Information Leaks and Voluntary Disclosure

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We study managers' decisions to voluntarily disclose information to the capital market when they face a risk of information leakage. Our analysis offers three main insights. First, we find that leaks that are less informative create market discipline and motivate more voluntary disclosure. Second, an increasing likelihood of information leakage has ambiguous effects. It fosters market discipline but increases managers' rewards from successful non-disclosure. Consequently, a higher likelihood of leakage impedes disclosure if leaks represent rare events and fosters voluntary disclosure if leaks are sufficiently probable. Third, we find that market discipline is more effective for myopic managers who focus on short-term prices and cannot react to information leaks in a timely manner. Such managers are willing to preempt information leakage and to disclose their private information.

Keywords: voluntary disclosure, information leaks, market discipline, managerial myopia

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I. Introduction

Digitization and the increasing connectedness with customers, suppliers, and creditors create challenges for firms in protecting their private information. Despite the considerable amounts spent on data security,[1] there is abundant empirical evidence of information leakage into capital markets (Khan and Lu 2013; Hendershott et al. 2015; Kacperczyk and Pagnotta 2019; Huang et al. 2020). Empirical studies suggest that inside information is leaked via various channels. For instance, firms may be affected by accidental or hostile data breaches (Amir et al. 2018). They share information with contractual partners such as suppliers (Anand and Goyal 2009; Chen and Özer 2019) and creditors (Bushman et al. 2010; Ivashina and Sun 2011) who break confidentiality clauses. Moreover, order flow information of insiders may be leaked to the market and indicate their private expectations (McNally et al. 2017; DiMaggio et al. 2019).

An important, yet largely neglected aspect is that information leaks may affect firms' willingness to provide voluntary disclosures.[2] Existing studies show the crucial role of the information environment in shaping firms' disclosure incentives (Einhorn 2018; Frenkel et al. 2020; Michaeli and Wiedman 2021). The possibility of information leaks affects firms' information environment. Moreover, leaks have a specific information structure, which has not been considered by prior work. Investors who identify a leak learn two types of information. First, they come to know part of the firm's inside information, for instance, the progress of R&D processes, details about new products, or partnerships. Second, information leaks reveal that the management is endowed with information but has decided not to share it. Such information on managers' strategic behavior is useful in making inferences on the favorability of the information. In this regard, leaks differ from information that is originated outside the firm such as analyst reports.

We use a standard model of discretionary disclosure (Dye 1985; Jung and Kwon 1988) to study the consequences of information leakage for firms' willingness to share their private information. Our results show that the effects of information leaks depend on the informativeness and the likelihood of information leakage. If information leaks are not

[1] For instance, a recent survey among the members of the Financial Services Information Sharing and Analysis Center (FS-ISAC) finds that on average financial institutions spent 0.48% of their overall revenues on cybersecurity (Deloitte Center for Financial Services 2021).

[2] Although investors have access to multiple information sources, firms' voluntary disclosures are still a major source of value-relevant information (e.g., Beyer et al. 2010; Miller and Skinner 2015).

perfectly informative (i.e., if investors cannot gauge their value implications), managers face a threat of adverse market reactions. Therefore, less informative leaks introduce market discipline and motivate more disclosure. An increasing likelihood of information leakage has ambiguous effects. It amplifies the disciplining effect of uninformative leaks but also causes a countervailing force. If leaks occur with higher probability, it is more difficult for managers to hide their private information. At the same time, the market price following successful non-disclosure increases, and informed managers face stronger incentives to withhold their information. Interestingly, the market discipline caused by uninformative leaks is more effective if managers are myopic and interested in short-term market prices. Managers who maximize long-term stock prices are less vulnerable to adverse market reactions because they can respond to information leaks by revising their initial non-disclosure decisions.

As in Dye (1985), we consider a risk-neutral manager who observes a private signal about the firm value with positive probability. An informed manager can truthfully disclose or withhold his information; an uninformed manager cannot credibly convey that he is uninformed. We extend this model considering the possibility that the private information leaks into the capital market. We distinguish two characteristics of leaks. The likelihood of leaks is the probability of a leak following a non-disclosure decision.[3] The informativeness of leaks is the probability that investors understand the economic implications of the leaked information conditional on the fact that a leak occurs. Practical examples show that leaks differ in their comprehensiveness. For example, managers' order-flow information provides only coarse evidence on their private information.[4] In contrast, leaks that reveal details of a firm's contractual obligations towards its suppliers can provide considerable information on future financial surpluses. To account for this fact, we distinguish *uninformative leaks*, which only reveal that the manager has received a signal, from *perfect leaks*, which also show the corresponding value implications. The informativeness of leaks is given by the probability distribution over these two events.

