Shareholder Voice and Executive Compensation

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August 15, 2023

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Abstract

Can non-binding shareholder votes impact real corporate policies? Answering this requires understanding how much the *threat* of failing a vote impacts corporate decision-makers. I estimate a model of CEO compensation with non-binding shareholder approval votes ("Say-on-Pay"). Compensation decisions are made by the Board of Directors, which is imperfectly informed of CEO skill and biased towards offering a high wage. Shareholders, whose beliefs about CEO ability may differ from the Board's, choose whether to pass or fail the Say-on-Pay (SOP) vote. Failed SOP votes punish the Board for overpaying, but also lead to a perceived or reputational cost of failure to shareholders for dissenting from the Board. To match observed CEO pay levels and SOP failure rates, the cost of SOP failure to the Board (shareholders) must be equivalent to 2.06% (0.76%) of firm value. The cost of failure to the Board reveals that the (off-equilibrium) threat of SOP failure disciplines wages, even with high SOP support; yet shareholder impact on wages is limited by their own (perceived) cost of SOP failure. Using my estimates, I construct a counterfactual SOP mechanism in which a focal shareholder holds an advisory position on the Board; this mechanism lowers the SOP failure rate, decreases wages and increases firm value.

Keywords: shareholder voice, corporate governance, executive compensation, shareholder voting, say-on-pay, structural estimation

[†]I thank John Graham, Alon Brav, Simon Gervais, Vish Viswanathan, and the entire Finance department at Fuqua for comments. James Pinnington played a key role in the earlier stages of this project; the paper in current form would not be possible without his input. This paper is a work in progress, and results are subject to change. All errors are my own.
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1. Introduction

When shareholders disagree with a company's choices and exercising control is not possible, a primary way for shareholders to convey their dissent is by sharing their opinion, commonly called using their "voice" (Hirschman, 1970; Cuñat et al., 2016). Non-binding, advisory shareholder votes are a channel through which shareholders express their views, among which Say-on-Pay (SOP) is the most prominent. SOP is a non-binding approval vote on executive compensation and is in essence a vote of confidence on the remuneration and performance of the firm's top executive. Executive compensation is an important and visible firm policy, thus SOP votes are a potentially important governance mechanism in today's corporate world.

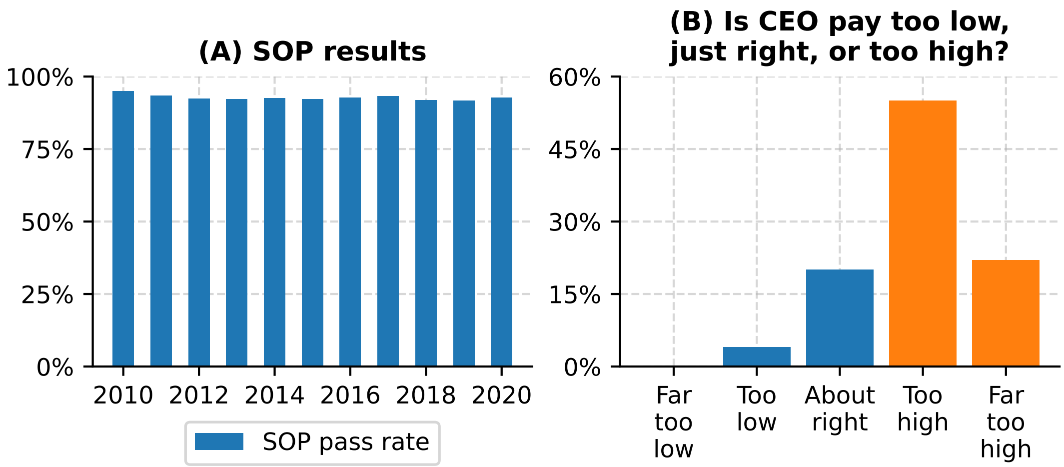
Yet the impact of non-binding advisory votes on real corporate policies is unclear. In particular, SOP votes receive over 90% support on average and only about 7% of SOP votes in the US fail.[1] And yet, as shown in Figure 1, shareholder dissatisfaction with CEO pay from survey evidence is hard to square with such apparent approval of CEO pay (Edmans et al., 2021), and the well-developed literature studying CEO influence on the pay-setting process (e.g., Morse et al., 2011; Coles et al., 2014) and CEOs' ability to demand a large share of rents (Gabaix and Landier, 2008; Custódio et al., 2013; Cziraki and Jenter, 2022) is again hard to square with such apparently high SOP support.

An important consideration is that SOP votes are *ex post* outcomes, occurring after the compensation contract has been set and firm performance has been realized. Observed SOP failure rates belie that the *ex ante* threat of failure is what influences pay policy. Understanding the preferences of shareholders (who control the SOP) and the board of directors (which sets the compensation) is necessary to understand what drives observed SOP vote outcomes.

This paper's goal is to quantify these preferences by estimating a structural model of CEO compensation with non-binding approval (SOP) votes. In the model, the Board sets the CEOs wage every period and is biased towards setting it above its profit-maximizing level. Share-

[1] SOP was introduced in the US as part of Dodd-Frank in 2010. SOP proposals are put forth by management at the annual shareholder meeting, and shareholders are asked to vote on the CEO's compensation from the just-passed fiscal year, *not* on the proposed compensation for the next year. Throughout the paper, I use "failure" to refer to SOP proposals that do not garner the required/expected majority support from shareholders. In the US, SOP votes are non-binding, so there is no threshold which forces management to change compensation policy. However, the widely understood threshold for "failure" of an SOP is 70% support (that is, 30% voting against, see ISS, 2022, Section 5 "Compensation"). 50% and 80% support are also important thresholds (Hauder, 2019).

Figure 1. Say-On-Pay Results and Shareholder Satisfaction with CEO Pay
This figure displays motivation for the paper. Panel A displays average SOP pass rates in the USA by year from 2010 to 2020; it shows that the percentage of SOP votes that pass (garner over 70% support, see Appendix B) is about 93%. Panel B displays survey data from from Edmans et al. (2021), based on a question that asks UK institutional investors how they feel about the level of the CEO's pay; over 70% of survey respondents believe that their CEO is overpaid.



holders then decide whether to approve the CEO's pay (i.e., whether to pass or fail the SOP).[2] Some CEOs are more skilled than others (or, equivalently, their skills are a better match for the firm), meaning their effort translates into higher output for the firm. The Board and shareholders cannot observe CEO ability, but learn it over time, and can have different beliefs about the CEO's true ability. They learn by observing company productivity, with each further receiving a private signal of CEO ability every period.

I estimate model parameters via indirect inference (i.e., simulated method of moments) and the model matches key moments in this setting. In particular, the model replicates the observed SOP failure rate of the sample very closely — 7% in both the simulated and real data. The model also closely matches average CEO wages and the sensitivity of SOP failure likelihood to changes in the wage. Finally, it incorporates the effect of company performance on SOP vote outcomes, which plays an important role in determining SOP outcomes (i.e., SOP is not just about pay, Fisch et al., 2018).

The structural estimation produces three key results. First, Boards must be strongly biased towards overpaying CEOs (relative to the profit-maximizing, unbiased wage), which I refer to

[2] A common misconception about SOPs is that they are advisory votes on *proposed* compensation. Rather, they are *ex post* approval votes on the previous year's CEO compensation, hence the timing structure of the model (Appendix B and Novick, 2019).

as *board capture*. Board capture reflects both CEO influence on the compensation committee (Coles et al., 2014) and the CEO's ability to demand a larger share of the surplus produced by the match with the firm (Gabaix and Landier, 2008; Cziraki and Jenter, 2022). For the average CEO in my sample, I estimate that board capture leads to a \$657 thousand difference in the optimal CEO salary between the Board and shareholders.[3]

It is not obvious that one can infer such a conflict of interest between the Board and shareholders in the pay-setting process with such a seemingly low observed SOP failure rate.[4] Squaring the observed low SOP failure rate requires understanding Board and shareholder preferences concerning the outcome of SOP votes. For SOP to impact compensation policy, it must be that the compensation committee (the Board) internalizes the threat of vote failure. I estimate that Boards internalize a cost from SOP failure that is equivalent to 2.06% of firm value.[5] The (off-equilibrium) threat of SOP failure thus keeps CEO pay closer the shareholder-desired level even when the probability of SOP failure is low. Hence, *non-binding advisory votes affect real corporate policies.*

My third structural result is that failed SOP votes are perceived as costly by shareholders themselves. This cost reflects a distaste for failing SOP votes, even though SOP is often thought as a costless governance mechanism which allows shareholders to engage with management. To match the data, shareholders must internalize a cost from SOP failure that is equivalent to 0.76% of firm value. This aligns with recent survey evidence (Edmans et al., 2021), in which shareholders explicitly state that failing the SOP may be undesirable.[6]

Thus, while shareholders can influence wages via SOP, they are limited by their own perceived cost of failure. After incorporating these costs and other model forces, my simulated data reveals that the existence of SOP brings wages down by 4.4% on average, in line with

[3]The average observed wage in my sample is \$855 thousand. Absent SOP, the Board would pay this CEO \$1.075 million, however based on this CEO's skill and how their effort is capitalized into cash flows, the profit-maximizing wage is \$417 thousand. While the difference may seem small, the model makes a tight link between how CEO wage influences CEO effort, and how CEO effort leads to changes in firm value.

[4]Kaplan (2013) argues that the low failure rate is consistent with pay levels being determined in a competitive market — boards are not biased towards overpaying CEOs and shareholders are satisfied with CEO pay.

[5]In the model, SOP failure does not lead to a drop in revenues or value. Rather, the Board internalizes a non-pecuniary utility cost of vote failure that maps to 2.06%.

[6]This cost to shareholders may arise for several reasons. For example, shareholders wish to have a constructive relationship with management and prefer to address concerns through engagement rather than voting against; there is thus a reputational cost from disagreeing with management on such a prominent issue (Edmans et al., 2021). See Section 2.2 for a detailed discussion.

Correa and Lel (2016) that shows the introduction of SOP votes brought down CEO total pay by 7% in a cross-country analysis.

While uncovering these parameters and their implications is valuable, the structural approach allows me to go further. Using my estimates, I construct a counterfactual way of implementing SOP. In my baseline model, differing beliefs about the CEO between the Board and shareholders play a large role in determining SOP vote results. Giving a focal shareholder a non-voting, advisory seat on the Board is often seen as a way to align beliefs between management and shareholders (Kakhbod et al., 2023), and hence coordinate actions. In my model, this is equivalent to the Board and shareholders *cooperating* when setting CEO pay, via sharing their private beliefs about the CEO's ability. In this counterfactual, the SOP failure rate falls, wages decrease and firm value increases on average. Importantly, I do not change any parameters, changing the way information is revealed along engenders these effects.[7]

It is challenging to disentangle the relative importance of these reasons in explaining observed compensation decisions and SOP vote results. Compensation decisions and SOP outcomes are endogenous. Model elements are unobservable — CEOs' true and perceived abilities, the Board and shareholders' private signals about CEO ability, the precision of these signals, and each party's cost from vote failure. The structural model uses observed, endogenous patterns in company performance, CEO pay and SOP vote outcomes to infer the magnitude of unobservable model parameters. While useful, the success of the structural approach relies on valid identification of parameters in the data, and sensible empirical patterns to reinforce the structural results. My model admits empirical outcomes with direct empirical counterparts in the data, so I can cleanly identify the model's parameters. Further, I document several new motivational facts that provide support for the forces in the model.

To provide reduced-form evidence in support of my board capture structural result, I analyze an important empirical measure of CEO influence used in the literature — board co-option as in Coles et al. (2014). Board co-option measures the proportion of the board of directors that has been appointed during the current CEO's tenure. CEOs may influence director selec-

[7] As will be discussed in Section 6, the key change in this counterfactual from the baseline model is that the Board and shareholders *share* their private beliefs before playing their strategies, as opposed to those strategies being determined by their private beliefs, as in the main model.

tion (Weisbach, 1988), hence board co-option maps to a measure of CEO influence on board decision-making. Following Coles et al. (2014), I first confirm the relation between CEO pay levels and board co-option — higher board co-option implies higher CEO pay. Further, this result is robust to industry and time fixed effects, suggesting that observed board overpayment is not just a function of high CEO bargaining power (to the extent that CEO outside options are well-explained by fixed industry and time effects). However, my model cannot distinguish between explicit CEO influence on the pay-setting process and the CEO's ability to demand a large share of surplus (Cziraki and Jenter, 2022).

I further find that board co-option modulates the relation between *changes* in CEO pay and SOP outcomes. When SOPs fail, companies decrease their CEO's wage considerably on average; higher board co-option attenuates this relation towards zero. In other words, board capture lessens the disciplining effect of SOP votes on wages.

For the model to work, SOP failure must be costly to directors, so SOP failure should correlate with negative outcomes for directors. I find that SOP failure is associated with career concerns for directors. SOP failure is associated with a 2 percentage point (pp) increase in the likelihood that a compensation-committee director leaves or is removed from the Board (which is a 20% larger likelihood of turnover relative to the non-SOP-fail group). Importantly, this excludes directors in their last year of office when the SOP occurs. For directors that remain on the board following SOP failure, I find that they are more likely to be removed or step down from the compensation committee — SOP failure is associated with a 1.5 pp increase in the likelihood that they are removed from the compensation committee the next year (a 26% larger likelihood relative to the non-SOP-fail group of compensation committees).

In addition, I find that failed SOP votes lead to *external* reputation damages for directors. A failed SOP at a director's current firm is associated with a decrease in outside Board positions at other firms (that is, a 2 pp increase in the likelihood that a director loses at least one outside board position). This evidence is in line with Fos and Tsoutsoura (2014) and Aggarwal et al. (2019, 2023), however to the best of the knowledge, my paper is the first to document such internal and external reputation costs to directors coming directly from SOP failure.

A key result of my paper is that SOP vote failures are perceived as costly to shareholders. It is not *ex ante* obvious what this cost is. While the aforementioned survey evidence from Edmans et al. (2021) provides soft support for its existence, deeper empirical evidence is needed. The model suggests that the SOP is about more than pay — it is a public signal revealing shareholders' beliefs about the CEO's ability to run the firm. Hence, the model indirectly predicts that CEO turnover likelihood should be increasing in SOP disapproval. I find that CEO turnover likelihood is around 30% higher in SOP failure relative to pass (an increase from a 9% to roughly 12% turnover rate in SOP failure). Given the value destruction associated with CEO turnover (Taylor, 2010), and the increases in uncertainty both for the firm and the stock price (Clayton et al., 2005), this suggests a motivation for why SOPs do not fail— shareholders prefer to avoid the uncertainty and cost associated with CEO turnover, which maps to the SOP cost I estimate.

Lastly, I present empirical evidence of excess density in the distribution of SOP vote outcomes directly below important failure thresholds. In particular, defining SOP *dis*approval as one minus the proportion of shareholder that approve the SOP, I uncover bunching directly below the failure thresholds of 30% and 50%.[8] The density of observed percentages of shareholders voting against is discontinuously higher directly below the failure threshold (where the vote passes) than above (where the vote fails).

I argue that bunching helps to identify the parameters which measure Board and shareholder costs from SOP failure. In the data, bunching below SOP failure thresholds is clearly consistent with shareholders internalizing a cost from SOP failure. If blockholders, who are often pivotal in SOP votes, perceive a cost from a failed SOP, they have an incentive a force a close pass relative to a close fail, as they do not want to deal with the public fallout or reputational damage arising from a failed vote (Edmans et al., 2021), even if they believe CEO's wages are too high.

In the model, the shareholders' decision balances the cost from increasing the probability of SOP failure against the benefits of forcing the Board to pay wages closer to the profit-maximizing level. As explained in Section 3, shareholders set a threshold and if they receive a

[8]In SOP, 30% and 50% proportion of shareholders voting against the SOP are very important thresholds (see Appendix B and Hauder, 2019).

signal below this threshold the vote fails. Importantly, this threshold is itself a function of the wage, so different wage choices by the Board lead to different likelihoods of SOP failure. Like shareholders, the Board's wage choice is a function of their private signal. The board thus has an incentive to *bunch* wage choices for close realizations of their signal, if the benefit (decrease in probability that SOP fails) outweighs the cost (paying the CEO a lower wage) of such behavior. However, this bunching is only possible if the shareholder sets failure thresholds in the region of their signal's distribution where small absolute changes in the failure threshold leads to large(r) changes in the probability that the SOP fails (i.e., where the the distribution of shareholders' signal is densest).

Similar empirical evidence of bunching was first found in Babenko et al. (2019) in the broader context of management proposals, however I am the first to use it to directly identify vote failure cost parameters in a structural model featuring shareholder voting.[9] Further, Babenko et al. (2019) focus on company management undertaking steps to induce a close pass (which implies the existence of a management cost to vote failure); I show how bunching helps identify *shareholder cost* to proposal failure.

The rest of the paper is organized as follows. I first describe the paper's contribution and context within the literature. Section 2 describes the data and presents some empirical facts about CEO compensation and SOP, which both motivate and discipline the model. Section 3 presents the structural model. Section 4 describes the identification estimation methodology and Section 5 presents the results of the structural estimation. Section 6 analyzes several counterfactuals based on the estimated parameters. Appendix B provides a brief institutional summary of SOP. Additional model results are in Appendix C and estimation details are in Appendix D.

Literature review. This paper contributes to the literature on shareholder voice as a way to influence corporate policies (e.g. Hirschman, 1970; Gillan and Starks, 2007). Levit and Malenko (2011) studies non-binding votes as a form of communication, showing how a large (activist)

[9]From a structural perspective, this methodology has been used in the public finance literature (Saez, 2010; Chetty et al., 2011; Kleven and Waseem, 2013), and has been used recently in corporate finance in a bankruptcy setting (Antill, 2021).

investor can make votes more effective at influencing management. My paper estimates how much the Board internalizes the cost of failing a SOP and my subsample analysis shows that this cost varies with the presence of large shareholders. Levit (2019) studies the effectiveness of communication (voice) in influencing the decision-maker (the Board), which is directly related to the voice mechanism in my paper — the Board and shareholder costs to SOP failure determine the effectiveness of SOP failure in disciplining wages. Kakhbod et al. (2023) studies how large, passive investors (for whom exit is not a viable path) can act as a coordinating force among the shareholder base.

My empirical results speak to the literature on how non-binding or non-consequential shareholder voting can influence the board of directors. Fos and Tsoutsoura (2014) studies how proxy contests impact the careers of incumbent directors and Aggarwal et al. (2019) studies how dissent votes in uncontested director elections impact their careers; my paper explicitly shows the career and reputation consequences from a specific form of shareholder activism — SOP disapproval.[10]

My paper also contributes to the literature on Say-on-Pay. Several papers study how the implementation of SOP was valued by market participants (e.g., Cai and Walkling, 2011; Larcker et al., 2011; Ferri and Maber, 2013; Correa and Lel, 2016; Cuñat et al., 2016). These papers study whether the increase in voice granted by the adoption of SOP leads to higher shareholder value. However, given the high SOP support, several papers (Armstrong et al., 2013; Kaplan, 2013) have concluded that, once implemented, SOP has not influenced compensation and questioned its effectiveness in practice. My paper shows that Boards do incorporate the threat of SOP failure into the *ex ante* compensation policy, even though the observed SOP failure rate is low. Hence, SOP in practice does impact compensation policy and firm value.[11]

My paper also relates to how institutional investors impact executive compensation. The focal voter in SOP votes is almost always an institutional blockholder — the larger the institutional investor's share the more likely they are to be pivotal. Starting with Mehran (1995) and

[10] Aggarwal et al. (2023) studies shareholders' motivations for voting against corporate directors and find that shareholders hold directors accountable for a wide range issues, with governance being the main driver.

[11] In particular, I find that giving shareholders the right to hold SOP lowers CEO wages by 4.4% via this threat, similar to findings from Correa and Lel (2016) on how the *adoption* of SOP impacted CEO pay in a cross-country analysis.

Hartzell and Starks (2003), the literature has shown a negative relationship between blockholder ownership and the level of CEO pay. In fact, SOP was introduced in the US explicitly to increase (large) shareholders' ability to monitor compensation policy. My estimates show that SOP is successful in lowering the level of CEO pay, yet there is a subtlety. The public nature of the vote means that shareholders internalize a cost to SOP failure, hence limiting its effectiveness in curbing pay.

The study of executive compensation from a theoretical and/or structural perspective is too vast to properly reference here.[12] Recently, a structural literature that studies shareholder voting has emerged. However, to the best of my knowledge, this is the first paper to estimate a structural model of executive compensation with a shareholder vote.

2. Empirical Analysis of CEO Compensation and Say-on-Pay

2.1. Data

For the analysis in Section 2.2 and the estimation described in Section 4, I use data on SOP vote results (ISS), Executive Compensation (Execucomp), firm accounting data (Compustat), and stock prices (CRSP). The sample period is 2011-2020, and the sample is limited to S&P1500 firms as Execucomp does not cover firms outside of the S&P1500.

Table 1 displays summary statistics for the empirical sample. It displays statistics for firm-level variables, CEO-level variables and outcome of SOP votes. The average vote against is about 9% (i.e., the average support rate is about 91%). Only 6.8% of votes have more than 30% vote against, and only 1.8% receive less than 50% support. Firms are on the larger end (due to focus on S&P1500 firms) — there is a significant right skew in size and revenues.

The average CEO in the sample receives \$855 thousand in salary, and \$138 thousand in bonus. However, bonus is not a strong feature of the sample, with only 15% receiving a bonus greater than zero. An important thing to note — the model is silent on the structure of long-term and equity compensation. See Page (2018) for a structural analysis of the CEO's contract. CEO tenure is about 8.3 years on average, which will inform the separation probabilities in the estimation.

[12]See Taylor (2010, 2013); Page (2018) for seminal structural papers.

2.2. Empirical Facts

This section documents key empirical facts about SOP outcomes and executive compensation. Specifically,

0. SOP disapproval is increasing in the level of the CEO's wage and decreasing in company/stock performance; CEO compensation decreases following failed SOP votes.
1. CEOs exert influence over compensation policy via *board capture*.
2. SOP disapproval leads to costly outcomes for directors.
3. SOP voting behavior is consistent with shareholders facing a cost from SOP failure.

Facts 0 and 1 are largely a summary of empirical results known to the literature, collected and framed within my setting, whereas Facts 2 and 3 are new results and clarify important features of SOP; each serves to motivate and discipline the model.

Fact 0. *SOP disapproval and failure likelihood increase in the level of CEO pay, and decreaes in company/stock performance; CEO pay decreases dramatically following SOP failure.*

This introductory fact clarifies two important features of SOP and provides a basis for analysis. First, SOP votes are driven by two main forces — the probability of SOP failure is increasing in the level of CEO's wage, and decreasing in company and stock performance.

Table 2 Panel A displays regressions in which the dependent variable is an indicator for SOP failure (more than 30% voting against the SOP, in columns 1-4), or the percentage of shareholders voting against the SOP (the continuous measure, columns 5-8). The main independent variable log current CEO compensation (salary and bonus). The table shows that SOP failure likelihood and SOP disapproval rates are strongly increasing in the level of CEO wages. This relation is robust to the inclusion of performance controls and fixed effects (even as fine as firm × CEO), as well as lagged CEO pay.

The same panel shows that SOP disapproval is *decreasing* in company and stock performance (the firm's return on assets (ROA) and the 12-month stock return, respectively), conditional on the CEO's pay confirming findings from Fisch et al. (2018).[13]

[13]Table A.1 tests the company/stock performance hypothesis separately.

These strong relations, provide clarification for the the quantitative model. Shareholders fail SOPs when wages are (too) high, given what they believe about the CEO. If the company is doing well, then shareholders are less likely to fail the SOP, even if wages are high. Both of these forces will inform the structure of the SOP vote in the model, in which the probability of SOP failure is an increasing function of the Board's wage choice.

That SOP as much about performance as CEO pay must also be incorporated. In the model, the Board sets a fixed wage contract before output occurs; shareholders vote on performance after seeing output and receiving more information about CEO ability. Performance is a signal of CEO ability which informs vote outcomes. If wages are high (relative to shareholder beliefs) but observed productivity is also high, then shareholders are less likely to fail the vote, all else equal. The relative precision of the shareholder's private signal and the public output signal determine which signal informs shareholders' voting decisions more.

While Panel A of Table 2 shows that shareholders respond to the level of wages and company performance, it is not clear whether the Board responds to negative SOP outcomes. Panel B displays the results of a regression of year-on-year changes in CEO compensation (from t to $t + 1$) on the SOP vote result from the previous year (t). The table shows a strong negative relation between changes in CEO pay and SOP disapproval; the change in CEO compensation is about four percentage points lower following SOP failure (columns 1-4). Similarly, columns 5-8 show that a one standard deviation in the percentage of shareholders that vote against the SOP is associated with about a 1.5 percentage point smaller change in CEO pay. This relation is robust to performance controls and firm × CEO fixed effects, and the inclusion of the previous level of CEO pay.

More than anything, Table 2 Panel B is motivation for the model — SOP disapproval leads to a decrease in CEO compensation, suggesting that boards respond to shareholder voice. However, it is hard to draw definitive conclusions from this result. Shareholders' beliefs about the performance, ability or match quality of the CEO likely must be very bad to result in such low SOP approval; it is likely the the Board's beliefs about the CEO are similarly low. I cannot say that low SOP approval causes changes in compensation, but I consider it a necessary condition in order for the mechanism to work.

Fact 1. *CEOs exert influence over their compensation via* board capture.

