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ABSTRACT

An objective of many proposed corporate governance reforms is increased transparency. This goal has been relatively uncontroversial, as most observers believe increased transparency to be unambiguously good. We argue that, from a corporate governance perspective, there are likely to be both costs and benefits to increased transparency, leading to an optimum level beyond which increasing transparency lowers profits. This result holds even when there is no direct cost of increasing transparency and no issue of revealing information to regulators or product-market rivals. We show that reforms that seek to increase transparency can reduce firm profits, raise executive compensation, and inefficiently increase the rate of CEO turnover. We further consider the possibility that executives will take actions to distort information. We show that executives could have incentives, due to career concerns, to increase transparency and that increases in penalties for distorting information can be profit reducing.

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1 Introduction

In response to recent corporate governance scandals, governments have responded by adopted a number of regulatory changes. One component of these changes has been increased disclosure requirements. For example, Sarbanes-Oxley (SOX), adopted in response to Enron, Worldcom, and other public governance failures, required detailed reporting of off-balance sheet financing and special purpose entities. Additionally, SOX increased the penalties to executives for misreporting. The link between governance and transparency is clear in the public's (and regulators') perceptions; transparency was increased for the purpose of improving governance.

Yet, most academic discussions about transparency have nothing to do with corporate governance. The most commonly discussed benefit of transparency is that it reduces asymmetric information, and hence lowers the cost of trading the firm's securities and the firm's cost of capital.[1] To offset this benefit, commentators typically focus on the direct costs of disclosure, as well as the competitive costs arising because the disclosure provides potentially useful information to product-market rivals.[2] While both of these factors are undoubtedly important considerations in firms' disclosure decisions, they are not particularly related to corporate governance.

In this paper, we provide a framework for understanding the role of transparency in corporate governance. We analyze the effect that disclosure has on the contractual and monitoring relationship between the board and the CEO. We view the quality of information the firm discloses as a choice variable that affects the contracts the firm and its managers. Through its impact on corporate governance, higher quality disclosure both provides benefits and imposes costs. The benefits reflect the fact that more accurate information about performance allows boards to make better personnel decisions about their executives. The costs arise because executives have to be compensated for the increased risk to their careers implicit in higher disclosure levels, as well as for the incremental costs they incur trying to distort information in equilibrium. These costs and benefits complement existing explanations for disclosure. Moreover, because they are directly about corporate governance, they are in line with common perceptions of why firms disclose information.

We formalize this idea through an extension of Hermalin and Weisbach (1998) and Hermalin's (2005) adaptation of Holmstrom's (1999) career-concerns model to consider the question

[1] Diamond and Verrecchia (1991) were the first to formalize this idea. For empirical evidence, see Leuz and Verrecchia (2000), who document that firms' cost of capital decreases when they *voluntarily* increase transparency.

[2] See Leuz and Wysocki (2006) for a recent survey of the disclosure literature. Feltham et al. (1992), Hayes and Lundholm (1996), and Wagenhofer (1990) provide discussions of the impact of information disclosure on product-market competition.

of optimal transparency. Section 2 lays out the basics of this model, in which the company chooses the "quality" of the performance measure that directors use to assess the CEO's ability. In this model, the optimal quality of information for the firm to reveal can be zero, infinite, or a finite positive value depending on the parameters. When we calibrate the model to reflect actual publicly traded large US corporations, we find that the parameters implied by the calibration lead to a finite value for optimal disclosure quality. Thus, our analysis suggests that disclosure requirements going beyond this optimal level are likely to have unintended consequences and to reduce value.

Section 4 of the paper considers how the CEO could exert effort to distort this signal.[3] We consider three ways in which the CEO could potentially distort the signal. First, CEOs can take actions that increase the signal without changing the firm's underlying profitability; we refer to this type of action as "exaggerating effort." In addition, CEOs can take actions that affect signal noise; we denote such actions as "obscuring effort." Finally, we briefly consider the possibility that CEOs can conceal information.

We evaluate the implications of penalties and incentives that potentially affect the motives of CEOs to distort the information coming from their firms. Measures that punish exaggerating effort can be effective if they are sufficiently severe to curtail this effort; however, relatively minor penalties can be counterproductive. In addition, incentives for CEOs to improve the accuracy of information can harm shareholders because such incentives push a CEO to disclose more than the value-maximizing quantity of information.

We discuss the model's implications and conclude in Section 5. Proofs not given in the text can be found in the appendix.

2 The Model

The focus of our model is the relationship between the CEO and the firm's owners (alternatively, between the CEO and the directors acting on behalf of the owners). The owners seek to assess the CEO's ability based on the information available to them, and to replace him if the assessment is too low. The CEO has career concerns, so he is concerned about information transmittal to the broader market. This concern provides him incentives to do what

[3]Inderst and Mueller (2005), Singh (2004), and Goldman and Slezak (in press) are three other recent papers concerned with the CEO's incentives to distort information. Like us, the first is concerned with the board's making inferences about the CEO's ability. Inderst and Mueller's approach differs insofar as they assume the CEO possesses information not available to the board, which the board needs to induce the CEO to reveal. There is no uncertainly about the CEO's ability in Singh's model; he is focused on the board's obtaining accurate signals about the CEO's actions. Goldman and Slezak are concerned primarily with the design of stock-based compensation. In addition, unlike us, they treat disclosure rules as exogenous, whereas we derive the profit-maximizing rules endogenously.

he can to influence the value and informational properties of the information to which the owners have access. Exogenous regulatory changes that affect disclosure quality thus affect both the information available to the owners, and the CEO's response to the information.

2.1 Timing of the Model

The model has the following timing and features.

STAGE 1. The owners of a firm establish a level of reporting quality, q (its choice may be constrained by legal restrictions—*e.g.,* SEC requirements). The owners also hire a CEO from a pool of *ex ante* identical would-be CEOs. Assume the owners make a take-it-or-leave-it offer to the CEO. A given CEO's ability, α, is an independent random draw from a normal distribution with mean 0 and known variance $1/\tau$ (τ is the *precision* of the distribution). Normalizing the mean of the ability distribution to zero is purely for convenience and is without loss of generality.

STAGE 2. After the CEO has been employed for some period, a public signal, s, pertaining to the CEO's ability is realized. The signal is distributed normally with a mean equal to α and a variance equal to $1/q$. Letting the precision, q, of the distribution be the same as the quality of reporting, q, is without loss of generality as we are free to normalize "reporting quality" using whatever metric we wish.

STAGE 3. The owners decide, on the basis of the signal, whether to retain or dismiss the CEO.

STAGE 4. The CEO hired at Stage 1 has his *future* salary set by competition among potential employers, where these employers base their valuation of him on the public perception of his ability.

STAGE 5. At the same time as Stage 4, the firm realizes a payoff that depends on the ability of the CEO hired at Stage 1 if he was retained at Stage 3. If he was dismissed, then the owners realize an alternative payoff. Payoffs are dispersed immediately to the firm's owners.

The simultaneity of Stages 4 and 5 warrants comment, as an order in which the latter strictly preceded the former might seem more natural. Our primary reason for assuming the order we do is to keep the analysis straightforward. If we assumed this alternative order, then the CEO-labor market might also update its beliefs about the CEO's ability based on the firm's payoffs. This would not, however, change in any substantive way our conclusions, but would complicate the analysis insofar as we would need to keep track of the updating on both pieces of information (*i.e.,* the signal s and the payoffs). In addition, we could justify this timing if we take "payoffs" as shorthand for the long-term financial consequences of the CEO's management, which may be realized after his tenure with the firm.

