Leaks, disclosures and internal communication*

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Abstract

We study how leaks affect a firm’s communication decisions and real efficiency. A privately informed manager strategically chooses both public disclosure and internal communication to employees. Public disclosure is noisy, but in the absence of leaks, internal communication is perfectly informative because it maximizes employee coordination and efficiency. We show that the possibility of public leaks distorts these choices: a higher likelihood of leaks worsens internal communication and can reduce real efficiency, despite increasing public disclosure by the manager. We discuss the implications of our results for recent regulations that protect and encourage whistleblowers in financial markets.

Keywords: leaks, whistleblower, disclosure, internal communication, efficiency

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1 Introduction

\textit{Publicity is justly commended as a remedy for social and industrial diseases. Sunlight is said to be the best of disinfectants; electric light the most efficient policeman.}

— Louis Brandeis, Other People’s Money – and How Bankers Use It (1914)

Regulators encourage public leaks of internal information to deter wrongdoing by firms. For example, the SEC’s Dodd-Frank Whistleblower Program is designed to improve stakeholder protection and provide incentives to whistleblowers in financial markets.\footnote{The SEC Whistleblower Program is a recent addition to a number of other, similar financial market regulations (e.g., US Whistleblower Protection Act (1989), Section 806 of Sarbanes-Oxley Act (2002), Whistleblower Protection Enhancement Act (2007)). See the U.S. Securities and Exchange Commission, 2016 Annual Report to Congress on The Dodd-Frank Whistleblower Program (https://www.sec.gov/files/owb-annual-report-2016.pdf) for more details.} Since inception, the program has awarded more than $111 million to 34 whistleblowers, and has led to SEC enforcement actions with sanctions in excess of $584 million. In fiscal year 2016 alone, the SEC’s Office of the Whistleblower received over 4,200 tips and awarded over $57 million as part of the program.

While these policies are arguably effective at detecting unlawful behavior by market participants, they can also have unintended consequences. By increasing the likelihood that internal communication is leaked publicly, these policies may distort how a firm’s employees communicate with each other within the firm and to market participants. Specifically, we show that increasing the likelihood of leaks leads to more public disclosure, but coarser internal communication. Moreover, the overall effect of leakage on real (allocative) efficiency is not monotonic, and depends on the ex-ante informativeness of internal communication.

We consider a setting where a manager, who is privately informed about the firm’s fundamentals, strategically chooses both public disclosure and internal communication. Because public disclosures affect the short-term stock price, the manager has an incentive to withhold negative news about fundamentals from the public. However, she prefers her internal communication to be as informative as possible, since this improves the extent to which her employees can coordinate on the appropriate action for the firm. We assume that the manager’s public disclosures are verifiable, but that internal communication is cheap talk.\footnote{These assumptions reflect the notion that while public disclosures to financial markets often consist of “hard” information (e.g., earnings reports and guidance), internal communication is likely to be “softer,” and more difficult to verify or audit. However, our analysis in Appendix B suggests that many of our conclusions are qualitatively similar if both external and internal communication is verifiable.}

In Section 3, we show that the possibility of leakage introduces a tradeoff between internal and external communication. On the one hand, the benefit from withholding negative news
from the public is lower since it may be leaked anyways. As a result, more leakage leads
the manager to publicly disclose more information. On the other hand, conditional on not
disclosing information publicly, the possibility of leaks creates an endogenous incentive for
the manager to distort her message to employees. In turn, this makes it more difficult to
sustain informative communication internally, and so more leakage is associated with less
informative internal communication.

In our model, real efficiency is driven by the degree of coordination among employees.
As a benchmark, Section 4 considers the case when the manager’s incentives are aligned
with those of the employees. In this case, we show efficiency is maximized when there are
no leaks: internal communication is perfectly informative, and as a result, coordination is
maximized. An increase in leakage has two offsetting effects on efficiency. On the one hand,
internal communication is coarser, which reduces the information available to employees and,
consequently, makes coordination more difficult. On the other hand, there is more public
disclosure, which provides more information to employees and, thereby, improves coordina-
tion. Initially, the first effect dominates and so efficiency decreases with leakage. However,
when the probability of leaks is sufficiently high, internal communication is uninformative
and the second effect takes over. As a result, when the likelihood of leakage is very high,
real efficiency increases with leakage.

Since the manager’s incentives are aligned with those of the employees, our benchmark
model is not well suited to study the disciplinary role of whistleblowing. To capture the
notion that leaks may discourage managers from behaving badly, in Section 5 we extend the
analysis to the case in which there are conflicts of interest between the manager and the
firm’s other stakeholders. Specifically, we assume that the manager’s preferences are biased,
so that the actions she would like her employees to take do not maximize shareholder value.
As in the benchmark, leaks introduce a distortion in internal communication. However, in
this case, we show that leaks can have a disciplinary effect: real efficiency can be higher in
the presence of leaks than in the absence of leaks. Because the manager’s incentives are not
aligned with the employees’, internal communication is coarse even in the absence of leakage.
When the probability of a leak is sufficiently high, the impact of the more public disclosure
offsets the decrease in efficiency due to worse internal communication, and overall efficiency
can be higher as a result.

Our analysis suggests a novel channel through which regulatory policy towards whistle-
blowers can affect firm behavior, and offers a number of implications that we discuss in
Section 6. A higher likelihood of leakage should be associated with more public disclosure,
but less informative internal communication. These effects should be especially pronounced
in firms where compensation contracts over-weight short-term performance (e.g., through

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higher stock / option grants). An important implication of our results is that policies that increase leakage (by encouraging whistleblowing) affect firms differently depending on firm governance and culture. While such regulations may benefit firms with severe conflicts of interest and poor internal communication, they reduce real efficiency in firms with good governance and internal communication. As a result, when evaluating the effectiveness of regulatory policies, it is important to account for this cross-sectional variation.

Our model builds on the seminal work by Crawford and Sobel (1982) on cheap talk and by Dye (1985) and Jung and Kwon (1988) on strategic verifiable disclosure. Our paper is part of a larger literature that studies communication in settings with a single sender and multiple receivers (e.g., Farrell and Gibbons (1989), Newman and Sansing (1993) and Goltsman and Pavlov (2011)). However, much of this literature has restricted attention to cheap talk communication. In contrast, the sender engages in different types of communication in our model: public disclosures are verifiable but internal communication is via cheap talk. Moreover, the incentives for the two types of communication are interdependent due to the possibility of leakage. The manager’s incentive to distort her cheap-talk message to employees arises endogenously because her internal communication can be leaked publicly, and such leaks affect the short-term stock price.

2 Model

There are three dates \( t \in \{1, 2, 3\} \), and three types of players: a manager \( M \), a continuum of shareholders \( s \in S \), and a continuum of employees \( i \in I \). The value of the firm, \( V \), depends on its fundamentals \( \theta \), and the action \( x_i \) of its employees. We assume that the value is increasing in both fundamentals and the degree of coordination across its employees. Specifically, suppose the firm’s value is given by:

\[
V = \theta - \beta \int_{i \in I} (x_i - \theta)^2 di,
\]

where \( \beta > 0 \) measures the relative importance of coordination within the firm. For tractability, suppose that \( \theta \) is uniformly distributed between \( l \) and \( h > l \) i.e., \( f(\theta) = \frac{1}{h-l} \).

Date \( t = 1 \). At date \( t = 1 \), the manager observes fundamentals \( \theta \) with probability \( \pi \), where the indicator variable for this event is denoted by \( \xi \in \{0, 1\} \) (so that \( \Pr(\xi = 1) = \pi) \).

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\(^3\)The linear-quadratic specification for \( V \) and the distributional assumption for \( \theta \) are made for tractability. We expect the qualitative nature of our results to survive in more general settings, but a formal analysis is not immediately tractable.

\(^4\)Since \( \pi < 1 \), voluntary disclosure is not fully unraveling. This approach has been extensively adopted in the literature starting with Dye (1985) and Jung and Kwon (1988).
An informed manager chooses whether to publicly disclose her information \((d = \theta)\) or not \((d = \emptyset)\). This public disclosure is observable by both shareholders and employees. Moreover, while the manager can choose not to publicly disclose her information, we assume she cannot publicly lie, i.e., such external disclosures are verifiable. The manager can also internally communicate to her employees via a cheap-talk message \(m\). This internal communication is not verifiable (i.e., the manager can lie) and not immediately observable to shareholders.

The nature of public communication reflects the notion that managerial disclosures to financial markets often consist of “hard,” verifiable information (e.g., earnings statements, management guidance). In contrast, one might expect that internal communication is “softer” and hence more difficult to verify or audit, and thus, we model it as cheap talk. While this difference is an empirically relevant feature of the model, our results are robust to other specifications. For instance, in Appendix B, we show that the model’s implications are qualitatively similar in a setting where both internal and external communication is verifiable.

**Date** \(t = 2\). At date \(t = 2\), employees optimally choose their action to maximize the value of the firm. In particular, employee \(i\) chooses action \(x_i\) to maximize:

\[
x_i \equiv \arg \max_x \mathbb{E}[V|m,d]
\]

\[
\Rightarrow x_i = \mathbb{E}[\theta|m,d].
\]

Importantly, the message \(m\) to employees may be leaked to shareholders with probability \(\rho\), where the indicator variable for this event is denoted by \(\lambda \in \{0,1\}\). Given their information, shareholders set the price \(P\) of the firm equal to its conditional expectation:

\[
P = \mathbb{E}[V|d,\lambda \times m].
\]

**Date** \(t = 3\). At the final date, the value of the firm is publicly revealed. The manager receives a payoff \(U\) which depends on a weighted average of the date-2 price and the final value \(V\) of the firm:

\[
U = (1 - \delta) P + \delta V,
\]

where \(\delta \in [0,1)\). We assume that \(\delta < 1\) to ensure that the manager’s payoff depends on the price \(P\), and so her disclosure policy is non-trivial. Specifically, when \(\delta = 1\), the manager can only affect her payoff through the information she conveys to her employees. As a result, she is indifferent between a large class of disclosure / messaging strategies, as long as they ensure employees are perfectly informed about \(\theta\).\(^5\)

\(^5\)For instance, she is indifferent between disclosing \(\theta\) publicly, or not disclosing \(\theta\) to shareholders, but
Moreover, to ensure that an informed manager has an incentive to withhold information for sufficiently low fundamentals, we make the following assumption.

**Assumption 1.** Assume that \( \frac{h+l}{2} - \beta \frac{(h-l)^2}{12} > l \).

When the manager is uninformed about fundamentals, the unconditional expected value of the firm is given by

\[
E[V] = E[\theta] - \beta E[(\theta - E[\theta])^2] = \frac{h+l}{2} - \frac{\beta}{12} (h-l)^2.
\]

(6)

In contrast, by revealing her information perfectly to her employees (and thereby enabling perfect coordination), a manager of type \( \theta = l \) can ensure that the firm has value of \( V = l \). Assumption 1 ensures that a manager of the lowest type (i.e., \( \theta = l \)) would strictly prefer to withhold her type and be pooled with the uninformed managers.

We focus on pure strategy, Perfect Bayesian equilibrium. In particular, an equilibrium is characterized by: (i) communication strategies \( \{d, m\} \) that maximize the manager’s expected utility \( U \) at date 1, (ii) optimal employee actions \( x_i \) that maximize the conditional expected value of the firm, (iii) a pricing rule given by (4), and (iv) participants’ beliefs that satisfy Bayes’ rule wherever it is well-defined. Since the manager communicates with her employees using cheap talk, there always exist equilibria that feature babbling. We shall instead focus on characterizing equilibria that feature informative cheap-talk communication between the manager and employees.

**Remark 1.** The manager’s payoff specification in (5) implies that there is no explicit conflict of interest between the manager and the shareholders or employees. This serves as a useful benchmark in which to study the effects of leakage on the manager’s external and internal communication. In Section 5, we relax this assumption by allowing for biases in the manager’s payoffs that explicitly distort her incentives relative to those of the other stakeholders in the firm.