A key tenet of principal-agent theory is that shareholders set CEO pay in order to align incentives between the firm's CEO and its owners, e.g. by limiting the negative effects of moral hazard in CEO decision-making. However, an important aspect of the compensation-setting process is the role of the compensation committee — an intermediary (presumably) appointed by the firm's shareholders to design and implement an appropriate compensation contract. Corporate finance research has long argued that CEOs exert influence over their pay via *capturing* the directors who sit on the compensation committee.[14]

To confirm the presence of board capture in my data, I examine a well-established measure of board capture from the literature: *board co-option* (Coles et al., 2014). Board co-option measures what percentage of directors (including independent) were appointed within the CEO's tenure. Coles et al. (2014) show that board co-option correlates with the level of CEO pay for the full sample of Execucomp firms. In Table 3 Panel A, I confirm this relation in my data. The level of CEO pay rises as board co-option is higher. As in Coles et al. (2014), I include CEO tenure fixed effects in each specification as co-option mechanically rises with tenure. The table predicts that CEO compensation increases by 7-9 percentages points for each standard deviation increase in board co-option.

Panel B of Table 3 presents a new result. I regress log changes in CEO pay (from t to $t+1$) on an interaction between board co-option and the outcome of the SOP vote (both from year t). The table shows that board co-option modulates the relation between changes in CEO pay and SOP disapproval. In other words, higher board capture lessens the influence that SOP outcomes have on compensation policy.

Figure A.2 illustrates the results of Table 3. Panel A displays a binned scatterplot of log CEO pay on board co-option; Panel B displays how board co-option modulates the effect of SOP disapproval on compensation policy. The relation between changes in CEO pay and the percentage of shareholders voting against in SOP varies greatly going from zero to full board capture.

[14]This is a well-developed literature. For studies of CEO influence on directors, see, e.g. Weisbach (1988); Hermalin and Weisbach (1998, 2001); Taylor (2010); Coles et al. (2014). For studies of CEO influence directly on pay-setting, see, e.g. Crystal (1992); Mehran (1995); Bertrand and Mullainathan (2000, 2001); Adams et al. (2005); Kuhnen and Zwiebel (2008); Morse et al. (2011); Goldman and Huang (2015); Page (2018); Edmans et al. (2021).

The model incorporates CEO board capture directly into the Board of director's pay-setting process. In the model, the Board wants to overpay the CEO by a constant proportion (determined by a parameter λ, which will be discussed in detail in Section 3).

Fact 2. *Low SOP approval correlates with costly outcomes for directors.*

A further basic premise of the model is that SOP failure is costly for directors. I document this cost in three areas. First, Table 4 Panel A shows that SOP disapproval correlates with director turnover. Following Iliev et al. (2015) and Fischer et al. (2009), I identify turnover events occurring between SOP votes and regress a director turnover indicator on the SOP vote in the vote previous to the turnover event. Columns 1-3 of Panel A show that the likelihood that a director is turned over is between 1.5 and 2.3 percentage points (pp) higher after a SOP vote failure. Relative to non-SOP failure, the probability of director turnover is 20% higher. This finding is robust to controlling for firm performance (ROA and firm's stock return over the past 12 months), along with a battery of controls covering board composition, and director and CEO features. Columns 4-6 show that a standard deviation increase in the percentage of shareholders disapproving the SOP also correlates with director turnover.

Panel B of Table 4 presents the second source of cost to directors from SOP disapproval. Focusing on the subsample of directors that remain on the board (i.e., directors not turned over), I identify cases where compensation committee members voluntarily or involuntarily leave their role on the compensation committee. I then correlate this compensation committee turnover with measures of SOP disapproval, as in Panel A. SOP failure is associated with a 1.12-1.46 pp higher probability of being removed from or leaving the compensation committee. Relative to non-SOP failure, this is a 26% increase.

Panels A and B of Table 4 present evidence that SOP disapproval affects the careers of directors at the firm where SOP disapproval takes place. Panel C evaluates how SOP disapproval affects the *reputation* of directors — via its effect on the number of outside Boards that the director sits on. In particular, I focus on compensation committee directors that sit on at least one outside Board the year the SOP vote takes place. I then identify directors that see a reduction in outside Board seats from t to $t + 1$. The Panel shows that SOP failure is associated with a 1.72-1.93pp increase in the likelihood that the director loses at least one outside

Board position. Failing SOP impacts directors *outside of the firm where they work*, suggesting that reputation costs from shareholder disapproval of compensation policy affects directors' ability to sit on outside Boards.

Table 4 shows that failing SOP votes represents a career concern for directors. In the model, SOP impacts compensation policy as shareholders can *threaten* the Board with the (off-equilibrium cost) of SOP failure. Table 4 presents evidence that the cost parameter (labeled χ_B) is large.

This finding is consistent with evidence from Fos and Tsoutsoura (2014) and specifically Aggarwal et al. (2019), who find that dissent votes in uncontested director elections lead to negative consequences for directors. My results are more directed, focusing specifically on directors that serve on compensation committees, and the effect of SOP disapproval on re-appointment and reputation; they suggest that SOP disapproval leads to strong negative outcomes for directors.[15]

Fact 3. *SOP voting behavior is consistent with shareholders facing a cost from SOP failure*

This paper explores the idea that failed SOP votes are perceived as costly by shareholders, with the goal of estimating the magnitude of this cost and exploring its importance in determining SOP votes and compensation policy. Edmans et al. (2021) provide survey evidence that this costs exists: in interviews, institutional investors express their reluctance to fail SOP votes. Failed SOP costs are viewed as a reputation cost, via dissenting from management on such a prominent and important firm policy. Additionally, shareholders feel that dissent constitutes a future monitoring cost, as management will repeatedly contact shareholders to discuss changes in compensation policy.[16]

In the model, SOP failure occurs when the Board and shareholders strongly disagree about

[15] Cost to SOP failure can also be gleaned directly from evidence (both empirical and anecdotal) of firms adjusting their compensation policies *in advance* of SOP laws being implemented. Correa and Lel (2016) show that, in response to the adoption of SOP laws around the world, firms lowered CEO pay — suggesting Boards internalize the likelihood of SOP failure into their compensation objectives. Dowell and Lubin (2011) give a specific example of GE altering the compensation policy of their CEO in advance of the introduction of SOP in the US.

[16] This evidence is taken from Online Appendix A of Edmans et al. (2021). Investors also mentioned that they often follow proxy advisors, as resource constraints prevent them from fully analyzing compensation policy. I present anecdotal evidence of future monitoring costs using the 2022 Netflix proxy statement in Figure A.1. After failing the 2021 SOP, Netflix engaged with large shareholders about compensation numerous times throughout the year.

CEO ability. The model thus suggests that a low level of SOP support signals shareholder dissatisfaction with the CEO. That is, they believe the CEO's ability to run the firm is quite low relative to what the Board believes. In other words, SOP is about more than just pay, it is also a referendum on the CEO's ability to run the firm. Given this vote of "no confidence" in the CEO, the forces of the model predict that CEO turnover likelihood should be higher when there is low SOP support.

However, changing the CEO is a significant event in the life of a firm. Taylor (2010) estimates that CEO turnover constitutes a cost equivalent to 1.3% of firm assets, and Clayton et al. (2005) show that CEO turnover leads to long-term increases in stock return volatility. For the shareholder, avoiding turnover costs and long-term volatility may be preferable to exerting more control on CEO wages. As such, if forcing SOP failure cascades into the CEO being replaced, it may be preferable to pass the SOP.

Table 5 shows that SOP disapproval is associated with increases in the likelihood of CEO turnover. When the SOP fails, the CEO is 2.3 to 3.2 percentage points more likely to be turned over, about a 25% increase relative to turnover rate when SOPs pass. The table also shows that CEO turnover likelihood increases by about 0.8 percentage points for a standard deviation increase in the percentage of shareholders voting against the SOP.

While the survey and CEO-turnover based evidence are suggestive of the existence of a cost to shareholders from failing SOPs, I can use the distribution of vote outcomes around SOP failure thresholds to further uncover information on this cost. A higher occurrence of close passes relative to close fails suggests that shareholders strategically avoid failing SOPs.[17]

I test for density manipulation (Cattaneo et al., 2018) around the important SOP failure thresholds of 30% and 50%, the commonly understood thresholds for SOP failure (ISS, 2022). Figure 2 displays the result. The light blue and orange bars show the observed frequencies of SOP vote outcomes in 0.5 percentage point relative to the failure threshold.[18] Around 12%

[17] This type of strategic behavior requires coordination across diffuse shareholders, or the presence of blockholders. Given the prevalence of blockholder owners in US firms, the latter seems likely — large pivotal blockholders can effectively swing the outcome of a vote by strategically keeping the percentage of votes against the SOP below failure threshold.

[18] See Cattaneo et al. (2020) and Cattaneo et al. (2021) for details. The figure focuses on votes with greater than 20% share of votes against and at most 40% (for the threshold of 30%, and greater than 40% and at most 60% for the 50% threshold

of SOP votes analyzed in the figure fall in the two bins directly below the threshold (i.e., $[-1\%, 0.5\%)$ and $[0.5\%, 0\%)$), and under 8% fall in the two bins directly above. I also find a statistical difference in the density of votes directly at the failure threshold using the density estimation procedures from (Cattaneo et al., 2018).[19]

Although density manipulation is not definitive evidence of a cost to failing SOP votes, the presence of even a small discontinuity at the failure threshold is consistent with shareholder costs to vote failure. Blockholders, who have a tangible role in the outcome of the vote, have an incentive to force a vote to fall below the threshold, even if they believe the CEO's wage is too high.

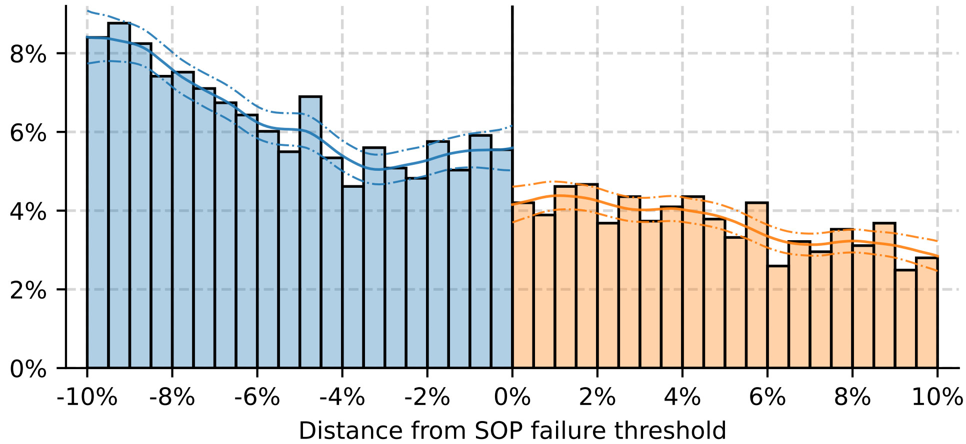
Further, the discontinuity at the failure threshold may provide information on how costly failed votes are to Boards; whom can also alter compensation policy to swing a (counterfactual) close fail to a close pass. This is explored in Babenko et al. (2019), in which the authors find systematic evidence of management (i.e., the Board) influencing the outcome of close votes. In my model, the likelihood of SOP vote failure is itself a function of the CEO's wage — the Board can push down the probability of failure by setting a lower wage; depending on shareholders' beliefs, small changes in wage policy can have large impacts on the *ex ante* likelihood that a vote fails.

The identification of the model's SOP failure cost parameters heavily relies on how the votes are distributed around the SOP failure threshold. In the model, which will be explained in detail in Section 3, shareholders take into account the discrete disutility cost of a failed vote *vs.* its impact on the Board's wage decision when SOP failure is more probable. In turn, the Board is aware of the distribution of shareholders' beliefs and understands that in some states, even slight reductions in wages can significantly reduce the likelihood of the vote failing. While the underlying signal distributions for both parties are continuous, the model predicts that there will be a clustering of vote outcomes directly below the failure threshold with a corresponding gap in the distribution directly above it. The magnitude of the empirical discontinuity will be used to identify the key failure cost parameters in the model.

[19] Appendix Figure A.3 conducts a test where I set "placebo" vote failure thresholds of 20% and 40%, as opposed to the commonly accepted thresholds of 30% and 50%. The figure shows no change in density at these thresholds.

Figure 2. Density manipulation of SOP outcomes

This figure displays the results of testing for density manipulation of SOP disapproval at the failure threshold of $\tau = 30\%$, following the methodology described in Cattaneo et al. (2018). In particular, I look for bunching at τ in $\Delta^{\text{data}} = \text{share against} - \tau, \quad \Delta^{\text{data}} \geq 0 \iff$ SOP fail. I focus on SOP votes falling within 15% of the failure threshold. I test for density manipulation of Δ^{data} 0. The blue and orange bars display observed frequencies of Δ^{data} in 0.5% bins ranging from -10% to $+10\%$. The blue and orange lines (and shaded areas) display the estimated local-polynomial densities. To estimate the densities, I set the order of the local polynomial (and the order of the bias-corrected density estimator) equal to 1.



The evidence in this section presents several new stylized facts about CEO pay and SOP vote outcomes. These facts discipline the model in Section 3, and inform the identification and estimation in Section 4. In particular, the motivation for the model parameters which embed the Board's bias towards over-paying the CEO (board capture), and the magnitude of the Board and shareholder cost arising from SOP failure.

3. Model

This section outlines the model, which presents a simplified view of the world. These simplifications are chosen to focus the model on the key aspects of this setting and allow for clean identification of model parameters in the data.

3.1. Technology and Environment

Time is annual.[20] The CEO's effort function is increasing in the wage

$$n_t = w_t^{\gamma}, \quad \gamma \in (0, 1]$$

[20]Though SOPs only need to occur once every three years, in practice most firms have them annually. I abstract away from this — if a firm has an SOP every two year three years, in the data analysis, I take only the year that an SOP occurs (rather than averaging across years), but either method works just as well.

The parameter γ captures some agency friction, such as effort aversion, that causes the CEO's effort to be concave in the wage. Firms produce with a decreasing returns to scale production function in CEO effort n_t and productivity A_t.

$$y_t = A_t n_t^{\beta}, \quad \beta \in (0, 1]$$

I can rewrite y_t as $A_t w_t^{\gamma\beta}$. I am not interested in separately identifying γ and β, I merely need a parameter that captures that there is decreasing returns to paying the CEO a higher wage. I thus define the parameter $\alpha = \gamma\beta \in (0, 1]$, which governs the degree of returns-to-scale of output to the CEO's wage.[21] I can rewrite output as

$$y_t = A_t w_t^{\alpha} \tag{1}$$

Idiosyncratic productivity is centered around a, the current CEO's skill, but influenced by a mean-zero shock ε_{yt},

$$\ln A_t = a + \varepsilon_{yt}, \quad \varepsilon_{yt} \sim N\left(0, \sigma_y^2\right) \tag{2}$$

The a in (2) should contain a CEO subscript i, as different CEOs can have different levels of ability. Type a is only observed perfectly by the CEO — other actors in the model can only make predictions about a based on the signals they observe. Equation (2) also defines the notion of CEO skill — higher types achieve higher average productivity. Net operating

[21]The CEO is largely a passive actor within the model and this assumption makes the model silent on the contracting problem between the Board and the CEO. There is a vast theoretical literature on CEO agency issues. From a structural standpoint, a relevant paper from an agency and contracting standpoint is Page (2018), who estimates the effect of CEO attributes on cross-sectional compensation, as well as the magnitude of CEO agency issues. I shut this valve off and focus directly on the interaction between shareholders and the compensation committee.

income in year t is revenue minus the CEO wage bill:[22]

$$op\ inc_t = A_t w_t^{\alpha} - w_t$$

The firm's board of directors (B) has one responsibility within the firm — it sets the wage w_t. Importantly, the Board does not perfectly maximize firm profits. That is, absent dynamic considerations and any influence from the SOP, the Board chooses w_t to maximize

$$\text{biased } op\ inc_t = A_t w_t^{\alpha} - (1 - \lambda) w_t$$

where $\lambda \in [0, 1)$ governs the influence CEO utility has on the Board's decision making, and more generally captures agency costs in the form of CEO influence on pay, what I refer to as *board capture* (see Section 2.2 and, e.g., Bertrand and Mullainathan, 2000; Morse et al., 2011; Coles et al., 2014; Page, 2018). When $\lambda > 0$, the Board wants to pay the CEO a wage above that which maximizes net operating income. This bias can reflect a large CEO outside option or some other channel that allows CEOs to demand a high wage (Cziraki and Jenter, 2022). It can also reflect CEO's influence on the pay-setting process, for example via personal relationships with members of the board (Coles et al., 2014). In my model, I do not attempt to separate these forces, rather λ captures the idea is a gap between the wage that would maximize shareholder value and the wage that Board would pay the CEO.

Empirically, CEO wages rarely decrease year-on-year (See Figure A.5, which shows that the vast majority of changes to CEO compensation are non-negative). In reality, CEOs receive long-term compensation contracts, with a specific wage structure decided at hiring. Hence, in order to be able to match observed patterns in CEO compensation, the model needs to incorporate the dynamic aspect of the Board's problem. I include an adjustment cost which

[22] Absent dynamic considerations, the profit-maximizing level of wage/effort is thus given by $w_t^{\mathrm{U}} = \alpha^{\frac{1}{1-\alpha}} E_t \left[A_t\right]^{\frac{1}{1-\alpha}}$, where $E_t\left[\cdot\right]$ is an unspecified expectations operator that conditions on information at time t. Hence, the unbiased wage/effort level is proportional to the skill of the CEO. Profits (by assumption) are paid out immediately as dividends (including negative profits), and thus firm size is fixed over time and will not factor into the model (Taylor, 2010).

forces a degree of smoothness in CEO wages,

$$AC\left(w_t; w_{t-1}, \tau\right) = c_w \times w_t \left(\frac{w_t - w_{t-1}}{w_t}\right)^2 \mathbb{1}\left[w_t < w_{t-1}\right] \mathbb{1}\left[\tau > 0\right] \tag{3}$$

Following Barrero (2022), this is quadratic in the wage and scales with wage levels, and only activates if the Board decreases the wage from $t-1$ to t; c_w controls how costly adjustment is, and is a parameter to be estimated. The one-sidedness of the cost is chosen to match the observed distribution of within-CEO changes in CEO compensation, as in Figure A.5. Further, the adjustment cost does not activate for CEOs in their first year of office, hence the indicator function for CEO tenure being greater than zero.[23]

The firm's shareholders, hold a vote each year on the level of CEO compensation, i.e., a Say-on-Pay (SOP).[24] This vote is non-binding, in the sense that it does not force the Board to set a new wage contract, and occurs at the end of each period (after the wage decision and output have occurred). I assume that a failed vote results in a cost for the Board. The parameter $\chi_B \geq 0$ governs how costly SOP failure is to the Board. This cost *non-pecuniary*, in that it represents a perceived cost from SOP failure — the Board does not pay any monetary cost for SOP failure in the model. The Board's per-period utility is thus

$$A_t w_t^{\alpha} - (1-\lambda) w_t - \chi_B \times \mathbb{1}\left[\text{SOP fail}_t\right] - AC(w_t; w_{t-1}, \tau) \tag{4}$$

Shareholders in the model seek to maximize net operating income. Thus, if wages are "too high," given shareholders' current beliefs about CEO ability, the SOP vote may fail and the Board is forced to pay the failure cost. However, upon vote failure, the shareholders will also face a failure cost. The shareholders' per-period utility is

$$A_t w_t^{\alpha} - w_t - \chi_S \times \mathbb{1}\left[\text{SOP fail}_t\right] \tag{5}$$

[23]In tandem, Table 2 and Figure A.5 show why the adjustment cost is needed. The table shows that CEO pay falls when SOPs fail, whereas the figure shows that CEO wages rarely decrease. SOP failure *forces* the Board to alter their compensation policy and face the negative effects of lowering the CEO's wages.

[24]While the structure of the CEO's pay package certainly influences SOP outcomes, shareholders predominantly vote in response to the level of CEO pay, as detailed in Fact 0 and Table 2 Panel A.

where $\chi_S \geq 0$ is the cost of failing the SOP for shareholders. As discussed in Section 2.2, survey and empirical evidence shows that χ_S is likely greater than zero (Edmans et al., 2021; Babenko et al., 2019).

The differences between (4) and (5) are that, absent the SOP, B and S have (possibly) different underlying preferences about the wage to pay the CEO (board capture), and they face (possibly) different costs from SOP failure; shareholders further do not incorporate the effect of the adjustment cost.[25]

In sum, Shareholders can alleviate the effects of board capture (λ) by threatening to fail the SOP and force the Board to pay a cost (χ_B); however they also internalize their own perceived cost from failed SOP votes (χ_S). These three parameters will be the focus in estimation.

3.2. Signals, Beliefs and Model Timeline

3.2.1. Board and Shareholder Signals

When the firm matches with a new CEO, both the Board and shareholders start with normally distributed prior beliefs about ability $a \sim N(\mu_0, \sigma_0^2)$, which matches the distribution of ability in the CEO talent pool.

The Board and shareholders observe all parameters in the model except CEO ability a. When productivity is high (equation 2), they cannot be sure if this is due to randomness (ε_y) or CEO ability. Seeing productivity $\ln A_t$ thus acts as a public signal about CEO ability, which I label z_{yt}.

$$z_{yt} = \ln A_t = a + \varepsilon_{yt}, \quad \varepsilon_{yt} \sim N\left(0, \sigma_y^2\right) \tag{6}$$

Further, the Board and each shareholder receive a private signal about CEO ability. The Board's signal,

$$z_{bt} = a + \varepsilon_{bt}, \quad \varepsilon_{bt} \sim N\left(0, \sigma_{z_b}^2\right) \tag{7}$$

[25] The assumption that shareholders do not incorporate the adjustment cost is crucial to keeping the shareholders' problem static, which vastly simplifies the numerical solution. Moreover, Table 2 Panel A shows that lagged log pay does not have an impact on SOP outcomes, hence it is likely that shareholders vote in a “static" sense.

is centered around CEO ability a and is not seen by shareholders. B receives the signal at the beginning of the period — their signal influences the wage decision.

Each shareholder in the continuum of shareholders draws a signal about CEO type that is private knowledge, but correlated across shareholders. The standard voting model with incomplete information assumes that signals are completely private. However, with proxy voting, signals are correlated. For example, this correlation could reflect proxy advisors' recommendations. This correlated signal structure among the firm's shareholders makes it informationally equivalent (from the econometrician's perspective) to focus on a representative shareholder S, as microfounded in Appendix C.1.[26] Given this assumption, I henceforth refer to the single representative Shareholder, labeled S. Lastly, It is important to note that this assumption about the shareholder base means influence of blockholder incentives on the SOP process, which undoubtedly play role, are outside the model.

Each period, the Shareholder S aggregates information from the shareholder base into the signal

$$z_{st} = a + \varepsilon_{st}, \quad \varepsilon_{st} \sim N\left(0, \sigma_{z_s}^2\right) \tag{8}$$

which is also centered at CEO ability a. A key point about timing in the model is that S sees the signal z_{st} at the end of the period, whereas the Board sees their signal at the beginning; this timing convention is chosen to reflect how B and S receive information in reality and will influence how B and S set their strategies (see Figure 3).

In sum, the Board B and shareholder S receive a private signal about CEO ability, centered at the true type a, where the signals can have different precision, i.e. $\sigma_{z_b} \neq \sigma_{z_s}$. B and S also receive a public signal z_{yt} of CEO ability via observing output and productivity Sections 3.3 and 3.4 explain how the signals that B and S receive influence their respective strategies.

[26]When all atomistic shareholders receive a correlated signal and vote with the same threshold strategy, there is informational equivalence in focusing on a representative shareholder that aggregates information across the shareholder base into a single signal and votes with the same threshold strategy. Further, this assumption of correlated private signals also embeds proxy advisors into the model. If a proxy advisor gives a negative recommendation, this is like a strong, negative signal of CEO ability. While I remain largely silent on the role of proxy advisors in the SOP process, I do acknowledge their importance.

3.2.2. Board and Shareholder Beliefs

Given starting prior $a \sim N(\mu_0, \sigma_0^2)$, both B and S use Bayes' rule to update beliefs about CEO ability after receving signals. As will be described in Section 3.3, due to signal disclosure in the wage-SOP game, B and S share the same beliefs at the beginning of each period.[27] While I leave the full derivation to Appendix C.2, following Taylor (2010), the variance of beliefs about CEO ability a declines deterministically from period to period according to,

$$\sigma_{at+1}^2 = \sigma_a^2(\tau_t + 1) = \sigma_0^2 \left[1 + (\tau_t + 1)\sigma_0^2 \left(\sigma_{z_b}^{-2} + \sigma_{z_s}^{-2} + \sigma_y^{-2}\right)\right]^{-1} \tag{9}$$

where σ_{at}^2 describes the variance of beliefs about CEO ability at time t, and $\sigma_a^2(0) = \sigma_0^2$. σ_a can be written as a function of τ as the variance is entirely determined by the tenure of the CEO. The mean evolves according to

$$\mu_{at+1} = \sigma_a^2(\tau_t + 1) \left[\frac{\mu_{at}}{\sigma_a^2(\tau_t)} + \frac{z_{bt}}{\sigma_{z_b}^2} + \frac{z_{st}}{\sigma_{z_s}^2} + \frac{z_{yt}}{\sigma_y^2}\right] \tag{10}$$

which resets to μ_0 if the firm matches with a new CEO. Because of the rate of decline of the variance σ_a^2, μ_a tends toward the CEO's true ability over time.

