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Optimal and Mandatory Transparency: Implications for Corporate Governance Regulation*

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Abstract

In light of recent corporate scandals, numerous proposals have been introduced for reforming corporate governance. This paper provides a theoretical framework through which to evaluate these reforms. We show that reforms that seek to improve the quality of information that is reported will reduce welfare, raise executive compensation, and inefficiently increase the rate of CEO turnover.

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1 Introduction

Corporate governance is again an area of interest. After the scandals at Enron, Worldcom, and other firms, many authors, politicians and even practitioners have called for regulatory changes designed to "improve" governance. Reforms such as Sarbanes-Oxley (SOX), the Cadbury recommendations, and numerous other proposals emphasize the attention that corporate governance has received in the public policy arena. Yet, the issue is in fact a very old one; if Smith (1776) did not write in such an elegant style, some of his *Wealth of Nations* could have come from a recent issue of *Fortune* or *Business Week*.[1] That complaints about corporate governance being "ineffective" have been heard since the beginnings of the corporate form suggest that corporate governance is not easily "fixed."

Much of the confusion concerning corporate governance likely occurs because discussions of governance issues typically assume implicitly governance is "out of equilibrium." That is, unlike other economic activity, commentators often talk as if the invisible hand has yet to guide governance to an equilibrium point. With such a mindset, "reforms," which consist of requiring all firms to adopt what seems to be a good idea or has been shown historically to be a trait associated with good-performing firms, can seem a sensible course of action. For example, the SOX reform requires a powerful audit committee on the board, and heightened personal consequences for directors if the firm engages in financial "misconduct." Yet, the consequences of firms voluntarily adopting these measures are likely to be quite different from the involuntary imposition of these measures on firms. Just as the labor-market equilibrium is quite different when firms voluntarily raise wages as opposed to when wages rise because of a government-imposed minimum wage, the resulting "improvement" in governance from a regulatory-imposed change could be very different from a voluntarily adopted change.

We illustrate this principle by considering the question of transparency. We choose transparency because it is a common component of governance reforms such as SOX, and also because it is relatively noncontroversial. While there has been much criticism of some of the elements of Sarbanes-Oxley, most observers take the view that mandated increased transparency is a good idea. After all, requiring firms to disclose more information should increase the ability of shareholders to make informed decisions, and in fact, Leuz and Verrecchia (2000) find that firms' cost of capital decreases when they increase transparency. Yet, if firms could increase value simply by increasing transparency, then it is surprising why before SOX was passed, firms did not voluntarily increase transparency to the mandated levels, and even beyond. In other words, why is it necessary to regulate transparency if in fact transparency increases value?

We argue that the answer to this question is that increasing disclosure en-

[1] "The directors of [joint stock] companies, however, being the managers rather of other people's money than of their own, it cannot well be expected, that they should watch over it with the same anxious vigilance [as owners] ... Negligence and profusion, therefore, must always prevail, more of less, in the management of the affairs of such a company" (Smith, 1776, p. 700).

tails costs as well as benefits. We focus on the role of disclosure in corporate governance, and in particular, on the effect it has on the contractual and monitoring relationship between the board and the CEO.[2] In our Coasian setup, mandated disclosure beyond the level voluntarily chosen by firms can reduce welfare. In particular, reforms that require a higher level of disclosure can increase executive compensation dramatically, and inefficiently increase the rate of CEO turnover.[3]

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 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.[4] We consider two 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 make the signal noisier (and consequently their jobs more secure); we denote such actions as "obscuring effort." 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 their disclosure can reduce welfare if they have the push the CEO to disclose more than the optimal quantity of information.

We discuss the model's implications and conclude in Section 5. Proofs not

[2]In doing so, we abstract from other potential costs of disclosure to a firm, in particular, potential competitive disadvantages resulting from rivals knowing more about the firm.

[3]In fact, firms sometimes find disclosure to be so costly that they redact information from their financial statements, even though such redactions increase their cost of capital (see Verrecchia and Weber, 2006).

[4]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.

given in the text can be found in the appendix.

2 Structure of the Problem

Among the key elements of Sarbanes-Oxley and other reform proposals are increased disclosure requirements. Sarbanes-Oxley, for example, requires increased reporting of off-balance-sheet financing and special-purpose entities (*e.g.,* the activities that Enron allegedly used to deceive investors). Intuitive arguments, formalized by Diamond and Verrecchia (1991), suggest that the cost of capital should decrease when firms provide better information about their companies. Indeed, Leuz and Verrecchia (2000) find evidence suggesting that firms' cost of capital does decrease when they *voluntarily* switch to a reporting regime that requires greater disclosure.