[3]We consider leaks as random events and not as strategic decisions. This is in line with empirical findings, which mainly point at negligence and third party involvement as causes of leaks. Although managers may have incentives to strategically leak information, such behavior can be very costly. Leaks interfere with firms' disclosure management, bring up legal risks, and cause proprietary costs. Moreover, firms invest significant amounts in information security to reduce the risk of information leakage.

[4]An illustrative example is the leakage of product information at Apple. In 2017, the daughter of an Apple employee shared a picture of a new smartphone, which had not been announced to the public (see Griffin 2017). This leak provided investors with an update about Apple's production progress. Yet, it is questionable whether the information was useful in learning about future profits.

In equilibrium, an informed manager follows a threshold strategy. He discloses sufficiently favorable information exceeding a threshold value and withholds unfavorable news. The structure of the partial-pooling equilibrium is reminiscent of prior studies (e.g., Dye 1985; Dye and Hughes 2018; Cheynel and Levine 2020; Friedman et al. 2020) and can be aligned with empirical evidence on firms' actual disclosure behavior (see Kothari et al. 2009; Bao et al. 2019; Bertomeu et al. 2022).[5] We show that the threshold level and, thus, the manager's propensity to share his information depends on the likelihood and informativeness of leaks. More specifically, our analysis yields three main findings.

First, a lower informativeness of information leaks disciplines the manager and fosters voluntary disclosure. Rational investors who observe an uninformative leak do not understand the actual economic implications of the leaked information and interpret the manager's decision to withhold information as bad news. They therefore assign a low market price.[6] This adverse market reaction poses a threat for managers of firms with intermediate firm values. Such managers disclose their information in order to preempt uninformative leaks and to separate themselves from managers with even worse information. In contrast, perfect leaks do not affect the manager's disclosure incentives.[7]

This result has noteworthy implications for the interpretation of the disclosure threshold. In the standard disclosure model of Dye (1985) and Jung and Kwon (1988) the equilibrium disclosure threshold minimizes the no-information price—a result which is known as *minimum principle* (Acharya et al. 2011; DeMarzo et al. 2019). The interpretation is that the equilibrium market price expresses maximal skepticism. The possibility of uninformative leaks allows for equilibria with more voluntary disclosure than suggested by the minimum principle. Intuitively, uninformative leaks create additional market discipline complementing investors' skepticism. This result distinguishes our model from related work such as Frenkel et al. (2020).

[5] A number of studies identify disclosure equilibria with multiple pooling regions. This might be the case if managers are uncertain about the market reaction to their reports (Suijs 2007), if they can distort disclosures by real decisions (Beyer and Guttman 2012), if the quality of their information is not publicly known (Hummel et al. 2018), if investors have access to competing information sources (Einhorn 2018), and if firm owners use disclosures as performance measures to mitigate moral hazard (Versano 2020).

[6] An example is the release of Apple's iPhone 12. In early 2020, a series of leaks indicated delays in the production process. The absence of an official statement led to speculations about a delay of several months and considerable stock price drops (Spence 2020). In July 2020, Apple's CFO succumbed to the pressure and announced a delay of a few weeks correcting less favorable market expectations (Kelly 2020).

[7] In this regard, our results are in line with other studies that question the positive association between a more transparent information environment and market discipline (e.g., Dang et al. 2017).

Second, we find that a higher likelihood of leaks has ambiguous effects. It amplifies the disciplining effect of uninformative leaks and thus causes a *revelation effect*. At the same time, there is a countervailing *concealment effect* that motivates the manager to withhold his information. Consider the investors' inferences on firm value if they do not receive any information, neither from the manager nor through a leak. This might be the case because the manager is uninformed or because he hides unfavorable news. With increasing likelihood of leakage, it is less probable that a strategic manager can hide his private information. Investors therefore deem it more likely that the manager is uninformed and assign a higher market price. Paradoxically, this provides incentives for an informed manager to withhold his information. If leaks constitute rare events, the concealment effect is the dominant force and an increasing likelihood of leaks reduces disclosure. If leaks are sufficiently probable, further increases in their likelihood foster voluntary disclosure due to the revelation effect. We find that there may be more or less voluntary disclosure compared to a world without information leakage.

Third, our results suggest that market discipline is more effective if the manager is myopic, i.e., if he maximizes short-term prices. We assume that the manager can react to leaks by revising a non-disclosure decision, and he maximizes the weighted average of the market prices before and after a disclosure revision. Intuitively, the opportunity to react to an uninformative leaks attenuates the threat of adverse market reactions. Instead of preempting leaks by voluntary disclosure, the manager can always counter an adverse market reaction and share his private information retroactively. The opportunity to react to an information leak therefore obviates market discipline. Note however that this rationale only applies if the manager is interested in the long-term market price. If managers are more myopic and assign higher weight to short-term prices, they are more forthcoming and increase theirs disclosures. These results indicate that managerial myopia fosters market discipline and increases firms' voluntary disclosure.