3.2.3. Model Timeline

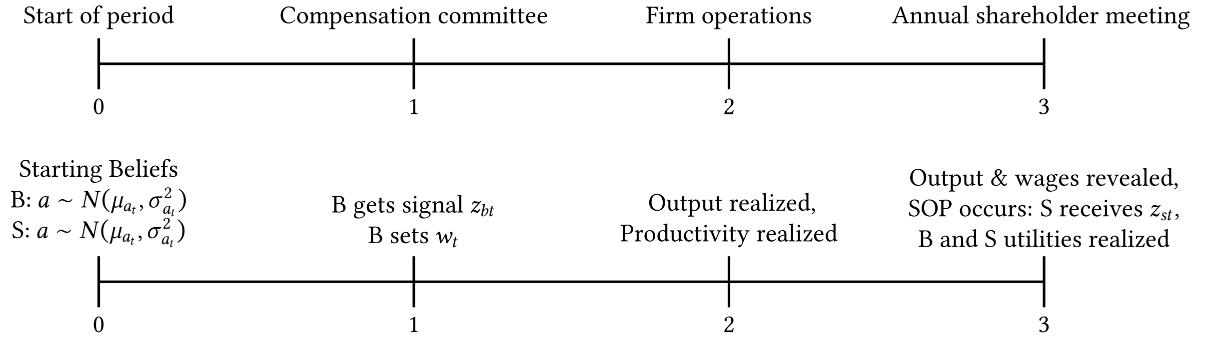
Figure 3 displays the sequence of events within the model. At the start of each period, B and S each believe that CEO ability $a \sim N\left(\mu_{at}, \sigma_{at}^2\right)$. This is due to the fact that B's wage choice fully reveals their private signal, and the outcome of the SOP vote fully reveals S' signal (Section 3.3 formalizes this).

At the compensation committee, B receives their signal z_{bt}, which informs their wage decision. Then, firm operations take place — the CEO receives their wage and expends effort, and firm productivity and output are realized. At the annual shareholder meeting, S receives the firm's 10-K and proxy statement (with CD&A, summary compensation tables and compensation committee report), which reveal the wage, output and productivity, thus revealing z_{yt},

[27] To fix conventions going forward, I use the subscript a to refer to beliefs shared by B and S (i.e., μ_{at} refers to shared beleifs at the beginning of period t). When B and S can have different beliefs, I use the subscripts b and s, respectively.

Figure 3. Model Timeline

This figure displays the within-period model timeline. The top timeline displays the timeline as it maps to the real world; the bottom timeline displays the timeline as it maps to the sequencing of events within the model. Figure A.6 displays a more in-depth timeline which incorporates the timing of commitment to strategies by the Board and Shareholder.



the productivity signal about CEO ability. At the same time, the representative shareholder S aggregates signals from the shareholder base, and the SOP vote occurs. An important timing convention in the model is that S receives the signal at the *end* of the period, after the Board receives their signal. This convention will influence how B and S play their strategies.

Each period, B sets the CEO wage and then S decides whether to fail the SOP. These decisions are informed by each party's private signal, and their beliefs about the other's signal. The game played between the Board and shareholders is the heart of the model, but as the goal is estimation, I aim to keep this part tractable, while also being realistic about the strategies used by Board and shareholders. In the following sections, I detail how B and S set their strategies for the SOP vote and wage. I first detail S' strategy, holding the Board's wage choice fixed (Section 3.3), then I describe the Board's dynamic problem (Section 3.4).

3.3. The Say-On-Pay Vote

In Appendix C.3, I detail several assumptions I make about the SOP vote. In line with the reasoning above. In line with the reasoning above, each assumption is intended to simplify, while keeping the interaction between the Board and shareholders similar in spirit to what occurs in reality.

3.3.1. The Shareholder's Strategy

Informally, S will fail the SOP vote if the CEO's wage is "too high" given their beliefs. Fixing the wage choice of the Board, the notion of being "too high" will incorporate S' current beliefs about CEO ability, and how costly vote failure is to Shareholders. Formally, I am interested in finding the threshold posterior belief about CEO ability (or type) for which S would be indifferent between the vote failing and passing. This is equivalent to finding the threshold in S' signal distribution that leads to this posterior belief. If shareholders receive a signal below this threshold, the vote fails. A higher threshold implies a higher probability of SOP failure. Via the Board's SOP failure cost χ_B, this will lead to lower wages on average; however it also leads to a higher likelihood that S has to pay their cost χ_S. S' strategy can thus be described as choosing the threshold k_{st} that sets a probability of SOP failure which maximizes S utility

$$\Pr\left(\text{SOP fail}_t\right) = \Pr\left(Z_{syt} \leq k_{st}\right)$$

The signal Z_{syt} is the full signal that the Shareholder receives that will determine the outcome of the vote and is different to the private signal z_{st} as it incorporates the effect of firm performance on S' beliefs (as detailed in Fact 0). Further, as Fact 0 shows, holding all else constant, a higher CEO wage leads to a higher probability that the SOP vote fails. I thus make the assumption that the threshold S chooses takes the form

$$k_{st} = s_t \times w_t$$

The threshold is increasing in the wage choice of the Board, and the choice variable s_t controls the *sensitivity* of the probability of SOP failure to changes in the wage. The rest of this section is devoted to formally describing (i) the distribution that determines SOP failure and (ii) the Shareholder's optimal strategy.

Shareholder's information set when the SOP vote is held. As in Figure A.6, when the firm's 10-K is published, output and the wage decision are revealed to shareholders. The wage decision reveals z_{bt}. S receives two further signals about CEO ability: their private signal z_{st} and the productivity signal z_{yt}. S, a consummate Bayesian, considers the weighted average of these two signals, with weights determined by the precisions of the noise terms. Let $p = \frac{\sigma_{z_s}^{-2}}{\sigma_{z_s}^{-2}+\sigma_y^{-2}}$ be the ratio of the precision of ε_{st} to the precision of both shocks. Hence, *ex ante* the shareholder's signal is distributed according to

$$Z_{syt} = pz_{st} + (1-p)z_{yt} = a + p\varepsilon_{st} + (1-p)\varepsilon_{yt}, \quad \tilde{z}_{st} \sim N\left(\mu_{at}, \sigma_{at}^2 + \frac{\sigma_{z_s}^2 \sigma_y^2}{\sigma_{z_s}^2 + \sigma_y^2}\right) \tag{11}$$

This is the distribution that matters for the *probability of vote failure.* That is, S incorporates both signals, placing more weight on the signal with better precision. At the time that they commit to their threshold, S has beliefs about CEO ability $\left(\mu_{at}, \sigma_{at}^2\right)$. Given this, the signal Z_{syt} has distribution as in (11). Further, B knows this is the distribution that S' signal will be drawn from; B takes into account the precision of S' signal when setting the wage.

Fact 0: company performance and SOP outcomes. (11) is how firm performance affects SOP outcomes in the model. Research has demonstrated that the performance of a company is a critical factor in determining the outcome of SOP voting (Fisch et al., 2018). In the model, if the firm's productivity is high (low), S is unable to distinguish whether it is due to the CEO's expertise or an external shock affecting output. A higher z_{yt} (be it due to randomness or true CEO ability) will lower the probability of SOP failure, all else equal.

Distance from the unbiased wage. Suppose board capture does not exist and there were no SOP. The profit-maximizing, or *unbiased wage* that Shareholders desire is given by

$$\max_{w_t} \quad E_{st}\left[\exp\left(a + \varepsilon_{yt}\right)\right] w_t^{\alpha} - w_t \qquad \Longrightarrow \qquad w_t^{\mathrm{U}} = \alpha^{\frac{1}{1-\alpha}} \left(E_{st}[\exp(a + \varepsilon_{yt})]\right)^{\frac{1}{1-\alpha}} \tag{12}$$

Fundamentally, the goal of Shareholders in the model is to get the Board's wage choice as close to the unbiased wage as possible, given parameters and the current state. It stands to reason then, that SOP failure should be determined via *distance* in observed wages from the unbiased wage.

w_t^{U} above is log-normally distributed, with distribution determined by belief tuple $\left(\mu, \sigma^2\right)$

and parameters

$$w_t^{\mathrm{U}} \sim \log N\left(\frac{\mu}{1-\alpha}+C, \frac{\sigma^2}{(1-\alpha)^2}\right), \quad C=\frac{\log\alpha+\frac{1}{2}\sigma_y^2}{1-\alpha} \tag{13}$$

Thus, given the distribution of Z_{syt} in (11), there is a random variable $w_t^{\mathrm{U}}\left(Z_{syt}\right)$ given by (13) that is the conversion of Z_{syt} to its unbiased wage counterpart.[28] I refer to the CDF of this distribition as F_{at}^{U}, where subscript at signifies period t beliefs about CEO ability.

Determining the probability of SOP failure. Given the previous discussion, it follows that shareholders choose a threshold relative to the unbiased wage they desire. If the unbiased wage associated with the signal realization of Z_{syt} is below the threshold $s_t \times w_t$, the SOP vote will fail.[29] The probability of failure, given w_t is thus

$$\Pr\left(\text{SOP fail}_t\right) = \Pr\left(w_t^{\mathrm{U}}\left(Z_{syt}\right) \leq s_t \times w_t\right) = F_{at}^{\mathrm{U}}\left(s_t \times w_t\right) \tag{14}$$

Fixing the Board's best response w_t for now, S chooses s_t to maximize expected net operating income, conditional on their beliefs at the start of period t $\left(\mu_{at}, \sigma_{at}^2\right)$. Importantly, as explained above, S only influences expected wages. When setting the voting policy, conditional on the shared belief μ_{at} at the beginning of period t, S takes expectations over signals z_{bt}. (At the same time, given z_{bt}, B updates beliefs to $\mu_{bt|z_b}$ following standard updating. B then optimally offers $w_t(z_{bt}, s_t)$, which will be detailed in Section 3.4). Expected net operating income, conditional on S' beliefs, given B's wage choice equals

$$E_{st}\left[A_t\right] w_t(z_{bt}, s_t)^{\alpha} - w_t(z_{bt}, s_t) \tag{15}$$

[28]Formally, the distribution of $w_t^{\mathrm{U}}\left(Z_{syt}\right)$ is found by plugging μ_{at} and $\sigma_{at}^2+\frac{\sigma_{z_s}^2\sigma_y^2}{\sigma_{z_s}^2+\sigma_y^2}$ into (13).

[29]Conveniently, the transformation to the log-normal, unbiased wage distribution ensures that S' strategy s_t is just a non-negative, real number, and that the threshold is always increasing in the wage. The wage is guaranteed to be positive (due to log-normal productivity), however CEO ability can be both positive and negative (and hence, draws from the distribution of S beliefs about CEO ability can be both positive and negative. In order to keep k_{st} increasing over all $s_t \geq 0$, I can either normalize type to be positive, or evaluate probability of failure using the log-normal distribution, which is always positive.

So S' problem is

$$\max_{s_t} \quad \int_{z_b} f(z_b) \left[E_{st} \left[A_t \right] w_t(z_{bt}, s_t)^{\alpha} - w_t(z_{bt}, s_t) - \chi_S F^{\mathrm{U}}_{at} \left(s_t \times w_t \right) \right] dz_b \tag{16}$$

Effectively, s_t and w_t are decided upon simultaneously, though w_t is chosen after B observes z_{bt}; S commits to voting via a threshold before receiving z_{st} and z_{yt} (see Figure 3). This setup is chosen to reflect the realities of shareholder voting and CEO compensation. The Board has operational interaction with the CEO and conducts performance reviews before deciding wages. Shareholders use the SOP to influence the direction of wages, and are not overly detailed in their voting strategy (i.e., they focus on influencing expected wages). Further, SOPs are influenced by performance, and the productivity shock affects voting outcomes in the model.

3.4. The Compensation Committee

Each period the Board meets, receives their signal about CEO ability z_{bt}, and then decides the wage to pay the CEO. Their beliefs at the beginning of t are $a \sim N(\mu_{at}, \sigma^2_{at})$. Upon receiving z_{bt}, their beliefs become $\left(\mu_{bt|z_b}, \sigma^2_{bt|z_b}\right)$, where

$$\begin{aligned} \mu_{bt|z_b} &= \sigma^2_{bt|z_b} \left(\frac{\mu_{at}}{\sigma^2_{at}} + \frac{z_{bt}}{\sigma^2_{z_b}} \right) \\ \sigma^2_{bt|z_b} &= \left(\sigma^{-2}_{at} + \sigma^{-2}_{z_b} \right)^{-1} = \frac{\sigma^2_{at}\sigma^2_{z_b}}{\sigma^2_{bt} + \sigma^2_{z_b}} \end{aligned} \tag{17}$$

which is standard Bayesian updating (see Appendix C.2). If B revises their beliefs about CEO ability downwards, they will want to decrease w_t relative to w_{t-1}. To match dynamics in wages, I include the wage adjustment cost from (3) in the Board's problem.

Thus, in year t, B has beliefs $\left(\mu_{at}, \sigma^2_{at}\right)$ about CEO ability, observes the CEO's previous wage, and chooses compensation for the upcoming fiscal year, and solves the following problem

$$V(\mu_{bt}, \tau, w_{t-1}) = \max_{w_t} \quad E_{bt|zb} \left[A_t \right] w_t^{\alpha} - (1-\lambda) w_t - \chi_B \times F^{\mathrm{U}}_{at} \left(s_t \times w_t \right) - AC \left(w_t, w_{t-1}; \tau \right) \; +$$

$$\delta_B\Big[(1-f_\tau)E_{bt|zb}\left[V(\mu_{bt+1},\tau+1,w_t)\right]+f_\tau V^R\Big] \tag{18}$$

To be clear, w_t is a function of both z_{bt} and the shareholder's strategy s_t, however for tractability this notation is omitted from (18). Also, w_t is *fixed* — it is purely salary (no other possible elements of the compensation contract, e.g. bonus, enter into the problem). $F^{U}_{at}(s_t \times w_t)$ specifies the probability of SOP failure as detailed in Section 3.3.

The Board's state is described by the tuple (μ_{bt},τ,w_{t-1}) — their beliefs about the CEO's mean ability at the beginning of the period; the CEO's tenure, which determines the variance of the beliefs, see (9), and the wage set in the previous period. $E_{bt|zb}[\cdot]$ is taken with respect to B's beliefs about CEO ability, after they receive their signal z_{bt} (so beliefs are distributed according to eq. 17). The Board must calculate the expected productivity of the firm A_t, which is also influenced by the productivity shock ε_{yt}; the likelihood the shareholders will fail the SOP vote; and the expected continuation value. The hazard function f_τ controls how often the firm separates from the CEO and is an input to the model. Pooling all CEO spells, f_τ is the frequency of turnover after τ years, conditional on the CEO surviving $\tau-1$ years.[30]

V^R describes the termination value. Upon separating from the CEO, the Board of Directors accesses the CEO talent pool and hires a new CEO. Hence, beliefs reset to (μ_0,σ_0)

$$V^R = V(\mu_0,\tau=0,0) \tag{19}$$

the value function returns to its starting value (prior beliefs) and there is no previous wage.

The Board trades off paying the CEO a biased wage (due to board capture via parameter λ) against the probability that the SOP vote fails after S receives their signal z_{st} and output is realized. B also factors in adjustment costs. It is clear then that the Board's choice of w_t perfectly reveals their signal z_{bt} — S can back out the Board's signal upon seeing w_t.

[30] I follow Taylor (2010) in the computation of the hazard rates. For simplicity, $f_0 = 0$ in the estimation, and $f_{\mathbf{T}} = 1$, where **T** is the cap on the length of CEO tenure. Further, the estimation sample excludes CEO spells that only last the first year.

3.4.1. Objective Firm Value

The Board's optimal wage policy admits the model's definition of objective firm value. Given the state, and the Board's choice of the wage, firm value is thus

$$V^{\text{OBJ}}\Big(w_t, \mu_{at}, \tau_t, w_{t-1}\Big) = \pi_t^{\text{OBJ}}(w_t; w_{t-1}) + \delta_B \times E_{at}\left[V^{\text{OBJ}}\Big(w_{t+1}, \mu_{at+1}, \tau_t + 1, w_t\Big)\right] \tag{20}$$

where $\pi_t^{\text{OBJ}} = E_{at}[A_t]\,w_t^{\alpha} - w_t - AC(w_t; w_{t-1}, \tau)$ is the firm's true cash flow. In contrast to the Board's problem, objective value does not include board capture. Hence, on average the Board's policy w_t will be above the value-maximizing wage. Secondly, firm value does not contain any inputs from the SOP vote, it merely represents the discounted cash flows of the firm. When I undertake counterfactuals, (20) will allow me to analyze how changes to SOP affect true firm value.

3.5. Model Solution and Predictions

I use Bayes' rule to derive Board and shareholder beliefs about CEO ability and substitute these beliefs into (18) to obtain the Board's Bellman equation and (16), which is solved numerically. Appendix C.4 provides full derivation of the solution.

I now discuss the model's predictions and, when relevant, provide comparative statics on key model parameters. Unless otherwise stated, I focus on the static version of the model. That is, the last two terms in (18) are dropped and (16) remains the same.

3.5.1. The Shareholder's Strategy

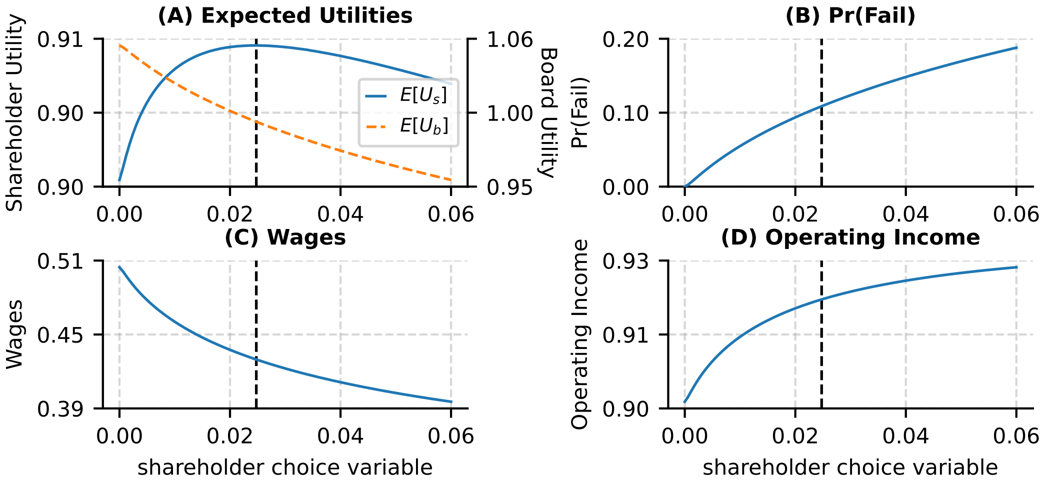
To elucidate how the interaction between shareholders and the Board works, first consider what happens when I vary s_t, the shareholder's strategy. Figure 4 displays comparative statics of the shareholder's choice of s_t. Note — this figure is entirely off-equilibrium. For each point, I set S' strategy to $s \geq 0$, and then plot B's best response *as if* the threshold S plays were the equilibrium. Panel A shows the shareholders' maximization problem as a function

Figure 4. Comparative Statics over Shareholder Strategy s

This figure shows how shareholder strategy s influences per-period outcomes, such as Board and shareholder expected utility, expected wage outcomes and the expected probability of failure. To produce the figure, I fix $s \geq 0$ and produce the Board's best response for that s. Each plot shows expected values taken over the Board's signal z_b. For example, Panel A (blue line) displays shareholder utility averaged over the Board's singal z_b, $\int_{zb} f(z_b)\left(E_s[A]w(z_b)^{\alpha} - w(z_b) - F_a^{\mathrm{U}}(s \times w(z_b))\right) dz_b$. The vertical, black and dashed line displays the equilibrium — S' best response.

Parameters: $\mu_0 = 0$ $\quad \sigma_0 = 1$ $\quad \sigma_y = 1.5$ $\quad \sigma_{z_b} = 2.5$ $\quad \sigma_{z_s} = 3$

$\chi_B = 0.45$ $\quad \chi_S = 0.1$ $\quad \alpha = 0.25$ $\quad \lambda = 0.3$ $\quad c_w = 0$



of the expected threshold set in the SOP vote.[31] On the left y-axis, it shows shareholders' maximization problem (the solid blue line). The shareholder balances the probability of failure (and the likelihood that they face a cost from SOP failure) against bringing the wage closer to the profit-maximizing, unbiased wage. In the same Panel, the right y-axis shows the Board's expected utility (the dashed, orange line). If the shareholder's threshold is set to zero, the Board sets the biased wage (as if the SOP vote did not exist). As the threshold increases, this comes down with the wage. In other words, shareholders undo the effects of the board capture parameter λ.

Panel B displays the probability of failure, along with the expected utility-maximizing s from Panel A. At the optimal threshold, the probability of failure is about 10%. Panel C shows expected wages as a function of the threshold. The biased wage is when $s = 0$. Shareholders can successfully bring wages down by about 15%. However, they cannot bring wages down

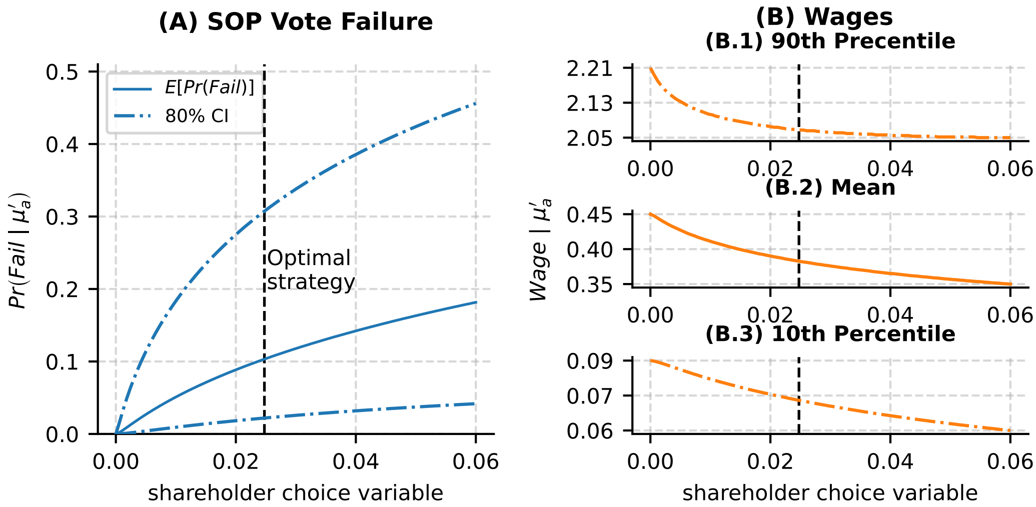
[31] Specifically, Panel A of Figure 4 shows Expected shareholder utility, as shown in (16), as a function of the *expected* threshold in the SOP vote. In other words, (16) is plotted as a function of

$$E_{st}[k_{st}] = s_t \times E_{st}[w_t]$$

where the expectation is taken with respect to shareholder beliefs at the time that they receive their signal.

Figure 5. Shareholder Strategy and Model Outcomes

This figure displays how the probability of failure and wages are affected by changes in the shareholder's choice variable s across the distribution of the Board's signal z_b. Like in Figure 4, I vary the Shareholder's strategy, and compute B's best response given that strategy. Unlike Figure 4, I display how probability of failure and wages change at different points in the distribution of z_b. Panel A displays how different realizations of z_b impact the probability of vote failure. The middle dashed line displays how wages look if $z_b = \mu_a$, i.e. if it is equal to the prior. The top, dashed line displays how SOP failure probability looks if the Board receives a very good signal of CEO ability. Under S' beliefs at the time they commit to their strategy, the Board is overpaying the CEO, hence the probability of failure is much higher. The converse is shown in the lower dashed line, when z_b is at the 10th percentile of the prior distribution. Panel B displays the accompanying wages given the separate realizations of z_b. As can be seen, the different probabilities of failure in the three states have different impacts on the wage the Board offers. Parameters are the same as in Figure 4.



to the unbiased level, as net operating income (see eq. 15) is not maximized, as in Panel D.[32] This panel clarifies the firm-level effect of shareholder costs to failing SOP on firm value in the model. The shareholder utility-maximizing threshold and the profit-maximizing threshold do not align. The inefficiency of SOP brought on by shareholders perceiving costs from SOP failure keeps operating income below its maximal level.

Figure 5 displays the uncertainty in SOP vote and wage outcomes in the model. Shareholders can only influence expected wages, hence there is uncertainty based on their threshold choice and the actual outcome of the SOP vote. This uncertainty is caused by divergence in B and S beliefs until the moment the vote occurs. Panel A displays the range of possible outcomes of failure probabilities for a given shareholder choice variables s. The black, dashed line displays the same optimal threshold from Figure 4. The solid blue line displays the expected probability of failure, given Board prior beliefs about CEO ability. The two dashed lines repre-

[32]Note, too high average SOP failure can have a *negative* effect on operating income. If S sets too high a threshold, the Board may bring wages down too far. Further, as the probability of failure tends toward one in all states, the Board will behave as if the threshold does not exist, and wages will tend back toward the biased level.

sent the 10th and 90th percentile in outcomes.[33] It shows that the exact value of the threshold is determined by deviation in shareholder and Board beliefs before their signals are revealed. The outcome of the SOP vote itself is random and determined by the threshold $k_{st} = s_t \times w_t$ revealed at the end of period. However, before that, there is an extra layer of uncertainty — the threshold of the vote itself is not set when shareholders decide their strategy.

Similarly, Panel B displays the 90th percentile (B.1), mean (B.2) and 10th percentile (B.3) of wage outcomes. As can be seen, when the Board gets a very high signal of CEO ability via z_{bt}, they update (positively) their beliefs about CEO ability. But, from the perspective of the Shareholders, this updating is "too high," in that it causes a divergence from S' beliefs that drive their choice of threshold (which is held at the prior). The Board further internalizes the higher probability of failure into their wage policy — wages decrease more sharply when z_{bt} is high relative to when z_{bt} is low (Panels B.1 and B.3, respectively).

4. Estimation

4.1. Estimation Strategy

I estimate the model's parameters at annual frequency using the simulated method of moments (SMM), or indirect inference (McFadden, 1989; Smith, 2016). I use a set of moments that are informative for the parameters, and minimize the distance between the empirical and model-generated moments. The moments arise from an auxiliary model. That is, I estimate a possibly *misspecified* model on the data, and seek to match the moments produced by that model in the simulated data. Most of the details of the estimation are relegated to Appendix D.

