamping board depends on (1) the degree of the CEO's agency problem and (2) the ability or effort costs of fellow directors. If the agency problem is not very severe an optimally incentivized CEO with a rubberstamping board may still be preferrable to an optimally incentivized non-expert activist board. On the other hand, if the CEO's agency problem is severe, then an active board comprised of experts can dominate all other alternatives. This implication regarding the role of expert directors is consistent with the findings of Easterbrook and Raheja (2006) and Duchin, Matsusaka and Ozbas (2007).

9.3 When discussion improves information quality

Consider the case in which discussions among fellow board members improve the quality and precision of the boards' aggregate information. This is as if each director had lower information costs and searched more ex ante. The interesting question is that what effort cost reduction or efficiency improvement should board discussion produce for an independent board to dominate a rubberstamping one?

To formally compare a rubberstamping board with an independent board, we denote by α the cost of effort for members of a rubberstamping board and by β, the cost of effort for members of an independent or active board whose directors voluntarily discuss and share their information prior to their vote. For given $\alpha \geq \beta$ independent boards dominate rubberstamping ones if $S^{***}(\beta)$ in (47) exceeds $S^{*}(\alpha)$ in (45). This is the case if for $\alpha \geq 0.5$ and $\beta < \alpha$

$$\alpha \geq \frac{1}{16(-2\beta^3 + (2\beta^2 + \frac{1}{2})\sqrt{\beta^2 + \frac{1}{4}} - \frac{3\beta}{4})} \tag{70}$$

holds and if for $\alpha < 0.5$ and $\beta < \alpha$

$$\alpha \geq 4(2\beta^3 - (2\beta^2 + \frac{1}{2})\sqrt{\beta^2 + \frac{1}{4}} + \frac{3\beta}{4} + \frac{1}{4}) \tag{71}$$

is met.

Figure 5 plots α as a function of β that satisfies (70) for equality. Figure 5 shows that independent boards dominate rubberstamping ones depending on the degree to which board discussions improve collective information quality. If board discussions substantially improve the quality of the collective information, then independent, interactive boards can dominate rubberstamping ones. As Figure 5 demonstrates, for many director types (as measured by α) board discussions must reduce collective effort costs by almost half in order for independent boards to dominate rubberstamping ones.

10 Conclusion

This paper develops a model of decision making by corporate boards to investigate the interplay between board characteristics, board compensation, voting rules and governance procedures and their aggregate impact on shareholder value. We show that neither board independence, nor optimal board compensation, nor the combination of the two assure active board monitoring or guarantee that active board monitoring increase shareholder value. Companies may be well run with a rubberstamping or captive board, and may significantly underperform despite having an optimally compensated independent board comprised of directors with impressive credentials and expertise. However, if the CEO's private benefits are high, and the board recognizes the severity of the agency problem, then active board monitoring by a diverse group of optimally compensated expert directors may increase firm value. We derive optimal compensation contracts under different voting rules and demonstrate that when it comes to optimal compensation contracts there is no "one size fits all". We show that optimal incentive contracts are voting-rule-specific and we predict that optimal compensation contracts in practice must be designed differently depending on the governance structure of the corporation.

11 Appendix

Proof of Proposition 3:

The third board member ignores his signal and votes with the board members who voted before him when those board members agreed with each other and follows his own signal otherwise, if by doing so, he can increase his payoff. This would happen if $(1-p)(1+p-2pq) < 1-q$ holds. Substituting in for $p = q$, we get $1-3q^2+2q^3 < 1-q$. Simplifying the expression yields $2q^2 - 3q - 1 = 2(q - \frac{3}{4})^2 - \frac{1}{8} < 0$. The roots of this quadratic equation are 1/2 and 1, the minimum of the quadratic function obtains at $q = 3/4$. Hence $2q^2 - 3q - 1 < 0$ for $q \in [0.5, 1]$. **Qed**

Proof of Proposition 4:

Suppose that the Proposition holds true, that is, suppose that $q^{BC} < q^{CEO}$. Then,

$$1/2 - \alpha + \sqrt{\frac{1}{4} + \alpha^2} < \frac{1}{2} + \frac{1}{4\alpha} \tag{72}$$

must be true. Simplifying yields

$$\sqrt{4\alpha^2 + 16\alpha^4} < \sqrt{16\alpha^4 + 8\alpha^2 + 1} = 4\alpha^2 + 1 \tag{73}$$

which trivially holds. Thus, when directors can rely on each others' information, they will exert less efforts to monitor. **Qed**

Proof of Proposition 6:

To solve for the optimal contract we need to set $q^{***} = q^{BC}$ as in (38). Simplifying the expression yields

$$\frac{1}{2} - \alpha + \sqrt{\frac{1}{4} + \alpha^2} = \frac{1}{2} - \frac{\alpha}{\lambda + \frac{2}{3}\gamma} + \frac{\sqrt{4\alpha^2 + \lambda^2 + \frac{20}{9}\gamma^2 4\gamma\lambda}}{2(\lambda + \frac{2}{3}\gamma)} \tag{74}$$

For this inequality to hold for every α independent of α it must be the case that (i) $\lambda + \frac{2}{3}\gamma = 1$ and (ii) $\lambda^2 + \frac{20}{9}\gamma^2 4\gamma\lambda = 1$. Substituting in the two conditions yields $(1 - \frac{2}{3}\gamma)^2 + \frac{20}{9}\gamma^2 + 4\gamma(1 - \frac{2}{3}\gamma) = 1$ which is only satisfied if $\gamma = 0$ and correspondingly $\lambda = 1$. This would require the shareholders to give 100 percent of the firm to *each* of the three board members which is obviously impossible. Hence there does not exist an optimal contract that would hold with the same terms for all α. **Qed**

Proof of Proposition 7:

We need to establish that $E[\pi^{BC}] < E[\pi^{CEO}]$ or that $.5 * [3(q^{BC})^2 - 2(q^{BC})^3] < .5q^{CEO}$. Plugging in q^{***} for q^{BC} (23) and q^* for q^{CEO} from (10), we get that

$$.5 * [3(q^{BC})^2 - 2(q^{BC})^3] = \frac{1}{4} + 4\alpha^3 + (\frac{1}{2} - 4\alpha^2)\sqrt{\frac{1}{4} + \alpha^2} \tag{75}$$

Comparing the above expression with $.5 * q^{CEO} = \frac{1}{4} + \frac{1}{8\alpha}$ yields

$$.5 * [3(q^{BC})^2 - 2(q^{BC})^3] = \frac{1}{4} + 4\alpha^3 + (\frac{1}{2} - 4\alpha^2)\sqrt{\frac{1}{4} + \alpha^2}\ ?<?\ \frac{1}{4} + \frac{1}{8\alpha} \tag{76}$$

or

$$32\alpha^4 + 4\alpha\sqrt{\frac{1}{4} + \alpha^2} - 32\alpha^3\sqrt{\frac{1}{4} + \alpha^2} - 1 < 0 \tag{77}$$

which holds $\forall \alpha \geq 1/2$.

For $\alpha \in (0, 1/2]$ the comparison with $.5 * q^{CEO} = 1/2$ yields

$$.5 * [3(q^{BC})^2 - 2(q^{BC})^3] = \frac{1}{4} + 4\alpha^3 + (\frac{1}{2} - 4\alpha^2)\sqrt{\frac{1}{4} + \alpha^2} < \frac{1}{2} \tag{78}$$

Since the LHS of (78) at $\alpha = 0$ equals 1/2 and the LHS of (78) is decreasing in α for $\alpha \in [0, 1/2]$, (78) holds $\alpha \in (0, 1/2]$ and it holds for equality for $\alpha = 0$.