**Remark 2.** In practice, leaks often reveal negative information about the firm. Our model captures this feature, since in equilibrium, the manager withholds relatively negative information, which is the information that may be leaked to the market. However, a limitation of our model is that the probability of leakage \( \rho \) is constant, and does not depend on either the fundamentals \( \theta \) of the firm, or the message \( m \) sent by the manager. This is primarily for tractability. Appendix B considers a variation of the model in which an employee’s decision to leak the manager’s message is an endogenous decision. Moreover, the analysis studies the robustness of the cheap-talk assumption by instead assuming that internal communication is disclosing it perfectly to employees.
also verifiable. While the analysis of this alternative model is not nearly as tractable as our benchmark model, we find that a number of our conclusions are robust to these alternative specifications. First, internal communication is perfectly informative and real efficiency is maximized in the absence of leakage. Second, increasing the likelihood of leaks can improve public disclosure but worsen internal communication. Finally, real efficiency may decrease with an increase in the likelihood of leakage.

3 Equilibrium Communication and Leakage

In this section, we characterize the equilibrium communication by the manager. We begin with the benchmark case where there is no possibility of leakage (i.e., $\rho = 0$), and show that in this case, an informed manager optimally chooses to perfectly reveal her information to her employees. We then consider the case with leakage (i.e., $\rho > 0$). The possibility that her internal communication is leaked to shareholders creates an endogenous incentive for the manager to mislead employees — all else equal, she would prefer to report that fundamentals are higher than they actually are. In equilibrium, this leads to noisy internal communication: the manager’s cheap-talk message is only partially informative.

3.1 Preliminaries

We first characterize an uninformed manager’s strategy. Since external disclosures to shareholders are verifiable, an uninformed manager must publicly report that she is uninformed i.e., $d = \emptyset$. Moreover, conditional on her beliefs, the value of the firm is maximized when

$$\max_{x_i} \mathbb{E} [V(\theta, \{x_i\})] = \max_{x_i} \mathbb{E} [\theta] - \beta \mathbb{E} \left[ \int_i (\theta - x_i)^2 \, di \right]$$

$$\Rightarrow x_i^* = \mathbb{E} [\theta] = \frac{h+l}{2}. \hspace{1cm} (8)$$

But the manager can induce this action by revealing to her employees that she is uninformed i.e., $m = \{\theta \in [l, h]\}$. This gives us the following result.

Lemma 1. In any equilibrium, an uninformed manager discloses that she is uninformed to shareholders and employees i.e., $d = \emptyset$ and $m = \{\theta \in [l, h]\}$.

The above result implies that in the following analysis, we can characterize the equilibrium by specifying the strategy of the informed manager, since an uninformed manager has the same communication strategy in equilibrium.
Next, consider an informed manager who observes a realization $\theta$ of fundamentals. Since external disclosures are verifiable and observable by both shareholders and employees, a disclosure of $\theta$ implies that $P = \theta$ and

$$V = \theta - \beta \int_{i \in I} (\mathbb{E}[\theta|\theta] - \theta)^2 di = \theta,$$

so that the manager’s payoff from disclosing $\theta$ is $U_D(\theta) = \theta$, irrespective of whether or not there is a leak. Moreover, this implies that the manager’s optimal disclosure policy must follow a cutoff rule: she should disclose $\theta$ only when $\theta \geq q$ for some disclosure threshold $q$. \footnote{We assume that the manager discloses $\theta$ when $\theta = q$.}

This leads to the following observation.

**Lemma 2.** In any equilibrium, an informed manager’s optimal disclosure decision follows a cutoff strategy.

Next, we turn to the benchmark case without leakage.

### 3.2 Equilibrium with no leakage

Suppose there is no possibility of leakage i.e., $\rho = 0$. Since the message to her employees will not be revealed to the shareholders, an informed manager has no incentive to distort her internal communication. In this case, we have the following result.

**Proposition 1.** Suppose Assumption 1 holds and there is no leakage i.e., $\rho = 0$. Let

$$q^{\text{NoLeak}} = h - (h - l) \frac{6 - \sqrt{6(1 - \pi)(6 - \pi\beta(h - l))}}{6\pi}. \quad (10)$$

Then, there exists an equilibrium in which an informed manager (i) discloses $\theta$ to shareholders if and only if $\theta \geq q^{\text{NoLeak}}$, and (ii) perfectly reveals $\theta$ to her employees.

In the equilibrium described above, the manager perfectly reveals her information to her employees, and so the value of the firm (conditional on the manager being informed) is $\theta$. The overall payoff to the manager depends on whether she discloses $\theta$ to shareholders. If she does, then her payoff is given by

$$U_D(\theta) = (1 - \delta) P + \delta \theta = \theta,$$

since $P = \mathbb{E}[V|\theta] = \theta$. On the other hand, by not disclosing her information publicly, she
can pool with the uninformed managers, which yields a price

\[ P_{ND} (q^{NoLeak}) = \frac{(1 - \pi) \mathbb{E} \left[ V | \xi = 0 \right] + \pi \Pr (\theta < q^{NoLeak}) \mathbb{E} \left[ V | \xi = 1, d = \emptyset \right]}{1 - \pi + \pi \Pr (\theta < q^{NoLeak})} \]  

(12)

and an overall payoff of

\[ U_{ND} (\theta) = (1 - \delta) P_{ND} + \delta \theta. \]  

(13)

The equilibrium disclosure cutoff \( q^{NoLeak} \) is pinned down by the natural indifference condition: a manager with fundamentals \( \theta = q^{NoLeak} \) is indifferent between disclosing her information to shareholders and not:

\[ U_{ND} (q^{NoLeak}) = U_D (q^{NoLeak}). \]  

(14)

As we show in the proof of Proposition 1, Assumption 1 ensures the existence of such a cutoff \( q^{NoLeak} \in [l, h] \).

The cutoff threshold \( q^{NoLeak} \) is decreasing in \( \beta \) and \( \pi \). All else equal, a higher \( \beta \) reduces the value of an “uninformed” firm (i.e., the expected value of the firm conditional on the manager being uninformed), and consequently decreases the benefit of pooling with the uninformed managers. This leads an informed manager to disclose more often. Similarly, when \( \pi \) is higher, the benefit from not disclosing \( \theta \) is lower since conditional on no disclosure, shareholders attribute a higher likelihood of the manager being informed. In the limit, when \( \pi = 1 \), shareholders assume that the manager is informed irrespective of whether she discloses or not, and as a result, there is no benefit from withholding information i.e., \( q^{NoLeak} = l \).

Proposition 1 characterizes the equilibrium with the most informative internal communication. Since the manager uses cheap talk to communicate with her employees, there exist other equilibria in which internal communication is coarser. However, the above result establishes that, in the absence of leaks, perfectly informative cheap talk can be sustained in equilibrium. Next, we show that this is no longer the case when there is leakage.

### 3.3 Equilibrium with leakage

The possibility that messages to her employees may be leaked to shareholders distorts an informed manager’s external and internal communication decisions. On the one hand, the likelihood of a leak reduces the manager’s incentives to withhold information from shareholders. On the other hand, the possibility of a leakage creates an incentive for the manager to distort her message to employees: because the message will be leaked to shareholders with positive probability, she has an incentive to bias it upwards relative to the true \( \theta \). This
incentive makes it impossible to sustain fully informative cheap talk between the manager and her employees. However, as the following result establishes, there may exist equilibria with partially informative cheap talk.

**Proposition 2.** Suppose Assumption 1 holds and there is leakage i.e., $\rho > 0$. Then there exists a positive integer $\bar{N} \geq 1$ such that, for every $N$ with $1 \leq N \leq \bar{N}$, there exists an equilibrium characterized by cutoffs $l = a_0 < \ldots < a_N = q_{Leak}^N \leq h$, where an informed manager (i) discloses $\theta$ to shareholders if and only if $\theta \geq q_{Leak}^N$, (ii) perfectly reveals $\theta$ to her employees if and only if $\theta \geq q_{Leak}^N$, and (iii) reports only the partition $\theta \in [a_n, a_{n+1}]$ to her employees when $\theta < q_{Leak}^N$. There always exists an equilibrium for $N = 1$. Moreover, for a fixed $N \leq \bar{N}$, the disclosure cutoff $q_{Leak}^N$ is unique.

We leave the details of the proof to the appendix, but provide an outline of the steps here. As in the case with no leakage, note that conditional on disclosure, the value of the firm and its price are given by $\theta$, since both shareholders and employees can observe fundamentals perfectly. In this case, the payoff to the manager is $U_D(\theta) = \theta$.

In contrast to the case with no leakage, however, when the manager does not disclose her signal to shareholders, her communication to employees is also coarse. Instead of revealing $\theta$ to her employees, the manager only reports the partition $[a_n, a_{n+1}]$ that it is in. This implies that, conditional on no disclosure, the value of the firm is given by

$$V_I(\theta) = \theta - \beta \left( \frac{a_n + a_{n+1}}{2} - \theta \right)^2, \quad (15)$$

which reflects the lack of coordination within the firm due to less informative internal communication.

The price of the firm depends on whether or not a leak happens. Conditional on a leak, the price is given by the conditional expectation of the value of the firm, given that $\theta$ is in the reported partition:

$$P_{I,L} = \mathbb{E} \left[ V_I(\theta) \mid \theta \in [a_n, a_{n+1}] \right]. \quad (16)$$

Conditional on no leakage, the price reflects a weighted average of two possible cases: (i) the manager is uninformed (i.e., $\xi = 0$) or (ii) the manager is informed, did not disclose and the information was not leaked (i.e., $\xi = 1, d = \emptyset$ and $\lambda = 0$). As a result, the price conditional on no leakage is given by

$$P_{NL} = \frac{(1 - \pi) \mathbb{E} \left[ V \mid \xi = 0 \right] + \pi (1 - \rho) \Pr (\theta < q_{Leak}^N) \mathbb{E} \left[ V \mid \xi = 1, d = \emptyset, \lambda = 0 \right]}{1 - \pi + \pi (1 - \rho) \Pr (\theta < q_{Leak}^N)}.$$  \quad (17)

By not disclosing her information, the expected price that the manager gets is therefore
given by:

\[ P_{ND} = \rho P_{I,L} + (1 - \rho) P_{NL}, \]  

(18)

and so her expected payoff from not disclosing is:

\[ U_{ND}(\theta, [a_n, a_{n+1}]) = (1 - \delta) P_{ND} + \delta \left( \theta - \beta \left( \frac{a_n + a_{n+1}}{2} - \theta \right)^2 \right). \]  

(19)

Finally, we can use the manager’s indifference between disclosure and no disclosure at \( \theta = q^{\text{Leak}}_N \) to characterize the disclosure cutoff i.e.,

\[ U_D(q^{\text{Leak}}_N) = U_{ND}(q^{\text{Leak}}_N, [a_{N-1}, q^{\text{Leak}}_N]), \]  

(20)

and indifference between adjacent messages \( \{\theta \in [a_{n-1}, a_n]\} \) and \( \{\theta \in [a_n, a_{n+1}]\} \) at \( \theta = a_n \) i.e.,

\[ U_{ND}(a_n, [a_{n-1}, a_n]) = U_{ND}(a_n, [a_n, a_{n+1}]), \]  

(21)

to characterize the sequence of cheap-talk cutoffs \( \{a_n\}_{n=0}^N \). The sufficient condition for the existence of these cutoffs produces an upper bound on the informativeness of the internal communication.

Proposition 2 highlights the main channel through which leaks affects the manager’s communication strategy. Because her internal communication to employees is leaked to shareholders with positive probability, the manager has an incentive to distort her message in an effort to push the price up. This misalignment in incentives makes fully informative cheap talk impossible, and as a result, internal communication in equilibrium is coarse. As we discuss in the next section, this can lead to a decrease in real efficiency.