Three key parameters are λ, which describes the degree of board capture; χ_B, which describes how costly SOP failure is for the Board; and χ_S, how costly SOP failure is for Shareholders. These are the focus of the estimation, and hence will dominate the discussion. Table D.1 displays each moment used in estimation, and the parameters that the moment targets.

[33]In Panel A of Figure 5, given that beliefs are normal, upon receiving signal z_{bt}, the Board will update their beliefs from μ_{bt} to $\mu_{bt|z_b}$. As beliefs must be a martingale, it follows then that the posterior mean of beliefs is equal to the prior. This is displayed in the solid blue line. The two dashed lines display the 10th and 90th percentiles of the posterior normal distribution

4.2. Identification Strategy

I make several heuristic arguments, linking moments in the data to model parameters, which motivate the choice of these moments. Given the setup of the model, there is a tight link between observed moments in the data and model parameters; nevertheless, I cannot perfectly pin each parameter to its moment in the data.

Identifying output and CEO skill parameters. I first specify the following functional form for company revenues

$$\log Y_{it} = \underbrace{\log \eta}_{\text{scaling factor}} + \underbrace{\mu_{CEO} + \alpha \log w_{it}}_{\text{CEO component}} + \underbrace{\kappa_1 \log K_{it} + \kappa_2 \log L_{it} + \mu_{ind} + \mu_t}_{\text{non-CEO component}} + \varepsilon_{yit}$$

where i refers to a firm-CEO match. I first residualize revenues by netting out the non-CEO component of output, which comes from the firm's factors of production (capital and non-executive labor), as well as industry and time productivity).[34] This gives the following form for revenue

$$\begin{aligned} \log y_{it} &= \log \eta + \mu_{CEO} + \alpha \log w_{it} + \varepsilon_{yit} \implies \\ y_{it} &= \eta A_{it} = \eta \exp(\mu_{CEO} + \varepsilon_{yit}) \end{aligned} \tag{21}$$

where μ_{CEO} is a CEO fixed effect (i.e., CEO ability a in the model). The parameter η is a time-invariant scaling factor which scales operating income to its appropriate level. It can also be thought of as how well the firm is able to translate the CEO's skill and effort into actual revenues (Page, 2018). This is not intended to represent physical capital, it merely allows me to translate how CEO effort and wages ultimately affect revenues. While η is inessential for solving the model, it is important in the estimation. First, it allows me to pin down how changes in the CEO's wage (effort) affect operating income and thus firm value. Secondly, it allows for appropriate comparison across subsamples (Page, 2018). For example, η varies with

[34] This step is important. For example, there is positive correlation between firm size (employees and/or capital) and CEO pay. The parameter α would then be biased and not represent a true elasticity of revenues to changes in CEO wage (via how the wag impacts CEO effort). Capital is here is gross PPE, and employees is the firm's number of employees, both from Compustat. The industry fixed effect is at the Fama-French 48 industry-level.

firm size — this scaling factors allows for appropriate comparison of other model parameters when comparing small and large firms.

I identify output and CEO skill parameters from the CEO component of company revenues, as in (21). Note that by specifying that revenues are composed of a CEO fixed effect, average CEO skill is not identifiable, as the average CEO fixed effect is only pinned down relative to the constant term, $\log \eta$. Hence, I normalize average CEO skill to zero, so that $\mu_0 = 0$.

The following regression in the data maps exactly to company output in the model

$$\log y_{it} = y_0 + y_1 \log w_{it} + \epsilon_{it}^{y} \tag{22}$$

where $\log y_{it}$ is the firm's CEO-driven log revenue and $\log w_{it}$ is the CEO's observed log of current compensation. Conditional on $\mu_0 = 0$, then $\hat{y}_0$ maps exactly to $\log \eta$, and α is identified via $\hat{y}_1$, the elasticity of firm revenues to the CEO wage, and σ_y via the variance of the residual, $\widehat{Var}\left(\epsilon_{it}^{y}\right)$.

Now, consider average log output over a CEO's tenure from the model less $\alpha \log w_{it}$, which is how the CEO's effort/wage impacts output

$$E_i\left[\tilde{y}_{it}\right] = E_i\left[\log y_{it} - \alpha \log w_{it}\right] = E_i\left[a_i + \varepsilon_{yit} + \alpha \log w_{it} - \alpha \log w_{it}\right] = E_i\left[a_i\right]$$

By taking expectation across each CEO, ε_{yit} drops out as it is mean-zero. I can thus use the variance of the CEO-average of $\tilde{y}_{it}$ to identify σ_0, as

$$Var\left(E_i\left[\tilde{y}_{it}\right]\right) = \sigma_0^2 \tag{23}$$

That is, I compute the variance of the data-equivalent $\widehat{Var}\left(E_i\left[y_{it} - \hat{y}_1 \log w_{it}\right]\right)$.

Parameters that drive the Board's decision. The optimal wage decision by the Board is a non-linear function of parameters and the current state. However, a parsimonious way of describing the optimal wage is that it depends on parameters, the Board's beliefs about the CEO at time t, the probability that SOP vote will fail (given the wage choice), and an adjustment cost if the Board chooses to lower the wage from $t-1$ to t.

It is useful to condition on the previous period's wage and focus on a one-period version of the model, which allows me to solve for the Board's first-order condition.[35] I can thus write an approximation to the optimal log wage as

$$\log w_{it} \approx \underbrace{\log \alpha + \log E_{bt}\left[A_t\right]}_{\text{Expected productivity}} - \underbrace{\log(1-\lambda)}_{\text{Board bias}}$$
$$- \underbrace{\log\left(1 + \chi_B (1-\lambda)^{-1} f(s_{it} \times w_{it}) s_{it}\right)}_{\text{Pr(SOP fail)}} + \underbrace{g(w_{it}, w_{it-1})}_{\text{Adjustment cost}}$$

where $f(s_{it} w_{it})$ is the likelihood function of the Shareholder's signal distribution, evaluated at $s_{it} \times w_{it}$ (i.e., it is the likelihood of SOP failure given the Shareholder's optimal strategy and the wage choice). This expression captures the forces that determine the equilibrium wage choice of the Board. The first two terms above map to CEO productivity, as CEOs are compensated for how their effort/wage maps to output (higher α), along with the Board's current beliefs about that CEO's productivity (higher expected A_t). The third term captures the Board's bias towards the CEO — higher λ implies that a Board will pay a higher wage, all else equal. The fourth term captures how the SOP enters into the wage decision. A higher wage will lead to a higher probability of failure, thus lowering the wage, all else equal. The final term, $g(w_{it}, w_{it-1})$ captures how adjustment costs enter into the optimal wage choice and create persistence in wage choices across periods.[36]

The regression in the data that maps to this expression is

$$\log w_{it} = b_0 + b_1 \mathbb{1}\left[\text{SOP fail}_{it}\right] + b_2 \log w_{it-1} + \epsilon^b_{it} \tag{24}$$

The moment $\hat{b}_0$ maps to productivity and the Board's bias. Expected productivity is determined by the Board's beliefs about the CEO's ability, $\left(\mu_{bt|z_b}, \sigma^2_{bt|z_b}\right)$ after seeing their signal,

[35]Here, I simplify the Board's problem by fixing w_{it-1} (so the Board is not acting dynamically and takes the adjustment cost as given).

[36]I can write the partial derivative of the adjustment cost with respect to w_t as $AC'(w_t, w_{t-1}) = -2c_w(w_t - w_{t-1})\mathbb{1}\left[w_t < w_{t-1}\right]$. Then,

$$g(w_t, w_{t-1}) \approx \log\left(2 + \frac{AC'(w_t, w_{t-1})}{1 + \chi_B \times (1-\lambda)^{-1} s_{it} f(s_{it} w_t)}\right)$$

and output/skill parameters that have already been identified. As b_0 captures the average, individual-Board beliefs are aggregated out, thus $\hat{b}_0$ identifies λ.

The moment $\hat{b}_1$ helps to identify χ_B, as it tells me directly how different wages are in SOP failure relative to SOP pass. Fixing other parameters, if χ_B approaches zero, it must be that b_1 is small (close to zero) — when χ_B is small, then the Board cares little about SOP and will set a similar wage in SOP pass and failure. As χ_B gets larger, it must be that the Board has received a good signal about the CEO (higher expected productivity) in order to deal with higher expected cost of failure. A large $\hat{b}_1$ implies a large χ_B, all else equal.

The Board's wage choice is determined by their signal z_{ibt}. $\widehat{Var}\left(\epsilon_{it}^{b}\right)$ tells me about the precision of the Board's signal. If this quantity is small, this implies that there is little noise in the Board's decision, and vice versa. Lastly, $\hat{b}_2$ corners the dynamic aspect of the Board's problem (persistence in wage across periods) and identifies c_w.

Parameters that drive the Shareholder's decision. In the model, the Shareholder's choice of an *ex ante* probability of SOP failure can be written as a function of their beliefs, their private signal z_{sit}, the productivity signal z_{yit}, and the wage w_{it}, which itself is determined by the Board's signal z_{bit}. In fact, SOP failure can be written closed-form as a function of the Board's wage choice and signal outcomes.

$$\mathbb{1}\left[\text{SOP fail}_{it}\right] = \mathbb{1}\left[s_{it}w_{it} - w_t^{\mathrm{U}}\left(pz_{sit} + (1-p)z_{yit}\right) \geq 0\right]$$

where $Z_{syit} = pz_{sit} + (1-p)z_{yit}$ is a linear combination of the two signals z_{sit} and z_{yit}, with weights determined by the volatilities σ_{z_s} and σ_y, transformed to the relevant log-normal distribution given the distribution of S' signal as in (11). The shareholder's choice variable s_{it} controls the sensitivity of SOP failure to the Board's wage choice, hence choices of s_{it} will be greatly influenced by χ_S. At the same time, s_{it} will be influenced by χ_B as S knows their influence on wages is increasing in the impact of the threat of SOP vote failure. The rate of SOP failure will also be increasing in the Board's bias, all else equal, as it will lead to higher wage choices. Higher productivity (larger z_{yit}) will lead to lower $\Pr(\text{SOP fail})$, all else equal, and similarly for better private signals of CEO ability z_{sit}.

The model-implied determination of SOP failure lends itself to the following regression in the data

$$\mathbb{1}\left[\text{SOP fail}_{it}\right] = s_0 + s_1 \log w_{it} + s_2 \epsilon_{it}^{y} + \epsilon_{it}^{s} \tag{25}$$

where ϵ_{it}^{y} is the residual from the output regression (22). It is clear that $\hat{s}_0$ is an informative moment for the two parameters χ_S, and λ as $\hat{s}_0$ directly maps to the unconditional SOP failure rate in the data. Higher board capture λ raises wages, which leads to more SOP failures, all else equal. Conversely, higher χ_S will lower the observe rate of SOP failure. The moment $\hat{s}_1$ which describes the sensitivity of (the probability of) SOP failure to the wage, is highly informative about χ_S and χ_B. If χ_B is large, then Shareholders know they can have a larger impact on wages and $\hat{s}_1$ will be larger.

The moment $\hat{s}_2$ tells me how performance affects SOP within the model (Fisch et al., 2018). Note that ϵ_{it}^{y} tells me not only the productivity shock, but also how CEO productivity across firms (hence it is also influenced by σ_0). As σ_0 and σ_y are already identified, $\hat{s}_2$ helps greatly to identify σ_{z_s}. While the Board's wage choice reveals their private signal, the Shareholder's signal is truly unobservable in the data. Hence, moments $\hat{s}_2$, which describes how performance changes S' beliefs about CEO ability and $\widehat{Var}(\epsilon_{it}^{s})$, the randomness that affects SOP outcomes, identify σ_{z_s}.

Bunching in Shareholder votes. The moments so far have identified most model parameters, however the distribution of SOP vote outcomes (relative to the failure threshold) is very informative about χ_B and χ_S.

First, I define the data's distance from SOP failure threshold

$$\Delta^{\text{data}} = \text{share against} - \tau, \quad \Delta^{\text{data}} \geq 0 \iff \mathbb{1}\left[\text{SOP fail}\right] \tag{26}$$

This object will be referenced below, and represents distance from the SOP failure threshold (in percentage points). The equivalent object in the model is

$$\Delta^{\text{model}} = F_{at}^{\text{U}}\left(w_t^{\text{U}}\left(s_t \times w_t\right)\right) - F_{at}^{\text{U}}\left(w_t^{\text{U}}\left(Z_{syt}\right)\right), \quad \Delta^{\text{model}} \geq 0 \iff \mathbb{1}\left[\text{SOP fail}\right] \tag{27}$$

which captures the distance (in percentage points) of the Shareholder's signal from the endogenously chosen failure threshold. Note that the Δ^{data} and Δ^{model} have fundamentally different distributions. In the data, vote failure is determined via distance from a public, fixed threshold. In the model, the failure threshold is endogenously determined. My identification argument relies on the fact that vote failure in the data is informative about vote failure in the model, and the conditional distribution of Δ^{data} close to the failure threshold is informative about the relevant conditional distribution of Δ^{model}.

In the model, the Shareholder commits to a single s, thereby committing to a different threshold given different realizations of the Board's signal z_b. While the outcome of the vote is fixed, S commits to a different (weighted) coin-flip given the realization of z_b. Given that s is fixed across z_b, there will be regions of the support of z_s where relatively small changes in w will lead to larger changes in the probability of failure (i.e., when z_s has the highest density, or its CDF has the steepest slope). First, χ_S dictates where each $s \times w(z_b, s)$ will fall in the distribution of S' signal. If χ_S is very high, then $s \to 0$ and bunching as in Figure 2 cannot occur. Similarly if χ_S is very low, then, holding other parameters constant, S will set higher thresholds and push the outcome of the vote to a flatter, less dense portion of the distribution of S' signal; hence bunching is unlikely to occur.

If χ_S is such that realizations of the threshold $s \times w(z_b, s)$ fall in a denser part of the distribution of the shareholder's signal, can set a similar wage for higher realizations of z_b, if the utility gain from lowering the probability of failure outweighs the loss from not paying the CEO a higher wage. Thus, given a value of χ_S, a higher degree of observed bunching implies a higher χ_B. Put simply, a shareholder cost to SOP failure, χ_S is a necessary condition for bunching to occur, and *how much* bunching occurs identifies χ_B.

It is useful to draw comparison between the model's notion of bunching and the bunching that occurs in Figure 2. In the data, this type of bunching at least partially driven by large blockholders, that have an idea that they are likely pivotal (as in Pinnington, 2022), swinging the outcome of a vote from a close fail to a close pass. There is no notion of blockholders within the model (there is only a single, representative shareholders). However, the *economic* force is the same. In both cases, the blockholder (in the data) and the Shareholder (in the model) must have bad enough beliefs about CEO ability (or the wage paid is too high) in order fail the vote. In both cases, χ_S pushes the failure threshold toward zero and to the region where bunching is possible in the model.

The estimation targets a simple, reduced-form measure of bunching (Antill, 2021), which is similar to the estimation used in Figure 2 (Cattaneo et al., 2018), but is just easier to implement within the estimation step. Informally, the measure captures how much extra mass is shifted below the failure threshold, relative to a counterfactual density. To start, I bin the data into widths of 0.5% and index each bin by b. I label the bin mid-point as x_b.[37] N_b is the number of SOP vote outcomes that fall in bin b. To estimate a counterfactual density of vote outcomes absent the failure threshold, I first fix a region around the threshold, $\mathcal{E}$, which captures where bunching is most likely to occur

$$\mathcal{E} = \Big\{ b \quad \text{s.t.} \quad x_b \in [-e, e] \Big\}$$

in the estimation, I set $e = 2.5\%$. Excluding $\mathcal{E}$, I estimate the predicted bin counts as a flexible polynomial of the bin midpoints,

$$N_b = \sum_{m=0}^{M} \beta_m \left(x_b^m \right)$$

and then predict $\hat{N}_b$ for bins in $\mathcal{E}$. Thus, $\hat{N}_{b|b\in\mathcal{E}}$ represent a counterfactual count for the number of SOP votes that would fall in bin b given there was no bunching in the data. I use these predicted counts to construct the bunching estimator

$$\mathbb{B} = \underbrace{\frac{\sum_{b\in\mathcal{E}} \left(N_b - \hat{N}_b \right) \times \left(\mathbf{1}\left[x_b < 0 \right] - \mathbf{1}\left[x_b \geq 0 \right] \right)}{\sum_{b\in\mathcal{E}} \hat{N}_b}}_{\text{Proportion of mass shifted to below threshold}} \tag{28}$$

$\mathbb{B}$ measures how many SOP votes are shifted from above the failure threshold to below, expressed as a proportion of the sum of the predicted counts. (28) is easily estimable on model-simulated data, so can be used as a targeted moment during the estimation step.

Figure A.7 displays the degree of bunching in the data. I zoom in on votes that fall within 10% of the failure threshold $\tau = 30\%$. Setting the order of the polynomial $M = 3$ and focusing

[37] For example, for the bin $[-0.5\%, 0)$, $x_b = -0.25$.

on 0.5% bins, I evaluate the degree of bunching within 2% of vote failure. In the figure and the empirical sample, $\mathbb{B}$ from (28) is 0.121. What does this mean? It means that there is too high a mass to the left of the threshold (just passed) and too little a mass just to the right (just failed). The result of this Figure will thus make up a key moment in the estimation.

5. Results

Section 5.1 displays the results of the estimation. I first display the results of the moment-matching exercise, and then the parameters that drive the quality of the model's fit. The rest of the section provides detail on the quality of the model's fit, and robustness by estimating the model on subsamples.

5.1. Estimation Results

5.1.1. Estimated Moments

Table 6 Panel A displays the closeness of model and data moments. The final column displays the t-statistic arising from a two-way t-test between each model and data momentOverall, the estimated model can match the data moments well.

Average log output (moment 1, $\hat{y}_0$), which identifies the scaling factor, is perfectly matched. As η serves only to scale up CEO skill and effort into observed revenues and operating income, it has no impact on other moments and is exactly identified by $\hat{y}_0$.

The elasticity of output to the wage (moment 2, $\hat{y}_1$) slightly under-estimated in the model, but there is no statistically significant difference. This is reassuring as it signals I have identified α.[38] The variance of CEO-average output (adjusted by wage) is very closely matched, suggesting σ_0 is identified and the output residual variance is very closely matched, suggesting σ_y is identified.

Average log wage (moment 5, $\hat{b}_0$) and the difference in wages when the SOP fails (moment 6, $\hat{b}_1$) are both matched well. That the model can match the observed average wage when the SOP passes and when it fails is reassuring for its fit and identification of the key parameters

[38]While α is estimated to be 0.263, an elasticity of output to the wage greater than one is determined largely by variation in CEO skill. More (less) skilled CEOs demand non-linearly larger (smaller) wages and this maps into a larger output-wage elasticity in the model.

λ and χ_B. Persistence in log wages is over-estimated in the model, so it is likely that the estimation requires too-high of an adjustment cost c_w to match other moments. The variance of the wage residual (moment 8, $\widehat{Var}\left(\varepsilon^b\right)$) is over-estimated in the model. This likely implies that the volatility of the Board's signal σ_{z_b} is too large.

The observed SOP failure rate (moment 8, $\hat{s}_0$) is matched well (7% in the data *vs.* 6.7% estimated). The sensitivity of SOP failure to the wage (moment 9, $\hat{s}_1$), though $\hat{s}_1$ is under-estimated in the model, but there is no statistically significant difference. Again, that the model can match these key moments closely is reassuring.

The sensitivity of SOP failure rate to the output residual is very over-estimated in the model (moment 10, $\hat{s}_2$) . By incorporating the effect of company performance (by way of it being a signal of CEO ability) into the SOP vote outcome (Fisch et al., 2018), I make the outcome of the vote *too* dependent on the productivity shock. Given the parsimony of the model, it is natural that too much gets shifted towards the productivity signal. In the data, other forces drive SOP so the effect of performance on SOP outcomes, while important, has a smaller magnitude. The model matches the variance of the SOP regression residual very closely.

Lastly, the bunching of shareholder votes (moment 13, $\hat{\mathbb{B}}$) is matched closely in magnitude (0.121 *vs.* 0.116 in the estimation), even though there is a statistically significant difference the data and model bunching estimators.

5.1.2. Parameter Estimates

Table 6 Panel B displays the estimated parameters. The estimated board capture parameter is 0.612. To translate what this parameter means in dollar value, this parameter value implies that for the average CEO in her first year of tenure, the Board's optimal wage (absent SOP and adjustment costs) is roughly \$1.075 million, and the Shareholder's profit-maximizing roughly \$417 thousand, a difference of \$657 thousand. Compared to the average, observed wage in my data (roughly \$855 thousand), this suggests that observed board capture in the data is large.

The cost of SOP failure to shareholders χ_S is estimated to be 0.088, and the cost to the Board χ_B is 0.240. To interpret these magnitudes, I normalize them by average firm value. I estimate that the Board considers SOP failure to be worth a utility cost equivalent to 2.06% of unbiased value. For shareholders, this cost is 0.76%, and both normalized SOP failure costs are statistically different from zero. Even though the *expected* cost from vote failure is low, the off-equilibrium threat of failing the SOP is very costly to the Board (See Fact 3), which disciplines wages, even in states where SOP failure is very unlikely. Hence, *non-binding SOP votes influence compensation policy.*

It is important to note that these cost parameters are in units of utility, so it is not as if SOP failures affect output, the Board and shareholders merely must behave *as if* they do for the model to match observed outcomes. Thus, the shareholder cost to SOP failure makes shareholders pass some SOP votes that would fail if this non-pecuniary cost did not exist. The exact source of the shareholder cost from SOP failure cannot be determined from the model, (see Fact 3 for sources of this cost).

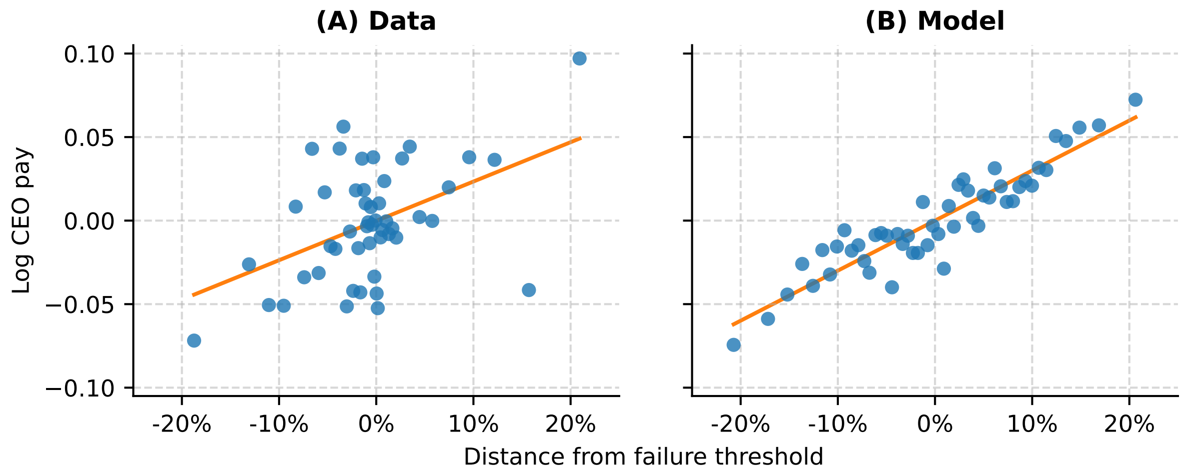
The standard deviation of CEO ability needed to match the variance of observed log revenues is 0.542. To put this in perspective, this implies that the CEO at the 75th percentile of ability has about three times the effect on output as the CEO at the 25th percentile of output.[39] These differences suggest that CEO skill matters.

The standard deviation of the Board and shareholder's private signals are 1.996 and 0.697 respectively. While the volatility of the innovation in the Board's signal is larger than the Shareholder's, it is important to remember that the Board receives their signal in advance of making their wage choice, and the Shareholder uses their signal to determine the outcome of the SOP vote. At the point when B and S set their strategies, the Board unilaterally has more precise beliefs than the Shareholder. The output shock volatility σ_y is 1.043. This implies that a large portion of observed variation in output comes from randomness, rather than CEO skill.

Figure A.8 displays the rate of decline of Board and shareholder beliefs about CEO ability as a function of CEO tenure. By the sixth year ($\tau = 5$) of the CEO's tenure, the volatility of beliefs halves. While uncertainty about CEO ability decreases relatively quickly, there is still quite a lot of uncertainty until the median length of the CEO's tenure ($\tau = 7$, as in Table 1).

[39]The difference in productivity of the 2th and 75th percentile CEOs can be computed as $\approx \exp(2 \times \sigma_0) = \exp(2 \times 0.542) \approx 3$.

Figure 6. The relation between CEO pay and SOP vote outcomes
This figure displays the relation between the level of CEO pay (log CEO pay) and the outcome of the SOP vote. In both panels, I display a binned scatterplot estimated from a regression of log CEO pay on SOP disapproval, expressed as the vote outcome's distance from the failure threshold. Each regression includes CEO and CEO tenure fixed effects. Panel A is estimated using the real data; For Panel B, I simulate a dataset from the model using the parameters presented in Table 6.