However, it is not obvious that just because firms appear to benefit when they *voluntarily* increase disclosure that all firms should be required to have higher disclosure. In particular, higher disclosure likely leads to a behavioral response by market participants; the overall welfare change will incorporate the impact of these responses. To evaluate the effect of mandated changes in transparency, it is important to have a model of disclosure in which participants' responses to disclosure changes are endogenously determined inside the model.[5]

We present such a model below. The focus of the 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, which provides him incentives to do what 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

[5] The *endogenous* determination of disclosure is one of the dimensions that differentiates this paper from Goldman and Slezak (in press); in their article they treat disclosure rules as being set exogenously.

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 at or after his tenure with the firm or if we assumed the payoffs contained no more information than is contained in the signal.

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, given the sorts of reforms considered here, 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 is to *benefit* shareholders, 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.[6]

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.

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. We discuss this issue below ...

In our analysis, we will assume the CEO is risk averse. 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,

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

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

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.

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

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

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 y 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

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

[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 $\lim_{\rho\downarrow 0} u(w) = w$.

[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.

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,

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

and what they expect to receive if they dismiss him,

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

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.*

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*.

Assume that 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. Assume future employers are risk averse, 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 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 be noisier rather than less noisy.

3 Optimal Reporting Quality

As demonstrated above, the firm's owners prefer higher reporting quality to lower reporting quality *ceteris paribus*, while the CEO prefers lower reporting quality to higher reporting quality *ceteris paribus*. 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) $$\phi(0) < \frac{-\int_{-\infty}^{\infty} u'\left(\frac{\gamma z}{\sqrt{\tau}} + \delta\right)\gamma z \phi(z)dz}{u'\left(u^{-1}\big(u_R - \int_{-\infty}^{\infty} u\left(\frac{\gamma z}{\sqrt{\tau}} + \delta\right)\phi(z)dz\big)\right)}.$$

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

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

Consequently, condition (iii) of Proposition 1 is

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

Expression (8) offers some ability to calibrate 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. This implies a $\rho \approx 6.922 \times 10^{-7}$. 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 *The following comparative statics hold:*

(i) The optimal level of the quality of reporting, q, is non-increasing in the firing cost, f; moreover, it is strictly decreasing in the disruption cost if the optimal reporting quality is an interior solution.

(ii) The optimal level of the quality of reporting is non-increasing in the sensitivity of future CEO salary to the signal, γ; moreover, it is strictly decreasing in γ if the optimal reporting quality is an interior solution.

(iii) The optimal level of the quality of reporting is non-decreasing in the precision of the prior estimate of CEO ability, τ; moreover, it is strictly increasing in the precision of the prior estimate if the optimal reporting quality is not infinite.

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.*

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

[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.

[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.

boost the value of the signal y *ceteris paribus*. Obscuring effort is effort designed to make the signal y noisier *ceteris paribus*.

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] As is typical, 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:

- 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 $\tilde{y} = y + x$.

[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.

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 $y = \tilde{y} - \hat{x}$ 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

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

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 $\hat{x} = x^e$:

$$0 \geq \int_{-\infty}^{\infty} \frac{\gamma H}{\tau} u'\left(\frac{\gamma H}{\tau} y\right)\sqrt{\frac{H}{2\pi}}\exp\left(-\frac{H}{2}y^2\right)dy - \frac{\partial C(x^e,r)}{\partial x}$$
$$= \int_{-\infty}^{\infty} \gamma\tau Q^2 u'(\gamma Q z)\phi(z)dz - r - c'(x^e)\,, \qquad (11)$$

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 $u'(\gamma Sz)$) 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

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

The constraint is binding in equilibrium, hence

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

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

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

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
>
> $$I \equiv \gamma Q^2 \tau \exp\left(\gamma^2 Q^2/2\right).$$
>
> 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. But if a punishment doesn't fully deter bad behavior, then it is costly. It can be so costly, that it is better not to punish than to punish.

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

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

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

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

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.*

[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.

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

5 Discussion and Conclusion

In response to the spate of recent corporate scandals, countries have passed a number of "reforms" aimed at improving corporate governance. Economics, despite a long history of studying regulation, has been slow in the case of governance reforms to provide a conceptual framework for their evaluation. Such a framework requires treating governance institutions as endogenous, so that we can evaluate behavioral changes in response to a new governance restriction. We argue here that such an endogenous governance approach is a useful way to understand how firms decide on an optimal level of transparency, as well as the implications of attempts to regulate transparency.