In a model extension, we consider the effects of proprietary costs in the presence of information leaks. If information is disclosed or leaked into the capital market, the firm incurs a cost that reduces the firm value. This assumption reflects the fact that proprietary information can be used by rivals or other related parties to take harmful actions (e.g., Verrecchia 1983; Darrough and Stoughton 1990; Wagenhofer 1990). In our setting, proprietary costs are triggered not only by firm disclosures but also by information leaks. Thus, proprietary costs penalize both disclosure and non-disclosure decisions, and their total effect depends on the likelihood and informativeness of leaks. Our analysis sheds light on the nuanced effects of proprietary costs in the presence of information leaks. We show that the additional consideration of disclosure costs does not affect the previously mentioned findings. This highlights the robustness of our results.

Our study contributes to three strands of literature. First, our results relate to the literature on firms' voluntary disclosure in the presence of additional information sources (e.g., Dye 1998; Banerjee and Kim 2017; Einhorn 2018; Frenkel et al. 2020; Petrov 2020; Michaeli and Wiedman 2021). Dye (1998) considers managers' voluntary disclosure decisions when investors may learn that he withholds information. In line with our results, managers extend disclosures if their information endowment is exposed with positive probability. Our result show that leaks may reduce voluntary disclosure if they reveal the inside information along with the managers' information endowment. Banerjee and Kim (2017) consider the effects of information leaks when managers can adapt their internal communication. Coarser communication reduces firm performance but inhibits information leakage. They find that a higher likelihood of leaks motivates a coarser internal communication and more disclosure. Michaeli and Wiedman (2021) study a manager's decision to provide voluntary disclosures either before or after the arrival of a public signal. The public signal is correlated with the firm value but, in contrast to our model, independent of the manager's information endowment. Perhaps most closely related to our analysis, Frenkel et al. (2020) study the joint effect of voluntary disclosure and analyst coverage on market efficiency. Analysts perfectly learn the firms' inside information and truthfully reveal their signal. Thus, analyst reports represent an information source that is reminiscent of perfect information leaks in our model. In an extension, they discuss the possibility that analysts provide noisy signals about inside information. This setting is similar to our model of uninformative leaks because managers' and analysts' information endowment is correlated. However, the authors conclude that this set of assumptions is intractable in their capital market setting and do not provide a model analysis (p. 187).[8]

A second strand of literature addresses managers' legal obligation to share value-relevant information and studies the effects of shareholder litigation (see Trueman 1997; Evans III and Sridhar 2002; Dye 2017; Schantl and Wagenhofer 2021). Trueman (1997)

[8]To consider imprecise analyst information, Frenkel et al. (2020) study a modified setting, where managers observe leaks before they decide on firm disclosure. This assumption differs from our analysis.

and Schantl and Wagenhofer (2021) study a manager's disclosure decision if the firm's shareholders can litigate. Litigation is costly and yields uncertain damages payments. Trueman (1997) finds that the manager discloses sufficiently favorable and unfavorable news but withholds intermediate information. He assumes that the litigation lawyer earns the net benefit from litigation. In contrast, Schantl and Wagenhofer (2021) assume that the shareholders receive all damages payments. The litigation option therefore creates a premium to the firm's market price. For low litigation costs, this premium is crucial and changes the disclosure equilibrium. Dye (2017) considers the disclosure decision of a seller who may be privately informed about an asset and is liable for buyers' damages. If the seller does not share his information with the buyer, this behavior is revealed with some probability, and the seller must make a damages payment. Dye (2017) finds that a higher probability of discovery can reduce the likelihood of voluntary disclosure. Our results do not arise from shareholder litigation and legal damages payments but from market pressure that is exerted by the rational price reactions to information leaks.

Third, our analysis is related to models of dynamic voluntary disclosure such as Einhorn and Ziv (2008), Acharya et al. (2011), Beyer and Dye (2012), Guttman et al. (2014), Cianciaruso and Sridhar (2018), Menon (2020), and Aghamolla and An (2021). As in Bagnoli and Watts (2021), we consider a manager's decision to revise a previous non-disclosure decision after the arrival of public information. In contrast to our analysis, they assume that the manager generally observes private information but faces proprietary costs of early and late disclosure. The manager's willingness to revise his initial decision depends on the favorability of the public information. According to our results, the manager's decision depends on the informativeness of the leaked signal.