5.2. Model Estimation Validation

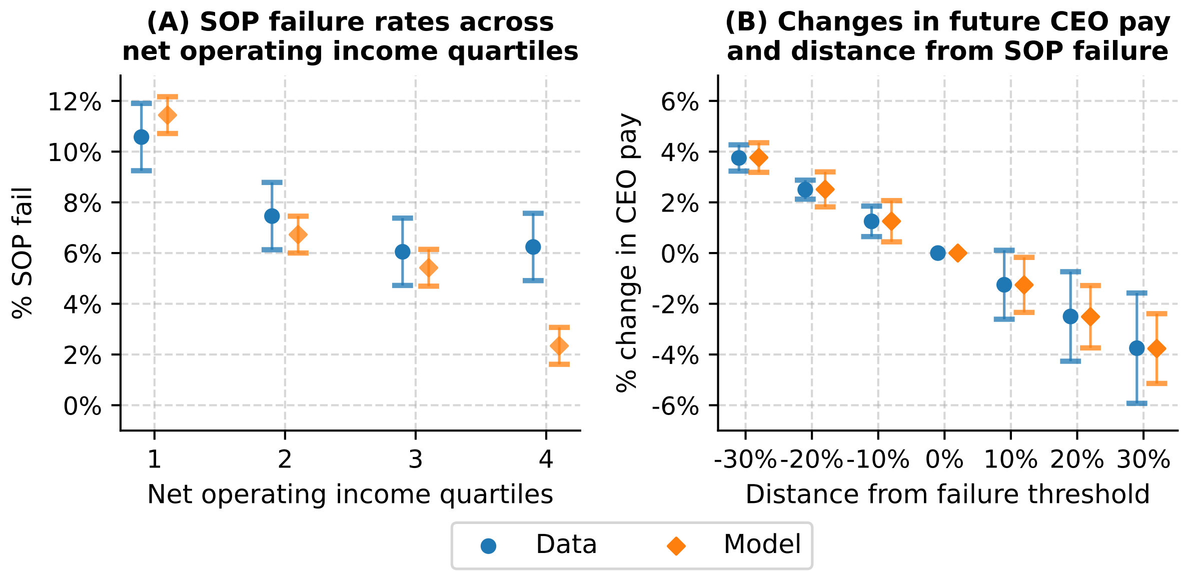
5.2.1. Untargeted Moments

The relation between CEO pay and SOP vote outcomes. How well can the model match the correlation between CEO pay levels and SOP votes? I test this in Figure 6. I simulate data using the parameters in Table 6. For the real and simulated data, I estimate a regression of current log CEO pay on the outcome of the SOP vote, which is expressed in distance from the failure threshold (see equations 26 and 27). I include CEO and CEO tenure fixed effects. The figure shows a striking similarity in the slope relation between CEO pay and the SOP vote outcome, though the relationship is understandably tighter in the model than the data.

SOP failure across the distribution of operating income. I compare observed SOP failure rates in the simulated and real data along the distribution of net operating income. Importantly, the model targets the unconditional SOP failure rate and how the productivity shock affects SOP results, not how SOP results vary across the operating income distribution. Figure 7 Panel A displays observed SOP failure rates by quartiles of net operating income.[40] As can be seen the observed model and data SOP failure rates in the first three quartiles of op-

[40]Net operating income is industry-adjusted revenue less the CEO's wage.

Figure 7. SOP failures by firm performance and changes in CEO pay after SOP disapproval
This figure displays two model and estimation validation exercises. I simulate a dataset from the model using the parameters presented in Table 6. Panel A displays observed SOP failure rates across different quartiles of net operating income (industry-adjusted revenue less CEO compensation). Panel B displays estimated changes in CEO compensation in response to how far the previous year's SOP was from the SOP failure threshold. That is, I estimate the regression % Change in Compensation$_{i,c,t,t+1} = \alpha + \beta$Distance from SOP failure$_{i,c,t}$ for firm i, CEO c and year t, and display the predicted change in compensation for different SOP vote outcomes. For both the model and data, I normalize the change in compensation to be 0% at vote failure.



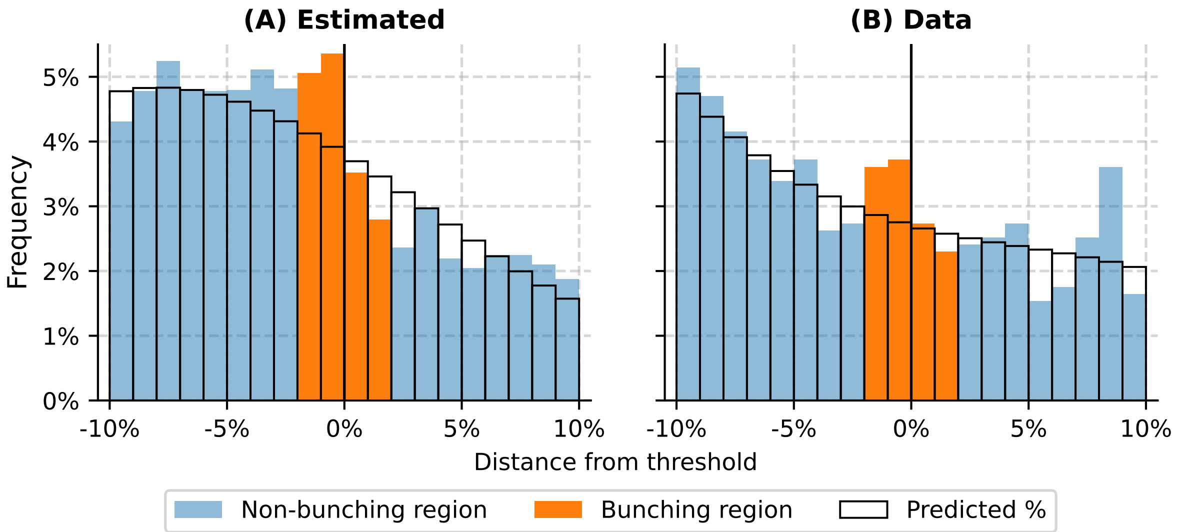
erating income line up very closely. However, the model cannot match the observed failure rate in the top quartile of operating income (2.1% in the model *vs.* 6.1% in the data).[41]

Changes in CEO pay after SOP disapproval. Figure 7 Panel B displays how the model and data compare in terms of *changes* in CEO compensation in response to difference SOP disapproval rates. That is, what is the correlation between the SOP disapproval rate (relative to the failure threshold) and the change in CEO compensation from t to $t + 1$. The panel shows that the slope of this relationship is very similar in the model and data. How does this work? In the model, the Board are dis-incentivized from lowering CEO wages because of the adjustment cost. However, when SOP votes go badly, this means that the shareholders have received a negative signal about CEO ability, either via the productivity shock or their own signal. Hence, high SOP disapproval implies a very *negative* signal about CEO ability. When

[41] The reason for the higher failure rate in the data in the top quartile of operating income is that CEOs in the top quartile simply receive higher compensation, both in terms of current compensation (salary and bonus) and long-term compensation (stock options); these are the CEOs at the most productive firms and thus they demand higher pay. Shareholders react to the level of CEO pay (see Table 2 Panel A), which can help explain why the model cannot match this moment exactly.

Figure 8. Bunching of SOP Vote Outcomes in Simulated and Real Data

This figure displays bunching of SOP vote outcomes close to the failure threshold in the simulated dataset and real dataset. Bunching is as described in (28), and represents the proportion of mass shifted from directly above the vote failure threshold to directly below, relative to the counterfactual distribution. Panel A displays bunching in the simulated data, Panel B displays bunching in the real data. Bunching in Panel A is estimated on the simulated variable Δ^{model} as defined in (27); bunching in Panel B is estimated on the real variable Δ^{data} as defined in (26). To estimate, in both figures, I focus in on votes occurring within 15 percentage points of vote failure. I focus on 0.5% bins and I set the region around the threshold $\mathcal{E} = \{b \text{ s.t. } x_b \in [-2\%, 2\%]\}$, where x_b is the bin mid-point. To create the counterfactual distribution, I estimate the observed bin counts as a function of a third-order polynomial of the bin midpoints for observation $\notin \mathcal{E}$, and predict bin-counts using this regression. In both panels, 0% and above means SOP vote failure, whereas to the left of zero means that the vote passed.



the disapproval rate in the model is high, the Board realizes that the CEO is likely not a high type, so they pay the adjustment cost and lower wages.

Visual evidence of similarity in model and data bunching. A key moment in the estimation is (28), which captures how much bunching there is below SOP failure thresholds. Figure 8 displays the outcomes from this estimation. This is an exact visual counterpart to (28), and visually produces moment 12 from Table 6 Panel B. As can be seen, there is clear evidence of shifting-of-mass from directly above the SOP failure threshold to directly below. That the model can so closely match this moment lends credence to the real existence of shareholder cost to SOP failure.

5.2.2. Is the Shareholder Cost to SOP Failure Necessary?

A key innovation of this paper is presenting evidence of shareholder cost to SOP failure and estimating the precise magnitude of this cost. Despite the survey evidence from Edmans et al.

(2021) and the observed bunching in SOP votes below thresholds (Fact 3), direct evidence of this cost comes entirely from the structural model. Identification of parameters in my setting is largely heuristic — the possibility remains that a better minimum exists where the shareholder cost is zero or negligible.

I can use the model to allay this concern by estimating a version of it in which I remove the shareholder cost to SOP failure. If the model struggles to approach the key moments in the data *without* this parameter, then I have evidence that, at least, the model requires a positive shareholder cost to SOP failure in order to match moments in this setting.

Table A.2 displays the results of the estimation procedure. I estimate the model in Section 3 with $\chi_S = 0$, using the same moments and estimation procedure as the main estimation. Panel A displays the parameters; Panel A displays the estimated moments. As can be seen, this version of the model is rejected by the data. Average wages are too low and in particular, the SOP failure rate (moment 9) is too low — 7% in the data *vs.* 4.6% in the estimation. The estimation further fails to match the bunching estimator (moment 13). Overall, the model is soundly rejected by the data.

With no shareholder cost, shareholders are willing to fail the SOP in any state. Hence, to match the low failure rate, the model must push the degree of board capture down towards zero. With $\lambda = 0.092$, this implies a difference in the biased and unbiased wages of only \$108 thousand (the difference in the main estimation is \$657 thousand). The Board SOP failure cost χ_B shoots up to 7.15% of firm value (relative to 2.06% in the main estimation). Even with these unbelievable magnitudes, the model cannot match the moments in the data well.

6. Counterfactual Analysis

In this section, I present three counterfactual scenarios. In the first, I present a differently structured version of the model that replicates giving a focal shareholder a non-voting, advisory seat on the compensation committee, a governance mechanism often put forth to align the the beliefs (and actions) of management and shareholders. In the second and third, I study the role of the Board and Shareholder costs to SOP failure. Setting the Board cost χ_B to zero, while holding other parameters constant, allows me to uncover how much SOP disciplines wages, and reveal the true impact of non-binding advisory SOP votes on compensation policy. Setting the Shareholder cost χ_S to zero uncovers how the shareholders' perceived cost to SOP failure limits SOP's impact on wages.

6.1. Giving a Focal Shareholder an Advisory Seat on the Board

The degree of board capture I estimate implies there is a conflict of interesting regarding CEO pay between Boards and shareholders. While SOP helps to mitigate this distortion, my model and estimates imply that SOP votes are determined as much by *differences in beliefs* about the CEO as by this conflict of interest.

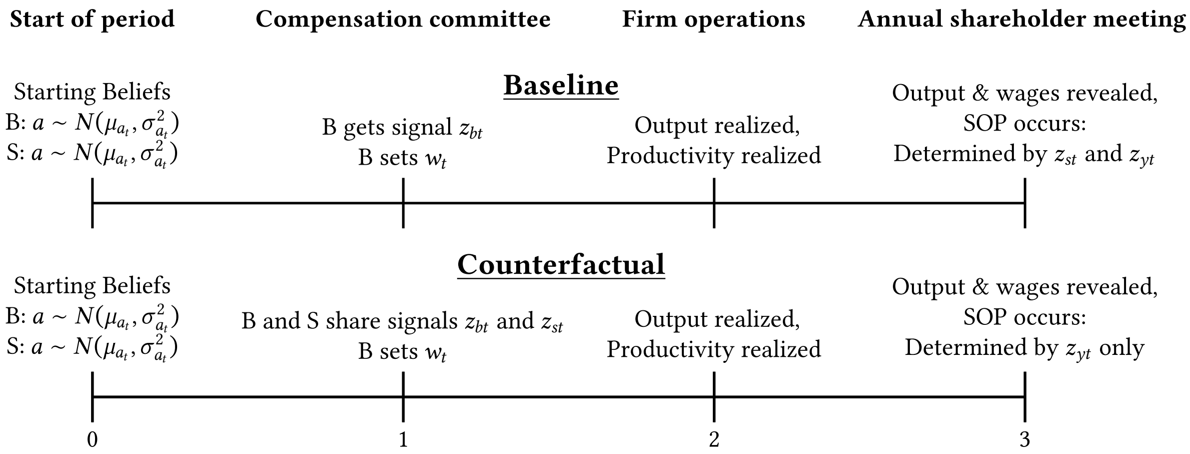
In the corporate governance literature, giving a focal shareholder a non-voting advisory board seat is often seen as a way to align the beliefs of management and investors (Kakhbod et al., 2023), and hence coordinate corporate actions. For example, activists often take board seats (Bebchuk et al., 2020) and venture capitalists will often take on a "board observer" role, where they attend meetings and share their views, but hold no rights. Giving a focal shareholder an advisory board position engenders alignment of beliefs. I can use my estimates to empirically assess how a focal shareholder joining the compensation committee affects SOP as a wage-disciplining mechanism. Beyond SOP, this counterfactual provides insight into whether aligning management and shareholder beliefs coordinates preferences for a key corporate policy (CEO pay) and improves firm value.

In the baseline model, the Board and Shareholder strategies are determined by their private beliefs, as shown in the top timeline in Figure 9. The baseline inherently implies *disagreement*, as B and S signals remain private until the end of the period. In the counterfactual, B and S share their signals in advance of the vote — disagreement becomes *cooperation*. By the bottom timeline in Figure 9, sharing of private signals means the SOP vote is solely a vote on performance *vs.* pay (only the productivity signal influences the vote outcome), private disagreement between B and S about the CEO does not influence the vote.

A key thing to note is that I do not change any underlying parameters. The structure of my model means that this counterfactual is equivalent to simply changing when the Board and Shareholder reveal their private signals.

Figure 9. Sharing of beliefs: Counterfactual model timeline

This figure displays the within-period model timeline of the counterfactual where shareholders have a non-voting position on the compensation committee. The top timeline ("Baseline") displays the timeline from the main version of the model (re-printed from Figure 3), the bottom timeline ("Counterfactual") displays the counterfactual timeline.



It must be mentioned that this counterfactual is not without its flaws. For example, investors state that they prefer not to vote against in SOPs because of the monitoring cost associated with SOP failure (repeated meetings with the compensation committee to discuss future compensation policy, Edmans et al., 2021). Sitting on the compensation committee would likely imply a larger cost.

6.1.1. The Compensation Committee

Like in Section 3.4, each period t the Board meets and receives their signal z_{bt} about CEO ability. However, now the focal Shareholder S shares their signal z_{st} with B. Suppose beliefs at the beginning of t are $a \sim N(\mu_{at}, \sigma^2_{at})$. Let $\mathbf{z}_t = \begin{pmatrix} z_{bt} & z_{st} \end{pmatrix}$, so the shared beliefs upon meeting at the compensation committee are

$$\mu_{at|\mathbf{z}_t} = \sigma^2_{at|\mathbf{z}_t} \left[\frac{\mu_{at}}{\sigma^2_{at}} + \frac{z_{bt}}{\sigma^2_{z_b}} + \frac{z_{st}}{\sigma^2_{z_s}} \right]$$
$$\sigma^2_{at|\mathbf{z}_t} = \left[\sigma^{-2}_{at} + \sigma^{-2}_{z_b} + \sigma^{-2}_{z_s} \right]^{-1} \tag{29}$$

Two aspects separate this from the compensation committee meeting in the main model. First, beliefs are more precise, incorporating S' signal lowers the variance. Second, the change in the mean will be driven by the average of B and S' signals, weighted by their precisions. Thus, in cases when B and S receive divergent signals of CEO ability, this will not reflect in higher disagreement about CEO ability, rather the new mean will settle in the middle.

Now, the Board's wage decision is a function of both z_{bt} and z_{st}, so the wage choice is a function of $\mathbf{z}_t$. S uses the same strategy as before, but the outcome of the vote is determined entirely by the productivity signal z_{yt}. The Board's dynamic problem is very similar to (18), yet their beliefs are as in (29).[42]

Because B and S share their signals, S no longer needs to integrate out B's signal. Hence, they choose s_t to maximize

$$\max_{s_t} \quad E_{at|\mathbf{z}_t}\left[A_t\right] w_t(\mathbf{z}_t, s_t)^{\alpha} - w_t(\mathbf{z}_t, s_t) - \chi_S F^{\mathrm{U}}_{at}\left(s_t \times w_t(\mathbf{z}_t, s_t)\right) \tag{30}$$

The information sharing removes the possibility of private disagreement between B and S — the operator $E_{a_t|\mathbf{z}_t}\left[\cdot\right]$ implies that B and S have the same beliefs when they set their strategies. The outcome of the vote is solely a function of the relative size of the CEO's wage and the firm's productivity.

Two positive effects occur. First, there is a *cooperation effect*. By sharing their beliefs, B and S "meet in the middle," removing the possibility of disagreement over the CEO's skill. Second, there is a *precision effect*, as beliefs mechanically become more precise for both parties. The cooperation effect helps to align compensation policy — B and S arrive at a midpoint in cases when B and S would have very different beliefs after seeing their signals; it also means that Shareholders can be more directed in when they threaten SOP failure (as they can set a different failure threshold for each realization of the Board's signal). The precision effect means that the Board's wage choice converges faster to wage appropriate for the CEO's true type, and further removes some uncertainty from the outcome of the SOP vote.

I solve this version of the model using the same parameters as in Section 5. The counterfactual admits the same outcomes as the main model, so I can compare observed quantities. Table 7 displays the results. I display the counterfactual SOP failure rate, along with the aver-

[42]Formally, the Board's Bellman equation is

$$V(\mu_{at}, \tau, w_{t-1}) = \max\nolimits_{w_t} E_{at|\mathbf{z}_t}\left[A_t\right] w_t^{\alpha} - (1-\lambda) w_t - \chi_B F^{\mathrm{U}}_{at}\left(s_t \times w_t\right) - AC\left(w_t, w_{t-1}; \tau\right) \; + \delta_B\Big[(1-f_\tau) E_{at|\mathbf{z}_t}\left[V(\mu_{at+1}, \tau+1, w_t)\right] + f_\tau V^R\Big]$$

The only difference to (18) is that the expectations operator follows from (29), as opposed to (17).

age percentage change in the CEO wage and firm value (see eq. 20 for the model's definition of firm value). I further display the distribution (quartiles) of the percentage changes.

The SOP failure rate falls from 6.7% in the main estimation to 5% in the counterfactual. While the change is small, this means that shareholders face their perceived cost less often.

Wages also fall on average however this is not a given. In fact, in cases when the Board and Shareholder both receive good signals about the CEO, wages rise (at the 75th percentile, the increase in wages is 5%). Yet, on average they fall because type of agency in my model. The Board's bias leads to sub-optimal (from the shareholders' perspective) over-production via empire-building. When the Board learns that the Shareholder thinks the CEO is low-type (S gets a bad private signal), this has a relatively stronger effect on decreasing the wage than when the Shareholder thinks the CEO is high-type. This occurs via the curvature of the production function. As such, the 25th percentile change in wages (10.8% decrease) is much larger in magnitude than the 75th (5% increase).

Firm value increases on average by 4.9%. Even at the lower end of the distribution, firm value increases considerably (at the 25th percentile, the increase is 3.7%). This is because wages fall on average, so in most cases operating income is brought closer to its profit-maximizing level. However, because of the precision effect, Board beliefs converge faster to the CEO's true ability, avoiding situations when a bad (good) CEO is overpaid (underpaid) early on in their tenure, leading to another source of increase in firm value.

6.2. The Impact of Board and Shareholder SOP Failure Costs

6.2.1. How much does SOP impact CEO pay?

6.2.2. The Impact of the Shareholder SOP Failure Cost

What if the shareholder cost χ_S did not exist? In other words, if SOP were a truly *costless* governance mechanism, what would be the effect on SOP failure rates, CEO pay and firm value? A caveat applies — removing this shareholder cost represents a *significant* change to the underlying preferences of shareholders. The counterfactual exercise of changing χ_S while holding other parameters at their estimated values may push the model beyond its limits. Further, to the extent that lowering wages would cause CEOs to reject the firm and take the outside option (on which the model makes no statements), there may unintended negative value effects from this counterfactual.

Table 8 Panel B displays the results. When $\chi_S = 0$, the *ex ante* probability of SOP failure would increase from 6.88% to 55%. The reason the failure rate does not go beyond this Figure 4; shareholders do not want to decrease the wage to below the unbiased wage, hence there is a uniquely-defined probability of failure that shareholders want.

CEO wages would fall by 4.7% on average, and the 25th percentile is a fall of 8.6%. Firm value value increases, but marginally. By enforcing a much higher degree of SOP failure, there are states when shareholders over-discipline the Board. That is, while wages being kept low for bad CEOs is good, it may often be the case that the Board's signal means the CEO is talented and should be paid more.

7. Conclusion

This paper establishes if and how shareholders can influence real corporate policies via non-binding, advisory shareholder votes through the lens of the impact of Say-on-Pay (SOP) votes on executive compensation policies.

First, I document several key facts about the relationship between CEO compensation and SOP vote outcomes. In particular, SOP disapproval is associated with negative outcomes for compensation-committee directors; and shareholders internalize a cost from failing SOP (Edmans et al., 2021).

Second, I write down a model of executive compensation with non-binding SOP votes to explain these observed facts and fit it to several data moments arising from the establishing empirical analysis. The model is able to match these moments closely, and is further validated by similarity in several untargeted moments.

Third, the estimated model reveals the degree of CEO-board capture, the Board's overpayment bias is equivalent to 4.83% of CEO-created firm value. This bias captures CEO influence on the pay-setting process as well as the CEO's ability to capture a large share of rents. It also reveals the magnitude of the internalized costs by the Board and shareholders. The Board internalizes a cost to SOP failure that maps to 0.623% of CEO-created firm value; the cost for shareholders is 1.399%.

Lastly, I can use my estimates to construct a counterfactual governance mechanism which gives Shareholders a non-binding advisory position on the Board of directors. The mechanism, which works bia the Board and shareholders sharing their private beliefs about CEO ability leads to a lower SOP failure rate (thus leading to Shareholders having to face SOP failure costs less often), as well as lowering wages and ultimately increasing the value of the firm (at least, the CEO's contribution to firm value). However, while this counterfactual analysis is valuable, it takes on several strong assumptions. For example, it assumes that Shareholders face no effort cost from taking a non-advisory position on the Board. In survey data, shareholders say directly that a reason SOP failure rates are low is precisely because they wish to avoid the monitoring cost of having input into compensation policy. Future research could take these costs more seriously and construct better mechanisms which allow shareholders to influence corporate policies, in particular compensation.

Summing up, this paper stresses that non-binding advisory votes do impact real policies, while simultaneously revealing deep parameters about shareholders' preferences in these votes. I am silent, however, on many important aspects. For example, the model merely presents the magnitude of the shareholder cost from SOP failure, it cannot say anything about the true source of this cost.

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Table 1. Summary statistics

This table displays descriptive statistics of the variables used in the empirical analysis and estimating the model. The sample is based upon a merge of Compustat, Execucomp and ISS for the years 2011-2020. I present statistics for the firm, SOP outcomes and the CEO. There are a total of 2,528 CEO spells in the dataset. I limit to CEO spells of greater than one year and at most 25 years.

	N	Mean	Std Dev	25%	50%	75%
Firm						
Assets ($b)	10,001	22.717	128.168	0.879	2.858	9.416
Revenues ($b)	10,001	7.703	21.147	0.596	1.749	5.612
Return on assets (%)	10,001	0.124	0.094	0.070	0.119	0.172
12-month stock return (%)	10,001	0.132	0.323	-0.056	0.113	0.293
Say-on-Pay						
% voting against in SOP	10,001	0.090	0.121	0.023	0.044	0.092
$\mathbb{1}$ [Less than 20% support]	10,001	0.129				
$\mathbb{1}$ [Less than 30% support]	10,001	0.068				
$\mathbb{1}$ [Less than 50% support]	10,001	0.018				
CEO						
Salary ($m)	10,001	0.855	0.383	0.600	0.808	1
Bonus ($m)	10,001	0.138	0.640	0	0	0
CEO tenure (years)	10,001	6.502	5.144	2	5	10
Length of CEO tenure (years)	2,528	8.311	5.449	4	7	12

Table 2. SOP results, CEO pay and company performance

This table explores the relation between SOP outcomes and CEO compensation, in support of Fact 0. Panel A estimates the relation between SOP outcomes and the level of CEO pay. The dependent variable in columns 1-4 is an indicator for SOP failure (at least 30% of shareholders voting against the SOP), and in columns 5-8 it is the percentage of shareholders that vote against. Log CEO compensation is the natural logarithm of the CEO's total current pay (salary and bonus). Panel B estimates the relation between changes in CEO compensation (from t to $t+1$) and SOP results (from t). The dependent variable is the log change in CEO compensation from t to $t+1$. SOP fail is an indicator if a SOP vote fails, i.e. the % voting against is above 30%. % vote no in SOP is the proportion of shareholders voting to fail the SOP. All covariates are defined in the appendix. Stock return and Return on assets are standardized to mean zero, unit variance. Standard errors are displayed below coefficients and clustered at the firm × CEO level. ***, **, * denote significance at 1%, 5%, 10%.