4 Comparative statics and real efficiency

In this section, we first characterize how the informativeness of internal and external communication changes with the parameters of the model. This analysis reveals a key tradeoff between internal and external communication in our setting. An increase in the probability of leaks decreases the cost of public disclosure, but also makes informative internal communication more difficult to sustain. As a result, when leaks are more likely, public disclosure is higher, but internal communication is less informative. We then describe how the possibility of leaks affect real efficiency. In our setting, the source of inefficiency is the lack of coordination by employees. We show that real efficiency is maximized either when there are no leaks, or when leaks happen with probability one. However, for intermediate probabilities, real efficiency is lower than at either extreme.
4.1 Comparative statics

As Proposition 2 highlights, there exist multiple equilibria, each with a different level of informativeness of internal communication (i.e., a different $N$). Moreover, the level of external disclosure (i.e., the cutoff $q_{N}^{\text{Leak}}$) itself depends on the informativeness of internal communication (i.e., $N$). To develop our intuition for how these equilibrium measures of informativeness depend on the underlying parameters, we first characterize how $q_{N}^{\text{Leak}}$ changes as a function of parameters, treating $N$ as a (fixed) parameter. We then study how $\bar{N}$, the upper bound on $N$ that characterizes the equilibrium with the most informative internal communication, changes as a function of parameters. We conclude with a set of numerical illustrations of the overall effects on the cutoff $q_{N}^{\text{Leak}}$ that highlight the interaction of these two effects.

The next result characterizes how $q_{N}^{\text{Leak}}$ changes with parameters for a fixed $N$.

**Proposition 3.** Suppose there is leakage (i.e., $\rho > 0$). For a fixed $N \leq \bar{N}$, the disclosure cutoff decreases in the probability of a leak ($\rho$), the probability that the manager is informed ($\pi$), and the value relevance of coordination ($\beta$). Moreover, holding other parameters fixed, the disclosure cutoff $q_{N}^{\text{Leak}}$ decreases as the informativeness of internal communication decreases (i.e., $N$ decreases).

The above result characterizes the impact of leaks on public disclosure. The manager’s incentives to communicate are driven by two considerations: she would like to strategically withhold negative information from shareholders in order to increase the price $P$, but she would prefer to be as informative to employees as possible to encourage coordination. The presence of leaks affects both these channels. Leaks decrease the benefits of withholding information, since there is a positive probability this information is made public anyways. Leaks also decrease the informativeness of internal communication since they create incentives for the manager to distort her message to employees. On the margin, this encourages the manager to disclose more information publicly in an effort to mitigate the effect of noisier internal communication.

Fixing the informativeness of internal communication, this implies that an increase in the probability of a leak increases public disclosure by the manager (decreases $q_{N}^{\text{Leak}}$) since it is less beneficial to withhold information. Moreover, for a fixed probability of leaks, when the informativeness of internal communication is lower (i.e., $N$ decreases), the manager partially compensates the decrease in coordination by increasing disclosure. As a result, the disclosure threshold $q_{N}^{\text{Leak}}$ decreases as $N$ decreases.

The effects of $\pi$ and $\beta$ on the disclosure threshold are more direct. An increase in the ex-ante likelihood of being informed, $\pi$, decreases the incentives for informed managers to pool with the uninformed managers by withholding information, and as a result, leads to greater
disclosure. For a fixed level of informativeness of internal communication, an increase in the relative importance of coordination $\beta$ encourages the manager to disclose more information publicly.

Next, we characterize the impact of leaks on the maximal informativeness of internal communication.

**Proposition 4.** The maximum informativeness of internal communication that can be sustained (i.e., $\bar{N}$) weakly decreases with the probability of a leak ($\rho$) and the probability that the manager is informed ($\pi$).

Note that while an increase in $N$ leads to an increase in the corresponding threshold $q^\text{Leak}_N$, the maximal informativeness $\bar{N}$ decreases when the manager is more likely to disclose information. Intuitively, $\bar{N}$ measures how finely the range of undisclosed $\theta$ can be partitioned. When there is more disclosure, the range of the undisclosed $\theta$ is smaller, and consequently, $\bar{N}$ is lower.

These observations help explain the intuition for how $\pi$ and $\rho$ affect $\bar{N}$. When the prior probability that the manager is informed ($\pi$) increases, the benefit from withholding information decreases. All else equal, the manager is more likely to disclose $\theta$, but this implies the non-disclosure region is smaller, and as a result, $\bar{N}$ is lower. Similarly, increasing the probability of a leak ($\rho$) increases the manager’s incentives to distort internal communication, since it is more likely to be leaked to shareholders. In turn, this makes it more difficult to sustain a higher level of $N$.

Figure 1 provides a numerical illustration of the overall effect of leakage on the disclosure threshold. First, note that disclosure is always lower without leakage, as evidenced by the solid line in the figure. Second, consistent with Proposition 3, when there is leakage, the cutoff $q^\text{Leak}_N$ increases with $N$ but decreases with $\rho$ for a fixed $N$. Moreover, the maximal level of informativeness, $\bar{N}$, decreases with $\rho$ as implied by Proposition 4, since informative communication is more difficult to sustain with higher leakage. As such, the effects on $q^\text{Leak}_N$ and $\bar{N}$ reinforce each other: an increase in $\rho$ decreases $q^\text{Leak}_N$ for a fixed $N$, and decreases $\bar{N}$, which leads the disclosure threshold in the most internally informative equilibrium to fall.

### 4.2 The effect of leaks on efficiency

The source of inefficiency in our setting is the lack of coordination by the employees. Specifically, conditional on the manager being informed, real efficiency is given by

$$RE_{\rho,N} = -E\left[\beta \int_{i \in I} (x^*_i - \theta)^2 | \xi = 1\right]$$  \hspace{1cm} (22)
Figure 1: Disclosure versus leakage

The figure plots the disclosure threshold $q$, when (i) there are no leaks and (ii) when there are leaks for different values of $N$. Benchmark parameters are $h = 2$, $l = 0$, $\delta = 0.75$, $\beta = 1$, and $\pi = 0.5$.

\[
q = \begin{cases} 
0 & \text{with no leakage} \\
-\beta F(q_{N}^{\text{Leak}}) \mathbb{E} \left[ \int_{i \in I} (x_i^* - \theta)^2 \left| \theta < q_{N}^{\text{Leak}}, \{a_n\}_{n=1}^N \right. \right] & \text{with leakage} 
\end{cases}
\]  

(23)

This implies the following result.

**Proposition 5.** Real efficiency is maximized when either (i) there is no leakage (i.e., $\rho = 0$), or (ii) leaks occur with probability 1 (i.e., $\rho = 1$).

On the one hand, when there is no leakage, Proposition 1 implies that the manager perfectly reveals her information to employees, and as a result, coordination is perfect. On the other hand, as we show in the proof of the above result, when leaks occur with probability 1 (i.e., when $\rho = 1$), there is no benefit from withholding information from shareholders, and so the manager discloses all her information (i.e., disclosure threshold is $q_{N}^{\text{Leak}} = l$). As a result, employees observe fundamentals perfectly, and again, coordination is perfect.

When the probability of leaks is positive, but less than one, real efficiency is lower than in the extremes since neither internal communication nor public disclosures are perfectly informative. As a result, employees only have noisy information about fundamentals and the firm incurs an efficiency loss due to decreased coordination.

Figure 2 illustrates how real efficiency changes with the probability of leakage. The overall effect of $\rho$ on real efficiency is non-monotonic, and depends on the level of internal communication.

Arguably, leakage with probability one is an unrealistic benchmark in general, since there are other (unmodeled) constraints on what information can be revealed publicly.
The figure plots real efficiency $RE$ as a function of parameters. Benchmark parameters are $h = 2$, $l = 0$, $\delta = 0.75$, $\beta = 1$, and $\pi = 0.5$.

communication (i.e., $N$). This relation is driven by two effects. First, consistent with Proposition 4, informative internal communication is more difficult to sustain as $\rho$ increases i.e., $\bar{N}$ falls with $\rho$. Second, for a fixed $N$, efficiency tends to decrease with $\rho$ when informativeness is high (e.g., $N = 3, 4$), but increases with $\rho$ when informativeness is low (e.g., $N = 1$).

To better understand the relation between efficiency and $\rho$ for a fixed $N$, note that an increase in $\rho$ has two offsetting effects. On the one hand, an increase in the probability of leaks (higher $\rho$) increases public disclosure (decreases $q$), which improves efficiency. On the other hand, more leakage increases the manager’s incentives to misreport her information internally and, consequently, makes internal communication less informative. The first effect dominates when internal communication is not very informative (i.e., $N$ is low), but the second effect dominates when internal communication is informative (e.g., $N$ is high). As a result, real efficiency initially decreases but eventually increases with $\rho$ and reaches its maximum at $\rho = 1$, when public disclosure is perfectly informative. In general, the analysis suggests that leaks are more likely to improve efficiency when internal communication is less informative. This observation has potentially important implications for regulatory policy, which we return to in our concluding remarks.

The results of this section imply that leaks have a negative effect: the possibility of leakage tends to decrease real efficiency, even though it can lead to more public disclosure. The next section considers a setting in which the possibility of leaks can play a more positive role.

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8As $\rho$ increases, the partition becomes less even and incurs worse coordination.
The effect of leaks with managerial bias

Leaks are often deemed to have a disciplinary role: the possibility of leaks discourages managers from misbehaving because they are concerned about the consequences of their behavior becoming public. Our benchmark model does not capture this aspect, since the incentives of the manager are well aligned with those of other stakeholders of the firm. As a result, leaks are counterproductive because they limit the manager’s ability to communicate with her employees.

However, we can analyze the disciplinary role of leaks by introducing a conflict of interest between the manager and the firm’s other stakeholders. In particular, suppose the value of the firm is given by (1), the employee’s optimal action is given by (3), and the shareholders’ pricing rule is given by (4). However, now assume the manager’s payoff is given by

\[ U = (1 - \delta) P + \delta \tilde{V}, \]  
\[ \tilde{V} = V (\theta + b) = \theta + b - \beta \int_{i \in I} (x_i - (\theta + b))^2 \, di, \]  

for \( b \geq 0 \).

The parameter \( b \) parsimoniously captures the degree to which the manager’s incentives differ from those of the employees. This bias may arise because the manager has different priors over the firm’s fundamentals (e.g., she is more optimistic about the firm so that \( b > 0 \)), or if she prefers coordinating employees’ actions towards a different objective. The additive specification is a standard approach to introducing such conflicts of interest, and is chosen primarily for tractability (e.g., Crawford and Sobel, 1982).

In this case, the equilibrium is characterized by the following result.

**Proposition 6.** Suppose Assumption (1) holds and \( b > 0 \). Then there exists a positive integer \( \bar{N} \geq 1 \) such that for every \( N \) with \( 1 \leq N \leq \bar{N} \), there exists an equilibrium characterized by cutoffs \( l = a_0 < \ldots < a_N = q_N^{Bias} \leq h \), where an informed manager (i) discloses \( \theta \) to shareholders if and only if \( \theta \geq q_N^{Bias} \), (ii) perfectly reveals \( \theta \) to her employees if and only if \( \theta \geq q_N^{Bias} \), and (iii) reports only the partition \( \theta \in [a_n, a_{n+1}] \) to her employees when \( \theta < q_N^{Bias} \). There always exists an equilibrium for \( N = 1 \). Moreover, for a fixed \( N \leq \bar{N} \), the disclosure cutoff \( q_N^{Bias} \) is unique.

The proof of this result extends that of Proposition 2 by accounting for the bias in the

\[ \tilde{V} = \theta + b_0 - \beta \int_{i \in I} (x_i - (\theta + b))^2 \, di \]  

where \( b \) and \( b_0 \) can potentially be different. The key parameter is the bias in the quadratic term \( b \) since this affects the manager’s cheap talk strategy.
manager’s payoff. The key observation is that even when there is no leakage (i.e., \( \rho = 0 \)),
the manager has an incentive to distort her report to employees, and consequently, internal
communication is not perfectly informative.