Another aspect of the model that warrants comment up front is our assumption that the owners both establish a level of reporting quality q and make a take-it-or-leave-it offer to the CEO in Stage 1. A common complaint is that shareholders actually lack power *vis-à-vis* the CEO and it is the CEO who both sets the rules and determines his own compensation; that is, the real world is at odds with our assumptions here. As Hermalin (1992) and others have observed, however, the issue of *initial* bargaining power is essentially irrelevant to the analysis of principal-agent problems. Certainly, the substantive conclusions of this paper would hold were we to assume that it was the CEO who made a take-it-or-leave-it offer to the owners of a contract specifying the degree of reporting quality and his compensation. In particular, as the CEO lowered reporting quality, he would be reducing the shareholders' well-being *ceteris paribus*; hence, to keep the shareholders at their participation constraint (*i.e.,* to keep them willing to sign), he would have to compensate the shareholders by "giving himself" lower compensation.

Moreover, there are a few reasons to set the bargaining power as we have done. First, boards of directors (the owners' representatives) do have clout over the hiring and firing of the CEO, as well as an ability to influence the firm's reporting practices. Hence, it is not wholly obvious in practice how bargaining power should be assigned and, as noted, its assignment is not critical for the analysis at hand. Second, if we gave the CEO all the bargaining power, then the owners would always be up against their participation constraint. As a consequence, the owners' equilibrium well-being would be a constant regardless of the reforms in place. The only consequences of reforms would be to affect the CEO's well-being. Since, presumably, a motive for these reforms (*e.g.,* SOX) is *shareholder* benefit, we need to start from a model in which they are capable of getting benefits; namely one in which all the surplus from their relation with the CEO is not being captured by the CEO.[4]

2.2 CEO Preferences and Ability

A CEO's ability is fixed throughout his career. We follow Holmstrom (1999) by assuming that the CEO, like all other players, knows only the *distribution* of his ability. We justify this assumption by assuming that both the CEO and potential employers learn about his ability from his actual performance (*i.e.,* no one is born knowing whether he'll prove to be a good executive or not) and potential employers can observe this past performance.

[4]We are unaware of any evidence that SOX serves to shift bargaining power from management to shareholders.

The CEO's lifetime utility is

$$u(w_1) + u(w_2)\,,$$

where w_1 is his salary as set in stage 1 and w_2 is his salary as set in stage 4. Observe, for convenience and without loss of generality, that we ignore intertemporal discounting. Also observe that we have ruled out deferred or contingent payments from the stage-one employer to the CEO at Stage 4.[5]

In our analysis, we assume the CEO is risk averse.[6] We assume that $u(\cdot)$ is at least twice differentiable and that $u(\cdot)$ is $\mathcal{L}^2$ with respect to any normal distribution (this is a slightly stronger assumption than simply assuming that expected utility exists—is not negative infinity—when income is distributed normally).

At some points in the analysis it is convenient to assume that the CEO has the CARA utility function,

$$u(w) = -\tfrac{1}{\rho}\exp(-\rho w)\,, \tag{1}$$

where ρ is the coefficient of absolute risk aversion. Note the CARA utility function satisfies the assumptions given above for the utility function.[7] We can consider the case of a risk-neutral CEO to be the limiting case as $\rho \downarrow 0$.[8]

The CEO has a reservation utility, u_R. That is, his expected utility cannot be less than u_R, otherwise he will not accept the employment contract.

2.3 Updating Beliefs

After the signal, s, is observed, the players update their beliefs about the CEO's ability. The posterior estimates of the mean and precision of the distribution of the CEO's ability are

$$\hat{\alpha} = \frac{qs}{q+\tau} \text{ and } \tau' = \tau + q\,, \tag{2}$$

[5]Deferred payments could, through wealth effects, change the effective degree of CEO risk aversion, but would have no substantive implications for the model. Contingent payments could either exacerbate or reduce the problems stemming from CEO risk aversion depending on how they are structured. Note that any full insurance in this model would have the perverse property that the CEO is paid more the worse he performs.

[6]Alternatively, we could assume the CEO is risk neutral but obtains private benefits of control, the lose of which is not something for which he can be compensated fully. The results below would carry over to this alternative model.

[7]To see the CARA utility is $\mathcal{L}^2$ observe that $\mathbb{E}\{\exp(-2\rho w)\} = \exp(-2\rho\mu + 4\rho^2\sigma^2) < \infty$ if the distribution is normal, where μ and σ^2 are the mean and variance, respectively.

[8]Take the limit as $\rho \downarrow 0$ using L'Hôpital's rule, which yields $\lim_{\rho\downarrow 0} u(w) = w$.

respectively (see, *e.g.,* DeGroot, 1970, p. 167, for a proof). The posterior distribution of ability is also normal.

We assumed that the distribution of the signal s given the CEO's *true* ability, α, is normal with mean α and variance $1/q$; hence, the distribution of s given the *prior* estimate of the CEO's ability, 0, is normal with mean 0 and variance $1/q + 1/\tau$.[9] Define

$$H = \frac{q\tau}{q+\tau}$$

to be the precision of s given the prior estimate of ability, 0.[10]

2.4 The Retention/Dismissal Decision

Suppose that the payoff realized by the firm in Stage 5 if the CEO was retained at Stage 3 is

$$R = \bar{r} + \alpha + \varepsilon - w_1 \, , \tag{3}$$

where $\bar{r}$ is a known constant and ε is an *ex ante* unknown amount distributed normally with mean 0 and variance σ_ε^2.

Assume that the owners are risk neutral. The decision that they make at Stage 3 is whether to keep the CEO, in which case their payoff will be R as given by expression (3) or to fire the CEO, in which case their payoff will be

$$\bar{r} + \alpha_N + \varepsilon - w_1 - f \, ,$$

where α_N is the ability of the new (replacement) CEO. We assume that the firm cannot escape its salary obligation to the *initial* CEO, hence the $-w_1$ term. The amount, f, which is assumed to be non-negative, reflects the costs associated with dismissing the initial CEO (firing costs). These costs are assumed to represent the cost of disruption plus the compensation necessary to employ the new CEO for the latter stages of the game.

Because the owners are risk neutral and the *un*conditional expectation of a CEO's ability is zero, the owners make their decision to keep or fire the initial CEO based on a comparison between what they expect to receive if they keep him,

$$\bar{r} + \hat{\alpha} - w_1 \, ,$$

[9] The random variable s is the sum of two independently distributed normal variables $s - \alpha$ (*i.e.,* the error in s) and α; hence, s is also normally distributed. The means of these two random variables are both zero, so the mean of s is, thus, 0. The variance of the two variables are $1/q$ and $1/\tau$ respectively, so the variance s is $1/q + 1/\tau$.