Increasing transparency provides benefits to the firm, but entails costs as well. In addition to the commonly discussed competitive disadvantages associated with providing information to a firm's competitors, transparency also affects the firm's governance. The firm's disclosure affects the ability of boards to monitor the CEO, so that changing a firm's disclosure policy effectively changes the contracts between executives and firms. In this setting, optimal disclosure is profit-maximizing because it maximizes the rents associated with this contract.

Our model is an extension of the Holmstrom (1999) career-concerns model. In our model, a CEO is evaluated by his board that receives a signal about the CEO's performance. The board will replace the CEO if, by its best estimate, a replacement CEO is expected to yield greater profits than the current one (once transition costs are accounted for). The CEO can exert effort to distort the signal the board receives and has incentives to do so because of the private benefits associated with how better values of the signal improve his future employment prospects. We assume that the board can specify *ex ante* how informative a signal the board will receive and the informativeness of the signal is assumed to be known at the time the CEO agrees to a contract.

The model implies that there is an optimal level of transparency. Attempts to mandate levels beyond this optimal decrease welfare. This welfare decrease occurs both because managers will have to be paid higher salaries to compensate them for the increased career risk they face, and also because high levels of disclosure will induce managers 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 for example 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 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 discussion of governance regulation is a special case of the Coase Theorem applied to contract regulation. Given the contractual nature of the firm, governance regulation is just a special case of contract regulation. Contract regulation has been extensively studied and Hermalin and Katz (1993) have established a set of conditions under which restrictions on contracts can potentially improve welfare. These authors show that regulations on contracts can improve welfare only if: 1) there is asymmetric information between the parties at the time of contracting; 2) the contract has externalities on third parties; or 3) courts can impose a remedy or penalty not available to the parties privately. While condition 3) possibly holds for the provision of Sarbanes-Oxley that holds executives personally liable for accounting misstatements, it is hard to see how general restrictions on transparency are likely to fall into these categories. Thus, our conclusions about the undesirability of regulating transparency can be seen as a consequence of a more general point about contract regulations.

For many years, people have tried to make the case that something is "wrong" with corporate governance and we should "reform" it. This view ignores the reality that the observed system of governance has been around for a long time and appear to be the market solution. Many proposed governance reforms, such as increased disclosure, or requirements about the composition of the board or CEO salaries, could have been chosen by the market but in fact were not. Models of endogenous governance provide a start to understanding the reasons why the market might not have picked a contracting arrangement that, on its face, seems appealing. This paper provides a first step in this type of analysis; we expect that, in the future, more such work will greatly improve our understanding of governance reform.

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

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

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

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

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

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

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,

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

with respect to γ is

$$-\underbrace{\frac{d^2}{du^2}u^{-1}\left(u_R-\int_{-\infty}^{\infty}u\big(w_2(z)\big)\phi(z)dz\right)}_{\substack{(+)\\ ①}}\underbrace{\int_{-\infty}^{\infty}-u'\big(w_2(z)\big)Qz\phi(z)dz}_{\substack{(+)\\ ②}}$$

$$\times\underbrace{\int_{-\infty}^{\infty}u'\big(w_2(z)\big)\gamma z\phi(z)dz}_{\substack{(-)\\ ③}}-\underbrace{\frac{d}{du}u^{-1}\left(u_R-\int_{-\infty}^{\infty}u\big(w_2(z)\big)\phi(z)dz\right)}_{\substack{(+)\\ ④}}$$

$$\times\int_{-\infty}^{\infty}\left(\underbrace{u''\big(w_2(z)\big)Q\gamma z^2}_{\substack{(-)\\ ⑤}}+\underbrace{u'\big(w_2(z)\big)z}_{\substack{(-)\\ ⑥}}\right)\phi(z)dz\,,$$

where $w_2(z)\equiv\gamma Qz+\delta$. 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, $\mathbb{E}\{u'\big(w_2(z)\big)\,z\}<0$.[16]

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 $q=\infty$). ■

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

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

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

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

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

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

Because $u'(\cdot) > 0$, the first integral is positive. The second integral is the covariance between $R(\gamma Qz)u'(\gamma Qz)$ and z).[17] The function $R(\gamma Qz)u'(\gamma Qz)$ 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

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

Hence, (ii) follows.

Observe

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

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

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

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.

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

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

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

[17]See footnote 16 for details.

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