When the manager publicly discloses her signal, both employees and shareholders observe
\( \theta \). In this case, \( P = \theta \), and so the manager’s payoff is
\[
U_D(\theta) = (1 - \delta) \theta + \delta (\theta + b - \beta b^2).
\] (27)

Conditional on no disclosure, the manager reports that \( \theta \in [a_n, a_{n+1}] \) to her employees and
her resulting payoff is
\[
U_{ND}(\theta, [a_n, a_{n+1}]) = (1 - \delta) P_{ND} + \delta \left( \theta + b - \beta \left( \frac{a_n + a_{n+1}}{2} - \theta - b \right)^2 \right).
\] (28)

Note that these expressions mirror the corresponding expressions for the benchmark model
in Section 3.3, but account for the bias term \( b \). As before, the disclosure cutoff is pinned
down by the indifference between disclosure and no disclosure at \( \theta = q_{Bias}^N \):
\[
U_D(q_{Bias}^N) = U_{ND}(q_{Bias}^N, [a_{N-1}, q_{Bias}^N]),
\] (29)

while the indifference condition between adjacent messages \{\( \theta \in [a_{n-1}, a_n] \) and \( \theta \in [a_n, a_{n+1}] \)\}
at \( \theta = a_n \) i.e.,
\[
U_{ND}(a_n, [a_{n-1}, a_n]) = U_{ND}(a_n, [a_n, a_{n+1}]),
\] (30)
pins down the sequence of cheap-talk cutoffs \( \{a_n\}_{n=0}^N \).

Intuitively, when the manager’s incentives are less aligned with those of the employees
(i.e., when \( b \) is larger), internal communication is less informative, even in the absence of
leakage. As a result, \( \bar{N} \) decreases with \( b \). Moreover, this decrease in informativeness decreases
the value of the firm due to worse coordination, which in turn, increases the relative benefit
from publicly disclosing information. As a result, for a fixed \( N \), the disclosure cutoff \( q_{Bias}^N \)
falls with the bias \( b \) i.e., a larger bias leads to more disclosure. These results are summarized
in the next result.

**Proposition 7.** Suppose \( N \leq \bar{N} \) and the manager is biased. For a fixed \( N \), the disclosure
cutoff \( q_{Bias}^N \) decreases in the bias \( b \). Moreover, the upper bound on the informativeness of
internal communication (i.e., \( \bar{N} \)) decreases in the bias \( b \).

Panel (a) of Figure 3 provides an illustration of the above results. The figure plots the
disclosure cutoffs as a function of the bias \( b \) when there are no leaks (solid lines) and when
there are leaks (\( \rho = 0.25 \), dotted lines). The plots suggest that in either case: (i) the cutoffs
Figure 3: Disclosure cutoffs with a biased manager

The figure plots the disclosure cutoff $q^{Bias}_N$ as a function of parameters. Benchmark parameters are $h = 2$, $l = 0$, $\delta = 0.75$, $\beta = 1$, $\pi = 0.5$, $\rho = 0.25$ and $b = 0.01$.

Panel (a) $q^{Bias}_N$ vs. $b$, with $\rho = 0.25$ and Panel (b) $q^{Bias}_N$ vs. $\rho$ with $b = 0.01$

are decreasing in $b$, and (ii) the maximal informativeness $\bar{N}$ is decreasing in $b$. Moreover, as in the benchmark base (with a bias $b = 0$), the disclosure cutoff is lower in the presence of leaks (i.e., dotted lines are lower than solid lines).

Panel (b) of Figure 3 also confirms that the effects of $\rho$ on the disclosure cutoff and the informativeness of internal communication are robust to the introduction of the managerial bias $b$. Specifically, an increase in the probability of leakage (i.e., $\rho$) leads to a decrease in the maximal informativeness of internal communication (i.e., $\bar{N}$) and, for a fixed $N$, a decrease in the disclosure threshold $q^{Bias}_N$. As before, leaks make internal communication coarser, but increase public disclosure.

Next, we turn to real efficiency when the manager is biased. When the manager’s bias is $b$, the probability of leakage is $\rho$, and the number of partitions of the internal communication is $N$, real efficiency denoted is given by

$$RE(\rho, N, b) = -E \left[ \beta \int_{i \in I} (x_i^* - \theta)^2 \right] = -\beta F \left( q^{Bias}_N \right) E \left[ \int_{i \in I} (x_i^* - \theta)^2 \mid \theta < q^{Bias}_N, \{a_n\}_{n=1}^N \right]$$

Since internal communication is noisy when the manager is biased, real efficiency is no longer maximized when there is no leakage (i.e., $\rho = 0$) as in the benchmark case. Moreover, as the following result highlights, real efficiency may be higher with some leakage than with no leakage.

**Proposition 8.** Real efficiency is maximized when leaks occur with probability 1 (i.e., $\rho = 1$). Moreover, for a fixed $b > 0$, there exists a threshold $\bar{\rho} > 0$, such that for $\rho \geq \bar{\rho}$,
The figure plots real efficiency $RE$ as a function of parameters. Benchmark parameters are $h = 2$, $l = 0$, $\delta = 0.75$, $\beta = 1$, $\pi = 0.5$, $\rho = 0.25$, and $b = 0.01$.

In contrast to our benchmark model, the above result implies that leaks can have a disciplinary role when there are conflicts of interest between the manager and the employees. The bias in the manager’s payoff induces coarse internal communication even in the absence of the leaks. While increasing the probability of a leak decreases the informativeness of internal communication further, it increases public disclosure. If internal communication is sufficiently informative initially (i.e., $N$ is high), then the first effect dominates, and an increase in $\rho$ decreases efficiency. However, when the manager’s bias (or the probability of leaks) is sufficiently high, informative internal communication can no longer be sustained (i.e., $N = 1$). In this case, the second effect dominates and, as a result, an increase in $\rho$ increases efficiency.

Figure 4 illustrates these effects for a specific parameterization. Panel (a) compares real efficiency for varying levels of managerial bias when there is zero or positive ($\rho = 0.25$) probability of leaks. When more informative internal communication is possible (e.g., $N = 2$), real efficiency tends to be lower with leakage (blue, dashed line) than without (blue, solid line), unless the manager’s bias is extremely small. In contrast, when internal communication is not informative (i.e., $N = 1$), the equilibrium with leaks is more efficient for all levels of $b$, since public disclosure is higher. Similarly, for a fixed bias $b > 0$, panel (b) illustrates how real efficiency eventually increases in the likelihood of leaks. Intuitively, a non-zero bias in the manager’s incentives limits the maximal informativeness of internal communication ($\bar{N} = 3$ in our numerical example). When the likelihood of leaks is sufficiently
high, informative internal communication cannot be sustained (i.e., \( N = 1 \)), but in this case, efficiency improves with \( \rho \).

The discussion in Section 4.2 on the relationship between efficiency and \( \rho \) carries over to the case of biased manager here: efficiency initially decreases with \( \rho \), but eventually increases until it reaches a maximum for \( \rho = 1 \). However, unlike the benchmark case with no bias (i.e., \( b = 0 \)), the equilibria without leaks (i.e., \( \rho = 0 \)) do not dominate the ones with \( \rho < 1 \), since internal communication is imperfect even in the absence of leakage. In fact, when internal communication is not informative (i.e., \( N = 1 \)), an increase in the probability of leakage improves efficiency for all values of \( \rho \). As in the case with no conflicts of interest (i.e., with \( b = 0 \)), the possibility of leaks is more likely to improve efficiency when internal communication is less informative. We turn to the implications of this observation in our final section.

6 Implications and Concluding Remarks

Our analysis highlights that leaks introduce an important tradeoff: more leakage makes public disclosure more informative, but internal communication less informative. As a result, the effect of leaks on real efficiency (welfare) is non-monotonic, and depends crucially on the informativeness of internal communication within the firm. While identifying appropriate empirical measures of the underlying parameters is extremely challenging, our model makes a number of testable predictions.

First, the average price reaction to information leaks is negative. This is intuitive: an informed manager publicly discloses good news, but withholds bad news (as in standard disclosure models). Hence, any leaks reveal negative news to the market. This is consistent with a number of papers in the literature, including Bowen et al. (2010) and Dyck et al. (2010).

Second, firms respond to an increase (decrease) in the probability of leaks by increasing (decreasing, respectively) public voluntary disclosures. For instance, our model predicts that voluntary disclosures by firms should increase following the implementation of the Whistleblower Program of the Dodd-Frank Act (see http://www.sec.gov/spotlight/dodd-frank/whistleblower.shtml). However, a key challenge in testing such a prediction empirically is to separately identify the impact of such regulation on the likelihood of leakage, while controlling for other aspects that might affect firms’ disclosure policies directly.

Third, all else equal, a higher likelihood of leakage is associated with less informative internal communication. Empirical tests of this prediction are confounded by the fact that following (the incidence of) a leak, firms usually make changes to the internal governance
and communication policies. As such a test of this prediction requires identifying firms that are ex-ante more likely to have leaks, and comparing their internal communication to a control group. Bowen et al. (2010) provide some preliminary evidence consistent with this prediction: in their sample, targets of employee whistle-blowing allegations are more likely to have unclear internal communications channels.

Fourth, an increase in the likelihood of leakage affects real efficiency across firms differently. Specifically, real efficiency decreases in firms with fewer conflicts of interest and informative internal communication, but can increase in firms with poor internal communication and bad governance. To the extent that firms with better governance and internal communication perform better ex ante, our model predicts that the cross-sectional variation in firm performance should decrease in response to regulatory changes that encourage leakage.

The above result is an important consideration when evaluating regulatory policies that improve whistleblower protection. An increased likelihood of leakage can have a disciplinary effect on firms, but not always. Such policies are more likely to be beneficial for firms that have severe agency problems, uninformative internal communication and more short-term compensation for managers (e.g., through stock / option grants). To the extent possible, targeting such firms may be important in ensuring that regulations have the intended effect.

Our current model is stylized for tractability, but provides a first step in understanding how external and internal communication is affected by leakage. Studying how leaks affect the aggregation of information in a setting where employees have private information would be a natural next step. Finally, along the lines of the preliminary analysis in Appendix B, it would also be interesting to develop a richer model of employee / insider incentives to study the effect of strategic leakage and to endogenize what information is leaked. We hope to explore these directions in future work.
References


Appendices

A Proofs of main results

Proof of Proposition 1. By Lemma 2, we know that the optimal disclosure strategy must be a cutoff strategy where the manager discloses $\theta$ only if $\theta \geq q$ for some cutoff $q$. Since there is no leakage, an informed manager optimally communicates $\theta$ perfectly to her employees. This implies that

$$V(\xi = 1) = \theta, \quad V(\xi = 0) = \mathbb{E}[\theta] - \beta \text{var}[\theta].$$

(32)

Conditional on disclosing her information to shareholders, this implies $U_{D}(\theta) = \theta$, which is strictly increasing in $\theta$. Conditional on no disclosure, the price is then given by:

$$P_{ND}(q) = (1 - \pi)V(\xi = 0) + \pi F(q)\mathbb{E}[V(\xi = 1, \theta)|\theta < q]$$

(33)

$$= \frac{(1 - \pi)\left(\frac{h+l}{2} - \beta \frac{(h-l)^2}{12}\right) + \pi \frac{a-l+q}{n-l} \frac{q-\frac{a+k}{2}}{2}}{(1 - \pi) + \pi \frac{\frac{a-k}{n-l}}{2}}$$

(34)

At $\theta = q$, the manager should be indifferent between disclosing or not, and so:

$$q = \delta q + (1 - \delta)P_{ND}(q)$$

(35)

$$\leftrightarrow q = \frac{(1 - \pi)\left(\frac{h+l}{2} - \beta \frac{(h-l)^2}{12}\right) + \pi \frac{a-l+q}{n-l} \frac{q-\frac{a-k}{2}}{2}}{(1 - \pi) + \pi \frac{\frac{a-k}{n-l}}{2}}$$

(36)

$$\leftrightarrow q = \frac{6\pi h - (h-l)6+\sqrt{6(1-\pi)(6-\pi\beta(h-l))}}{6\pi}.$$  

(37)

To ensure that the cutoff $q \in [l, h]$ we must select the larger root i.e.,

$$q = h - (h-l)^6+\sqrt{6(1-\pi)(6-\pi\beta(h-l))} \equiv q_{NoLeak}. \quad (38)$$

Finally, note that when Assumption 1 holds, we have:

$$\frac{h+l}{2} - \frac{\beta}{12} (h-l)^2 > l \Rightarrow 6 - \beta(h-l) > 0,$$  

(39)

which ensures $q_{NoLeak}$ is well-defined. Moreover, the above establishes that $q_{NoLeak}$ is uniquely determined.