Qed

Proof of Proposition 8:

Suppose that Proposition 8 holds true for $\alpha > 1/2$. Then it must be the case that

$$\frac{1}{4\alpha} > \sqrt{3}(\sqrt{.25 + \alpha^2} - \alpha). \tag{79}$$

Simplifying the expression yields

$$1 + 4\sqrt{3}\alpha^2 > 2\sqrt{3}\alpha\sqrt{4\alpha^2 + 1} \tag{80}$$

or

$$\sqrt{48\alpha^4 + 8\sqrt{3}\alpha^2 + 1} > \sqrt{48\alpha^4 + 12\alpha^2} \tag{81}$$

Since $8\sqrt{3}\alpha^2 + 1 = 13.856\alpha^2 + 1$ and $13.856\alpha^2 + 1 > 12\alpha^2$ trivially holds.

Next suppose that Proposition 8 holds for $\alpha \in [0, 1/2]$. Then it must be the case that

$$1 > \sqrt{3}(\sqrt{.25 + \alpha^2} - \alpha) \tag{82}$$

or

$$\frac{1}{\sqrt{3}} + \alpha > \sqrt{.25 + \alpha^2} \tag{83}$$

or

$$\frac{1}{12} + \frac{2\alpha}{\sqrt{3}} > 0 \tag{84}$$

which trivially holds. Thus, the optimal executive compensation contract specifies lower payments for independent or active boards than for controlling CEOs with rubberstamping boards. **Qed**

Proof of Proposition 9:

(1) First we prove that for $\alpha \in [0, \frac{1}{2}]$

$$\frac{1}{4} + \frac{1}{2}\alpha + 2\alpha^3 - (2\alpha^2 + \frac{1}{2})\sqrt{\alpha^2 + \frac{1}{4}} \geq 0 \tag{85}$$

Let $f(x) = \sqrt{x}$. The tangent line to $f(x)$ at $x_0 = \frac{1}{4}$ is

$$y = f'(x_0)(x - x_0) + f(x_0) \tag{86}$$

or

$$y = \frac{1}{2\sqrt{x_0}}(x - x_0) + f(x_0) \tag{87}$$

Substituting in for $f(x)$

$$y = x + \frac{1}{4} \tag{88}$$

Since (88) is tangent to $\sqrt{x}$,

$$x + \frac{1}{4} \geq \sqrt{x} \tag{89}$$

Similarly, for $x = \alpha^2 + 1/4$,

$$\alpha^2 + \frac{1}{2} \geq \sqrt{\alpha^2 + \frac{1}{4}} \tag{90}$$

For (85) it implies that

$$\begin{aligned} \frac{1}{4} + \frac{1}{2}\alpha + 2\alpha^3 - (2\alpha^2 + \frac{1}{2})\sqrt{\alpha^2 + \frac{1}{4}} &\geq \frac{1}{4} + \frac{\alpha}{2} + 2\alpha^3 - (2\alpha^2 + \frac{1}{2})(\alpha^2 + \frac{1}{2}) \\ &= \frac{\alpha}{2}(1 - 3\alpha + 4\alpha^2 - 4\alpha^3) \end{aligned} \tag{91}$$

Let

$$g(\alpha) = 1 - 3\alpha + 4\alpha^2 - 4\alpha^3 \tag{92}$$

Then $g(0) = 1$ and $g(\frac{1}{2}) = 0$ and

$$g'(\alpha) = -3 + 8\alpha - 12\alpha^2 = -12[(\alpha - \frac{1}{3})^2 + \frac{5}{36}] < 0 \tag{93}$$

So $g(\alpha)$ is strictly decreasing for $\alpha \in [0; 1/2]$ and it is bounded from below by 0. This implies that for any $\alpha \in [0, \frac{1}{2}]$

$$\frac{1}{4} + \frac{1}{2}\alpha + 2\alpha^3 - (2\alpha^2 + \frac{1}{2})\sqrt{\alpha^2 + \frac{1}{4}} \geq 0 \tag{94}$$