Panel A. SOP outcomes and the level of CEO wages

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	SOP fail {0, 1}				% vote no in SOP			
Log CEO compensation	0.015***	0.014***	0.019***	0.032***	0.007***	0.007***	0.010***	0.015***
	(0.004)	(0.003)	(0.006)	(0.011)	(0.002)	(0.002)	(0.003)	(0.005)
Stock return		-0.013***	-0.011***	-0.004		-0.010***	-0.009***	-0.007***
		(0.003)	(0.003)	(0.004)		(0.001)	(0.001)	(0.002)
Return on assets		-0.021***	-0.022***	-0.020**		-0.016***	-0.017***	-0.014***
		(0.006)	(0.007)	(0.008)		(0.003)	(0.003)	(0.004)
Log firm assets		0.039***	0.041***	0.030*		0.018***	0.018***	0.009
		(0.013)	(0.014)	(0.018)		(0.006)	(0.006)	(0.008)
Lagged log CEO compensation				-0.014*				-0.005
				(0.008)				(0.004)
Observations	9,841	9,841	9,556	6,736	9,841	9,841	9,556	6,736
R-squared	0.313	0.322	0.378	0.386	0.392	0.410	0.468	0.487
Firm FE	Yes	Yes			Yes	Yes		
Year FE		Yes	Yes	Yes		Yes	Yes	Yes
CEO tenure FE		Yes	Yes	Yes		Yes	Yes	Yes
Firm × CEO FE			Yes	Yes			Yes	Yes

Table 2. Continued
Panel B. Changes in CEO wages and SOP outcomes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Log change in CEO compensation							
SOP fail {0, 1}	-0.037***	-0.032***	-0.027**	-0.031**				
	(0.012)	(0.012)	(0.011)	(0.014)				
% vote no in SOP					-0.016***	-0.014***	-0.012***	-0.013***
					(0.003)	(0.003)	(0.003)	(0.004)
Stock return		0.006**	0.005*	0.005		0.005*	0.004	0.004
		(0.003)	(0.003)	(0.003)		(0.003)	(0.003)	(0.003)
Return on assets		-0.003	-0.007	-0.006		-0.004	-0.008	-0.007
		(0.005)	(0.005)	(0.005)		(0.005)	(0.005)	(0.005)
Log firm assets		-0.020**	-0.024**	-0.015		-0.020*	-0.024**	-0.015
		(0.010)	(0.011)	(0.012)		(0.010)	(0.011)	(0.012)
Lagged log CEO compensation				-0.039***				-0.039***
				(0.007)				(0.007)
Observations	7,134	7,134	6,845	4,903	7,134	7,134	6,845	4,903
R-squared	0.176	0.193	0.224	0.226	0.179	0.195	0.226	0.228
Firm FE	Yes	Yes			Yes	Yes		
Year FE		Yes	Yes	Yes		Yes	Yes	Yes
CEO tenure FE		Yes	Yes	Yes		Yes	Yes	Yes
Firm × CEO FE			Yes	Yes			Yes	Yes

Table 3. Board capture and CEO compensation

This table displays how board co-option (Coles et al., 2014), an important empirical measure of *board capture* influences the level of CEO pay and modulates the effect of SOP results on changes in CEO compensation, in support of Fact 1. Panel A presents correlations between the level of CEO pay and the degree of board co-option. Panel B presents similar analysis to Table 2, with an interaction between board co-option and our two measures of SOP disapproval: an indicator for SOP failure (30% or greater vote against in the SOP), and the percent of votes against in the SOP. All covariates are standardized to mean zero, unit variance. Standard errors are displayed below coefficients and clustered at the firm × CEO level. ***, **, * denote significance at 1%, 5%, 10%.

Panel A. Board capture and the level of CEO pay

	(1)	(2)	(3)	(4)
	Log CEO compensation			
Board co-option	0.081***	0.096***	0.095***	0.070***
	(0.029)	(0.024)	(0.024)	(0.023)
Return on assets		0.213***	0.213***	0.135***
		(0.023)	(0.023)	(0.024)
Stock return		0.020*	0.020*	0.036***
		(0.012)	(0.012)	(0.013)
Log firm assets		0.568***	0.577***	0.644***
		(0.023)	(0.030)	(0.033)
Log board size			-0.013	0.018
			(0.024)	(0.023)
Observations	8,865	8,865	8,865	8,865
R-squared	0.023	0.277	0.277	0.333
CEO tenure FE	Yes	Yes	Yes	Yes
Year FE				Yes
Industry FE				Yes

Table 3. Continued

Panel B. Board capture modulates the effect of SOP disapproval on changes in CEO pay

	(1)	(2)	(3)	(4)	(5)	(6)
	Log change in CEO compensation					
Board co-option	0.014	0.010	0.006	0.015	0.016	0.012
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
SOP fail $\{0, 1\}$	-0.245***	-0.257***	-0.248***			
	(0.035)	(0.037)	(0.038)			
Board co-option × SOP fail $\{0, 1\}$		0.067*	0.063*			
		(0.037)	(0.037)			
% vote no in SOP				-0.078***	-0.081***	-0.079***
				(0.009)	(0.009)	(0.010)
Board co-option × % vote no in SOP					0.019**	0.019**
					(0.009)	(0.009)
Return on assets			-0.037***			-0.041***
			(0.008)			(0.008)
Stock return			0.056***			0.052***
			(0.009)			(0.009)
Log firm assets			-0.013			-0.007
			(0.013)			(0.013)
Log board size			0.002			-0.000
			(0.007)			(0.007)
Observations	6,388	6,388	6,388	6,388	6,388	6,388
R-squared	0.020	0.021	0.034	0.026	0.027	0.039
CEO tenure FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE			Yes			Yes
Industry FE			Yes			Yes

Table 4. Evidence of costs to directors from Say-on-Pay disapproval

This table displays correlations between costly outcomes for directors and SOP disapproval rates. I focus on directors that serve on the compensation committee during the year of an SOP vote. In Panel A, director turnover occurs when a director is no longer on the Board the year after an SOP vote, conditional on the next year not being the year the director's term ends. In Panel B, Compensation committee turnover occurs when a director is no longer on the compensation committee the year after an SOP vote, conditional on the director remaining as a member of the Board. In Panel C, a reduction in outside Board positions occurs when the number of outside Boards the director sits on decreases in the year after an SOP vote, conditional on the director sitting on at least one outside Board and the director remaining on their current Board the next year (i.e., it is an indicator variable). SOP fail is an indicator if a SOP vote fails, i.e. the % voting against is above 30%. % vote no in SOP is the proportion of shareholders voting to fail the SOP. All covariates are defined in the appendix; all continuous covariates are standardized to mean zero, unit variance. Standard errors are displayed below coefficients and clustered at the director level. ***, **, * denote significance at 1%, 5%, 10%.

Panel A. Director turnover

	(1)	(2)	(3)	(4)	(5)	(6)
	Director turnover {0, 1}					
SOP fail {0, 1}	2.303***	1.755***	1.512***			
	(0.537)	(0.504)	(0.513)			
% vote no in SOP				0.823***	0.673***	0.584***
				(0.176)	(0.168)	(0.173)
Stock return		-0.404**	-0.381**		-0.385**	-0.363**
		(0.174)	(0.173)		(0.174)	(0.174)
Return on assets		-1.460***	-1.625***		-1.443***	-1.603***
		(0.179)	(0.181)		(0.179)	(0.182)
Log firm assets		-0.354**	-1.032***		-0.386**	-1.033***
		(0.179)	(0.202)		(0.179)	(0.201)
Log board size			0.332**			0.342**
			(0.160)			(0.160)
Log director tenure			1.363***			1.364***
			(0.159)			(0.159)
Log director age			2.394***			2.391***
			(0.184)			(0.184)
Log CEO tenure			-1.199***			-1.204***
			(0.163)			(0.163)
Log CEO pay			0.567***			0.521***
			(0.150)			(0.151)
Constant	10.128***			10.418***		
	(0.173)			(0.162)		
Observations	33,213	33,213	33,213	33,213	33,213	33,213
R-squared	0.001	0.174	0.186	0.001	0.174	0.186
Year FE		Yes	Yes		Yes	Yes
Industry FE		Yes	Yes		Yes	Yes

Table 4. Continued

Panel B. Compensation committee turnover, conditional on remaining on Board

	(1)	(2)	(3)	(4)	(5)	(6)
	Compensation committee turnover {0, 1}					
SOP fail {0, 1}	1.462***	1.126**	1.227***			
	(0.449)	(0.452)	(0.459)			
% vote no in SOP				0.640***	0.519***	0.572***
				(0.156)	(0.157)	(0.161)
Stock return		-0.481***	-0.470***		-0.460***	-0.445***
		(0.141)	(0.141)		(0.141)	(0.141)
Return on assets		-0.514***	-0.545***		-0.495***	-0.515***
		(0.148)	(0.152)		(0.148)	(0.152)
Log firm assets		0.097	-0.112		0.071	-0.107
		(0.153)	(0.192)		(0.153)	(0.192)
Log board size			0.326**			0.336**
			(0.140)			(0.140)
Log director tenure			0.193			0.195
			(0.145)			(0.145)
Log director age			-0.234			-0.240
			(0.152)			(0.152)
Log CEO tenure			-0.795***			-0.805***
			(0.140)			(0.140)
Log CEO pay			0.091			0.032
			(0.156)			(0.158)
Constant	5.460***			5.646***		
	(0.144)			(0.137)		
Observations	29,752	29,752	29,752	29,752	29,752	29,752
R-squared	0.000	0.008	0.009	0.001	0.008	0.010
Year FE		Yes	Yes		Yes	Yes
Industry FE		Yes	Yes		Yes	Yes

Table 4. Continued

Panel C. Reduction in outside Board positions, conditional on remaining on Board

	(1)	(2)	(3)	(4)	(5)	(6)
	Reduction in outside board positions {0, 1}					
SOP fail {0, 1}	1.933**	1.879**	1.722**			
	(0.854)	(0.861)	(0.860)			
% vote no in SOP				0.488*	0.463*	0.398
				(0.262)	(0.265)	(0.266)
Log director tenure			-0.187			-0.192
			(0.274)			(0.274)
Log director age			1.935***			1.937***
			(0.290)			(0.290)
Log board size			0.203			0.200
			(0.257)			(0.257)
Outside firm average ROA			-0.126			-0.130
			(0.264)			(0.265)
Constant	9.486***			9.704***		
	(0.293)			(0.282)		
Observations	13,469	13,469	13,469	13,469	13,469	13,469
R-squared	0.000	0.002	0.006	0.000	0.002	0.006
Year FE		Yes	Yes		Yes	Yes
Industry FE		Yes	Yes		Yes	Yes

Table 5. CEO turnover and Say-on-Pay disapproval

This table analyzes how CEO turnover changes with SOP disapproval. In all specifications, the dependent variable is a CEO turnover indicator in the year following a SOP vote. In columns 1-4, the main independent variable is an indicator for SOP failure, in columns 5-8 it is the percentage of shareholders who vote against the CEO's compensation in the SOP. All controls variables are from the year of the SOP. In columns 5 and 8, I include 5th polynomials of the firm's stock return and return on assets to control for possibly non-linear effects of performance on CEO turnover. Standard errors are displayed below coefficients and clustered at the firm× CEO level. ***, **, * denote significance at 1%, 5%, 10%.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	CEO turnover $t+1$ {0, 1}							
SOP fail {0, 1}	3.169***	3.161***	2.458**	2.327**				
	(1.201)	(1.212)	(1.176)	(1.184)				
% vote no in SOP					1.142***	1.081***	0.806**	0.749*
					(0.377)	(0.382)	(0.383)	(0.386)
Log ceo compensation		-2.550***	-3.279***	29.524		-2.597***	-3.315***	29.119
		(0.629)	(0.684)	(24.560)		(0.631)	(0.689)	(24.553)
Stock return		-1.728***	-1.482***	-1.215		-1.695***	-1.459***	-1.200
		(0.349)	(0.353)	(1.183)		(0.349)	(0.353)	(1.181)
Return on assets		-1.197**	-1.654***	-0.277		-1.150**	-1.618***	-0.242
		(0.505)	(0.557)	(2.622)		(0.506)	(0.558)	(2.620)
Log firm assets		1.034***	1.136	1.168		1.059***	1.131	1.170
		(0.311)	(1.226)	(1.299)		(0.312)	(1.227)	(1.300)
Constant	9.435***				9.752***			
	(0.114)				(0.006)			
Observations	12,378	12,378	12,378	12,378	12,378	12,378	12,378	12,378
R-squared	0.123	0.131	0.214	0.216	0.123	0.131	0.214	0.216
Firm FE			Yes	Yes			Yes	Yes
CEO tenure FE			Yes	Yes			Yes	Yes
Year FE			Yes	Yes			Yes	Yes
Performance Polynomials				Yes				Yes

Table 6. Structural estimation results

This table contains outcomes of the estimation procedure. Panel A displays model and data moments, as well as the difference between each moment. In Panel A, I perform a t-test of the difference in each model and data moment; t-statistics are displayed in the last column. In the last row of the table, I display the result of the χ^2 test of overidentifying restrictions. Panel B displays estimates of the parameters that drive the model in Section 3. As explained in Section 4, μ_0 is normalized to 0, hence this parameter is not estimated. Parameters are estimated using SMM, which is described in detail in Appendix D. The panel also displays the magnitudes of the Board and Shareholder costs to SOP failure as a percentage of the model's average firm value. I compute average firm value in closed form as a function of model parameters, and use the delta method to calculate standard errors (see Appendix D.6 for a derivation).

Panel A. Data and model moments

	Description	**Notation**	**Data**	**Model**	**t-stat**
(1)	Average log output	y_0	7.540	7.540	0.001
(2)	CEO-average output variance	$Var\left(E_i\left[\tilde{y}\right]\right)$	0.880	0.829	1.000
(3)	Elasticity of output to wage	y_1	0.832	0.797	0.620
(4)	Output residual variance	$Var\left(\epsilon^y\right)$	1.278	1.260	0.235
(5)	Average log wage when SOP passes	b_0	−0.140	−0.137	−0.972
(6)	Change in log wage when SOP fails	b_1	0.042	0.055	−0.838
(7)	Log wage persistence	b_2	0.794	0.873	−6.466
(8)	Wage residual variance	$Var\left(\epsilon^b\right)$	0.059	0.077	−5.683
(9)	SOP failure rate	s_0	0.070	0.067	0.674
(10)	SOP failure—wage sensitivity	s_1	0.061	0.038	1.826
(11)	SOP failure—output residual sensitivity	s_2	−0.019	−0.034	2.456
(12)	SOP failure residual variance	$Var\left(\epsilon^s\right)$	0.064	0.063	0.164
(13)	Bunching estimator	$\mathbb{B}$	0.121	0.116	3.909
		χ^2 (p-val)	65.296 (0.000)		

Panel B. Parameter estimates

Description	**Notation**	**Value**
Parameters		
CEO board capture	λ	0.612 (0.010)
Board SOP failure cost	χ_B	0.240 (0.008)
Shareholder SOP failure cost	χ_S	0.088 (0.025)
Prior average of CEO ability	μ_0	0
Prior std dev of CEO ability	σ_0	0.542 (0.010)
Output—CEO wage elasticity	α	0.263 (0.010)
Std dev of productivity shock	σ_y	1.043 (0.014)
Std dev of Board signal	σ_{z_b}	1.996 (0.078)
Std dev of shareholder signal	σ_{z_s}	0.697 (0.016)
Scaling factor	$\log\eta$	7.572 (0.025)
CEO wage adjustment cost	c_w	5.201 (0.522)
SOP failure costs		
Board SOP cost (% average value)	$\frac{\chi_B}{V_0}$	2.06% (0.10%)
Shareholder SOP cost (% average value)	$\frac{\chi_S}{V_0}$	0.76% (0.23%)

Table 7. Counterfactual exercise: Giving the focal Shareholder an advisory Board position
This table displays a counterfactual experiment where I re-solve a different version of the model, in which the Board and shareholders are allowed to share their signals before the compensation contract is decided (i.e., the shareholder is given a non-voting, advisory seat on the Board). The first row displays the counterfactual SOP failure rate. Rows 2 and 3 display the counterfactual percentage change in wages and firm value. To compute these changes, I re-solve the counterfactual model, applying the same sequence of shocks to each firm. I solve for optimal choices, and solve for the percentage change in each quantity at the observation level. I then display the average percentage change, along with the 25th, 50th and 75th percentiles.

	Mean	**25%**	**50%**	**75%**
SOP failure rate	4.97%			
Percent change in				
Wages	-2.05%	-10.84%	-2.51%	+5.01%
Firm value	+4.87%	+3.68%	+4.19%	+5.07%

Table 8. Counterfactual analysis: Eliminating the Board and Shareholder cost to SOP failure
This table displays two counterfactuals related to changing the Board and Shareholder costs to SOP failure. Following Section XX, in Panel A I display the counterfactual in which I change χ_B to 0; this tells me the impact of SOP on CEO wages. Following Section XX, in Panel B I display the counterfactual in which I change χ_S to 0. In both panels, the first row displays the counterfactual SOP failure rate. Rows 2 and 3 display the counterfactual percentage change in wages and firm value. To compute these changes, I re-solve the counterfactual model, applying the same sequence of shocks to each firm. I solve for optimal choices, and solve for the percentage change in each quantity at the observation level. I then display the average percentage change, along with the 25th, 50th and 75th percentiles.

Panel A. No Board cost ($\chi_B = 0$)

	Mean	**25%**	**50%**	**75%**
SOP failure rate	—			
Percent change in				
Wages	-2.36%	-8.40%	0.00%	+2.80%
Firm value	+4.31%	+2.81%	+4.37%	+6.10%

Panel B. No Shareholder cost ($\chi_S = 0$)

	Mean	**25%**	**50%**	**75%**
SOP failure rate	55.25%			
Percent change in				
Wages	-4.74%	-8.64%	-2.97%	0.00%
Firm value	+0.47%	+0.18%	+0.22%	+0.53%

A. Appendix Figures and Tables

Figure A.1. Example of monitoring costs arising from SOP failure — 2021 Netflix SOP
This figure presents anecdotal evidence of monitoring costs incurred by shareholders when the SOP fails. The 2021 Netflix SOP saw 49.4% of shares voting against the SOP. Under the 30% failure rule, this presents a clear SOP failure. Netflix directors then repeatedly engaged with large stockholders in the following year over the compensation policy. See Netflix (2022).

Stockholder Engagement and the 2021 Say-on-Pay Vote Result

In 2021, 50.6% of voted shares approved the compensation of our Named Executive Officers. At the time of the vote in 2021, the Compensation Committee had already approved the design of our 2021 executive compensation program. The Compensation Committee reviewed these voting results, and in response, members of the Compensation Committee and management engaged with stockholders to solicit feedback regarding our compensation program.

Figure A.2. Board capture, CEO pay and SOP results: Illustration of Table 3 (Fact 1)

This figure illustrates the results of Table 3. Panel A displays a binned scatterplot of the log of CEO compensation on board co-option (as in Coles et al., 2014). Panel B illustrates the effect of SOP disapproval on changes in CEO compensation for varying levels of board co-option. It uses column 6 of Panel B to estimate the relation between changes in CEO pay and the percentage of shareholders voting against the SOP at different levels of board co-option — going from zero to full board co-option, the regression predicts that the effect of a one standard deviation increase in SOP disapproval on the log change in CEO pay increases from -0.12 to -0.05 log points.

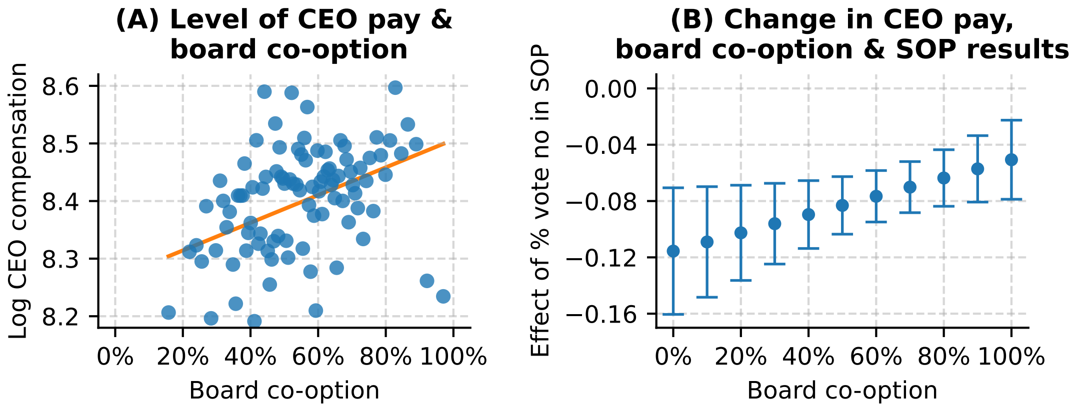

Figure A.3. Placebo test of density manipulation of SOP outcomes (robustness for Figure 2)
This figure displays the results of placebo testing testing for density manipulation of SOP disapproval at placebo thresholds. Whereas in Figure 2, I focus on the publicly accepted important vote failure thresholds of 30% and 50%, in this figure I shift the thresholds to 20% and 40% as a placebo test for density manipulation.

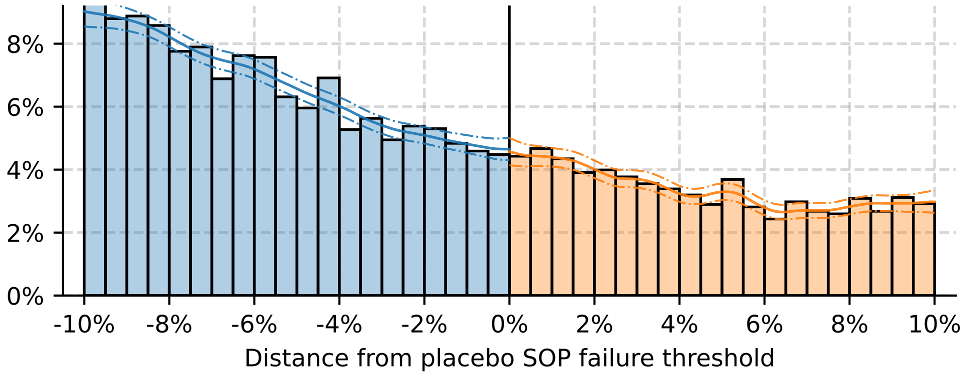

Figure A.4. Correlation between SOP % vote against and firm performance (Fact 0)

This figure displays correlations between SOP disapproval rates and measures of firm performance. Both panels display binned scatterplots. Panel A displays results from a regression of SOP disapproval (% vote against in SOP) on the firm's return on assets (ROA). Panel B displays results from a similar regression, where the independent variable is the firm's 12-month stock return. In both panels, I include year and industry fixed effects, and control for log CEO compensation and CEO tenure.

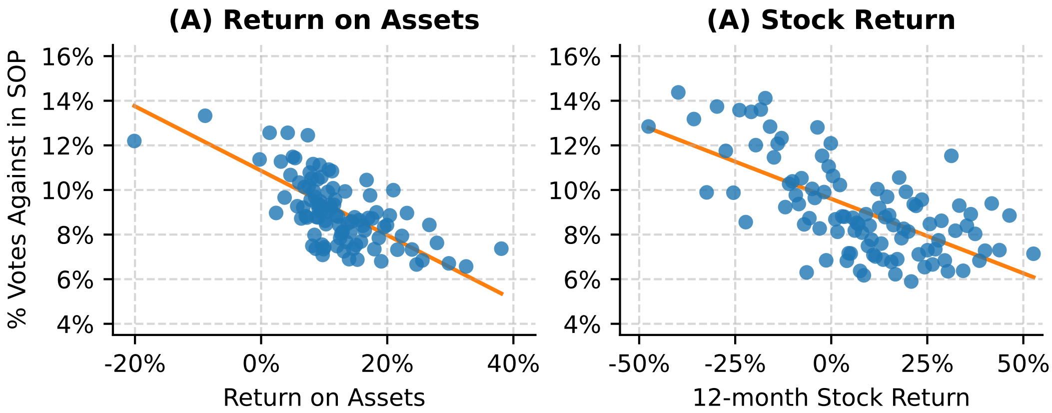

Figure A.5. Histogram of year-on-year changes in CEO compensation

This figure displays histograms of changes in CEO dollar compensation. Panel A displays total compensation (salary+bonus), Panel B displays just salary and Panel C displays bonus. The figure shows that CEO compensation rarely decreases. This reflects the structure of long-term contracts for CEOs, and motivates the inclusion of a one-sided convex adjustment cost on wages in the Board's problem.

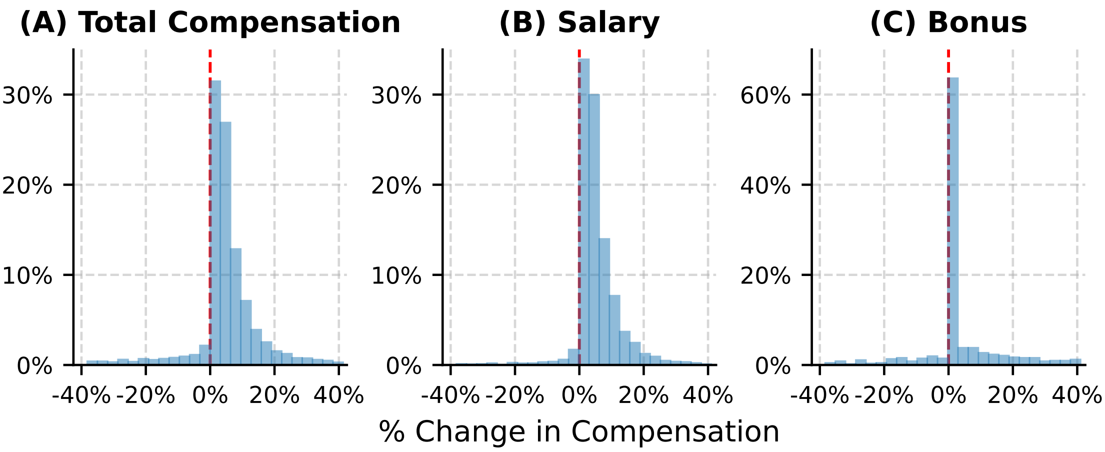

Figure A.6. Model timeline with exact time that strategies are played

This figure displays a more detailed model timeline, with mappings to the relevant assumptions, and when the Board and Shareholder play their strategies. See Figure 3 in the main text for the timeline as it maps to real-world outcomes.