Proof of Proposition 2. Conditional on a message $m_n = \{\theta \in [a_n, a_{n+1}]\}$, note that

$$\mathbb{E}[\theta|m_n] = \frac{a_n+a_{n+1}}{2}, \quad \text{var}[\theta|m_n] = \frac{(a_{n+1}-a_n)^2}{12}.$$  

(40)

Next, note that disclosure must follow a cutoff strategy (Lemma 2) and when $\theta$ is disclosed publicly, the manager’s payoff from disclosure is $U_{D}(\theta) = \theta$. When there is no disclosure, there are two possibilities:
• The manager is uninformed, in which case, the value of the firm is:

\[ V_{NI} = \frac{h+l}{2} - \frac{\beta}{12} (h-l)^2 = P_{NI}. \] (41)

• The manager is informed, and only sends message \( m_n \) to her employees. In this case, the value of the firm is

\[ V_I (\theta, m_n) = \theta - \beta \left( \frac{a_n+a_{n+1}}{2} - \theta \right)^2. \] (42)

If the message is leaked to shareholders, the price is given by

\[ P_{I,L} (m_n) = \mathbb{E} [V_I | m_n] = \frac{a_{n+1}+a_n}{2} - \frac{\beta}{12} (a_{n+1} - a_n)^2. \] (43)

On the other hand, if the message is not leaked, the price is given by

\[ P_{I,NL} (m_n) = \mathbb{E} [V_I | \xi = 1, d = \emptyset] = \mathbb{E} [V_I | \theta < q] = \frac{2n+1}{2} - \frac{\beta}{12} \sum_i \frac{(a_{n+1} - a_n)^3}{q_{n-i}}. \] (44)

As a result, conditional on no disclosure, the expected price is then given by:

\[ P_{ND} (m_n) = \rho P_{I,L} + \rho (\gamma P_{NI} + (1 - \gamma) P_{I,NL}), \] (45)

where \( \rho \) is the probability of a leak, and \( \gamma \) reflects the probability that the manager is uninformed, given that there is no disclosure (and no leak) i.e.,

\[ \gamma \equiv \frac{1 - \pi}{1 - \pi + \pi (1 - \rho) \Pr (\theta < q_N)}. \] (46)

As a result, an informed manager’s payoff from not disclosing her information is

\[ U_{ND} (\theta, m_n) = \delta V_I (\theta, m_n) + (1 - \delta) P_{ND} (m_n). \] (47)

The disclosure cutoff is pinned down by indifference for \( \theta = q \) i.e.,

\[ U_D (q) = U_{ND} (q, \{ \theta \in [a_{N-1}, q] \}), \] (48)

while the cheap-talk partitions are characterized by indifference at the cutoffs \( \theta = a_n \) i.e.,

\[ U_{ND} (a_n, \{ \theta \in [a_{n-1}, a_n] \}) = U_{ND} (a_n, \{ \theta \in [a_n, a_{n+1}] \}). \] (49)

The latter indifference condition implies that \( a_n \) satisfies the difference equation:

\[ \frac{a_{n+1} - a_n}{2} \left( \rho (1 - \delta) - \beta (3\delta + (1 - \delta)\rho) \frac{(a_{n+1}+a_n+1-3a_n)}{6} \right) = 0 \] (50)

\[ \Rightarrow a_{n+1} = \left\{ a_{n-1}, 2a_n - a_{n-1} + \frac{6\rho(1-\delta)}{\beta(3\delta+\rho(1-\delta))} \right\} \] (51)

Given the monotonicity of \( a_i \), the second solution solution must hold. The recursive equation
of the form:  
\[ a_{i+2} = 2a_{i+1} - a_i + 2c, \quad a_0 = l, \]
has the solution:  
\[ a_n = l + A_0 n + cn(n-1) \]
for a constant \( A_0 \) and  
\[ c \equiv \frac{3(1 - \delta)\rho}{\beta(3\delta + (1 - \delta)\rho)}. \]  
(52)

Since \( a_N = q \), we must have:  
\[ q - l = A_0 N + cN(N - 1) \geq cN(N - 1). \]  
(53)

The constant \( A_0 \) can be pinned down using \( a_N = q \), which implies:  
\[ A_0 = \frac{q-l}{N} - c(N - 1), \]  
(54)

\[ \Rightarrow a_n = \frac{(n-N)(nN-c-l)+nq}{N}, \quad a_{N-1} = \frac{t-(N-1)(cN-q)}{N}. \]  
(55)

Finally, note that the above implies:  
\[ \Sigma(q) \equiv \frac{1}{12(q-l)} \sum_{i=1}^{N} (a_i - a_{i-1})^3 = \frac{c^2(N^2-1)}{12} + \left(\frac{q-l}{12N^2}\right)^2. \]  
(56)

Given these expressions, one can solve for \( q \) (using (48)) as the fixed point to \( q = g(q) \), where

\[ g(q) \equiv U_{ND}(q, \{\theta \in [a_{N-1}, q]\}) \]

\[ = \delta \left( q - \beta \left( \frac{q+a_{N-1}}{2} - q \right)^2 \right) + (1 - \delta) \left( \rho \left( \frac{q+a_{N-1}}{2} - \frac{\beta}{\beta} \right) ^2 \right) + \left( (1 - \rho) \delta \right) \left( \frac{q+a_{N-1}}{2} - \beta \Sigma(q) \right) \]

\[ = \frac{q+l}{2} - \beta \Sigma(q) + \delta \left( \frac{q+l}{2} - 2\beta \Sigma(q) \right) + (1 - \delta)(1 - \rho)\gamma \left( \frac{h-q}{2} - \beta \left( \frac{(h-l)^2}{12} - \Sigma(q) \right) \right). \]  
(58)

Fix an \( N \geq 1 \) and recall that \( q - l \geq cN(N-1) \). To show the existence of a solution to \( q = g(q) \), where \( h > q > cN(N-1) + l \), it is sufficient to establish conditions for \( g(h) < h \) and \( g(l + cN(N-1)) > l + cN(N-1) \). When \( q = h \), note that

\[ g(h) = \delta V_I + (1 - \delta) \left( \rho P_{I,L} + (1 - \rho) \left( \gamma P_{NI} + (1 - \gamma) P_{I,NL} \right) \right) \]

(60)

for \( V_I, P_{I,L}, P_{NI} \) and \( P_{I,NL} \). And so \( g(h) < h \). Next, note that \( \beta c = \frac{3(1 - \delta)\rho}{(3\delta + (1 - \delta)\rho)} \leq 3 \), and so

\[ g(cN(N-1) + l) = l + (1 - \delta)(1 - \rho)\gamma \left( \frac{h-q}{2} - \beta \left( \frac{(h-l)^2}{12} \right) \right) \]

\[ + \frac{cN(N-1)}{2} \left( 1 + \delta - (1 - \delta)(1 - \rho)\gamma \right) \]

\[ - \frac{\beta^2((N-1)^2 + \Sigma^2)}{12} \left( 1 + 2\delta - (1 - \delta)(1 - \rho)\gamma \right). \]  
(61)
\[ l + (1 - \delta) (1 - \rho) \gamma \left( \frac{h-l}{2} - \beta \left( \frac{(h-l)^2}{12} \right) \right) \geq \frac{cN(N-1)}{h-l} \left( 1 + \delta - (1 - \delta) (1 - \rho) \gamma \right) - \frac{3c(2N(N-1))}{h-l} (1 + 2\delta - (1 - \delta) (1 - \rho) \gamma) \]
\[ = l + (1 - \delta) (1 - \rho) \gamma \left( \frac{h-l}{2} - \beta \left( \frac{(h-l)^2}{12} \right) \right) - \frac{cN(N-1)}{2} \delta, \]  
(62)

where
\[ \gamma = \frac{1 - \pi}{1 - \pi + \pi (1 - \rho) \frac{cN(N-1)}{h-l}}. \]  
(64)

To ensure that \( g(cN(N-1) + l) > l + cN(N-1) \), we must have:
\[ l + \frac{(1 - \delta) (1 - \rho) (1 - \pi)}{1 - \pi + \pi (1 - \rho) \frac{cN(N-1)}{h-l}} \left( \frac{h-l}{2} - \beta \left( \frac{(h-l)^2}{12} \right) \right) - \frac{cN(N-1)}{2} \delta > l + cN(N-1) \]
\[ \frac{(1 - \delta) (1 - \rho) (1 - \pi)}{1 - \pi + \pi (1 - \rho) \frac{cN(N-1)}{h-l}} > cN(N-1) \left( 1 + \frac{\delta}{2} \right) \]  
(65)

or equivalently,
\[ cN(N-1) \left( 1 + \frac{\delta}{2} \right) \left( 1 - \pi + \pi (1 - \rho) \frac{cN(N-1)}{h-l} \right) < (1 - \delta) (1 - \rho) (1 - \pi) \left( \frac{h-l}{2} - \beta \left( \frac{(h-l)^2}{12} \right) \right). \]  
(66)

Since the LHS of the above is always increasing in \( N \), the above condition is equivalent to ensuring that \( N \leq \bar{N} \) for some bound. Moreover, note that the above condition holds for \( N = 1 \), and so \( \bar{N} \geq 1 \).

For a fixed \( N \leq \bar{N} \), a sufficient condition for the uniqueness of \( q_N^{\text{Leak}} \) is that \( \frac{\partial g}{\partial q} < 1 \), since this implies \( g(q) \) intersect the 45 degree line (at most once) from above. Note that
\[ \frac{\partial g}{\partial q} = \frac{1}{2} (1 + \delta - \gamma (1 - \delta) (1 - \rho)) - \beta \Sigma_q (1 + 2\delta - (1 - \delta) (1 - \rho) \gamma) \]
\[ + \gamma_q (1 - \delta) (1 - \rho) \left( \frac{h-l}{2} - \beta \left( \frac{(h-l)^2}{12} - \Sigma \right) \right) \]  
(68)

where
\[ \Sigma_q = \frac{2(q-l)}{12N^2} > 0, \quad \gamma_q = -\frac{\pi(1-\pi)(1-\rho)}{(h-l)(1-\pi+\pi(1-\rho)\frac{q-l}{h-l})} < 0. \]  
(69)

At any point of intersection, we have \( q = g(q) \), and so
\[ (1 - \delta) (1 - \rho) \left( \frac{h-l}{2} - \beta \left( \frac{(h-l)^2}{12} - \Sigma \right) \right) = \frac{1}{\gamma} (q - (\frac{q+l}{2} - \beta \Sigma (q) + \delta (\frac{q-l}{2} - 2\beta \Sigma (q)))) \]
\[ = \frac{1}{\gamma} \left( \frac{q-l}{2} (1 - \delta) + (1 + 2\delta) \beta \Sigma (q) \right) \geq 0 \]  
(70)

Since \( 1 + 2\delta - (1 - \delta) (1 - \rho) \gamma > 0 \),
\[ \frac{\partial g}{\partial q} < \frac{1}{2} (1 + \delta) < 1. \]  
(72)

This establishes that any point of intersection \( q = g(q) \), \( g(q) \) intersects the 45-degree
line from below, which in turn implies there can be only one such intersection for \( q \in [l + cN(N - 1), h] \).