(2) Second we prove that for any $\alpha \geq 0$

$$\frac{1}{16\alpha} + 2\alpha^3 - (2\alpha^2 + \frac{1}{2})\sqrt{\alpha^2 + \frac{1}{4}} + \frac{3\alpha}{4} \geq 0 \tag{95}$$

Let $f(t) = \sqrt{1+t}$. The tangent line to $f(t)$ at $t = 0$ is

$$y = f'(0)(t) + f(0) = \frac{t}{2} + 1 \tag{96}$$

Since (96) is tangent to $\sqrt{x}$,

$$\frac{1}{2}t + 1 \geq \sqrt{1+t} \tag{97}$$

Since

$$\sqrt{\alpha^2 + \frac{1}{4}} = x\sqrt{1 + \frac{1}{4\alpha^2}} \tag{98}$$

This implies that

$$\frac{1}{8\alpha} + \alpha \geq \sqrt{\alpha^2 + \frac{1}{4}} \tag{99}$$

This implies that

$$\begin{aligned}\frac{1}{16\alpha} + 2\alpha^3 - (2\alpha^2 + \frac{1}{2})\sqrt{\alpha^2 + \frac{1}{4}} + \frac{3\alpha}{4} &\geq \frac{1}{16\alpha} + 2\alpha^3 - (2\alpha^2 + \frac{1}{2})\sqrt{\frac{1}{8\alpha} + \alpha} + \frac{3\alpha}{4} \\ &= \frac{1}{16\alpha} + 2\alpha^3 - \frac{\alpha}{4} - 2\alpha^3 - \frac{1}{16\alpha} - \frac{\alpha}{2} + \frac{3\alpha}{4} = 0 \end{aligned} \tag{100}$$

Thus, board monitoring reduce shareholder value relative to direct contracting between shareholders and the CEO. **Qed**

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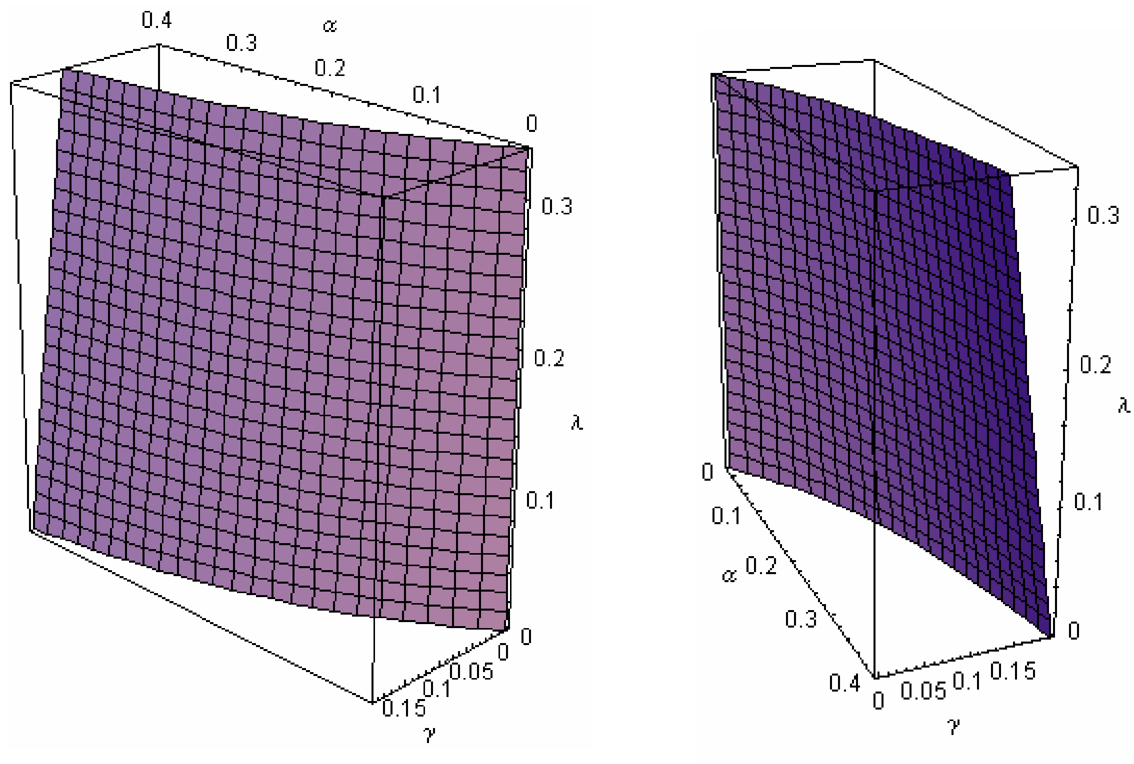