[10] As a convention, functions of many variables, such as H, will be denoted by capital letters.

and what they expect to receive if they dismiss him,

$$\bar{r} - w_1 - f$$

(recall $\mathbb{E}\{\alpha_N\} = 0$). The former is less than the latter—that is, they wish to fire the initial CEO—if and only if $\hat{\alpha} < -f$. Using expression (2), we can restate this dismissal condition in terms of the signal as follows: they dismiss the initial CEO if and only if

$$s < -\frac{(q+\tau)f}{q} \equiv S\,. \tag{4}$$

Given this option of change, the firm's expected value *prior* to receiving a signal with precision q is

$$\begin{aligned} V &= \bar{r} - w_1 + \int_{-\infty}^{\infty} \max\left\{-f, \frac{qs}{q+\tau}\right\} \sqrt{\frac{H}{2\pi}} \exp\left(-\frac{H}{2}s^2\right) ds \\ &= \bar{r} - w_1 + \frac{\sqrt{H}}{\tau}\phi\big(S\sqrt{H}\big) - \Phi\big(S\sqrt{H}\big) f\,, \end{aligned}$$

where $\phi(\cdot)$ is the density function of a standard normal random variable (*i.e.,* with mean zero and variance one) and $\Phi(\cdot)$ is the corresponding distribution function. The second line follows from the first using the change of variables $z \equiv s\sqrt{H}$. In what follows, it is useful to define

$$Z \equiv S\sqrt{H} = \frac{-f\tau}{\sqrt{H}}\,.$$

Note that

$$1 - \Phi(Z) = \Phi(-Z) \tag{5}$$

is the probability that the owners will retain the CEO after observing the signal.

Observe that owners prefer higher quality information to lower quality information *ceteris paribus.*

Lemma 1 *The owners' expected payoff (V) is increasing in the level of reporting quality, all else held equal.*

Intuitively, the ability to fire the CEO creates an option. An option that is never exercised is worthless; hence, if the signal were complete noise, there would be essentially no option. As the quality of the information improves, the more valuable this option becomes and, thus, the more valuable the firm becomes.

2.5 The CEO's Subsequent Labor Market

We now consider how the CEO's second-period compensation, w_2, is set in Stage 4. We consider the following structure, which has the feature that career concerns induced by Stage 4 lead the CEO to prefer lower reporting quality to higher reporting quality *ceteris paribus*.

Recall the CEO is risk averse. Assume, too, that the contribution of a CEO of ability α to a future employer is $\gamma\alpha + \delta$, where $\gamma > 0$ and δ are known constants. Finally, assume future employers are risk neutral, so that the value they place on the CEO is $\gamma\hat{\alpha} + \delta$.

Prior to the realization of the signal, $\hat{\alpha}$ is a normal random variable with mean 0 and variance

$$\frac{q^2}{(q+\tau)^2}\mathrm{Var}(s) = \frac{q^2}{(q+\tau)^2}\frac{1}{H} = \frac{q}{\tau(q+\tau)} = \frac{H}{\tau^2}\,.$$

Consequently, the CEO's second-period compensation is normally distributed with mean δ and variance $\gamma^2\mathrm{Var}(\hat{\alpha})$.

As is well known, if two normal distributions have the same mean, but different variances, then the one with the larger variance is a mean-preserving spread of the one with the smaller variance. It follows therefore that any risk-averse agent will prefer the latter distribution to the former. For the analysis at hand, this means that the smaller is the variance of w_2, the greater is the CEO's expected utility. This logic leads to the following.

Lemma 2 *Consider a risk-averse* CEO *whose second-period compensation is a positive affine function of the posterior estimate of his ability. The* CEO*'s expected utility decreases as the quality of reporting, q, increases.*

Proof: It is sufficient to show that $d\,\mathrm{Var}(\hat{\alpha})/dq$ is positive. Observe

$$\frac{d\,\mathrm{Var}(\hat{\alpha})}{dq} = \frac{d}{dq}\frac{q}{\tau(q+\tau)} = \frac{1}{(q+\tau)^2} > 0\,.$$

■

At first glance, Lemma 2 might seem counter-intuitive: wouldn't a risk-averse CEO prefer a more precise signal of his ability to a less precise signal? The reason the answer is no is that the CEO's future compensation is a function of a weighted average of the prior estimate of ability (*i.e.,* 0), which is fixed, and the signal, s, which is random. Being risk averse, the CEO prefers more weight be put on the fixed quantity rather than the random quantity (remember $\mathbb{E}\{s\} = 0$). The *less* precise the signal, the more weight is put on the prior estimate, making the CEO better off.[11]

[11] Hermalin (1993) also makes the point that a risk-averse agent would prefer that signals about his ability

3 Optimal Reporting Quality

As demonstrated above, all else equal, the firm's owners prefer higher reporting quality to lower reporting quality, while the CEO prefers lower reporting quality to higher reporting quality. These opposing preferences become linked through the CEO's first-period compensation, w_1: to satisfy the CEO's participation constraint, an increase in the reporting quality must be matched with an increase in w_1. Because the owners prefer lower CEO compensation to higher CEO compensation *ceteris paribus*, it follows that they must, therefore, tradeoff the benefits of higher reporting quality against the cost incurred through higher CEO compensation. Formally,

Lemma 3 *The first-period salary, w_1, is increasing in the precision of the signal, s; that is, $dw_1/dq > 0$.*

The firm's expected profit is

$$\bar{r} + \frac{\sqrt{H}}{\tau}\phi(Z) - \Phi(Z)f - \underbrace{u^{-1}\Big(u_R - \mathbb{E}\big\{u(w_2)\big\}\Big)}_{w_1}$$
$$= \bar{r} + Q\phi\left(\frac{-f}{Q}\right) - \Phi\left(\frac{-f}{Q}\right)f - u^{-1}\left(u_R - \int_{-\infty}^{\infty} u\big(\gamma Q z + \delta\big)\phi(z)dz\right), \quad (6)$$

where $Q = \sqrt{H}/\tau$. Because $dH/dq > 0$, Q is monotonically increasing in q and we can thus optimize (6) with respect to Q to determine the optimal q.

Proposition 1 *The optimal quality of information, q, for the firm to set is infinite if*

(i) The CEO *is risk neutral; or*

(ii) There is no second-period market for the CEO*'s services (i.e., $\gamma = 0$).*

But the optimal quality of information for the firm to set is finite *if*

(iii) $\phi(0) < \dfrac{-\int_{-\infty}^{\infty} u'\left(\frac{\gamma z}{\sqrt{\tau}} + \delta\right)\gamma z\phi(z)dz}{u'\left(u^{-1}\big(u_R - \int_{-\infty}^{\infty} u\left(\frac{\gamma z}{\sqrt{\tau}} + \delta\right)\phi(z)dz\big)\right)}.$

be noisier rather than less noisy.

Condition (iii) can be interpreted as saying that a finite quality of reporting is optimal (profit-maximizing) if the CEO is sufficiently risk averse that (a) the magnitude of the negative correlation between $u'(\gamma z/\sqrt{\tau}+\delta)$ and γz is big and (b) expected second-period utility is small. Observe that the greater the importance of the second period market, γ, or the more diffuse the prior beliefs (*i.e.,* the lower is τ), the greater the effective risk aversion of the CEO and, thus, the more we should expect a finite level of reporting quality to be optimal.