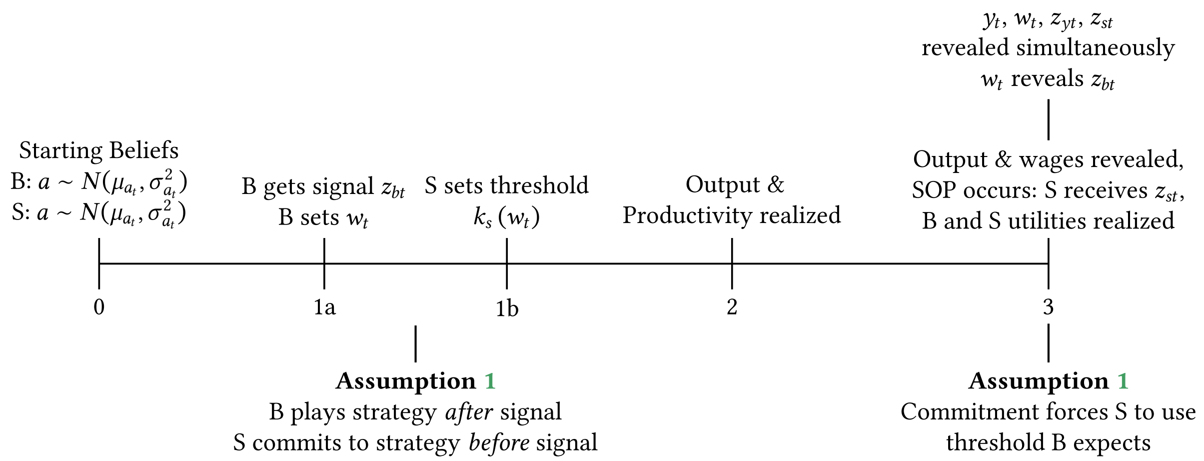

Figure A.7. Bunching estimator in the data

This figure displays the result of the reduced-form bunching estimator on the estimation sample. See (28). I set $M = 5$, the bunching region $\mathcal{E}$ to be within 1% of vote failure, and the bin width to be 0.5%. In the figure, the degree of bunching, $\mathbb{B} = 0.152$. The black bars are the predicted bin counts, i.e. the counterfactual distribution. The orange bars and blue bars display observed counts. $\mathbb{B}$ is estimated on the orange bars.

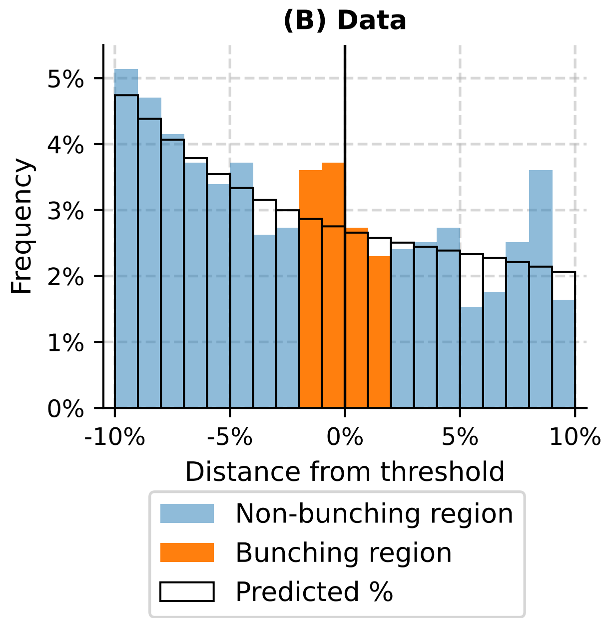

Figure A.8. Rate of decline of the variance of beliefs about CEO ability

This figure displays the rate of decline of the variance Board and shareholder beliefs about CEO ability as a function of CEO tenure τ. The figure uses the parameter estimates from Table 6. Volatility $\sigma_a(\tau)$ is defined in (C.1)

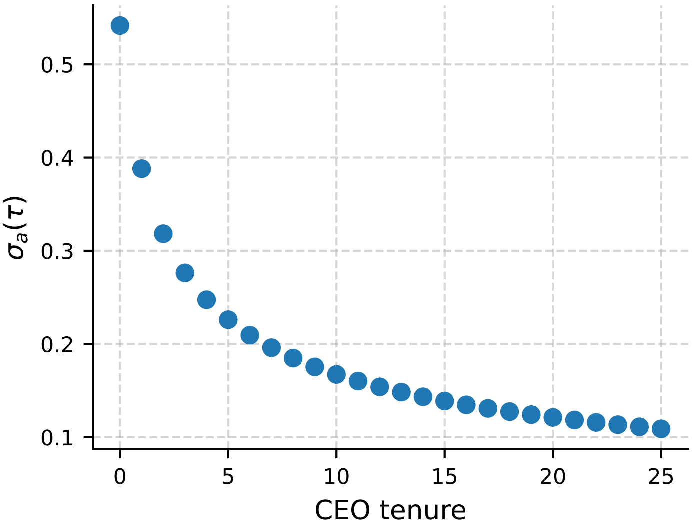

Table A.1. SOP outcomes and firm performance

This table displays regressions of SOP vote outcomes (failure and the percentage of shareholders voting against the SOP) on measures of firm performance: the firm's accounting return (return on assets), and the firm's market return (12-month stock return in between SOP votes), in support of Fact 0 and Figure A.4. All covariates are defined in the appendix; all continuous covariates are standardized to mean zero, unit variance. Standard errors are displayed below coefficients and clustered at the director level. ***, **, * denote significance at 1%, 5%, 10%.

	(1)	(2)	(3)	(4)	(5)	(6)
	SOP fail {0, 1}			% vote no in SOP		
Return on assets	-0.027***		-0.024***	-0.020***		-0.018***
	(0.007)		(0.007)	(0.003)		(0.003)
Stock return		-0.016***	-0.014***		-0.012***	-0.011***
		(0.003)	(0.003)		(0.001)	(0.001)
Log firm assets	0.061***			0.030***		
	(0.023)			(0.011)		
Log CEO compensation		0.053***	0.055***		0.027***	0.028***
		(0.009)	(0.010)		(0.005)	(0.006)
Observations	9,864	9,864	9,864	9,864	9,864	9,864
R-squared	0.330	0.329	0.331	0.417	0.417	0.422
CEO tenure FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes

Table A.2. Structural estimation results: No shareholder cost

This table contains outcomes of estimation where I remove the shareholder cost to SOP failure as an estimated parameter. Panel A displays model and data moments, as well as the difference between each moment. t-statistics are displayed in the last column. In the last row of the panel, I display the result of the χ^2 test of overidentifying restrictions. Panel B displays estimates of the nine remaining parameters. Parameters are estimated using SMM, which is described in detail in Appendix D.

Panel A. Data and model moments

	Description	Notation	Data	Model	t-stat
(1)	Average log output	y_0	7.540	7.539	0.053
(2)	CEO-average output variance	$Var\left(E_i\left[\tilde{y}\right]\right)$	0.880	0.895	−0.416
(3)	Elasticity of output to wage	y_1	0.832	0.847	−0.270
(4)	Output residual variance	$Var\left(\epsilon^y\right)$	1.278	1.308	−0.551
(5)	Average log wage when SOP passes	b_0	−0.140	−0.149	2.967
(6)	Change in log wage when SOP fails	b_1	0.042	0.057	−1.017
(7)	Log wage persistence	b_2	0.794	0.916	−9.328
(8)	Wage residual variance	$Var\left(\epsilon^b\right)$	0.059	0.074	−1.687
(9)	SOP failure rate	s_0	0.070	0.046	3.352
(10)	SOP failure—wage sensitivity	s_1	0.061	0.062	−0.051
(11)	SOP failure—output residual sensitivity	s_2	−0.019	−0.020	0.090
(12)	SOP failure residual variance	$Var\left(\epsilon^s\right)$	0.064	0.052	2.375
(13)	Bunching estimator	$\mathbb{B}$	0.121	0.051	54.149
		χ^2 (p-val)	218.344 (0.000)		

Panel B. Parameter estimates

Description	Notation	Value
Parameters		
CEO board capture	λ	0.092 (0.001)
Board SOP failure cost	χ_B	0.697 (0.042)
Shareholder SOP failure cost	χ_S	—
Prior average of CEO ability	μ_0	0
Prior std dev of CEO ability	σ_0	0.423 (0.022)
Output—CEO wage elasticity	α	0.521 (0.001)
Std dev of productivity shock	σ_y	1.087 (0.033)
Std dev of Board signal	σ_{z_b}	2.430 (0.095)
Std dev of shareholder signal	σ_{z_s}	0.561 (0.016)
Scaling factor	$\log\eta$	7.612 (0.025)
CEO wage adjustment cost	c_w	3.180 (0.379)
SOP failure costs		
Board SOP cost (% average value)	$\frac{\chi_B}{V_0}$	7.15% (0.12%)
Shareholder SOP cost (% average value)	$\frac{\chi_S}{V_0}$	—

Table A.3. Parameter estimates and model fit for subsample splits

This table displays the parameter estimates with standard errors and model fit for each subsample split presented in Table ??. For brevity, I omit descriptions of parameters and moments from the table.

Panel A.1. Low co-option

Parameters		Moments			
Notation	**Value**	**Notation**	**Data**	**Model**	***t*-stat**
λ	0.569 (0.014)	y_0	0.191	0.254	−1.521
χ_B	0.111 (0.019)	y_1	1.260	1.212	0.605
χ_S	0.257 (0.048)	b_0	−0.151	−0.148	−0.644
σ_{z_b}	2.808 (0.040)	b_1	0.036	0.043	−0.253
σ_{z_s}	2.034 (0.068)	b_2	0.864	0.816	**2.677**
σ_y	1.015 (0.018)	s_0	0.054	0.062	−1.387
μ_0	0.151 (0.011)	s_1	0.052	0.050	0.122
σ_0	0.782 (0.011)	s_2	−0.011	−0.047	**3.534**
α	0.305 (0.016)	$Var\left(E_i\left[\tilde{y}\right]\right)$	1.163	1.168	−0.167
c_w	0.643 (0.030)	$Var\left(\epsilon^y\right)$	1.488	1.518	−0.740
		$Var\left(\epsilon^b\right)$	0.050	0.047	0.425
		$Var\left(\epsilon^s\right)$	0.059	0.039	**3.863**
		$\mathbb{B}$	0.071	0.071	0.102

Panel A.2. High co-option

Parameters		Moments			
Notation	**Value**	**Notation**	**Data**	**Model**	***t*-stat**
λ	0.694 (0.015)	y_0	0.119	0.193	**−2.213**
χ_B	0.160 (0.028)	y_1	1.226	1.151	1.096
χ_S	0.339 (0.029)	b_0	−0.144	−0.158	**2.557**
σ_{z_b}	2.947 (0.063)	b_1	0.041	0.068	−1.140
σ_{z_s}	2.584 (0.111)	b_2	0.810	0.761	**2.064**
σ_y	1.095 (0.016)	s_0	0.077	0.069	0.903
μ_0	0.114 (0.009)	s_1	0.090	0.072	0.884
σ_0	0.775 (0.017)	s_2	−0.022	−0.046	1.748
α	0.229 (0.012)	$Var\left(E_i\left[\tilde{y}\right]\right)$	1.192	1.162	1.100
c_w	3.839 (0.077)	$Var\left(\epsilon^y\right)$	1.589	1.693	**−2.925**
		$Var\left(\epsilon^b\right)$	0.071	0.051	**3.234**
		$Var\left(\epsilon^s\right)$	0.074	0.043	**4.504**
		$\mathbb{B}$	0.202	0.202	0.050

B. Institutional Details of Say-on-Pay

The 2010 Dodd-Frank Wall Street Reform and Consumer Protection Act, commonly referred to as Dodd-Frank, made SOP compulsory at all US firms from 2011.[1] In the US, SOP is a non-binding vote that must occur at least once every three years on the level and structure of executive compensation. Though SOPs are required only every 3 years, in practice nearly all S&P1500 firms, the main sample, hold the SOP every year; I will commonly refer to SOP being “annual" in the paper, and the model time will be annual. While the vote itself is non-binding, in spirit a low level of shareholder approval for the SOP is likely to lead to tangible changes in the CEO’s compensation contract the next year (see Section 2.2 and, e.g., Balsam et al., 2016).

By rule, the SOP vote must cover all executive compensation disclosed pursuant to Item 402 of Regulation S-K. This includes the Compensation Discussion and Analysis (CD&A) section of the proxy statement, which is designed to put into perspective the level of executive pay, its structure (e.g., cash *vs.* stock options) and provide a clear narrative of *why* executives received such pay (Dalton and Dalton, 2008).

A key aspect of SOPs are that they are *backward-looking* and *reactive*. From Novick (2019), “Say-on-pay votes ask shareholders to opine retrospectively on the compensation of named executives that is disclosed in the proxy statement, rather than on the company’s compensation program going forward." SOPs in the US are clearly a non-binding confidence vote in the Board’s choice of CEO wage for the previous fiscal year, and not a vote in Shareholders’ confidence about the next year’s compensation contract. This backward-looking aspect will inform the timing of the model. In particular, the practice of the compensation committee setting the wage before and shareholders voting on the wage will play a key role in how the model structures the strategies of the Board and Shareholders.

What constitutes SOP failure? By nature in the US, they are non-binding votes, so there is no threshold at which the compensation committee must make a tangible change. Nevertheless there are three important thresholds for the vote. The most important is 70% support. If support falls below this, Institutional Shareholder Services (ISS) will publicly push the compensation committee and firm more generally to make changes to compensation policy and

[1]Technically, firms with revenue less than $1billion did not have to implement SOP until 2013.

engage with shareholders (ISS, 2022). Further, 80% (the threshold at which Glass-Lewis will pursue the Board) and 50% (the classic simple majority) also represent important thresholds.

Upon SOP failure, the firm's compensation committee will often reach out to the firm's large stockholders with a proposed change to the firm's compensation policy in future years, or simply to discuss how these large shareholders feel about the firm's compensation policy. For example, Figure A.1 displays an example of SOP failure, where the Netflix Board reach out to large shareholders to discuss compensation policy. The model is silent on the repeated nature of this interaction. In the model, there is no retrospective action if SOP fails, rather the Board and shareholders pay the utility cost from failure, and the model moves to the next period. I am not interested in perfectly modeling the game between the Board and shareholders, I merely look to put sensible structure on the data to be able to identify the key parameters driving incentives in this setting.

C. Model Appendix

C.1. Microfoundation of Representative Shareholder Assumption

Proposition C.1. *The expected proportion of shareholders voting against the SOP is informationally equivalent to*

$$F_a^U(k_s(w))$$

where F_a^U is the CDF of the distribution of the random variable which determines the outcome of the SOP vote and $k_s(w) = s \times w$, where w is the CEO's wage and s is the shareholder's choice variable.

Proof. In the model, there is a continuum of N_S shareholders, whom each draw a signal z_{si} that is private knowledge, but correlated across shareholders,

$$z_{si} = \bar{z} + \varepsilon_{si}, \quad \varepsilon_{si} \sim N\left(0, \sigma_{si}^2\right).$$

z_i is conditionally normal and independent across shareholders given the common, latent signal $\bar{z}$, distributed according to

$$\bar{z} = a + \varepsilon_{\bar{z}}, \quad \varepsilon_{\bar{z}} \sim N\left(0, \sigma_{\bar{z}}^2\right).$$

The standard voting model with incomplete information assumes that signals are completely private, i.e $z_{it} = a + \varepsilon_{zit}$. With proxy voting, signals are more likely to be correlated. For example, $\bar{z}$ could reflect proxy advisors' recommendations. Note, however, that $\bar{z}$ is not a public signal. Rather, each shareholder shares the same belief about $\bar{z}$. So, it is as if shareholders each receive the proxy advisor's signal with some "noise," which could reflect, e.g. idiosyncratic trust in the proxy advisor across shareholders.

Shareholders play a symmetric cutoff strategy, voting against the proposal if and only if they draw a signal below their cutoff value

$$\text{SOP fail}_i = 1 \iff z_i \leq k_s^i(w).$$

Note — I have abstracted away from the effect of the output shock on the vote, and adjudging failure using log-normals. Given that the output shock is common knowledge, it will affect all shareholers voting in the same way, so does not impact the proof; the conversion to lognormal is a technical assumption that again affects all shareholders equivalently.

Given $\bar{z}$, the probability that a single shareholder votes against is

$$\Pr\left(\text{SOP fail}_i \mid \bar{z}\right) = \Phi\left(\frac{k_s^i(w) - \bar{z}}{\sigma_{si}}\right)$$

and the probability I observe N out of N_S shareholders voting against is

$$Pr\left(N \mid \bar{z}\right) = C_N^{N_S}\left[\Phi\left(\frac{k_s^i(w) - \bar{z}}{\sigma_{si}}\right)\right]^N \left[1 - \Phi\left(\frac{k_s^i(w) - \bar{z}}{\sigma_{si}}\right)\right]^{N_S - N}.$$

Fixing the unknown type a, I can find the probability of observing N out of N_S against votes,

$$Pr\left(N \mid a\right) = \int f(\bar{z} \mid a) Pr(N \mid \bar{z})\, d\bar{z}.$$

Let p be the proportion of shareholders voting against: $p = N/N_S$. Since p is Binomial, as $N_S \to \infty$, the distribution of p becomes increasingly peaked around its mean. Since its mean is the probability any individual shareholder votes against the proposal, the likelihood of observing p vanishes in the limit when $Pr(SOP_i = 1 \mid \bar{z})$ is anything other than p. Given that $\bar{z}$ completely determines $Pr(SOP_i = 1 \mid \bar{z})$, there is a bijection between $\bar{z}$ and p

$$\bar{z}(p) = k_s\left(w\right) - \sigma_{si}\Phi^{-1}(p)$$

Using this peakedness, the limit of the density of observing p as $N_S \to \infty$ is

$$f(p) = \int f(a) f(\bar{z}(p) \mid a) \bar{z}'(p)\, da$$

The likelihood of observing p is driven by the likelihood of observing $\bar{z}(p)$, scaled by a change-of-variable term $\bar{z}^{'}(p)$. Since $\bar{z}$ is conditionally normal around the type a, I integrate over all types a and then take the likelihood of observing $\bar{z}(p)$ given the type a. I am more interested in $f(a \mid p)$ — the density of a conditional on observing p,

$$\lim_{N_S \to \infty} f(a \mid p) = \frac{\lim_{N_S \to \infty} f(a) f(p \mid a)}{\int \lim_{N_S \to \infty} f(a) f(p \mid a)\, da}.$$

The intuition is that the posterior likelihood of a is proportional to two components: the prior $f(a)$; and the likelihood that the latent signal $\bar{z}$, given a, is equal to $\bar{z}(p)$, which in the limit is the only $\bar{z}$ for which I would see p. This is a scaled product of Gaussians, so the posterior is also normal,

$$a \mid p \sim N(\mu_{ap}, \sigma_{ap}^2),$$

where

$$\mu_{ap} = \frac{\sigma_{\bar{z}}^2}{\sigma_a^2 + \sigma_{\bar{z}}^2} \mu_a + \frac{\sigma_a^2}{\sigma_a^2 + \sigma_{\bar{z}}^2} \bar{z}(p), \qquad \sigma_{ap}^2 = \frac{\sigma_a^2 \sigma_{\bar{z}}^2}{\sigma_a^2 + \sigma_{\bar{z}}^2}.$$

Thus, observing p is informationally equivalent to observing a signal $z_s = \bar{z}(p) = k_s(w) - \sigma_z \Phi^{-1}(p)$, where $z_s = a + \varepsilon_s$, and $\varepsilon_s \sim N(0, \sigma_{z_s}^2)$.

The proof arises because of the assumptions about the correlated signal and the continuum of shareholders. All shareholders play a symmetric cutoff strategy; in the limit, the exact proportion of shareholders that receive a signal below the cutoff *must* be equivalent to the probability that an informationally equivalent aggregate signal falls below the cutoff. Another way to think about this is to consider a representative shareholder that interacts with the Board, and aggregates the votes or signals of the shareholder base at the shareholder meeting.

■

C.2. Evolution of Board and Shareholder Beliefs

I first detail two Propositions, which define how beliefs update in the model. Then I define exactly how Board and shareholder beliefs change within each period.

C.2.1. Evolution of Beliefs Period to Period

Prop. C.2 shows how beliefs change from t to $t+1$. Prop. C.3 describes the distribution of next period beliefs given today's beliefs, which is used when the Board calculates their (expected) continuation value.

Proposition C.2. *From period t to $t+1$, the variance of beliefs for both the Board and shareholders declines deterministically according to*

$$\sigma_a^2(\tau+1) = \left[\sigma_a^{-2}(\tau) + \sigma_{z_b}^{-2} + \sigma_{z_s}^{-2} + \sigma_y^{-2}\right]^{-1} \tag{C.1}$$

where τ is the tenure of the CEO at year t. Equivalently, I can write the variance of beliefs about CEO ability entirely as a function of CEO tenure τ and model parameters

$$\sigma_a^2(\tau) = \sigma_0^2\left[1 + \tau\left(\kappa_{z_b}^{-1} + \kappa_{z_s}^{-1} + \kappa_y^{-1}\right)\right]^{-1} \tag{C.2}$$

where $\kappa_{z_b} = \sigma_{z_b}^2/\sigma_0^2$, $\kappa_{z_s} = \sigma_{z_s}^2/\sigma_0^2$ and $\kappa_y = \sigma_y^2/\sigma_0^2$

Similarly, from period t to $t+1$, the mean of beliefs for both the Board and shareholders evolves according to

$$\mu_{at+1} = \sigma_a^2(\tau+1)\left[\frac{\mu_{at}}{\sigma_a^2(\tau)} + \frac{z_{bt}}{\sigma_{z_b}^2} + \frac{z_{st}}{\sigma_{z_s}^2} + \frac{z_{yt}}{\sigma_y^2}\right] \tag{C.3}$$

Proof. The updating formulas are standard results in Bayesian learning (e.g., Pastor and Veronesi, 2009; Taylor, 2010).[2] The Board and shareholder reveal their signals each period. Thus, Board and shareholders share the same beliefs about the variance from period to period. ∎

[2]See also the internet appendix for Taylor (2010).

Proposition C.3. *The mean and variance of the mean of $t+1$ CEO beliefs at t are*

$$\begin{aligned} E_t\left[\mu_{at+1}\right] &= \mu_{at} \\ Var_t\left[\mu_{at+1}\right] &= \sigma_a^2(\tau) - \sigma_a^2(\tau+1) \end{aligned} \tag{C.4}$$

That is,

$$\mu_{at+1} \mid \mu_{at}, \tau \sim N\left(\mu_{at}, \sigma_a^2(\tau) - \sigma_a^2(\tau+1)\right)$$

Proof. I drop time subscripts for convenience, and use $\cdot'$ to denote next period. Via Prop. C.2, the mean evolves as

$$\mu_{a\prime} = \sigma_{a\prime}^2\left[\frac{\mu_a}{\sigma_a^2} + \frac{z_b}{\sigma_{z_b}^2} + \frac{z_s}{\sigma_{z_s}^2} + \frac{z_y}{\sigma_y^2}\right]$$

where $z_y = \ln A = a + \varepsilon_y$ is the productivity signal. Let $p' = \sigma_{a'}^{-2}$, i.e the next period precision of beliefs. Let p_a, p_b, p_s, p_y be precisions $\sigma_a^{-2}, \sigma_{z_b}^{-2}, \sigma_{z_s}^{-2}, \sigma_y^{-2}$ respectively. Then define $\rho_{X\in\{a,b,s,y\}}$ be each precision divided by p', e.g. $\rho_a = \frac{p_a}{p'}$. I can write,

$$E\left[\mu_{a'} \mid \mu_a\right] = \left(\rho_a + \rho_b + \rho_s + \rho_y\right)\mu_a = \mu_a$$

which of course must hold because beliefs are a martingale. I can write $Var\left(\mu_{a'} \mid \mu_a\right)$ as

$$\begin{aligned} Var\left(\mu_{a'} \mid \mu_a\right) &= E\left[\left(\rho_a\mu_a + \rho_b z_b + \rho_s z_s + \rho_y z_y - E[\mu_{a'} \mid \mu_a]\right)^2 \mid \mu_a\right] \\ &= E\left[\left(\rho_a(\mu_a - \mu_a) + \rho_b\left(z_b - \mu_a\right) + \rho_s\left(z_s - \mu_a\right) + \rho_y\left(z_y - \mu_a\right)\right)^2 \mid \mu_a\right] \\ &= E\left[\left(\rho_b\left(z_b - \mu_a\right) + \rho_s\left(z_s - \mu_a\right) + \rho_y\left(z_y - \mu_a\right)\right)^2 \mid \mu_a\right] \end{aligned}$$

Note that $E\left[(z_b - \mu_a)^2 \mid \mu_a\right] = \sigma_a^2 + \sigma_{z_b}^2$, which similarly holds for subscript s and y. Hence, I can write $Var\left(\mu_{a'} \mid \mu_a\right)$ as

$$Var\left(\mu_{a'} \mid \mu_a\right) = \sigma_a^2\left(\rho_b + \rho_s + \rho_y\right)^2 + \rho_b^2\sigma_{z_b}^2 + \rho_s\sigma_{z_s}^2 + \rho_y\sigma_y^2$$

Note that $\rho_b^2\sigma_{z_b}^2 = \frac{\rho_b}{p'}$, similarly for s and y, and $1 = \rho_a + \rho_b + \rho_s + \rho_y$, so I can again write

$$Var(\mu_{a'} \mid \mu_a) = \sigma_a^2(1-\rho_a)^2 + \frac{1-\rho_a}{p'}$$

Lastly, I note that $\sigma_a^2(1-\rho_a) = \sigma_a^2 - \frac{\sigma_a^2\rho_a}{p'} = \sigma_a^2 - \sigma_{a'}^2$, and

$$\begin{aligned} Var(\mu_{a'} \mid \mu_a) &= (\sigma_a^2 - \sigma_{a'}^2)(1-\rho_a) + \sigma_{a'}^2(1-\rho_a) \\ &= \sigma_a^2(1-\rho_a) \\ &= \sigma_a^2 - \sigma_{a'}^2 \end{aligned}$$

and I am done. Equivalently, I can write this as $\frac{p'-p}{p'p}$. Further, this expression of the conditional variance of the mean can be used for pair of normal prior + posterior beliefs. This quantity is useful when taking expectation of next period's continuation value ■

C.2.2. Differences in Board and Shareholder Beliefs Within Period

This subsection explains exactly how Board and shareholder beliefs evolve within each period. As the wage and vote perfectly reveal signals z_b and z_s, the Board and shareholders share the same beliefs at the beginning of any period. Let τ_t be the tenure of the CEO at time t. By Prop. C.2, I have that $\sigma_{bt}^2 = \sigma_{st}^2 = \sigma_a^2(\tau)$ from (C.2). At the beginning of the period, let μ_{at} be the beliefs about the mean at the beginning of period t. So, I can describe Board and shareholder beliefs as $\left(\mu_{at}, \sigma_a^2(\tau_t)\right)$ at the beginning of period t.