Figure 1: Optimal Board Compensation without Information Sharing (front and back view, respectively).

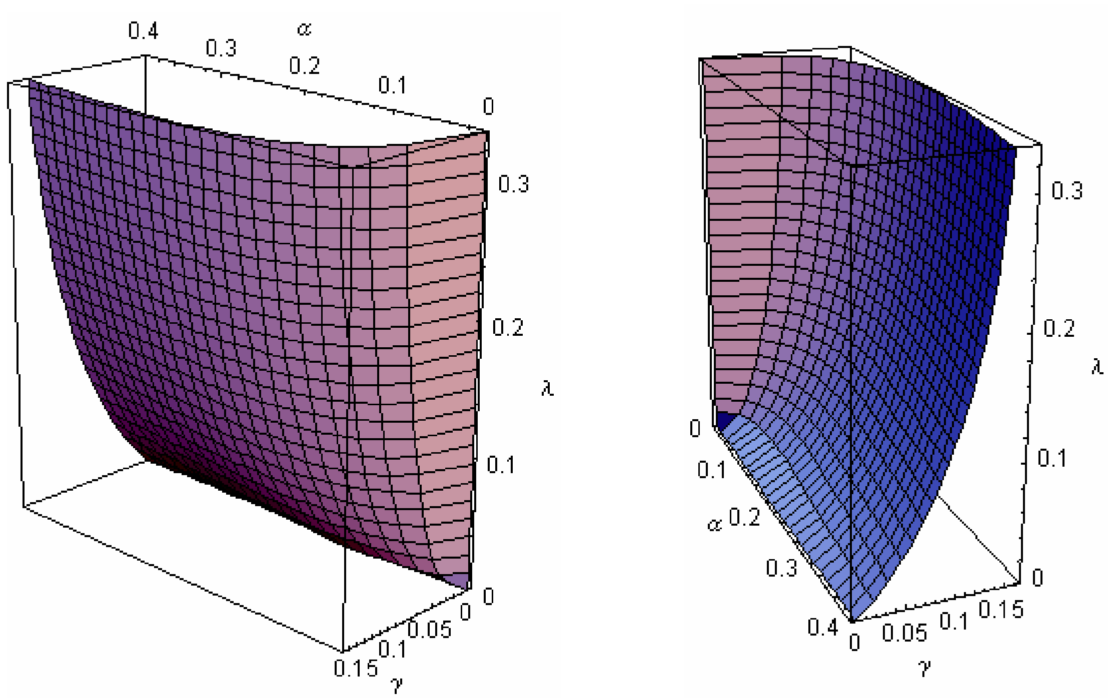

Figure 2: Optimal Board Compensation with Information Sharing (front and back view, respectively).