If the CEO's utility is CARA (*i.e.,* given by (1)), then (6) becomes

$$Q\phi\left(\frac{-f}{Q}\right)-\Phi\left(\frac{-f}{Q}\right)f+\frac{1}{\rho}\log\left(-\rho u_R-\exp\big(-\rho\delta+\frac{\rho^2\gamma^2Q^2}{2}\big)\right). \tag{7}$$

Consequently, condition (iii) of Proposition 1 is

$$\phi(0)<\frac{-\rho\gamma^2\exp\big(-\rho\delta+\frac{\rho^2\gamma^2}{2\tau}\big)}{\sqrt{\tau}\left(\rho u_R+\exp\big(-\rho\delta+\frac{\rho^2\gamma^2}{2\tau}\big)\right)}. \tag{8}$$

Expression (8) allows us to get a sense of whether plausible solutions are interior (*i.e.,* the optimal q is positive and finite) by allowing for a rough calibration of the model. Suppose, for instance, that the standard deviation of ability in terms of firm profits is \$10 million (*i.e.,* $1/\sqrt{\tau}=\$10$ million). Suppose that a CEO captures 20% of his ability and has a "base" pay of \$1 million (*i.e.,* $\gamma=1/5$ and $\delta=\$1$ million). Finally, suppose a CEO's certainty equivalence for a gamble in which he wins \$10 million if a coin comes up heads but nothing if it comes up tails is \$1 million. These assumptions imply a coefficient of absolute risk aversion, ρ, of approximately 6.922×10^{-7}. Finally, suppose that if the CEO were to pursue some alternative employment, then he would earn \$500,000 in each of the two periods (*i.e.,* $u_R=2\exp(-500,000\rho)/\rho$). Using these values, the right-hand side of (8) is approximately 3.279; hence, the firm would optimally choose a finite level of reporting quality. Indeed, the optimal q proves to be approximately 1.684×10^{-14}; that is, the standard deviation on reporting quality is \$7.71 million.

The above example notwithstanding, we note that there is no guarantee that the maximization of (6) with respect to q will yield an interior solution. Parameter values exist such that $q\to\infty$ is optimal, as do values such that $q=0$ is optimal. Nevertheless, we will focus on those cases for which interior solutions exist.

Proposition 2 *If the profit-maximizing level of reporting quality, q, is an interior maximum, then the following comparative statics hold:*

(i) The profit-maximizing level of the quality of reporting, q, is strictly decreasing in the firing cost, f.

(ii) The profit-maximizing level of the quality of reporting, q, is strictly decreasing in the sensitivity of future CEO *salary to the signal, γ.*

(iii) The profit-maximizing level of the quality of reporting, q, is strictly increasing in the precision of the prior estimate of CEO *ability, τ.*

Intuitively, an increase in the firing cost lowers the marginal return to reporting quality, without affecting the marginal cost of reporting quality (*i.e.,* the distribution of w_2); hence, the equilibrium value of reporting quality falls if disruption costs rise (except if the optimal reporting quality is zero or, possibly, if it is infinite). It can be shown that an increase in the importance placed on the signal by the CEO in terms of his second-period salary (*i.e.,* an increase in γ) raises the marginal cost of reporting quality (*i.e.,* dw_1/dq increases in γ), but leaves the marginal benefit untouched. Consequently, the impact of an increase in γ is a decrease in the optimal level of reporting quality.

Result (iii) of Proposition 2 might, at first, seem less obvious given that an increase in the precision of the prior estimate of ability reduces the option value of being able to make a change, which means an increase in q is less valuable. On the other hand, the greater the precision of the prior estimate, the less weight, relatively speaking, is placed on the signal; hence, the marginal cost of an increase in reporting quality is also falling. As the proof of Proposition 2(iii) shows, this second effect dominates the first and, thus, the overall effect of an increase in the precision of the prior estimate is to increase the net marginal return to an increase in reporting quality.

Empirically, Proposition 2(i) suggests that reporting quality will be lower, *ceteris paribus*, when the CEO is more entrenched (costly to change). Proposition 2 also suggests that, *ceteris paribus*, reporting quality should be better with older (lower γ) or better known (greater τ) CEOs. Note, to the extent that CEOs are older or better known because of the length of service, they may also be more entrenched, thus confounding the effects of age or familiarity.[12] Another confounding factor is that long-serving CEOs can develop bargaining power *vis-à-vis* the board and they can use this power to bargain for less intense monitoring (see Hermalin and Weisbach, 1998).

Finally, with respect to policy, we have

Corollary 1 *If the profit-maximizing level of reporting is finite, then regulations that force the firm to adopt higher reporting levels will reduce expected profits, raise* CEO *compensation, and increase the probability of* CEO *dismissal.*

[12] Although we assume the CEO is hired in Stage 1, it should be clear that nothing relies critically on this assumption. We could simply think of Stage 1 as the owners entering into a new contract with its incumbent CEO.

Proof: The first conclusion follows from the nature of optimization.[13] The second conclusion is simply Lemma 3. The third conclusion follows because, as is readily shown, $\partial\Phi(Z)/\partial q > 0$. ■

4 Efforts by the CEO

So far we have ignored the efforts that the CEO might undertake. In this section, we explore how the efforts of the CEO could be affected by reporting quality. We consider two kinds of effort: "exaggerating effort," denoted by $x \in \mathbb{R}_+$; and "obscuring effort," denoted by $b \in \mathbb{R}$. Exaggerating effort is effort designed to boost the value of the signal s *ceteris paribus*. Obscuring effort is effort designed to make the signal s noisier *ceteris paribus*. At the end of this section, we briefly consider how this analysis applies to situations in which the CEO can conceal signals.

What we seek to capture by exaggerating effort are actions that the CEO might take to boost the numbers. These include activities such as timing earnings announcements, aggressive accounting, and actually "cooking the books." Obscuring effort is meant to capture activities such as aggregating reported data more, substituting into more volatile assets, or otherwise pursuing riskier strategies. Negative values of b correspond to efforts to reduce noise, such as providing more detailed information, meeting more frequently with analysts, and so forth.

We assume that the CEO finds these efforts costly. Let $c(\cdot)$ denote the cost of effort (we consider only one kind of effort at a time, so there is no loss in having a common notation for the cost of effort). For the case of obscuring effort, assume $c(\cdot)$ is a function of $|b|$.[14] In addition, assume that this cost enters the CEO's utility function additively, that $c(\cdot)$ is twice differentiable on $\mathbb{R}_+$, no effort is "free" (*i.e.,* $c(0) = 0$), there is a positive marginal cost to effort (*i.e.,* $c'(\cdot) > 0$ on $(0, \infty)$), and this marginal cost is rising in effort ($c''(\cdot) > 0$). Finally, assume $\lim_{a\to\infty} c'(a) = \infty$.

We assume that the firm or regulations can impose a "tax" on the CEO for engaging in these efforts. Specifically, let r denote the tax rate, so the CEO incurs a cost ra if his effort is a, where a denotes x or b as appropriate. There are two interpretations to r:

[13] To be precise, if there were multiple optimal values of q, then a regulation could simply push the firm from a low-q optimum to a high-q optimum. Multiple optima are not, however, a generic property of this model.

[14] There is some lost of generality in assuming the cost of b and $-b$ are the same, but it is minor and without importance to the results.

- Through various practices (*e.g.,* reporting requirements, signing certificates, etc.), the marginal cost to the CEO of engaging in these efforts is raised by r.
- There is a severe penalty for engaging in these activities, which is applied if these efforts are detected. The penalty or probability of detection are increasing in the CEO's efforts, so ra is the expected penalty.

The CEO's lifetime utility is, therefore,

$$u(w_1) + u(w_2) - ra - c(a)\,, \tag{9}$$

$a = x$ or $= b$.