**Proof of Proposition 3.** We begin by proving a useful Lemma.

**Lemma 3.** Fix an \( N < \bar{N} \). The unique solution \( q^\text{Leak}_N \) to \( q = g(q; N) \) satisfies:

\[
q^\text{Leak}_N - l \geq cN(N + 1) > cN(N - 1).
\]  

(73)

**Proof.** Uniqueness of \( q^\text{Leak}_N \) is established in the proof of Proposition 2. Specifically, recall that for a fixed \( N \), \( g(q) \) intersects the 45-degree line from above. Next, note that

\[
G(q) = g(q, N) - g(q, N - 1) = -\left(\beta(1 + 2\delta - (1 - \delta)(1 - \rho)\gamma)\right)\left[\Sigma(N) - \Sigma(N - 1)\right] \tag{74}
\]

where \( \Sigma(N) - \Sigma(N - 1) = \frac{1}{12} \left(c^2(N^2 - (N - 1)^2) + (q - l)^2\frac{(N-1)^2-N^2}{N^2(N-1)^2}\right) \tag{75} \]

\[= \frac{2N-1}{12} \left(c^2 - \frac{(q-l)^2}{N^2(N-1)^2}\right) \tag{76} \]

This implies that for \( q = cN(N - 1) \), we have \( \Sigma(N) = \Sigma(N - 1) \). Since \( q^\text{Leak}_N - l \geq cN(N - 1) \), we have:

\[
G(q^\text{Leak}_N) = g(q^\text{Leak}_N, N) - g(q^\text{Leak}_N, N - 1) = q^\text{Leak}_N - g(q^\text{Leak}_N, N - 1) > 0 \tag{77} \]

Moreover, since \( g(x; N) \) intersects the 45-degree line from above, we have:

\[
l + cN(N - 1) \leq g(l + cN(N - 1); N), \tag{78} \]

and since \( G(l + cN(N - 1)) = 0 \), we have:

\[
l + cN(N - 1) \leq g(l + cN(N - 1); N - 1) \tag{79} \]

But this implies that the solution \( q^\text{Leak}_{N-1} \) to \( q = g(q; N - 1) \) must satisfy:

\[
l + cN(N - 1) \leq q^\text{Leak}_{N-1} \leq q^\text{Leak}_N \tag{80} \]

which completes the result. □

Note that the above result immediately implies that \( q^\text{Leak}_N \) is increasing in \( N \). Since \( q = g(q; \rho) \) and \( g_q \equiv \frac{\partial g}{\partial q} < 1 \), we have

\[
\frac{\partial q}{\partial \rho} = \frac{g_\rho}{1 - g_q} < 0 \quad \Rightarrow \quad g_\rho \equiv \frac{\partial g}{\partial \rho} < 0. \tag{81} \]

So to establish the comparative statics results for \( \rho \), (and analogously \( \pi \) and \( \beta \)) it is sufficient to show \( g_\rho < 0 \) (and analogously \( g_\pi < 0 \) and \( g_\beta < 0 \)). Given the expression for \( g(\cdot) \) above, we have:

\[
g_\rho = -\Sigma_\rho \left(1 + 2\delta - (1 - \delta)(1 - \rho)\gamma\right) + (1 - \delta) \left((1 - \rho)\gamma - \gamma\right) \left(\frac{h-q}{2} - \beta \left(\frac{(h-l)^2}{12} - \Sigma\right)\right) < 0, \]

27
since $$\gamma_\rho = \frac{2(1-\gamma)}{1-\rho} \geq 0$$ (see (46)), $$\frac{h-q}{2} - \beta \left( \frac{(h-l)^2}{12} - \Sigma \right) > 0$$ (see the argument for (71) above) and $$\Sigma_\rho = \frac{\partial \Sigma}{\partial c} \frac{\partial c}{\partial \rho} > 0$$, given (52) and (56). Similarly, note that

$$g_\pi = (1 - \delta)(1 - \rho) \left( \frac{h-q}{2} - \beta \left( \frac{(h-l)^2}{12} - \Sigma \right) \right) \gamma_\pi < 0$$

(82)

since $$\gamma_\pi < 0$$ (see (46)) and $$\frac{h-q}{2} - \beta \left( \frac{(h-l)^2}{12} - \Sigma \right) > 0$$, and that

$$g_\beta = -(1 + 2\delta - (1 - \delta)(1 - \rho)\gamma)(\Sigma + \beta \Sigma_\beta) - (1 - \delta)(1 - \rho)\gamma (\frac{(h-l)^2}{12}),$$

$$\Sigma + \beta \Sigma_\beta = \frac{1}{12} \left( \left( \frac{q_{\text{peak}}^\rho - l}{N^2} \right)^2 - c^2(N^2 - 1) \right) \geq \frac{1}{12} \left( c^2(N + 1)^2 - c^2(N^2 - 1) \right) > 0,$$

(83)

(84)

for $$N < \tilde{N}$$ from Lemma 3, and so $$g_\beta < 0$$ for $$N < \tilde{N}$$.

Proof of Proposition 4. As seen in the proof of Proposition 3, for all $$N \leq \tilde{N}$$, we have

$$l + cN(N - 1) \leq g(l + cN(N - 1)),\quad (85)$$

and for $$\tilde{N}$$ we also have

$$l + c\tilde{N}(\tilde{N} + 1) > g(l + c\tilde{N}(\tilde{N} + 1)).\quad (86)$$

As $$\pi$$ becomes larger, the left-hand side does not change for either inequality, while the right-hand side decreases since $$g_\pi < 0$$. For (86), this implies that the inequality holds for higher values of $$\pi$$, and so $$\tilde{N}$$ cannot increase with an increase in $$\pi$$. However, (85) may be violated if we increase $$\pi$$ sufficiently and $$\tilde{N}$$ is reduced by one. This implies that $$\tilde{N}$$ is non-increasing in $$\pi$$. Since $$c_\rho > 0$$ and $$g_\rho < 0$$, similar arguments across (85) and (86) imply that $$\tilde{N}$$ is non-increasing in $$\rho$$.

Proof of Proposition 5. Recall from the proof of Proposition 2 that $$q_{\text{peak}}^N$$ is the solution to $$q = g(q)$$, where $$g(q)$$ is defined by

$$g(q) = \frac{q + l}{2} - \beta \Sigma(q) + \delta \left( \frac{q - l}{2} - 2\beta \Sigma(q) \right) + (1 - \delta)(1 - \rho)\gamma \left( \frac{h-q}{2} - \beta \left( \frac{(h-l)^2}{12} - \Sigma(q) \right) \right),$$

$$\Sigma(q) = \frac{c^2(N^2 - 1)}{12} + \frac{(q - l)^2}{12N^2}, \quad c = \frac{3(1 - \delta)\rho}{\beta(3\delta + (1 - \delta)\rho)}, \quad \gamma = \frac{1 - \pi}{1 - \pi + \pi (1 - \rho) \frac{q - l}{h-l}}$$

(87)

(88)

and

$$cN(N - 1) \left( 1 + \frac{\delta}{2} \right) (1 - \pi + \frac{\pi(1-\rho)}{h-l} cN(N - 1)) \leq (1 - \delta)(1 - \rho) \left( 1 - \pi \right) \left( \frac{h-q}{2} - \beta \left( \frac{(h-l)^2}{12} \right) \right).$$

When $$\rho = 1$$, the above condition reduces to:

$$cN(N - 1) \left( 1 + \frac{\delta}{2} \right) (1 - \pi) \leq 0 \quad \Rightarrow N = 1,$$
i.e., when \( \rho = 1, N \leq \bar{N} = 1 \). Moreover, this implies that when \( \rho = 1 \),

\[
\Sigma(q) = \frac{(q-l)^2}{12}, \quad c = \frac{3(1-\delta)}{\beta(3\delta + (1-\delta))}
\]

\[
\Rightarrow g(q) - q = -(q-l) + \frac{q-l}{2} (1+\delta) - \beta \frac{(q-l)^2}{12} (1+2\delta)
\]

\[
= (q-l) \left\{ -1 + \frac{1+\delta}{2} - \frac{\beta(1+2\delta)}{12} (q-l) \right\}
\]

\[
\Rightarrow q = \left\{ l, l - \frac{6(1-\delta)}{\beta(1+2\delta)} \right\}
\]

but since \( q \geq l \), the only possible solution is \( q = l \). This implies that real efficiency is maximized at \( \rho = 1 \) since there is full public disclosure.

Proof of Proposition 6. The proof follows the structure of the proof of Proposition 2. In the case there is disclosure, both insiders and outsiders observe \( \theta \). In this case,

\[
P_D = \theta, \quad U_D = (1-\delta) \theta + \delta (\theta + b_0 - \beta b^2) = \theta + \delta (b_0 - \beta b^2)
\]

Next, note that

\[
\bar{V} = \begin{cases} 
\frac{h+l}{2} - \frac{\beta}{12} (h-l)^2 + b_0 - \beta b^2 & \text{when } \xi = 0 \\
\theta + b_0 - \beta \left( \frac{a_{n+1}+a_n}{2} - \theta - b \right)^2 & \text{when } \xi = 1
\end{cases}
\]

and conditional on a message \( m_n = \{ \theta \in [a_n,a_{n+1}] \} \),

\[
P = \begin{cases} 
\frac{h+l}{2} - \frac{\beta}{12} (h-l)^2 & \text{when } \xi = 0 \\
\frac{a_{n+1}+a_n}{2} - \frac{\beta}{12} (a_{n+1} - a_n)^2 & \text{when } \xi = 1, \ k = 1 \ (\text{leak}) \\
\frac{a_{n+1}}{2} - \beta \Sigma(q) & \text{when } \xi = 1, \ k = 0 \ (\text{no leak})
\end{cases}
\]

The expected price given no disclosure is:

\[
P_{ND}(m_n) = \rho \left( \frac{a_{n+1}+a_n}{2} - \frac{\beta}{12} (a_{n+1} - a_n)^2 \right) + (1-\rho) \left( \gamma \left( \frac{h+l}{2} - \frac{\beta}{12} (h-l)^2 \right) + (1-\gamma) \left( \frac{a_{n+1}}{2} - \beta \Sigma(q) \right) \right)
\]

where as before, \( \gamma = \frac{1-\pi}{1-\pi+\pi(1-\rho)^q_{n-1}} \). Conditional on no disclosure, the manager’s payoff is given by:

\[
U_{ND}(\theta, m_n) = \delta \left( \theta + b_0 - \beta \left( \frac{a_{n+1}+a_n}{2} - \theta - b \right)^2 \right) + (1-\delta) P_{ND}(m_n)
\]

The indifference condition to pin down \( q_{N}^{Bias} \) is given by:

\[
U_D(q) = U_{ND}(q, [a_{N-1}, q])
\]

\[
\Leftrightarrow q = \delta \left( q - \beta \left( \frac{(a_{N-1})^2}{2} + 2b \left( \frac{a_{N-1}}{2} \right) \right) \right) + (1-\delta) P_{ND}([a_{N-1}, q])
\]
The indifference conditions to pin down \( a_i \) is given by

\[
U_{ND}(a_n, [a_n, a_{n+1}]) - U_{ND}(a_n, [a_{n-1}, a_n]) = 0 \tag{102}
\]

\[
\Rightarrow -\delta \beta \left( \frac{a_{n+1}-a_n}{2} - b \right)^2 + (1 - \delta) \rho \left( \frac{a_{n+1}+a_n}{2} - \frac{\beta}{12} (a_{n+1} - a_n)^2 \right) = 0 \tag{103}
\]

Solving for \( a_{n+1} \), we get

\[
a_{n+1} = \left\{ a_n, 2a_n - a_{n-1} + \frac{6((1 - \delta) \rho + 2\beta \delta b)}{\beta (3\delta + (1 - \delta) \rho)} \right\}. \tag{104}
\]

Letting

\[
c = \frac{3((1 - \delta) \rho + 2\beta \delta b)}{\beta (3\delta + (1 - \delta) \rho)}, \tag{105}
\]

we have a solution of the type:

\[
a_n = l + A_0 n + cn (n - 1). \tag{106}
\]

Since \( a_N = q \), we have: \( q - l = A_0 N + cN (N - 1) > cN (N - 1) \), or equivalently, \( N < \frac{1}{2} \left( \sqrt{1 + \frac{4(q-l)}{c}} + 1 \right) \). The expressions for \( a_{N-1} \) and \( \Sigma \) correspond to the no bias case with the modified \( c \). Note however, that

\[
\lim_{\rho \to 0} c = \frac{3(2\beta \delta b)}{\beta (3\delta)} = 2b \neq 0 \tag{107}
\]

and so even when there are no leaks, \( N < \frac{1}{2} \left( \sqrt{1 + \frac{2(q-l)}{b}} + 1 \right) \) i.e., internal communication is coarse. Let

\[
\hat{g}(q) \equiv \delta \left( q - \beta \left( \frac{q-a_{N-1}}{2} \right)^2 + 2b \frac{q-a_{N-1}}{2} \right) \tag{108}
\]

\[
+ (1 - \delta) \ P_{ND} ([a_{N-1}, q]) \tag{109}
\]

where \( g(q) \) is given by (57), and note that \( q_{Bias}^N \) is the fixed point to \( q = \hat{g}(q) \). To show the existence of a solution to \( q = \hat{g}(q) \), where \( h > q > cN (N - 1) + l \), it is sufficient to establish conditions for \( \hat{g}(h) < h \) and \( \hat{g}(l + cN (N - 1)) > l + cN (N - 1) \). When \( q = h \), note that \( \hat{g}(h) \leq g(h) \leq h \). As before \( \beta c \leq 3 \), and so analogous calculations to those in the proof of Proposition 2, we have:

\[
\hat{g}(l + cN (N - 1)) \geq l + (1 - \delta) (1 - \rho) \gamma \left( \frac{h-l}{2} - \beta \frac{(h-l)^2}{12} \right) - \frac{cN(N-1)}{2} \delta - \beta b \delta \left( \frac{2cN(N-1)}{N} \right), \tag{110}
\]