Figure 3
Difference in Firm values between Independent and Rubberstamping Boards as a Function of Effort Cost
(X = Effort Cost (Alpha); Y = Firm Value)

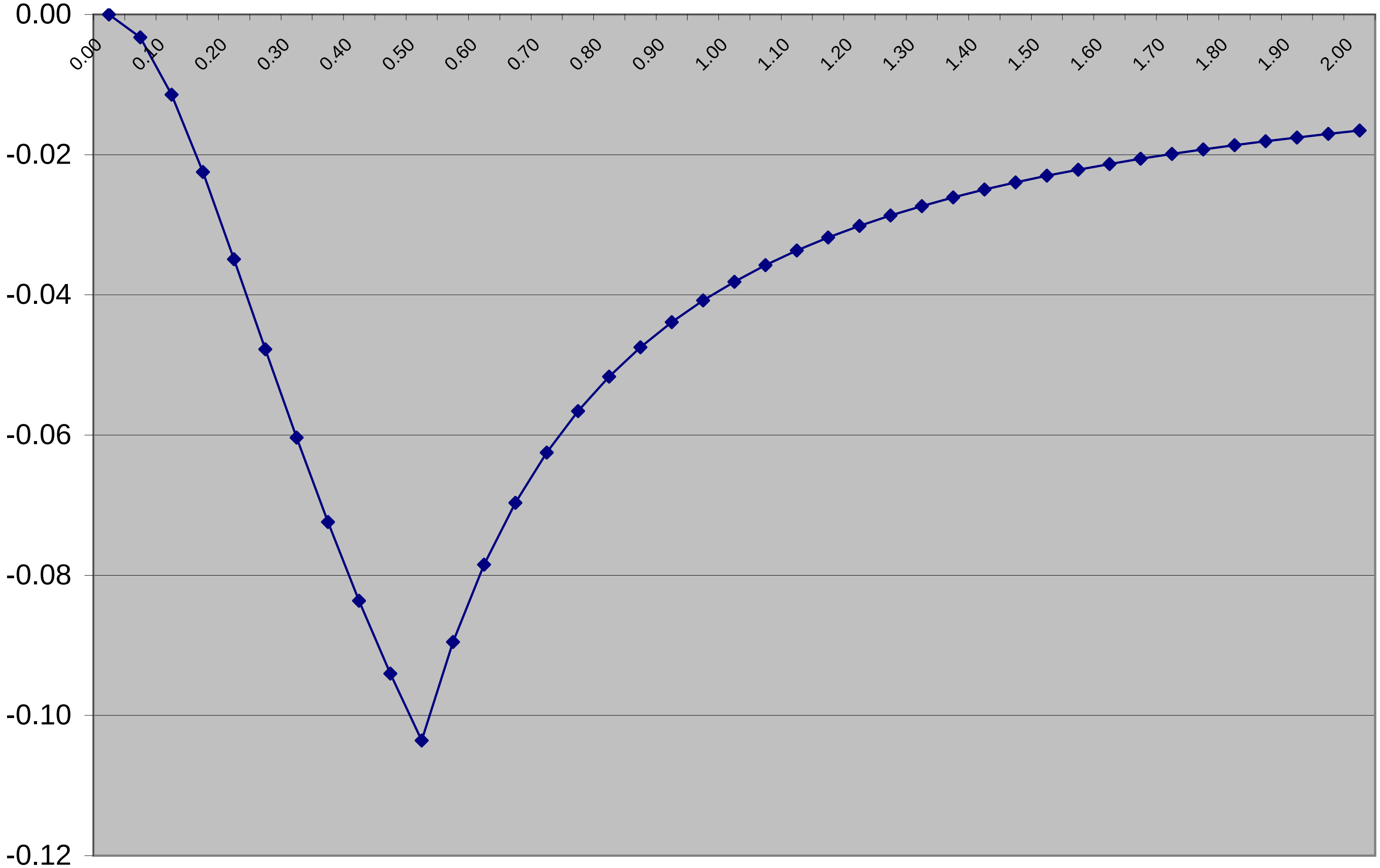

Figure 4
Difference in Shareholder Value between Independent and Rubberstamping Boards as a Function of Effort Cost
(X = Effort Cost (Alpha); Y = Shareholder Value)