Our model allows for novel empirical predictions. A higher likelihood of leaks fosters voluntary disclosure in environments, where leaks are less informative—for instance, because their economic implications are difficult to understand. This is typically the case in industries with complex business models and products. In contrast, if investors can easily infer the value implications of leaked information, a higher likelihood of leaks impedes disclosure. We therefore expect that the informativeness of leaks varies between different industries. We also find that the effects of information leaks depend on managers' time horizon. Leaks introduce market discipline on managers whose wealth is sensitive to short-term price reactions. These managers preempt information leakage by more extensive voluntary disclosures.

The remainder of the paper is structured as follows. We introduce the model in section II. In section III, we study the effects of information leaks on voluntary disclosure and present our main results. We extend the model for disclosure costs in section IV and highlight the robustness of our results in section V. In section VI, we conclude our study. All proofs are in the Appendix.

II. Model setup

We study the disclosure decision of a manager who is endowed with private information about firm value and faces the risk of information leaks when he decides against disclosure. Disclosures are made towards a competitive capital market, modelled as a representative investor. If the manager withholds his information but experiences a leak, he can revise the initial non-disclosure decision. All players are risk neutral.

The uncertain value of the firm is given by the random variable $\tilde{x}$. The manager and investors share prior beliefs about $\tilde{x}$ given by a continuous probability distribution with bounded support $[\underline{x}, \overline{x}]$, where $f(\cdot)$ and $F(\cdot)$ denote the p.d.f. and c.d.f., respectively. For $y \in [\underline{x}, \overline{x}]$, we use $\mu \equiv E[\tilde{x}]$ and $E(y) \equiv E[\tilde{x} \,|\, x \leq y]$ to denote the mean and truncated mean of the firm value. In line with prior literature, we assume that the distribution of $\tilde{x}$ is log-concave (e.g., Cianciaruso and Sridhar 2018; Bagnoli and Watts 2021).[9]

We build on a model of partially verifiable voluntary disclosure that is frequently used in the literature (e.g., Dye 1985; Jung and Kwon 1988). The manager of the firm privately learns the firm value x with probability $p \in (0, 1)$ and remains uninformed otherwise.[10] We denote the manager's information set as $\Omega_M \in \{x, \emptyset\}$, where $\Omega_M = \emptyset$ indicates a lack of private information.[11] His disclosure is a function of the available information, $d = d(\Omega_M)$. If the manager observes x, he can disclose it in a credible and costless manner or remain silent, i.e., $d(x) \in \{x, ND\}$, where ND denotes non-disclosure. He is unable, however, to make a credible claim that he has *not* observed x, i.e., $d(\emptyset) = ND$.

The innovation of our model is the possibility of a (more or less informative) leak. Similar to Frenkel et al. (2020) and Bagnoli and Watts (2021), we study information leaks

[9] Many common distributions (such as normal, exponential, and uniform distributions) share this property. Log-concavity implies that $dE(y)/dy < 1$ (see Bagnoli and Bergstrom 2005).

[10] We consider perfect information for ease of exposition. The insights from our analysis are unaffected if we assume that the manager observes an imperfect signal about the firm value.

[11] With a slight abuse of notation, we identify the realization of the firm value x and the singleton set $\{x\}$.

as probabilistic arrival of public information. Conditional on the fact that the manager is privately informed, a leak occurs with probability $\pi \in [0,1)$. With probability $1-\pi$, no information is leaked and investors remain uninformed. We interpret π as the likelihood of information leakage. It represents the residual risk of leaks given the firm's investments in data protection and information security. The ongoing trends towards digitization and the outsourcing of business processes hinder firms' attempts to avoid information leakage.[12] If leaks occur with probability 1, there is generally full revelation in equilibrium. We exclude this uninteresting case from our analysis.

Ex ante, there is uncertainty not only about whether a leak occurs but also about the information revealed by a leak. Some leaks provide extensive information, such as details of new products, demand forecasts, or contractual terms with suppliers. Other leaks are less extensive and difficult to interpret without insider knowledge. In our model, we allow for two extreme types of leaks. In case of a *perfect leak*, investors learn the firm value x, i.e., the economic implications of the leaked information are well understood. In contrast, an *uninformative leak* has unclear economic implications and does not change investors' beliefs.[13] Conditional on the fact that a leak occurs, it is perfect with probability ψ and uninformative with probability $1-\psi$. We use $\psi \in [0,1]$ as a measure of informativeness.[14] Low levels of ψ are descriptive of settings in which it is unlikely that leaks reveal the firm value. As ψ approximates 1, leaks tend to reveal the inside information. A common feature of both types of leaks is that investors learn the manager's information endowment. Information can only be leaked if the manager is informed. Thus, investors who observe a leak understand that the manager deliberately withholds his private information. This may be useful in making inferences about the firm value.