We assume that neither kind of effort has a positive impact on profits. Were this not the case, then obviously the benefits of restricting the CEO's effort would be reduced.

Finally, because it adds nothing to the analysis going forward, we will clean up the notation by henceforth setting $\delta = 0$.

4.1 Exaggerating Effort

Here we consider exaggerating effort. We assume that the signal observed by owners and outsiders is $\tilde{s} = s + x$.

We focus on pure-strategy equilibria. In a pure-strategy equilibrium, the CEO doesn't fool anyone on the equilibrium path: owners and outsiders infer the x he chooses and use $s = \tilde{s} - \hat{x}$ as the signal, where $\hat{x}$ is the value of x that they infer. Given that $\hat{x}$ is inferred effort and x is actual effort, the CEO chooses x to maximize

$$\int_{-\infty}^{\infty} u\left(\frac{\gamma H}{\tau}\big(\underbrace{s + x}_{\tilde{s}} - \hat{x}\big)\right)\sqrt{\frac{H}{2\pi}}\exp\left(-\frac{H}{2}s^2\right)ds - C(x,r)\,, \tag{10}$$

where $C(x,r) \equiv rx + c(x)$. Observe that (10) is globally concave in x; hence, the solution to (10) is unique.

In equilibrium, the inferred value and the chosen value must be the same. Hence, the equilibrium value, x^e, is defined by the first-order condition for maximizing (10) when $\hat{x} = x^e$:

$$\begin{aligned} 0 \geq & \int_{-\infty}^{\infty} \frac{\gamma H}{\tau} u'\left(\frac{\gamma H}{\tau}s\right)\sqrt{\frac{H}{2\pi}}\exp\left(-\frac{H}{2}s^2\right)ds - \frac{\partial C(x^e,r)}{\partial x} \\ & = \int_{-\infty}^{\infty} \gamma\tau Q^2 u'(\gamma Q z)\phi(z)dz - r - c'(x^e)\,, \end{aligned} \tag{11}$$

where $x^e = 0$ if it is an inequality. Lemma A.1 in the Appendix rules out the possibility that the integral in (11) is infinite. Consequently, because $c'(x) \to \infty$ as $x \to \infty$, it follows that $x^e < \infty$.

We have the following comparative statics:

Proposition 3 *If the coefficient of absolute risk aversion for the* CEO*'s utility function is non-increasing, then*

(i) the CEO*'s efforts to exaggerate performance are non-decreasing in reporting quality and strictly increasing if $x^e > 0$;*

(ii) the CEO*'s efforts to exaggerate performance are non-decreasing in the importance of his second-period labor market (i.e., γ) and strictly increasing if $x^e > 0$; and*

(iii) the CEO*'s efforts to exaggerate performance are non-increasing in the precision of the prior estimate of* CEO *ability (i.e., τ) and strictly decreasing if $x^e > 0$.*

Regardless *of the coefficient of absolute risk aversion,*

(iv) the CEO*'s efforts to exaggerate performance are non-increasing in the marginal penalty (i.e., r) for engaging in these efforts and strictly decreasing if $x^e > 0$.*

Moreover, there exists a finite value r^*, a function of the parameters, such that, if $r > r^*$, the CEO *engages in no efforts at exaggeration in equilibrium.*

Why attitudes to risk matter can be seen intuitively by considering expression (11). Note that an increase in γ or Q increase marginal utility for $z < 0$, but decrease marginal utility for $z > 0$. If this second effect were strong enough than it could dominate the first effect and the direct effect (*i.e.,* the terms preceding $u'(\gamma S z)$) of increasing γ or Q. Assuming the coefficient of absolute risk aversion to be non-increasing rules out that possibility. It is a common contention in economics that individuals exhibit non-increasing coefficients of absolute risk aversion (see, *e.g.,* the discussion in Hirshleifer and Riley, 1992).

Results (i) and (ii) can be read as saying that the more importance the CEO places on the signal, either because it is receiving greater weight in the determination of his future salary or because he places greater weight on his future salary, the greater his incentive to exaggerate and, hence, the more exaggeration that takes place in equilibrium. An increase of the precision of the prior estimate of ability, τ, reduces the weight placed on the signal with respect to constructing the posterior estimate, which means the signal has less impact on the CEO's future salary. Consequently, an increase in τ reduces his incentives to exaggerate and, thus, the less exaggeration that takes place in equilibrium.

Result (iv) is the standard result that increasing the marginal cost of an activity causes a reduction in the amount of that activity. That there is an r^* that curtails all exaggeration follows because the marginal benefit of exaggerating is bounded, while, by increasing r, the marginal cost can be made as large as desired.

If $x^e > 0$, then the CEO's participation constraint becomes

$$u(w_1) + \int_{-\infty}^{\infty} u(\gamma Q z)\phi(z)dz - rx^e - c(x^e) \geq u_R\,. \tag{12}$$

The constraint is binding in equilibrium, hence

$$w_1 = u^{-1}\left(u_R - \int_{-\infty}^{\infty} u(\gamma Q z)\phi(z)dz + rx^e + c(x^e)\right)\,.$$

Observe that the CEO's compensation has increased because he needs to be compensated for his efforts; that is, unless $r \geq r^*$, in which case w_1 is the same as if there were no opportunity for the CEO to expend effort (*i.e.,* as in Section 3). This insight yields the following result.

Proposition 4 *If there is no constraint on the "tax" rate, r, that can be imposed on the* CEO *to discourage efforts at exaggeration and if these efforts have no positive benefits for the firm, then it is optimal to set the rate large enough to discourage any exaggeration (i.e., set $r \geq r^*$).*

In other words, if the firm can prevent exaggeration and exaggeration has no benefit, then it should.

But what if the antecedents of Proposition 4 are not met? In particular, suppose that there is an upper bound on r, $\bar{r} < r^*$. This could arise because the ability of private parties to punish each other contractually tend to be limited by the courts (see, *e.g.,* Hermalin et al., in press, for discussion). Hence, $\bar{r}$ could be the effective legal limit. Suppose such a limit exists and observe, on the equilibrium path, dw_1/dr has the same sign as

$$\frac{d}{dr}\big(rx^e + c(x^e)\big) = x^e + \big(r + c'(x^e)\big)\frac{dx^e}{dr} = x^e - \frac{1}{c''(x^e)}\int_{-\infty}^{\infty} \gamma\tau Q^2 u'(\gamma Q z)\phi(z)dz\,, \tag{13}$$

where the last equality in (13) follows from (11) and comparative statics based on that expression. As a general rule, expression (13) need not be negative as the following example illustrates.

Let $c(x) = x^3/3$ and $u(w) = -e^{-w}$. The integral in (13) equals

$$I \equiv \gamma Q^2 \tau \,\exp\big(\gamma^2 Q^2/2\big)\,.$$

Observe, from (11),

$$x^e = \sqrt{I-r}\,.$$

Expression (13) is, therefore,

$$\sqrt{I-r} - \frac{I}{2\sqrt{I-r}}\,,$$

which has the same sign as $I - 2r$. Hence, because $I > 0$, the CEO's pay is first increasing in r and, then, decreasing in r (changing signs at $r = I/2$). It follows that if $\bar{r} \leq I/2$, then the optimal r for the firm to set given this constraint is zero.

As is well known, a punishment that fully deters bad behavior is costless. However, if a punishment does not fully deter bad behavior, it can be sufficiently costly to punish partially that it is better not to punish at all.