30
where \( \gamma = \frac{1 - \pi}{1 - \pi + \pi(1 - \rho) \frac{N(N - 1)}{h-l}} \). To ensure \( \tilde{g}(l + cN(N - 1)) \geq l + cN(N - 1) \), we must have:

\[
cN(N - 1) \left(1 + \frac{\delta}{2} + \frac{2b\delta}{N}\right) \left(1 - \pi + \pi \frac{(1-\rho)cN(N-1)}{h-l}\right) \leq (1 - \delta)(1 - \pi)\left(\frac{h-l}{2} - \beta \frac{(h-l)^2}{12}\right). \tag{111}
\]

Note that this coincides with the corresponding condition in Proposition 2 when \( b = 0 \). Since the LHS is increasing in \( N \), this corresponds to ensuring that \( N \leq \bar{N} \) for some bound. Moreover, the condition always holds for \( N = 1 \), which implies \( \bar{N} \geq 1 \). Finally, uniqueness of \( q_{Bias}^N \) requires \( \frac{\partial \tilde{g}}{\partial q} < 1 \), which holds since (72) holds and

\[
\frac{\partial \tilde{g}}{\partial q} = \frac{\partial q}{\partial q} - \frac{\beta b \delta}{N} \tag{112}
\]

for \( b > 0 \).

**Proof of Proposition 7.** From the proof of Proposition 6, we know that \( q_{Bias}^N \) is the fixed point to \( q = \tilde{g}(q) \), where

\[
\tilde{g}(q) = g(q) - \beta b \delta \left(\frac{cN(N - 1) + q - l}{N}\right) \tag{113}
\]

and \( g(q) \), which is given by (57), does not depend on \( b \). This implies that for a fixed \( N \),

\[
\frac{\partial}{\partial b} q_{Bias}^N = \frac{\frac{\partial \tilde{g}}{\partial b}}{1 - \frac{\partial \tilde{g}}{\partial q}} \leq 0 \tag{114}
\]

since \( \frac{\partial \tilde{g}}{\partial q} < 1 \) and \( \frac{\partial \tilde{g}}{\partial b} \leq 0 \). Next, note that the upper bound \( \bar{N} \) is characterized by a strict equality in condition (111). Let

\[
L \equiv c\bar{N}(\bar{N} - 1) \left(1 + \frac{\delta}{2} + \frac{2b\delta}{\bar{N}}\right) \left(1 - \pi + \pi \frac{(1-\rho)c\bar{N}(\bar{N}-1)}{h-l}\right) \tag{115}
\]

and note that \( \frac{\partial L}{\partial b} + \frac{\partial L}{\partial \bar{N}} \frac{\partial \bar{N}}{\partial b} = 0 \), or equivalently,

\[
\frac{\partial \bar{N}}{\partial b} = -\frac{\frac{\partial L}{\partial b}}{\frac{\partial L}{\partial \bar{N}}}. \tag{116}
\]

Next, note that

\[
\frac{\partial L}{\partial b} = c_b \left( 2\beta \delta (\bar{N} - 1) c \left( \frac{\pi(\bar{N}-1)(1-\rho)c}{h-l} - \pi + 1 \right) \right)
+ \left( \bar{N} - 1 \right) \bar{N} \left( \frac{2b\delta}{\bar{N}} + \frac{\delta}{2} + 1 \right) \left( \frac{\pi(\bar{N}-1)(1-\rho)c}{h-l} - \pi + 1 \right) \tag{117}
\]
and $c_b > 0$. Moreover,

$$\frac{\partial L}{\partial N} = c (2\bar{N} - 1) \left(1 + \frac{\delta}{2} + \frac{2\beta b}{N}\right) \left(1 - \pi + \pi \frac{(1 - \rho)c\bar{N}(N - 1)}{h - l}\right)$$

$$+ \frac{\pi(1 - \rho)c\bar{N}(N - 1)}{h - l} \left(1 + \frac{\delta}{2} + \frac{2\beta b}{N}\right) c (2\bar{N} - 1)$$

$$- \frac{2\beta b}{N^2} c\bar{N}(N - 1) \left(1 - \pi + \pi \frac{(1 - \rho)c\bar{N}(N - 1)}{h - l}\right)$$

(118)

For $\bar{N} = 1$, $\frac{\partial \bar{N}}{\partial \rho} = \frac{\partial L}{\partial b} = 0$. For $\bar{N} > 1$, we have $\frac{\partial L}{\partial b} > 0$ and

$$\frac{\partial L}{\partial N} = c (2\bar{N} - 1) \left(1 + \frac{\delta}{2} + \frac{2\beta b}{N}\right) \left(1 - \pi + \pi \frac{(1 - \rho)c\bar{N}(N - 1)}{h - l}\right)$$

$$- \frac{2\beta b}{N} c\bar{N}(N - 1) \left(1 - \pi + \pi \frac{(1 - \rho)c\bar{N}(N - 1)}{h - l}\right)$$

$$+ \frac{\pi(1 - \rho)c\bar{N}(N - 1)}{h - l} \left(1 + \frac{\delta}{2} + \frac{2\beta b}{N}\right) c (2\bar{N} - 1)$$

$$\geq \left[\left(2\bar{N} - 1\right) \left(1 + \frac{\delta}{2}\right) + \frac{2\beta b (2N - 1)}{N} - \frac{2\beta b (N - 1)}{N}\right] c \left(1 - \pi + \pi \frac{(1 - \rho)c\bar{N}(N - 1)}{h - l}\right)$$

(120)

$$\geq 0$$

(121)

which implies $\frac{\partial \bar{N}}{\partial \rho} < 0$.

**Proof of Proposition 8.** First, note that when $\rho = 1$, the condition that determines $\bar{N}$ (i.e., expression (111)) reduces to:

$$c\bar{N}(N - 1) \left(1 + \frac{\delta}{2} + \frac{2\beta b}{N}\right) (1 - \pi) \leq 0 \Rightarrow \bar{N} = 1.$$  

(122)

$$c\bar{N}(N - 1) \left(1 + \frac{\delta}{2}\right) (1 - \pi) \leq 0 \Rightarrow N = 1,$$

(123)

Moreover, this implies that when $\rho = 1$, $\Sigma(q) = \frac{(q - l)^2}{12}$,

$$\Rightarrow \tilde{g}(q) - q = \frac{q + l}{2} - q - \beta\Sigma(q) + \delta \left(\frac{q - l}{2} - 2\beta\Sigma(q)\right) - \beta b\delta (q - l)$$

(124)

$$= - (q - l) \left\{\frac{1}{2} - \delta + \beta\delta b + \frac{\beta}{12} (1 + 2\delta) (q - l)\right\}$$

(125)

$$\Rightarrow q = \left\{l, \ l - \frac{12b\beta\delta + 6 (1 - \delta)}{\beta(2\delta + 1)}\right\}$$

(126)

but since $q \geq l$, the only possible solution is $q^{Bias}_N = l$, which implies $RE(\rho = 1) = 0$.

Fix a $b > 0$, and $q^0_N$ denote the cutoff when there is no leakage. Since $c = 2b$ when $\rho = 0$, we have

$$\Sigma(\rho = 0, N) = \frac{(2b)^2 (N^2 - 1)}{12} + \frac{(q^0_N - l)^2}{12N^2}.$$  

(127)

In contrast, when there is leakage with probability $\rho$ but $N = 1$, we have

$$\Sigma(\rho, N = 1) = \frac{(q^0N - l)^2}{12}.$$  

(128)
Efficiency is higher with leakage when
\[ \frac{q_0^0 - l}{h - l} \sum (\rho = 0, N) > \frac{q_1^0 - l}{h - l} \sum (\rho, N = 1), \]
(129)
or equivalently,
\[ (q_0^0 - l) \left( \frac{(2b)^2(N^2 - 1)}{12} + \frac{(q_0^0 - l)^2}{12N^2} \right) > \frac{(q_0^0 - l)^2}{12}. \]
(130)
Note that for a fixed \( b > 0 \), the LHS is strictly positive and bounded away from 0, since \( q_0^0 > l \) and \( N \leq \bar{N} \). On the other hand, one can show that \( q_1 \) is always decreasing in \( \rho \) and \( \lim_{\rho \to 1} q = l \). This implies there exists a \( \bar{\rho} > 0 \) such that for all \( \rho > \bar{\rho} \), the above condition holds.

\[ B \hspace{1cm} \text{Verifiable internal communication and endogenous leakage} \]

In this appendix, we characterize a variant of the model which features (i) verifiable internal communication (instead of cheap talk), and (ii) endogenous leakage by the employees. While the nature of the equilibrium is different from the benchmark model of the paper, this analysis suggests that the important results of our benchmark model are robust to these changes. First, in the absence of leaks, internal communication is perfectly informative. Second, an increase in the likelihood of leaks improves public disclosure, but makes internal communication less informative. Finally, real efficiency initially decreases and then increases with the likelihood of leakage.

The setup of the model is similar to the benchmark model. There are a continuum of shareholders, one manager and a single, representative employee.\(^{10}\) The value of the firm is given by
\[ V = \theta - \beta (x - \theta)^2, \]
(131)
where the fundamental \( \theta \in \{l, h\} \) with probability \( \{1 - p, p\} \), and where \( l < 0 < h \), and where \( x \) is the action of the employee. At date \( t = 1 \), the manager observes \( \theta \) with probability \( \pi < 1 \) and let \( \xi \in \{0, 1\} \) denote the indicator variable for this event. An informed manager chooses whether to publicly disclose her information (i.e., \( d = \theta \)) or not (i.e., \( d = \emptyset \)), and whether to privately disclose her signal to the employee (i.e., \( m = \theta \)) or not (i.e., \( m = \emptyset \)). In contrast to the benchmark model, we assume that both public disclosures and internal communication are verifiable. The message \( m \) to the employee is not immediately observable by shareholders.

At date \( t = 2 \), the employee optimally chooses her action \( x \) to maximize the value of the firm. When there is no public disclosure but there is internal disclosure (i.e., \( d = \emptyset, m = \theta \)), the employee chooses whether to leak the message to shareholders (\( \lambda = 1 \)) or not (\( \lambda = 0 \)). If she leaks the message, she incurs a private cost \( \tilde{c} \) but receives a payoff \( \Pi \equiv |P_{NI} - V| \), where \( P_{NI} \) is the price of the firm conditional on no disclosure and no leaks. The payoff \( \Pi \) reflects the notion that the “value” of the leak is driven by how far the current, no-information price is from the true value of the firm. The realization of \( \tilde{c} = c \) is known to the employee.

\(^{10}\)Since the decision to leak information is endogenous in this model, the assumption of a single employee is made for tractability.
but unknown to the manager - instead, the manager believes the cost has a CDF $F(\cdot)$, i.e., $	ilde{c} \sim F(\cdot)$. The employee solves the following problem:

$$
\max_{x,\lambda} \mathbb{E} \left[ \theta - \beta (x - \theta)^2 + \lambda (\Pi - c) 1_{\{d=\emptyset, m=\theta\}} \right] \mid d, m].
$$

(132)

This implies that the optimal choice of action is $x = \mathbb{E} [\theta \mid d, m]$ and conditional on $d = \emptyset$ and $m = \theta$, the employee optimally chooses to leak when $\Pi > c$.