After observing a potential disclosure and information leak, the competitive market forms a market price for the firm.[15] Let Ω_I denote the risk-neutral investors' information set. The price $P(\Omega_I)$ coincides with the expected firm value conditional on the available

[12] Within our setting, there is no rationale for the manager to forgo the firm's disclosure channel and to strategically leak his private information to the market. This is in line with the observation that proprietary information is shared accidentally or leaked by contractual partners (e.g., Chen and Özer 2019).

[13] If there was no strategic disclosure by the manager, uninformative leaks would be ignored by investors.

[14] We consider a mixture of two extreme events to simplify the mathematical exposition. In section **??**, we consider an alternative notion of informativeness assuming that investors observe a noisy signal about the inside information. The qualitative insights from both analyses are identical.

[15] We follow Banerjee and Kim (2017) and Frenkel et al. (2020) and assume that leaks provide publicly available information. For studies that consider the information leakage to informed investors and the dissemination of information within capital markets see Brunnermeier (2005) and Indjejikian et al. (2014).

information and investors' beliefs about the disclosure strategy, $P(\Omega_I) = E[\tilde{x}\,|\,\Omega_I]$. It is sufficient to distinguish three realizations of the investors' information set. The investors potentially learn the actual firm value through firm disclosure or a perfect leak ($\Omega_I = x$). In case of an uninformative leak, investors know that the manager has observed the firm value but they don't learn the the inside information ($\Omega_I = \hat{x}$). If the manager keeps quiet and there is no leak, investors consider the possibility that the manager is either uninformed or he knows x but avoids disclosure ($\Omega_I = \emptyset$).

After the market price is formed, the manager can react by revising his initial disclosure as denoted by $d^r(\Omega_M^r) \in \{x, ND\}$, where $\Omega_M^r = \Omega_M \times \Omega_I$ describes his information set at this point in time. This option can only be used by informed managers who have not shared their information at the initial disclosure stage. Uninformed managers still cannot credibly reveal that they lack information, i.e., $d^r(\Omega_M^r) = ND$ for $\Omega_M = \emptyset$. However, informed managers who have initially decided to remain silent (i.e., $d(x) = ND$) can provide additional information choosing $d^r(\Omega_M^r) \in \{x, ND\}$ for $\Omega_M = x$. The investors observe a potential disclosure revision and adjust the market price $P^r(\Omega_I^r) = E[\tilde{x}\,|\,\Omega_I^r]$ to the updated information set $\Omega_I^r \in \{x, \hat{x}, \emptyset\}$, where $\Omega_I^r = x$ denotes the case that the investors learn the actual firm value either via disclosure or through a perfect leak. If investors observe an uninformative leak and the manager remains silent at the disclosure revision stage, $\Omega_I^r = \hat{x}$ is realized. The information set $\Omega_I^r = \emptyset$ is realized either if the manager is uninformed or if he withholds his private signal in the initial and revised disclosure decision and no leak occurs.

The risk-neutral manager uses his initial and revised disclosure decisions to maximize his utility, which is the weighted sum of the short-term and long-term market prices,[16]

$$U = \lambda P + (1 - \lambda)P^r, \tag{1}$$

where $\lambda \in (0, 1]$ represents the degree of managerial myopia. For low values of λ, the manager is mainly interested in the long-term market price P^r, which reflects the public information after disclosure revision. Increasing values of λ imply higher short-termism. For $\lambda = 1$, the manager is completely myopic and maximizes the short-term price P. For simplicity, we assume that an indifferent manager discloses his private information.

[16] This assumption coincides with Bagnoli and Watts (2021). In line with prior literature, we abstract from potential agency problems between current shareholders and the manager (see Dye 1985).