If $\bar{r}$ is small enough that the firm cannot prevent distortionary effort and the coefficient of absolute risk aversion is non-increasing, then a consequence of the CEO's being able to exert effort is that the owners want to *reduce* the quality of the signal. Observe the owners' optimization program is, from (6),

$$\max_Q Q\phi\left(\frac{-f}{Q}\right) - \Phi\left(\frac{-f}{Q}\right)f - u^{-1}\left(u_R - \int_{-\infty}^{\infty} u\big(\gamma Q z\big)\phi(z)dz + rx^e + c(x^e)\right)\,.$$

Given that $\partial x^e/\partial q > 0$ from Proposition 3 and, thus, $\partial x^e/\partial S > 0$, it follows that the optimal Q (*i.e.,* q) when the is less than when the CEO cannot expend effort (*i.e.,* when $x \equiv 0$). We can, therefore, conclude:

Proposition 5 *If the coefficient of absolute risk aversion for the CEO's utility function is non-increasing and it is impossible to block the CEO from exaggerating performance, then the optimal reporting quality is less than if the CEO were incapable of exaggerating performance (i.e., if it were possible to set $r \geq r^*$).*

4.2 Obscuring Effort

Now we turn to obscuring effort. Let the precision of the signal be $(1-b)q$, where b is efforts at obscuring the signal. Assume $\lim_{|b|\to 1} c'\big(|b|\big) = \infty$.

We again focus on pure-strategy equilibria. In such an equilibrium, owners and outsiders must correctly infer the b chosen by the CEO. Let $\hat{b}$ denote the value they infer. Define

$$H(b) = \frac{(1-b)q\tau}{(1-b)q+\tau}\,.$$

Observe $H'(b) < 0$.

Given that $\hat{b}$ is inferred effort and b is actual effort, the CEO chooses b to maximize

$$\int_{-\infty}^{\infty} u\left(\frac{\gamma H(\hat{b})}{\tau} s\right)\sqrt{\frac{H(b)}{2\pi}}\exp\left(-\frac{H(b)}{2}s^2\right)ds - C(b,r)$$
$$= \int_{-\infty}^{\infty} u\left(\frac{\gamma H(\hat{b})}{\tau\sqrt{H(b)}}z\right)\phi(z)dz - c(|b|) - rb\,. \quad (14)$$

Observe the integral in (14)—the CEO's benefit of obscuring the signal—is *decreasing* in b.[15] This might, at first, seem counter-intuitive in light of Lemma 2, which proved that a risk-averse CEO prefers a noisier signal to a less noisy signal. The difference is that in Lemma 2 everyone *knew* how noisy the signal is. Here, everyone (but the CEO) merely *infers* how noisy the signal is. What we've shown, then, is given that they are updating using their inferred precision, the CEO actually has an incentive to reduce the noise in the signal.

In equilibrium, as noted, $\hat{b} = b$. Hence, the equilibrium value of b, denoted b^e, is the solution to

$$-\frac{\gamma H'(b^e)}{\tau\sqrt{H(b^e)}}\int_{-\infty}^{\infty} u'\left(\frac{\gamma\sqrt{H(b^e)}}{\tau}z\right)z\phi(z)dz - c'\big(|b|\big)\mathrm{sign}(b) - r = 0\,. \quad (15)$$

Observe that the left-hand side of (15) is negative for $b > 0$. This establishes the following.

Proposition 6 *When the* CEO *can take actions, which are not observable to others, that make the signal noisier or less noisy and there is a non-zero penalty for making the signal noisier (*i.e., $r \geq 0$*), then the* CEO *takes actions to* reduce *the noisiness of the signal in equilibrium.*

Although the owners benefit from a less noisy signal (Lemma 1), they could always have chosen the equilibrium level of precision (*i.e.,* $(1-b^e)q$) themselves for free. If they did so and could somehow prevent the CEO from choosing a $b \neq 0$, then this would be welfare-improving

[15] Proof: Differentiating the integral with respect to $H(b)$ yields

$$-\frac{A}{H(b)}\int_{-\infty}^{\infty} u'\big(Az\big)z\phi(z)dz\,,$$

where the value of $A > 0$ is obvious. The integral is the covariance of $u'(Az)$ and z. Because $u'(Az)$ is decreasing in z, due to diminishing marginal utility, this covariance is negative; that is, the above expression is positive. Given that $H'(b) < 0$, it follows that the integral in (14) is decreasing in b.

relative to a regime in which they choose q and the CEO chooses and incurs the cost of b^e. Hence, all else equal, the owners are better off the fewer incentives the CEO has to set $b < 0$. With respect to policy, we have, therefore, the following.

Corollary 2 *Any regulations or measures that encourage the* CEO *to take actions that* improve *the quality of information relative to what the owners would wish to stipulate are welfare (profit)* reducing.

4.3 Concealing Information

In light of some recent corporate scandals, one concern is not that executives distort information, but rather that they conceal it. In this subsection, we briefly address what our analysis can say with respect to concealing information.

One question is whether the other players know if the CEO has concealed information? If so, then presumably they can punish the CEO for non-disclosure. Moreover, if it is common knowledge that the CEO knows the value of signals that he conceals, then an unraveling argument (Grossman, 1981) applies: Whatever the inferred expected value of unrevealed signals is, the CEO will have an incentive to reveal those above that expected value. Hence, the only equilibrium is one in which unrevealed signals are inferred to have the lowest possible value and the CEO is correspondingly induced to reveal all signals. We predict therefore that concealment is unlikely to be an issue if the other players know what the set of signals is.[16]

Suppose, in contrast, that the other players did not know what the complete set of signals was (*e.g.,* the set varies over time). If the CEO did not know the realized value when he deciding to reveal or conceal a signal, then he would wish to conceal all signals that he could: more signals means a more precise posterior estimate of his ability, which means greater career risk for him. Our model, thus, predicts that when (i) the CEO has discretion over what signals are revealed and (ii) must commit to reveal or conceal *prior* to learning the value of the signals, he will choose to commit to conceal all signals over which he has discretion.

If, instead, the CEO is not committed to a disclosure decision prior to learning the value of the signals, then he will be tempted to reveal those that are favorable to him. The other players will infer that they are getting a biased sample and, thus, make a downward

[16]One way the firm can set the profit-maximizing level of transparency would be to determine *ex ante* which signals will be released and which concealed. Of course, there must be *commitment* to this set *ex ante*, because otherwise, *ex post*, the CEO would be tempted to reveal those to-be-concealed signals if they reflected favorably upon him; but knowing this temptation exists, the unraveling argument would result in full revelation and, hence, *more* than the profit-maximizing level of transparency. We also note that if the set of possible signals is *unknown*, then regulation is difficult if not impossible.

adjustment. In this sense, the situation is similar to that of "exaggerating effort." The details of the analysis are, to be sure, different and await future analysis, but our general conclusions will generally hold.

5 Discussion and Conclusion

Most corporate governance reforms involve increased transparency. Yet, discussions of disclosure generally focus on issues other than governance, such as the cost of capital and product-market competition. The logic of how transparency potentially affects governance is absent from the academic literature.