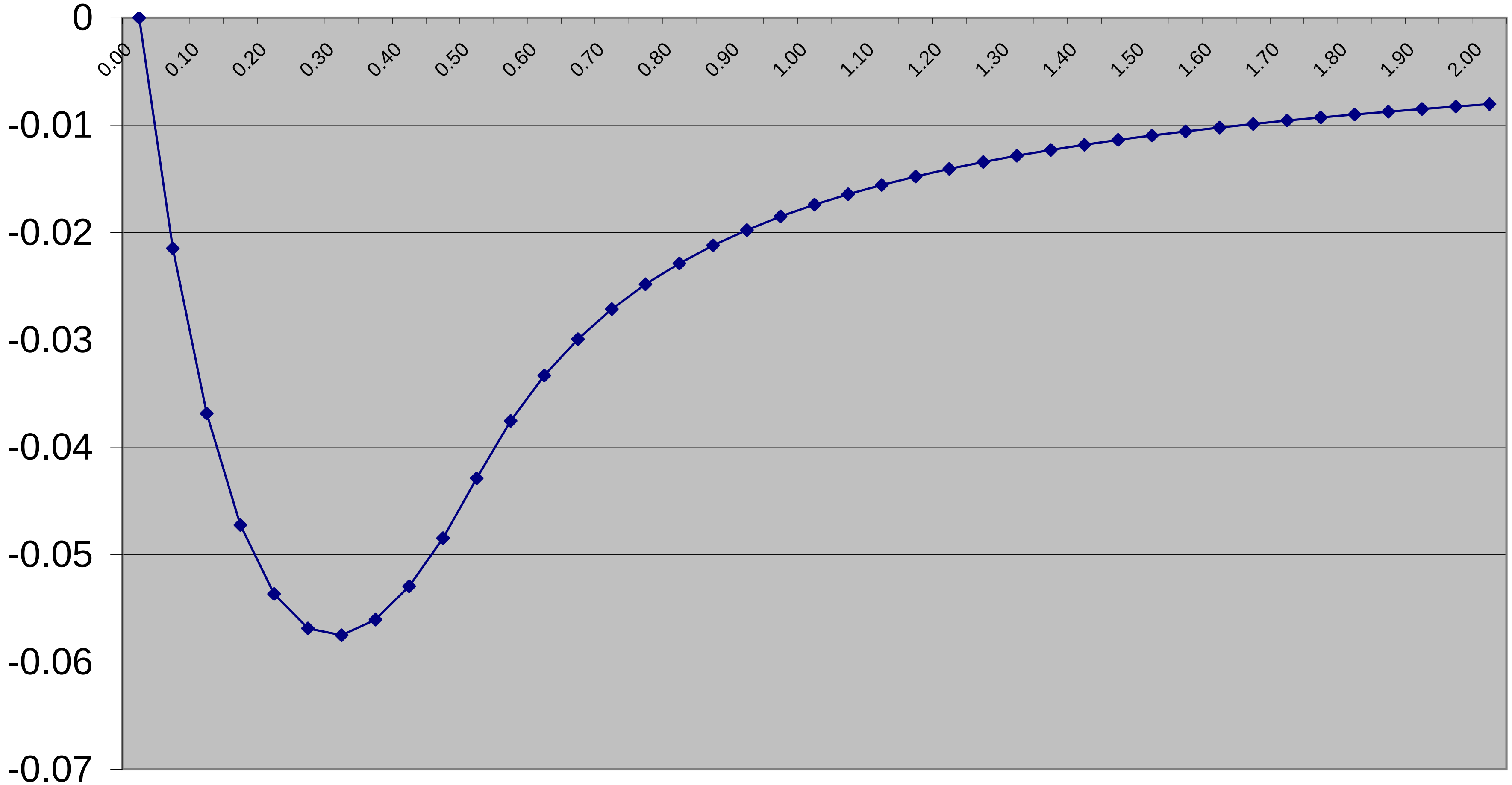

Figure 5
Independent Boards Dominate Rubberstamping Ones when Discussion Among Directors Substantially Improves Information Quality (X=Alpha; Y= Beta)
Alpha vs Beta = Individual vs Collective Ability