FIGURE 1
Decision tree of the disclosure game

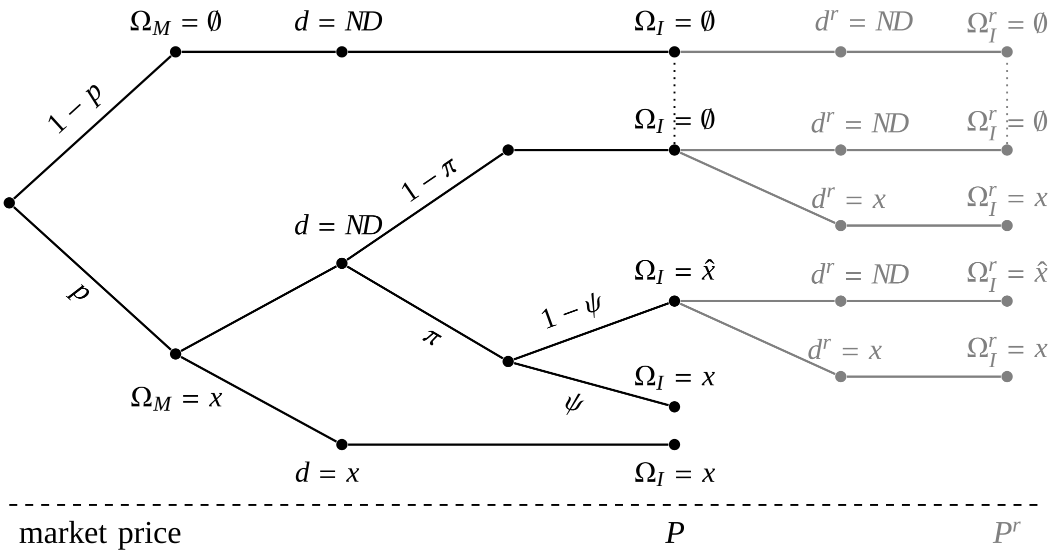


Figure 1 depicts the complete game. The information structure is common knowledge.

III. Results

Benchmark results without information leaks

In the absence of leaks, i.e., for $\pi = 0$, the manager fully controls the publicly available information about the firm value. No news arrive after the manager's initial disclosure choice, and, therefore, he does not benefit from revising his decision. Consequently, there is no price movement at the revision stage, $P^r = P$. The dynamic structure of the game is irrelevant, and the benchmark setting resembles the one-shot disclosure game studied by Dye (1985) and Jung and Kwon (1988). We find a unique *threshold equilibrium*, such that an informed manager reveals the firm value whenever it exceeds a threshold level $y \in (\underline{x}, \mu)$ and withholds his information otherwise, i.e., $d(x) = x$ if and only if $x \geq y$.

The economic intuition behind this result is that a manager who observes a sufficiently low firm value, $x < y$, remaining silent and pool with uninformed types. Investors who do not receive any information (i.e., $\Omega_I = \emptyset$) are unable to distinguish the possible causes.

First, the manager may be uninformed. In this case, the absence of disclosure does not convey value-relevant information, and the expected firm value equals the prior mean, $E[\tilde{x}] = \mu$. Second, an informed manager may withhold unfavorable news because the firm value falls below the disclosure threshold. Accordingly, the expected firm value is the truncated mean $E[\tilde{x}|x \leq y] = E(y)$. The appropriate market price is the weighted sum of both values, μ and $E(y)$, with weights that reflect the posterior probabilities of both events, i.e., $P(\emptyset) = \frac{1-p}{1-p+pF(y)}\mu + \frac{pF(y)}{1-p+pF(y)}E(y)$. Managers who observe firm values above the disclosure threshold separate themselves by revealing their information (i.e., $\Omega_I = x$) and yield a market price $P(x) = x$.

To characterize the threshold level, consider the decision of a manager who observes $x = y$. This *marginal type* must be indifferent between disclosing and withholding his information. That is, the price upon disclosure, $P(y) = y$, and the non-disclosure price, $P_{ND} = P(\emptyset)$, are identical. This yields the equilibrium condition in the benchmark setting,

$$y = P(\emptyset). \tag{EC^B}$$

The unique solution to this equation, $y \in (\underline{x}, \mu)$, satisfies the minimum principle, i.e., it minimizes the non-disclosure price, P_{ND}. An interpretation of this result is that strategic withholding causes the most skeptical market evaluation (Acharya et al. 2011; Frenkel et al. 2020). This observation generalizes the unraveling result of Grossman (1981) and Milgrom (1981) to a setting in which investors are uncertain about managers' information endowment (see DeMarzo et al. 2019). It is easy to see that the equilibrium threshold, y, decreases with p. A higher probability of being informed reduces the benefits from pooling with uninformed types. Consequently, there is more voluntary disclosure.

Equilibrium with a myopic manager

Next, we turn to the main model with information leaks. We study the equilibrium in two steps. First, we consider the case that the manager is completely myopic (i.e., $\lambda = 1$). In a second step, we extend our analysis to show how a longer time horizon affects the results. A myopic manager's decision at the initial disclosure stage maximizes the short-term price P. Thus, we can focus on the initial disclosure decision and neglect any revisions at a later point in time. Lemma 1 characterizes the equilibrium of the disclosure game.