We provide such analysis in this paper. We show that the level of transparency can be understood as deriving from the governance relation between the CEO and the board of directors. The directors set the level of transparency (*e.g.,* amount and quality of disclosure) and it is, thus, part of an endogenously chosen governance arrangement.[17]

Increasing transparency provides benefits to the firm, but entails costs as well. Better transparency improves the board's monitoring of the CEO by providing it with an improved signal about his quality. But better transparency is not free: The better able the market is to learn about the CEO's ability, the greater the risk to which the CEO is exposed. In our setting, the profit-maximizing level of transparency requires balancing these two factors.

Our model implies that there can be an optimal level of transparency. Consequently, attempts to mandate levels beyond this optimum decrease profits. Profits decrease both because managers will have to be paid higher salaries to compensate them for the increased career risk they face, and because greater transparency increases managerial incentives to engage in costly and counterproductive efforts to distort information. We emphasize that these effects occur in a model in which all other things equal, better information disclosure increases firm value.

One key assumption we make throughout the paper is that the board relies on the same information that is released to the public in making its monitoring decisions. Undoubtedly, this assumption is literally false in most firms, as the board has access to better information than the public. Nonetheless, CEOs do have incentives to manipulate information transfers to improve the board's perception of them, and this idea has been an important factor in a number of recent studies (see, *e.g.,* Adams and Ferriera, in press). In addition, in a number of publicized cases, boards have been kept in the dark except through their ability to access publicly disclosed documents; the circumstances in which boards must rely on

[17] We could have alternatively allowed for the level of transparency to be set through a bargaining process in which the CEO has bargaining power. Our substantive results are robust to such a change.

publicly available information are likely the cases in which the board-CEO relationship is most adversarial, and hence are the cases in which board monitoring is likely most important. Certainly, our basic assumption that the quality of public disclosure has a large impact on the board's ability to monitor management is plausible.

Our model is set in the context of a board that is perfectly aligned with shareholders' interests. One could equally well apply it to direct monitoring by shareholders. If there were an increase in the quality of available information either due to more stringent reporting requirements or because of better analysis (*e.g.,* of the sort performed by institutional investors or a more attentive press), then our model contains clear empirical predictions. In particular, it suggests that consequences of improved information would be increases in CEO salaries and the rate of CEO turnover. In fact, both CEO salaries and CEO turnover have increased substantially starting in the 1990s, with at least some scholars' attributing the increase to the higher level of press scrutiny and investor activism (see Kaplan and Minton, 2006). This pattern of CEO salaries and turnover is consistent with our model; moreover, it is consistent with the idea that better information has both costs and benefits through its impact on corporate governance.

Some issues remain. As discussed above, we have only scratched the surface with respect to issues of managerial concealment of information. We have abstracted away from any of the concerns about revealing information to rivals or regulators that earlier work has raised. We have also ignored other competing demands for better information, such as to help better resolve the principal-agent problem through incentive contracts (see *e.g.,* Grossman and Hart, 1983, Singh, 2004). Finally, we have ignored the mechanics of how the firm actually makes information more or less informative (*e.g.,* what accounting rules are used, what organizational structures, such as reporting lines and office organization, are employed, etc.). While future attention to such details will, we believe, shed additional light on the subject, we remain confident that our general results will continue to hold.

Appendix A: Technical Details and Proofs

Lemma A.1 *Given that $u(\cdot)$ is $\mathcal{L}^2$ for any normal distribution, it follows that $u'(\cdot)$ is $\mathcal{L}$ for any normal distribution; that is, that $\mathbb{E}\{u'(z)\}$ exists (is finite) if z is distributed normally.*

Proof: We wish to show that $d\mathbb{E}\{u(\lambda z)\}/d\lambda$ is finite evaluated at $\lambda = 1$. Observe

$$\mathbb{E}\{u(\lambda z)\} \equiv \int_{-\infty}^{\infty} u(\lambda z)\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{1}{2\sigma^2}(z-\mu)^2}dz$$
$$\equiv \int_{-\infty}^{\infty} u(\zeta)\frac{1}{\lambda\sigma\sqrt{2\pi}}e^{-\frac{1}{2(\lambda\sigma)^2}(\zeta-\lambda\mu)^2}d\zeta\,.$$

Hence,

$$\frac{d\mathbb{E}\{u(\lambda z)\}}{d\lambda} = -\frac{1}{\lambda}\int_{-\infty}^{\infty} u(\zeta)\frac{1}{\lambda\sigma\sqrt{2\pi}}e^{-\frac{1}{2(\lambda\sigma)^2}(\zeta-\lambda\mu)^2}d\zeta + \frac{1}{\lambda^3\sigma^2}\int_{-\infty}^{\infty} u(\zeta)\zeta(\zeta-\lambda\mu)\frac{1}{\lambda\sigma\sqrt{2\pi}}e^{-\frac{1}{2(\lambda\sigma)^2}(\zeta-\lambda\mu)^2}d\zeta\,.$$

The first integral is finite because $u(\cdot)$ is such that expected utility exists for all normal distributions. The second integral is the expectation of the product of two $\mathcal{L}^2$ functions with respect to normal distributions, $u(\zeta)$ and $\zeta(\zeta-\lambda\mu)$, and thus it is also integrable with respect to a normal distribution (see, *e.g.,* Theorem 10.35 of Rudin, 1964). Since both integrals are finite, their sum is finite. Hence, $d\mathbb{E}\{u(\lambda z)\}/d\lambda$ is everywhere defined, including at $\lambda = 1$. ■

Proof of Lemma 1: Observe

$$\frac{d}{dZ}\left(\frac{\sqrt{H}}{\tau}\phi(Z) - \Phi(Z)f\right) = -Z\frac{\sqrt{H}}{\tau}\phi(Z) - \phi(Z)f$$
$$= \left(\frac{f\tau\sqrt{H}}{\tau\sqrt{H}} - f\right)\phi(Z) = 0\,.$$

Hence,

$$\frac{\partial V}{\partial q} = \frac{1}{2\tau\sqrt{H}}\phi(Z)\frac{\partial H}{\partial q}$$
$$= \frac{1}{2\tau\sqrt{H}}\phi(Z)\frac{\tau^2}{(q+\tau)^2} > 0\,, \tag{16}$$

where the second fraction in the last line is $\partial H/\partial q > 0$. ■

Proof of Lemma 3: Employment requires that

$$u(w_1) + \mathbb{E}\big\{u(w_2)\big\} \geq u_R\,.$$

Because the owners make a take-it-or-leave-it offer and their well-being is decreasing in w_1, the constraint above must bind. From Lemma 2, an increase in q lowers the CEO's expected second-period utility, so his first-period utility must increase to maintain equality. Hence w_1 is increasing in q. ■

Proof of Proposition 1: If the CEO is risk neutral or $\gamma = 0$, then

$$\int_{-\infty}^{\infty} u\big(\gamma Qz + \delta\big)\phi(z)dz = u(\delta)\,.$$

Hence, (6) is increasing everywhere in q by Lemma 1. The optimal q is, thus, infinite.