Given their information, the shareholders set the price $P$ as the conditional expectation of the value, i.e.,

$$
P = \mathbb{E} [V \mid d, \lambda \times m]
$$

(133)

$$
= \begin{cases} 
\theta & \text{if } d = \theta \text{ or } \lambda \times m = \theta \\
PNI & \text{if } d = \emptyset \text{ and } \lambda = 0 
\end{cases}
$$

(134)

At date $t = 3$, the value of the firm is publicly revealed. The manager receives a payoff $U$:

$$
U = (1 - \delta) P + \delta V - \lambda \kappa,
$$

(135)

where $\delta < 1$ captures the relative weighting of the terminal value and the price and $\kappa > 0$ is a penalty incurred by the manager when the employee leaks information to the market. Finally, we assume that $\theta$, $\xi$ and $\tilde{c}$ are independently distributed, and analogous to Assumption 1, we assume that

$$
ph + (1 - p) l - \beta p (1 - p) (h - l)^2 > l.
$$

(136)

Consider an equilibrium in which (i) an informed manager with $\theta = h$ publicly discloses her information i.e., $d = h$, (ii) an informed manager with $\theta = l$ publicly discloses her information with probability $\alpha_d$, and (iii) conditional on no public disclosure (i.e., $d = \emptyset$), an informed manager with $\theta = l$ sends a message $m = l$ with probability $\alpha_m$.

We begin with some observations. First, conditional on $d = m = \emptyset$, beliefs about $\theta$ are given by:

$$
\theta_{ND} \equiv \mathbb{E} [\theta \mid d = m = \emptyset] = \omega h + (1 - \omega) l, \text{ where }
$$

$$
\omega \equiv \Pr (\theta = h \mid d = m = \emptyset) = \frac{(1 - \pi) p}{1 - \pi + \pi (1 - \alpha_d) (1 - \alpha_m)} \in [(1 - \pi) p, p].
$$

(137)

(138)

Next, conditional on no public disclosure and no leak (i.e., $d = \emptyset$ and $\lambda = 0$), the price is given by

$$
P_{NI} = \mathbb{E} [V \mid d = \emptyset, \lambda = 0] 
$$

(139)

$$
\equiv \tau V_{NI} + (1 - \tau) l,
$$

(140)

where the probability that the employee is uninformed, conditional on no public disclosure is given by:

$$
\tau \equiv \Pr (m = \emptyset, d = \emptyset \mid d = \emptyset) = \frac{1 - \pi + \pi (1 - \alpha_d) (1 - \alpha_m)}{1 - \pi + \pi (1 - \alpha_d)} \in [1 - \pi, 1],
$$

(141)
and where the value of the firm when the employee is not informed is given by

\[ V_{NI} = E \left[ \theta - \beta (\theta - \theta_{ND})^2 \right] | m = d = \emptyset \]

\[ = \theta_{ND} - \beta \omega (1 - \omega) (h - l)^2. \]  

(142)

Finally, this implies that the payoff to the manager (i) from disclosing is given by \( U_D(\theta) = \theta \), (ii) from not publicly disclosing, but sending a message \( m = \theta \) is

\[ U_{ND,m}(\theta) = \Pr (c > \Pi) \{(1 - \delta) P_{NI} + \delta \theta\} + \Pr (c \leq \Pi) \{\theta - \kappa\}. \]

(144)

and (iii) from not disclosing publicly or internally (i.e., \( m = d = \emptyset \)) is

\[ U_{ND,ND}(\theta) = (1 - \delta) P_{NI} + \delta (\theta - \beta (\theta - \theta_{ND})^2). \]

(145)

Note that since \( \omega \leq p \) and \( \tau \in [0,1] \), we have \( \theta_{ND} < h \), \( V_{NI} < h \) and \( P_{NI} < h \). This implies that the \( \theta = h \) manager always strictly prefers to disclose her information, i.e.,

\[ U_D(h) > U_{ND,m}(h), \text{ and } U_D(h) > U_{ND,ND}(h). \]

(146)

On the other hand, the \( \theta = l \) manager is indifferent between public disclosure (i.e., \( d = \theta \)) and private communication (i.e., \( d = \emptyset \) and \( m = \theta \)) when

\[ \Delta_d \equiv U_D(l) - U_{ND,m}(l) = 0 \]

(147)

and is indifferent between internal disclosure and not when

\[ \Delta_m \equiv U_{ND,m}(l) - U_{ND,ND}(l) = 0. \]

(148)

To explicitly characterize the equilibrium, we need to specify a CDF \( F(\cdot) \) for the cost function. To ensure tractability for the ensuing analysis, suppose \( \bar{c} \in \{0, \bar{c}\} \) with probability \( \{\rho, 1 - \rho\} \), where \( \rho \in [0,1] \) and \( \bar{c} > h - l \). In this case, the above expressions simplify to:

\[ \Delta_d = \rho \kappa - (1 - \rho) (1 - \delta) (P_{NI} - l) = 0 \]

(149)

and

\[ \Delta_m = \beta \delta (l - \theta_{ND})^2 - \rho (\kappa + (1 - \delta) (P_{NI} - l)) = 0 \]

(150)

These observations together lead to the following result.

**Proposition 9.** When \( \rho = 0 \), there exists an equilibrium in which an informed manager of type \( \theta = h \) always publicly discloses her signal, and an informed manager of type \( \theta = l \) never publicly discloses her signal, but internally discloses her signal with probability one. i.e., \( \alpha_d = 0 \) and \( \alpha_m = 1 \).

**Proof.** Note that when \( \rho = 0 \), the LHS of (150) is strictly higher than the RHS, which implies an \( l \)-type manager strictly prefers to reveal her information to her employee i.e.,
\( \alpha_m = 1 \). This implies \( \omega = p \), and by the assumption in (136), \( V_{NI} > l \). As a result, the RHS of (149) is strictly higher, which implies an \( l \)-type manager strictly prefers to not publicly disclose her type i.e., \( \alpha_d = 0 \). \( \blacksquare \)

**Proposition 10.** Suppose \( \beta(h-l) \leq 1 \). There exists \( \bar{\rho}, \check{\rho} \in [0,1] \) such that, for \( \rho \in [\rho, \check{\rho}] \), there exists an equilibrium in which an informed manager of type \( \theta = h \) always publicly discloses her signal, and an informed manager of type \( \theta = l \) publicly discloses her signal with probability \( \alpha_d \in (0,1) \) and internally discloses her signal with probability \( \alpha_m \in (0,1) \).

**Proof.** When both \( \alpha_d, \alpha_m \in (0,1) \), we must have (149) and (150) hold simultaneously. Solving these equations for \( \tau \) and \( \omega \) gives:

\[
\omega = \frac{1}{h-l} \sqrt{\frac{\kappa \rho}{\beta \delta (1-\rho)}}, \quad \tau = \frac{\kappa \rho}{(1-\rho)(1-\delta)\omega(h-l)(1-\beta(1-\omega)(h-l))},
\]

and solving for \( \alpha_d \) and \( \alpha_m \) gives:

\[
\alpha_d = \frac{\tau \omega - (1-\pi)p}{\pi \tau \omega}, \quad \alpha_m = \frac{p(1-\tau)}{p-\tau \omega}.
\]

Since we need \( \alpha_d \in (0,1) \), we must have

\[
\tau \omega \geq (1-\pi)p, \quad \tau \omega - (1-\pi)p \leq \pi \tau \omega
\]

Similarly, since we need \( \alpha_m \in (0,1) \), we must have

\[
p(1-\tau) \leq p - \tau \omega, \quad 1 - \tau > 0.
\]

The binding constraints are \( \tau \leq 1, \ \omega \leq p, \ (1-\pi)p \leq \tau \omega \). Plugging in the expression for \( \tau \) and \( \omega \), we have:

\[
\frac{\kappa \rho}{1-\rho} \leq \beta \delta p^2(h-l)^2, \quad (1-\delta)\omega(h-l)(1-\beta(1-\omega)(h-l))
\]

Note that since \( \beta(h-l) < 1 \), we have \( \omega(1-\beta(1-\omega)(h-l)) \) is increasing in \( \omega \). As a result, sufficient conditions for existence of the equilibrium are

\[
\rho \geq \frac{(1-\pi)p(1-\delta)(h-l)}{(1-\pi)p(1-\delta)(h-l)+\kappa} \equiv \rho
\]

\[
\rho \leq \min \left\{ \frac{\beta \delta p^2(h-l)^2}{\beta \delta p^2(h-l)^2 + \kappa}, \quad \frac{(1-\delta)p(h-l)(1-\beta(1-p)(h-l))}{(1-\delta)p(h-l)(1-\beta(1-p)(h-l)) + \kappa} \right\} \equiv \check{\rho}.
\]

which establishes the result. \( \blacksquare \)
Figure 5: Equilibrium disclosure and real efficiency as a function of $\rho$
Other parameters are $h = 2$, $l = 0$, $p = 0.5$, $\delta = 0.5$, $\kappa = 0.2$, $\pi = 0.5$, $\beta = \frac{0.95}{h-l}$.

Note that the above sufficient conditions are not tight. Figure 5 provides a numerical illustration of the equilibrium disclosure probabilities $\alpha_m$ and $\alpha_d$ as a function of $\rho$. Consistent with the first result, when $\rho = 0$, there is no public disclosure (i.e., $\alpha_d = 0$), but perfectly informative internal communication (i.e., $\alpha_m = 1$). Moreover, as in the benchmark model with cheap talk, an initial increase in the likelihood of a leak (i.e., an increase in $\rho$) leads to a deterioration of internal communication (i.e., a decrease in $\alpha_m$), but (eventually) more public disclosure i.e., $\alpha_d$ increases in $\rho$. However, in contrast to the benchmark model, once $\rho$ is sufficiently high, an increase in leakage leads to an increase in internal communication as well. To gain some intuition for this, recall that for $\alpha_d, \alpha_m \in (0, 1)$, we must have $\Delta_d = 0$ and $\Delta_m = 0$. The former indifference condition can be expressed as:

$$P_{NI} - l = \frac{\rho}{1 - \rho} \frac{\kappa}{1 - \delta}, \quad (160)$$

and using the above expression for $P_{NI} - l$, one can express the condition $\Delta_m = 0$ as

$$\beta \delta (l - \theta_{ND})^2 = \rho \left( \kappa + (1 - \delta) (P_{NI} - l) \right) = \frac{\rho}{1 - \rho} \kappa. \quad (161)$$

Intuitively, as $\rho$ increases, the distance between $\theta_{ND}$ and $l$ also increases. Intuitively, as $\rho$ increases, more $l$-managers publicly disclose their information. As a result, conditional on
no disclosure (i.e., \(d = m = \emptyset\)), the expected type of the firm is higher (i.e., \(\omega\) increases). However, this upward revision in the employee’s beliefs leads to more inefficient outcomes conditional on \(\theta = l\), and the manager improves internal disclosure in response. In fact, for sufficiently high \(\rho\), the manager reverts to perfectly informative internal communication and incur the expected penalty (i.e., \(\rho \kappa\)) in order to reduce the loss to due inefficient actions by the employee.

Figure 5 also provides an illustration of real efficiency in this setting. As before, conditional on an informed manager, real efficiency is given by: real efficiency is given by

\[
RE = -\mathbb{E} \left[ \beta (x^* - \theta)^2 \big| \xi = 1 \right] = -\beta (1 - \alpha_d) (1 - \alpha_m) (l - \theta_{ND})^2. \tag{162}
\]

As in our benchmark model, real efficiency is maximized with zero leakage since internal communication is perfectly informative. Moreover, with an initial increase in leakage, real efficiency falls as internal communication deteriorates. However, once the likelihood of leakage is sufficiently high, real efficiency increases again because (i) there is more public disclosure by the manager (i.e., \(\alpha_d\) increases) and (ii) there is more internal communication (i.e., \(\alpha_m\) increases). As in the benchmark case, real efficiency is again maximized for a sufficiently high likelihood of leakage.

Taken together, the analysis in this appendix suggests that much of the intuition from our benchmark model is robust. Specifically, an increase in the likelihood of leakage can lead to an improvement in public disclosure, a deterioration in internal communication, and consequently, decrease in real efficiency. However, when the likelihood of leakage is sufficiently high, real efficiency is likely to improve with leakage.