Lemma 1. *If the manager is completely myopic ($\lambda = 1$), there is a unique equilibrium given by a disclosure threshold, $y \in (\underline{x}, \mu)$, such that*

$$d(x) = \begin{cases} x & \text{if } x \geq y \\ ND & \text{else} \end{cases} \quad \text{and} \quad P(\Omega_I) = \begin{cases} x & \text{if } \Omega_I = x \\ E(y) & \text{if } \Omega_I = \hat{x}\,, \\ \frac{1-p}{1-p+p(1-\pi)F(y)}\mu + \frac{p(1-\pi)F(y)}{1-p+p(1-\pi)F(y)}E(y) & \text{if } \Omega_I = \emptyset \end{cases}$$

where $E(y) \equiv E[\tilde{x} \,|\, x \leq y]$. The threshold satisfies the equilibrium condition

$$y = \frac{\pi(1-\psi)}{1-\pi\psi}E(y) + \frac{1-\pi}{1-\pi\psi}P(\emptyset). \tag{EC^M}$$

Lemma 1 shows that, in equilibrium, an informed manager follows a threshold strategy. He discloses favorable information, $x \geq y$, and conceals low firm values. To understand this result, consider the decision of a manager who learns the firm value x. He discloses his information whenever the price upon disclosure, $P(x)$, weakly exceeds the expected non-disclosure price $P_{ND}(x)$. The latter is given by[17]

$$\begin{aligned} P_{ND}(x) &= E[P(\tilde{\Omega}_I) \,|\, d(x) = ND] \\ &= \pi[\psi P(x) + (1-\psi)P(\hat{x})] + (1-\pi)P(\emptyset). \end{aligned} \tag{2}$$

In contrast to the benchmark setting, strategic withholding implies the no-information price, $P(\emptyset)$, only with a probability of $1-\pi$. With a probability of π, a leak occurs and the investors learn either the actual firm value, $\Omega_I = x$, or the fact that the manager withholds his private information, $\Omega_I = \hat{x}$. Perfect and uninformative leaks occur with probabilities of ψ and $1-\psi$ and yield market prices of $P(x)$ and $P(\hat{x})$ respectively.

For given information set Ω_I, the investors hold rational beliefs about the manager's strategy. If they learn the firm value via disclosure or a perfect leak (i.e., $\Omega_I = x$), the market price reflects this information, $P(x) = x$. If the investors remain uninformed (i.e., $\Omega_I = \emptyset$), they receive information neither about the firm value nor about the manager's information endowment. They infer that the manager is uninformed, or he withholds unfavorable news. The appropriate no-information price, $P(\emptyset)$, is the weighted sum of the prior mean μ and the truncated mean $E(y)$ as stated in Lemma 1. In contrast to

[17] Note that perfect leaks might reveal the firm value even if the manager does not disclose his information. Thus, in contrast to the benchmark setting, both the disclosure price, $P(x)$, and the expected non-disclosure price, $P_{ND}(x)$, depend on the realized firm value.

the benchmark setting, an uninformative leak may expose the manager's information endowment without revealing the firm value (i.e., $\Omega_I = \hat{x}$). Investors understand that the manager withholds unfavorable news. The appropriate price is $P(\hat{x}) = E[\tilde{x} \mid x \leq y] = E(y)$.

In equilibrium, the marginal type who observes the firm value $x = y$ must be indifferent between disclosing and withholding his information, i.e., $P(y) = P_{ND}(y)$ or, equivalently, $y = \pi[\psi y + (1 - \psi)E(y)] + (1 - \pi)P(\emptyset)$. Rearranging this equation yields the equilibrium condition for a completely myopic manager, (EC^M), which differs from the condition (EC^B) in the benchmark case in two ways. First, the right-hand side is not the no-information price, $P(\emptyset)$, but the weighted sum of $P(\emptyset)$ and the price reaction $E(y)$ to a manager who is found hiding his private information. The weights depend on the likelihood and informativeness of leaks, π and ψ. Second, the no-information price $P(\emptyset)$ itself is affected by π and differs from that in the benchmark model. We conclude that the possibility of leaks affects the equilibrium threshold y. We use condition (EC^M) to derive the relevant comparative static results.

Lemma 2. *Suppose that the manager is completely myopic, i.e.,* $\lambda = 1$. *As the probability* p *of an informed manager increases, there is more voluntary disclosure, i.e.,* $dy/dp < 0$.

An increasing probability of an informed manager affects the disclosure threshold via the no-information price, $P(\emptyset)$. In the absence of public information, this price reflects the probability that the manager is either uninformed or withholding his information. With increasing p, investors deem it more likely that their lack of information results from strategic behavior. They shift probability weight from the prior mean μ toward the skeptical evaluation $E(y) < \mu$, and the no-information price, $P(\emptyset)$, decreases. This reduces the manager's incentives to conceal unfavorable news. The threshold y decreases.

Next, we study how the informativeness of information leaks ψ affects the equilibrium disclosure threshold.

Proposition 1. *Suppose that the manager is completely myopic, i.e.,* $\lambda = 1$. *As leaks become more informative (i.e., they are more likely to reveal the firm value), there is less voluntary disclosure, i.e.,* $dy/d\psi > 0$ *for* $\pi > 0$.