Turning to condition (iii), the derivative of the right-hand side of (6) with respect to Q is

$$D(Q,f) \equiv \phi\left(\frac{-f}{Q}\right) + \frac{\int_{-\infty}^{\infty} u'(\gamma Qz + \delta)\gamma z\phi(z)dz}{u'\Big(u^{-1}\big(\int_{-\infty}^{\infty} u(\gamma Qz + \delta)\phi(z)dz\big)\Big)}\,.$$

Observe

$$\frac{\partial D(Q,f)}{\partial f} = \frac{\partial \phi(-f/Q)}{\partial f} = \frac{-f}{Q^2}\phi(-f/Q) \leq 0\,,$$

where the inequality follows because $f \geq 0$. It follows, therefore, if the optimal q is finite, then the optimal q is non-increasing in f. Hence, if the optimal q is finite when $f = 0$ it is finite for all f. Observe that $\lim_{q\to\infty} Q = 1/\sqrt{\tau}$. Hence, the optimal q is finite if

$$0 > D(1/\sqrt{\tau},0) = \phi(0) + \frac{\int_{-\infty}^{\infty} u'(\gamma z/\sqrt{\tau} + \delta)\gamma z\phi(z)dz}{u'\Big(u^{-1}\big(\int_{-\infty}^{\infty} u(\gamma z/\sqrt{\tau} + \delta)\phi(z)dz\big)\Big)}\,.$$

But this is just condition (iii). The result follows. ■

Proof of Proposition 2: Consider conclusion (i). It was shown in the proof of Proposition 1 that $dq/df \leq 0$. The result follows

Consider conclusion (ii). The marginal benefit of Q is unaffected by a change in γ. The derivative of the marginal cost of Q,

$$-\frac{d}{du}u^{-1}\left(u_R - \int_{-\infty}^{\infty} u(\gamma Qz + \delta)\phi(z)dz\right)\int_{-\infty}^{\infty} u'(\gamma Qz + \delta)\gamma z\phi(z)dz\,,$$

with respect to γ is

$$
\begin{aligned}
&\underbrace{-\frac{d^2}{du^2}u^{-1}\left(u_R - \int_{-\infty}^{\infty} u\big(w_2(z)\big)\phi(z)dz\right)}_{\substack{(+)\\ ①}}\underbrace{\int_{-\infty}^{\infty} -u'\big(w_2(z)\big)Qz\phi(z)dz}_{\substack{(+)\\ ②}} \\
&\qquad \times \underbrace{\int_{-\infty}^{\infty} u'\big(w_2(z)\big)\gamma z\phi(z)dz}_{\substack{(-)\\ ③}} - \underbrace{\frac{d}{du}u^{-1}\left(u_R - \int_{-\infty}^{\infty} u\big(w_2(z)\big)\phi(z)dz\right)}_{\substack{(+)\\ ④}} \\
&\qquad\qquad \times \int_{-\infty}^{\infty}\left(\underbrace{u''\big(w_2(z)\big)Q\gamma z^2}_{\substack{(-)\\ ⑤}} + \underbrace{u'\big(w_2(z)\big)z}_{\substack{(-)\\ ⑥}}\right)\phi(z)dz\,,
\end{aligned}
$$

where $w_2(z) \equiv \gamma Q z + \delta$. The expression is positive because

① $u(\cdot)$ is concave, so $u^{-1}(\cdot)$ is convex.

② Given $u(\cdot)$ is concave, $u'\big(w_2(z)\big)$ is a decreasing function of z. Hence, the covariance of $u'\big(w_2(z)\big)$ and z is negative; hence, $\mathbb{E}\{u'\big(w_2(z)\big)\,z\} < 0$.[18]

③ Same covariance argument as ②.

④ Because marginal utility is positive, inverse utility is increasing.

⑤ $u''(\cdot) < 0$ and $z^2 > 0$, so expectation of this term must be negative.

⑥ Same covariance argument as ②.

Hence, because the marginal cost of Q (equivalently, q) is increasing in γ, the result follows.

Finally, consider (iii). Suppose Q were optimal (maximized (6)). Observe,

$$\frac{\partial Q}{\partial \tau} = -\frac{q^2(2\tau + q)}{2H^{3/2}(q+\tau)^3} < 0\,. \tag{17}$$

As noted earlier, $\partial Q/\partial q > 0$. Hence, to restore Q to its optimal value, the response to an increase in τ must be an increase in q; that is, $dq/d\tau > 0$ (unless $q = \infty$). ■

[18]Recall that $\mathbb{E}\{z\} = 0$, so $\mathbb{E}\{z\,f(z)\}$ is the covariance of z and $f(z)$.

Proof of Proposition 3: Let $R(\cdot)$ denote the coefficient of absolute risk aversion (note $R(\cdot) = \rho$ if utility is CARA). By the usual comparative statics arguments and the fact that Q is monotonic in q, (i) holds if the derivative of (11) with respect to Q is positive. That derivative is

$$\int_{-\infty}^{\infty} \big(2\gamma\tau Q u'(\gamma Q z) + \gamma^2 \tau Q^2 z u''(\gamma Q z)\big)\phi(z)dz$$
$$= \gamma\tau Q \int_{-\infty}^{\infty} \big(2 - \gamma Q z\, R(\gamma Q z)\big) u'(\gamma Q z)\phi(z)dz\,.$$

Except if $Q = 0$ (in which case $x^e = 0$ and thus non-decreasing), this derivative has the same sign as

$$\int_{-\infty}^{\infty} 2u'(\gamma Q z)\phi(z)dz - \gamma Q \int_{-\infty}^{\infty} z \times R(\gamma Q z) u'(\gamma Q z)\phi(z)dz > 0\,. \tag{18}$$

Because $u'(\cdot) > 0$, the first integral is positive. The second integral is the covariance between $R(\gamma Q z)u'(\gamma Q z)$ and z).[19] The function $R(\gamma Q z)u'(\gamma Q z)$ is a non-increasing function of z, hence its covariance with z is non-positive. Consequently, the sign of the left-hand side expression in (18) is positive.

Similar calculations reveal that the derivative of (11) with respect to γ has the same sign as

$$\int_{-\infty}^{\infty} u'(\gamma Q z)\phi(z)dz - \gamma Q \int_{-\infty}^{\infty} z \times R(\gamma Q z) u'(\gamma Q z)\phi(z)dz > 0\,.$$

Hence, (ii) follows.

Observe

$$\tau Q^2 = \frac{q}{q+\tau}\,.$$

Hence, the derivative of (11) with respect to τ is

$$\int_{-\infty}^{\infty} \left(\frac{-\gamma q}{(q+\tau)^2} u'(\gamma Q z) + \gamma^2 \tau Q^2 z u''(\gamma Q z) \frac{\partial Q}{\partial \tau} \right) \phi(z)dz$$
$$= -\frac{\gamma q}{(q+\tau)^2} \int_{-\infty}^{\infty} u'(\gamma Q z)\phi(z)dz - \gamma^2 \tau Q^2 \frac{\partial Q}{\partial \tau} \int_{-\infty}^{\infty} z\, R(\gamma Q z)\big) u'(\gamma Q z)\phi(z)dz\,.$$

Given that $\partial Q/\partial \tau < 0$ (recall (17)), the same arguments used above imply this expression is negative provided $q > 0$, which it must be if $x^e > 0$. Hence (iii) follows.

Turning to result (iv), clearly the derivative of (11) is negative with respect to r.

[19] See footnote 18 for details.

Finally, consider the "moreover" claim. By Lemma A.1, the integral in (11) is finite. Let

$$r^* = \int_{-\infty}^{\infty} \gamma\tau Q^2 u'(\gamma Q z)\phi(z)dz\,.$$

Then, if $r > r^*$, (11) is negative for all $x \geq 0$, hence $x^e = 0$ if $r > r^*$. ■

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