1. **Board beliefs after the compensation committee meeting**

   At the meeting, the Board receives signal z_{bt}, and Board beliefs update to

$$\mu_{bt|z_b} = \sigma_{bt|z_b}^2\left(\frac{\mu_{at}}{\sigma_a^2(\tau_t)} + \frac{z_{bt}}{\sigma_{z_b}^2}\right) \tag{C.5}$$

$$\sigma_{bt|z_b}^2 = \frac{\sigma_a^2(\tau_t)\sigma_{z_b}^2}{\sigma_a^2(\tau_t) + \sigma_{z_b}^2} = \sigma_0^2\left[1 + (\tau_t+1)\kappa_{z_b}^{-1} + \tau_t(\kappa_{z_s}^{-1} + \kappa_y^{-1})\right]^{-1} \tag{C.6}$$

   I use $\mu_{bt|z_b}$ and $\sigma_{bt|z_b}$ to follow conventions in the main text. The Board makes their wage decision based upon these beliefs. Before the wage is revealed, shareholders still maintain beliefs $\left(\mu_{at}, \sigma_a^2(\tau_t)\right)$.

2. **Shareholder beliefs when they commit to signal threshold k_{st}**

   When Board and shareholders play the wage-SOP game, their beliefs differ, in that the Board believes $\left(\mu_{bt|z_b}, \sigma_{bt|z_b}\right)$ and shareholders believe $\left(\mu_{at}, \sigma_a^2(\tau_t)\right)$. But shareholders can discern $\left(\mu_{bt|z_b}, \sigma_{bt|z_b}\right)$ for any z_{bt}, which they factor in when choosing their threshold. Shareholders thus factor in what $\mu_{bt|z_b}$ will be when calculating expected wages in their objective function in (16).

3. **Board and shareholder beliefs about shareholders' *ex ante* signal distribution at the time of the SOP vote**

   Before the SOP vote, when the shareholders commit to their threshold, both B and S know that the shareholders' aggregated signal will be

$$\tilde{z}_{st} = a + p\varepsilon_{st} + (1-p)\varepsilon_{yt} \tag{C.7}$$

   with $\tilde{z}_{st} \sim N\left(\mu_{at}, \sigma_{at}^2 + \frac{\sigma_{z_s}^2 \sigma_y^2}{\sigma_{z_s}^2 + \sigma_y^2}\right)$.[3] Notice that shareholder beliefs about *a do not update* to $N\left(\mu_{bt|z_b}, \sigma_{bt|z_b}\right)$. This is because the timing convention in the model states that the wage w_t (and equivalently z_{bt}), productivity z_{yt} and the signal z_{st} are all revealed concurrently. At the exact time that z_{bt} and Z_{syt} are revealed, the Board and Shareholders may disagree about CEO skill. This timing convention is key for determining SOP outcomes.

4. **Board and shareholder beliefs after the annual shareholder meeting and release of 10-K**

   The 10-K and compensation committee report reveals the wage to shareholders, hence reveals z_{bt}. Shareholders vote at the annual meeting and Z_{syt} and thus z_{st} are revealed. Hence, B and S beliefs update to $\left(\mu_{at+1}, \sigma_a^2(\tau_t+1)\right)$, by Prop. C.2.

[3]The variance of the signal is $Var(a + p\varepsilon_{st} + (1-p)\varepsilon_y) = \sigma_a^2 + p^2\sigma_{st}^2 + (1-p)^2\sigma_y^2$, where $p = \frac{\sigma_{z_s}^{-2}}{\sigma_{z_s}^{-2}+\sigma_y^{-2}}$. Expanding this expression out leads to the expression for the variance.

C.3. Assumptions about Shareholder strategy

See Section 3.3 for the full discussion of the Shareholder's strategy. A primary goal of this paper is to model how the threat of SOP failure influences the Board's wage decision. I model this threat as an *ex ante* probability that the SOP will fail, which is increasing in the wage. In this spirit, the first assumption specifies precisely when shareholders commit to this threat.

Assumption 1. *Shareholders commit to their voting strategy in advance of the annual shareholder meeting.*

S must set their probability of failure *before* they receive their private signal or see wages and productivity. This threat of vote failure influences the Board's wage decision. The threat of vote failure does not need to be revealed to the Board before the annual shareholder meeting, however commitment forces S to play the threshold strategies that the Board expects. Unlike Kakhbod et al. (2023), there is no notion of cheap talk here. Commitment means S cannot choose an *ex ante* optimal non-zero failure probability and then renege at the shareholder meeting once the Board sets their wage.[4]

Assumption 2. *Shareholders seek to optimize operating income, given their beliefs about CEO ability.*

This assumption is a main source of disagreement about CEO ability between the Board and shareholders. The Board's signal z_{bt} causes B to update their beliefs about CEO ability. At the time that the Shareholder commits to their voting strategy, B and S hold different beliefs about CEO ability. This assumption means that S wants to force the Board to pay a wage closer to the unbiased wage, given their beliefs after receiving the signal at the shareholder meeting. Technically, this means that shareholders choose a single s_t for the Board's entire wage schedule — S influence expected wages. Or, put equivalently, S sets an average (across the distribution of z_{bt}) probability of SOP failure that the shareholder base is comfortable with.

[4]Based on Assumption 1, Figure A.6 provides a more detailed version of the model timeline (slightly adapting Figure 3). In particular, in period 1 (or 1a and 1b), B and S set their strategies. These strategies are not revealed at this time, but this timing convention defines the notion of the Board's informational advantage. In particular, the Board plays their strategy *after* receiving signal; the shareholder plays their strategy *before*. the assumption of commitment forces S to stick with the strategy that B expects.

Assumption 3. *Shareholders are* myopic. *That is, the SOP vote is only influenced by today, and is not a fully dynamic problem.*

Effectively, this means that shareholders play a static game, while the Board plays a dynamic one. This assumption matches reality. There is ample evidence that voting in SOPs is influenced by short-run outcomes, such as current firm or stock performance (see Figure A.4, or Fisch et al., 2018; Novick, 2019, 2020). Further, Table 2 Panel A shows that lagged CEO pay does not influence SOP outcomes. This makes the solution method much simpler, as it avoids higher-order beliefs and an infinite-regress problem in B and S forecasting each other's beliefs (Foster and Viswanathan, 1996; Bonatti et al., 2017).

C.4. Full Derivation of Model Solution

Proposition C.4. *The Board's problem can be written as*

$$V(\mu_a, \tau, w_{-1}) = \max_{w(s)} \quad \exp\left(\mu_{b|z_b} + 0.5\left(\sigma^2_{b|z_b} + \sigma^2_y\right)\right) w(s)^\alpha - (1-\lambda)w(s) - \chi_B F^U_{\tilde{z}_s}(s \times w(z_b, s)) - AC(w(s), w_{-1}; \tau) + \delta_B\left[f_\tau V^R + (1-f_\tau)E_{b|z_b}\left[V(\mu'_a, \tau+1, w(s))\right]\right] \tag{C.8}$$

where

- $\mu_{b|z_b}$ *and* $\sigma^2_{b|z_b}$ *are defined in* (C.5) *and* (C.6),
- $E_{b|z_b}[V] = F^U_{\tilde{z}_s}(s \times w)$ *where* $F^U_{\tilde{z}_s}$ *is the CDF of the following distribution (see* 13*)*

$$w^U \sim \log N\left(\frac{\mu_s}{1-\alpha} + C, \frac{\sigma^2_s}{(1-\alpha)^2}\right), \quad C = \frac{\log\alpha + \frac{1}{2}\sigma^2_y}{1-\alpha}$$

- $AC(w, w_{-1}; \tau)$ *(adjustment cost) is defined in* (3),
- f_τ *are CEO tenure-specific hazard rates, with* $f_0 = 0$ *and* $f_T = 1$
- $V^R = V(\mu_0, 0, 0)$ *as in* (19)
- $\mu'_a \mid \mu_{b|z_b}, \tau \sim N\left(\mu_{b|z_b}, \sigma^2_{b|z_b} - \sigma^2_a(\tau+1)\right)$ *from Prop.* C.3

The shareholder's problem can be written as

$$\max_{s} \quad \int_{z_b} f(z_b \mid \mu_a, \sigma_a^2) \left[\exp\left(\mu_a + 0.5\left(\sigma^2_{b|z_b} + \sigma_y^2\right)\right) w(z_b, s)^{\alpha} - w(z_b, s) - \chi_S F^U_{\tilde{z}_s}(s \times w(z_b, s)) \right] dz_b \tag{C.9}$$

where $f\left(z_b \mid \mu_a.\sigma_a^2\right)$ is the density function of z_b given prior beliefs about CEO ability, and all other objects are defined as above.

Proof. I start with (C.8). $\mu_{b|z_b}$ and $\sigma^2_{b|z_b}$ are Board beliefs after receiving their signal, hence are known from the perspective of the Board. As $A = \exp(a + \varepsilon_y)$, with a (and beliefs about a) normally distributed, I can write its expectation in terms of means and variances. The probability of vote failure is described in Section 3.3, but as brief overview it is given by the CDF $F^{\mathrm{U}}_{\tilde{z}_s}$, of the unbiased (log-normal) wage of beliefs implied by realizations of $\tilde{z}_s$. The adjustment cost makes the Board's problem dynamic, as they have to factor in the effect of wages on the continuation value.

V^R is value if the CEO retires, so beliefs reset and there is no adjustment cost. In other words, the Board's problem reverts to its $t = 1$ value; it is constant for any state as the prior belief of ability about the CEO talent pool is distributed $N(\mu_0, \sigma_0^2)$ for any state. Hence, it is a boundary condition.

The distribution of μ'_a conditional on μ_a and τ is given in Prop. C.3. However, because the Board has beliefs $\left(\mu_{b|z_b}, \sigma^2_{b|z_b}\right)$, the variance of next period *mean* beliefs (not the variance of beliefs) at the time the Board makes their decision is $\sigma^2_{b|z_b} - \sigma^2_{a'}$. This quantity wil be used to take expectation over the continuation value. If the CEO continues, the tenure increases by 1, and the Board must consider the adjustment cost in the next period.

For (C.9), the objects are the same as the Board's problem, however the shareholders choose s under the distribution of z_b, while holding belief of average CEO ability μ_a. That is, shareholders figure out the Board's wage decision for each z_b, including how they would react to the choice of a particular s. Under Assumption 3, shareholders do not behave dynamically, and only vote on the current period. Crucially, as the wage, the productivity signal and the shareholder's private signal are all revealed simultaneously (see Section 3.2.3 and Figures 3 and A.6), the Board and shareholders *disagree* about CEO ability at the point the vote is held. In other words, they hold different beliefs about (mean) CEO ability.

The solution $(w(z_b), s)$ is to be found numerically, each $(w(z_b), s)$ is a best response in equilibrium under commitment (Assumption 1). To sketch the intuition of the solution, fix S' strategy s under commitment. The Board can then back out the probability of failure for each choice of $w(z_b)$, knowing that S must play the threshold. In other words, there is no notion of deviation for the Board. S just needs to maximize (C.9) for their strategy to be a best response; they cannot deviate at the vote and play a lower threshold. ■

D. Estimation Appendix

D.1. Identifying the CEO component of output

To undertake my empirical analysis, I need to identify the CEO component of output. Consider the following functional form for the firm's log revenue

$$\log SALE_{jit} = \mu_i + \mu_t + \gamma_k \log PPE_{jit} + \gamma_e \log EMP_{jit} + \mu_{CEO} + \alpha \log w_{jit} + \epsilon_{it}^y$$

where j represents industry, i represents firm and t represents year. That is, revenue is composed of an industry-level, time-invariant component (μ_i), a time component (μ_t), contributions from capital and labor, the contribution of the CEO's ability and effort/wage, and finally a noise term. I am interested in the last three terms only. The issue with running this regression directly is that a regression directly including CEO fixed effects regression will not allow me to separately identify μ_i and μ_{CEO}. To net out μ_i and μ_{CEO} I first use data from 2000-2010 (pre-SOP), I estimate the following regression. For firm j in industry i and at year t,

$$\log SALE_{jit} = \mu_i + u_{jit}$$

under the constraint that the average value of μ_i equals the average value of $\log SALE$. The term μ_i thus represents the time-invariant industry-level average log output. Then, for the SOP period (2011-2020), I define $x_{jt} = \log SALE_{jit} - \mu_i$. I can drop the j subscript, as there is no longer an industry component. The functional form of revenue thus becomes

$$x_{it} = \mu_t + \gamma_k \log ppe_{it} + \gamma_e \log emp_{it} + \mu_{CEO} + \alpha \log w_{it} + \epsilon_{it}^y$$

By running this regression directly on the SOP period, then μ_{CEO} directly identifies average CEO ability. Lastly, ϵ_{it}^y directly identifies the output innovation. My final CEO-specific log revenue measure is thus

$$y_{it} = \mu_{CEO} + \alpha \log w_{it} + \epsilon_{it}^y$$

This process is similar to the analysis undertaken in Matveyev (2017).

D.2. Numerical Solution

The model requires 11 parameters, along with $\mathbf{T}+1$ externally calibrated CEO separation rates. I externally calibrate the Board's discount factor $\delta_B = 0.9$, following Taylor (2010). The CEO separation rates are generated by calculating the cross-sectional proportion of CEOs that separate from their firm for a given tenure. I group the remaining 10 parameters as Θ,

$$\Theta = \begin{pmatrix} \mu_0 & \sigma_0 & \sigma_y & \alpha & c_W & \sigma_{z_b} & \sigma_{z_s} & \lambda & \chi_B & \chi_S \end{pmatrix}$$

The model's solution proceeds as such

1. Start with a given Θ
2. Discretize each idiosyncratic shock into an N_z grid. E.g., fix the possible realizations of $\varepsilon_{z_{bt}}$, $\varepsilon_{z_{st}}$, etc.
3. Discretize the state space into a $(N_u, \mathbf{T}+1, N_w)$ grid, call it $\mathcal{S}$, where each tuple (μ_i, τ_j, w_k) indexes current mean belief about CEO ability, tenure (which fully determines beliefs of variance of CEO ability) and the current wage.
4. Start with a guess of $V_0(\mu, \tau, w)$ as the solution to the static game (i.e., where there is no wage adjustment cost), so V_0 is just the Board's per-period expected utility given optimal choices. Each $V(\mu, \tau, w_{1:N_w})$ starts with the same value.
5. Use Gauss quadrature and Prop. C.2 to estimate the continuation value for each tuple (μ, τ, w)
6. For each element in $\mathcal{S}$, solve (C.8) and (C.9),
   - If $i \,\%\, 10 = 0$
     - Solve B's optimal choice of w' given possible realizations of ε_{z_b}, and how this w' affects the continuation value and adjustment cost.
     - Concurrently backing out S' optimal choice of s for the tuple (μ, τ, w) given B's optimal choices of w'

– Update the guess of the value function

- Else,

  – Update B's optimal choices w'

  – Update the guess of the value function

7. Return to 4 and repeat until $\max |V_i - V_{i-1}| < \epsilon = 1\mathrm{e}-5$

This process returns the Board's wage policy for each element in $\mathcal{S}$, and each realization on the grid of ε_{z_b}. Concurrently, it returns the shareholder's policy for each element in $\mathcal{S}$.

D.3. Simulation

I set N_f firms, where N_f is chosen to match the number of firms in the data used for estimation. Given $a \sim (\mu_0, \sigma_0)$, I draw a CEO of skill a for each firm. A CEO spell is the length of time the CEO is matched with a firm. Each period, for each firm, I generate realizations of $\varepsilon_{z_{bt}}$, $\varepsilon_{z_{st}}$ and ε_{yt}. Given the state, I use the policies described in Section D.2 to generate optimal choices. Beliefs update given realizations of σ_{z_b}, σ_{z_s} and z_{yt}. At the end of each period, for CEOs with tenure $\tau > 0$, they separate (via firing, quitting or retirement) with exogenous probability f_τ.

I generate N_S samples for each simulation. I "fix" randomness across different simulations. That is, each $n_s \in N_S$ sample has the same seed across iterations, only the variance of each CEO ability and each shock changes.

D.4. Estimation

I estimate the 10 parameters

$$\Theta = \begin{pmatrix} \mu_0 & \sigma_0 & \sigma_y & \alpha & c_W & \sigma_{z_b} & \sigma_{z_s} & \lambda & \chi_B & \chi_S \end{pmatrix}$$

As mentioned above, the Board's discount factor δ_B is calibrated to 0.9. (Taylor, 2010), and separation rates are calibrated to match observed separation rates in the sample. I estimate the remaining model parameters by finding a vector Θ of parameters that minimizes the weighting distance between a vector of moments produced by the model and the corresponding moments computed in the data. That is, given model moment $m(\Theta)$ and data moments $m(X)$ and an appropriate weighting matrix W, I minimize

$$\min_{\Theta}\left[d(\Theta,X)\right]'W\left[d(\Theta,X)\right] \tag{D.1}$$

$d(\Theta,X)$ is a 13×1 vector of differences between model-simulated and empirical moments (Barrero, 2022). I set $d(\Theta,x)=m(\Theta)-m(X)$. The weighting matrix is the identity matrix The model moments can be expressed as the coefficients from the following system of equations, where each regression is indexed by i,c,τ,t

$$\begin{aligned}
\ln y &= y_0 + y_1 \ln \text{wage} + e_y \\
\left(E_{\text{CEO}}\left[\ln y\right] - E\left[E_{\text{CEO}}\left[\ln y\right]\right]\right)^2 &= Var\left(E\left[\ln y\right]\right) + e_{\text{CEO}} \\
\ln \text{wage} &= b_0 + b_1 \mathbb{1}\left[\text{SOP fail}\right] + b_2 \ln \text{lagged wage} + e_b \\
\mathbb{1}\left[\text{SOP fail}\right] &= s_0 + s_1 \ln \text{wage} + s_2 \epsilon^y + e_s \\
\left(\epsilon^y\right)^2 &= Var\left(\epsilon^y\right) + e_{\epsilon_y} \\
\left(\epsilon^b\right)^2 &= Var\left(\epsilon^b\right) + e_{\epsilon_b} \\
\left(\epsilon^s\right)^2 &= Var\left(\epsilon^s\right) + e_{\epsilon_s} \\
y_{\mathbb{B}} &= \mathbb{B}x_{\mathbb{B}} + e_{\mathbb{B}}
\end{aligned} \tag{D.2}$$

For the final moment $\mathbb{B}$, I reconstruct (28) using a regression specification.[5] In total, there are 13 moments to pin down 10 parameters. I estimate (D.2) jointly, with standard errors clusted at the CEO-spell level, and use the variance-covariance matrix of the moments to estimate standard errors of the parameter and moments. The full list of moments with notation is displayed in Table D.1.

[5]That is $x_{i,\mathbb{B}} = \sqrt{\frac{\hat{N}_b}{N_b}}$ and $y_{i,\mathbb{B}} = \left(x_{i,\mathbb{B}}\right)^{-1}\left(\mathbf{1}\left[x_b<0\right]-\mathbf{1}\left[x_b\geq 0\right]\right)\left(1-\frac{\hat{N}_b}{N_b}\right)$. This expression reconstructs (28) in terms of a regression, and conveniently allows me to include (28) in our regression system.

Table D.1. Moment targeting exercise
This table displays the notation and description for each targeted moment, along with the parameter(s) it targets.

	Moment	Description	Target
(1)	$\hat{y}_0$	Average log output	μ_0
(2)	$\hat{y}_1$	Elasticity of output to wage	α
(3)	$\widehat{Var}(\epsilon^y)$	Output residual variance	σ_y
(4)	$\widehat{Var}(E[\ln y - \hat{y}_1 \ln w])$	CEO-average output variance	σ_0
(5)	$\hat{b}_0$	Average log wage when SOP passes	λ
(6)	$\hat{b}_1$	Difference in log wage when SOP fails	χ_B
(7)	$\hat{b}_2$	Persistence in log wages	c_w
(8)	$\widehat{Var}(\epsilon^b)$	Wage regression residual variance	σ_{z_b}
(9)	$\hat{s}_0$	Observed SOP failure rate	λ, χ_S
(10)	$\hat{s}_1$	Sensitivity of SOP failure to log wage	χ_B, χ_S
(11)	$\hat{s}_2$	Sensitivity of SOP failure to output shock	σ_{z_s}, σ_y
(12)	$\widehat{Var}(\epsilon^s)$	SOP fail regression residual variance	σ_{z_s}
(13)	$\widehat{\mathbb{B}}$	Bunching estimator (28)	χ_B, χ_S

D.5. Optimization algorithm

My goal is to find the global minimum of the SMM/GMM objective function described in Section D.4. To leverage the efficiency of parallel computing, I use a somewhat modified version of the TikTak global optimization algorithm described in Arnoud et al. (2019).[6] The modifications are designed to take advantage of high performance computing to minimize computing time. The global optimization routine can be described as such:

1. **Parallel local minimization**

    i Generate bounds for each parameter. This is a holistic step, yet the bounds should be narrow enough to allow for the subsequent quasi-random sequences to adequately cove the space, but wide enough so that I maximize the chance of finding the global minimum.

[6] I modified code from https://github.com/tpapp/MultistartOptimization.jl, which is based upon the original TikTak code: https://github.com/serdarozkan/TikTak. See also Liu (2021) for a recent example.

ii Using the bounds, generate a Sobol sequence of length N. Sobol points are quasi-random points which are intended to mimic a draw from from a uniform distribution. In my setup, I set $N = 5000$.

iii For each $n \in N$ of the Sobol points, use a minimizer to find the local minimum of each point. Keep the portion p of the points with the smallest local minima to be used in the global stage. In my setup, I use Nelder-Mead locally, and keep the top 4% of points, so I am left with $N_p = 200$ "promising" candidates for the global minimum.

2. **Parallel global minimization**. This step slightly modifies the TikTak routine to take advantage of parallel computing. I employ SLURM with MPI to enable communication between ranked sets of iterations across the N_p points. This allows me to speed up the TikTak global optimization step, though at the expense of far greater expenditure of computing resources.

   i Take the $p \in N_p$ candidates for the global minimum from above and sort in ascending order. Set $i = 1$, so the best minimum so far is indexed by i.

   ii Take the best minimum so far, labeled p_i^*. Generate $N_p - i$ convex combinations using the TikTak methodology. That is, for $j \in N_p - i$, $p_{ji}^{cand} = \theta_{ji} p_i^* + (1 - \theta_{ji}) p_j$, where $\theta_{ji} \in [0, 1]$ and approaches 1 as j increases.

   iii Compute the local minimum of each $N_p - i$ point in parallel. If p_i^* is the best, then exit the routine and p_i^* is the candidate global minimum. Else,

   iv For the first j such that function value of p_{ji}^{cand} is less than that of p_i^*, stop all subsequent (unfinished) local minimization routines for $j' \in N_p - i$, and $j' > j$. Update $i \mathrel{+}= p$ and return to ii.

   This routine will return p_i^* as the global minimum.

3. **Polish global minimum**. Using stricter stopping criteria and a large number of function iterations, polish the global minimum p_i^* using a local minimization routine, i.e. Nelder-Mead.

D.6. Derivation of model statistics

This section derives several closed-form model statistics that are useful to interpret the magnitude of the main effects from the model. I can directly derive standard error for closed-form functions of model parameters, which is useful for comparing across models.

SOP failure cost as a percentage of unbiased value. To interpret the magnitude of the SOP failure cost, I first develop a measure of unbiased firm value. Unbiased firm value is the discounted stream of future cash flows produced by the CEO if the CEO were paid the profit-maximizing wage, under the assumption that Board and shareholder beliefs remain fixed at (μ_0, σ_0^2). First, note that

$$w_0 = \arg\max_w E_0 \left[A_0 w^\alpha - w\right] = \alpha^{\frac{1}{1-\alpha}} \times E_0 \left[A_0\right]^{\frac{1}{1-\alpha}}$$

is the optimal unbiased wage, absent SOP. Using this, average (unbiased) firm value can be written as

$$\begin{aligned}
\text{Average firm value} = V_0 &= \sum_{t=1}^{\infty} \delta_B^t E_t \left[y_t - w_t\right] \\
&= \sum_{t=1}^{\infty} \delta_B^t E_0 \left[y_0 - w_0\right] \\
&= \sum_{t=1}^{\infty} \delta_B^t E_0 \left[A_0 \times (w_0)^\alpha - w_0\right] \\
&= \frac{1}{1-\delta_B} \left[\exp\left(\mu_0 + 0.5\left(\sigma_0^2 + \sigma_y^2\right)\right) \times (w_0)^\alpha - w_0\right]
\end{aligned}$$

I can use unbiased firm value to interpret the magnitude of the SOP failure cost parameters χ_B and χ_S

$$\text{SOP failure cost (\% average value)} = \frac{\chi_{\{B,S\}}}{V_0} \tag{D.3}$$