A main result of our analysis is that a manager increasingly withholds his information if leaks become more informative. To understand this result, consider the equilibrium condition (EC^M), which formalizes the indifference condition of a marginal type, i.e.,

$P_D(y) = P_{ND}(y)$. The informativeness ψ affects the disclosure incentives of a marginal type in an unambiguous manner.

If leaks occur with positive probability, a marginal type strictly prefers a perfect leak over an uninformative leak. The price following a perfect leak is $P(y) = y$. This is exactly the price that the manager expects either from disclosing or withholding his information, $P_D(y) = P_{ND}(y) = y$. Hence, perfect leaks do not pose a threat for the marginal type. If the marginal type however faces an uninformative leak, he is pooled with all lower types, $x \leq y$, which results in a strictly lower price, $P(\hat{x}) = E(y) < y$. Thus, the manager regrets his non-disclosure decision. This threat of underpricing creates market discipline and increases the manager's incentives to preempt uninformative leaks by sharing his private information. As leaks become more informative, there is a higher likelihood of a perfect leak and a lower likelihood of an uninformative leak. The disciplining effect of uninformative leaks is mitigated with increasing ψ.

A well-known feature of the voluntary disclosure model of Dye (1985) and Jung and Kwon (1988) is the *minimum principle*, which states that the equilibrium disclosure threshold minimizes the no-information price, $P(\emptyset)$ (Acharya et al. 2011; Guttman et al. 2014). Investors interpret non-disclosure in with the highest skepticism. In this sense, the minimum principle generalizes the famous unraveling result outlined by Grossman (1981) and Milgrom (1981) (see DeMarzo et al. 2019). While the minimum principle applies to the benchmark setting without leaks, our results show that it no longer holds if uninformative leaks occur with positive probability.

Corollary 1. *Let* $y_{\min} \in [\underline{x}, \overline{x}]$ *denote the threshold level that minimizes the no-information price* $P(\emptyset)$*. We find that* $y \leq y_{\min}$*, where equality holds if and only if uninformative leaks do not occur with positive probability (i.e., for* $\pi = 0$ *or* $\psi = 1$*).*

Whenever there is chance of uninformative leaks, the equilibrium threshold y falls below $y_{\min}$, which minimizes the no-information price. This result immediately follows from Proposition 1 and the fact that $y_{\min} = y|_{\psi=1}$. The intuition is that uninformative leaks create additional market discipline complementing investors' skepticism. Consequently, the presence of information leaks allows for equilibria with more voluntary disclosure than suggested by the minimum principle. This result distinguishes our model from related work such as Frenkel et al. (2020) who study the effect of external information sources that generally reveal managers' private information.

Another focal question of our analysis is how the likelihood of leaks, π, affects voluntary disclosure. According to Proposition 1, uninformative information leaks motivate additional disclosure. This finding seems to suggest that a higher likelihood of leaks amplifies market discipline and fosters disclosure—a result which would be in line with prior literature (see Dye 1998). However, Proposition 2 shows that the effect of π in not monotone.

Proposition 2. *Suppose that the manager is completely myopic, i.e.,* $\lambda = 1$*. There is a critical value* $\pi^\dagger \in [0, 1]$ *such that the threshold* y *increases in* π *for* $\pi < \pi^\dagger$ *and decreases in* π *for* $\pi > \pi^\dagger$*. That is,* $\pi^\dagger$ *minimizes voluntary disclosure.*

The overall effects of increasing likelihood π are ambiguous. There is a critical value $\pi^\dagger$, which maximizes the equilibrium threshold y and minimizes voluntary disclosure. For sufficiently high likelihood of leakage, $\pi > \pi^\dagger$, further increases in π foster disclosure. In contrast, higher levels of π reduce voluntary disclosure if leaks are less probable, $\pi < \pi^\dagger$.

Note that the effects of increasing π on the expected non-disclosure price $P_{ND}(y)$ of the marginal type are twofold: First, there is a higher likelihood of uninformative leaks, and the punitive market price $P(\hat{x}) = E(y)$ receives a higher weight in the equilibrium condition, (EC^M). Hence, the manager faces higher incentives to disclose. We conclude that a higher likelihood of leaks has a *revelation effect*. Second, the no-information price $P(\emptyset)$ increases in π. As Lemma 1 shows, $P(\emptyset)$ is the weighted average of the unconditional mean, μ, and the expected firm value conditional on deliberate non-disclosure, $E(y)$. While neither of the two valuations directly depends on π, the probability weights do. Consider the case that the investors are uninformed, i.e., $\Omega_I = \emptyset$. If there is a high probability of leakage π, it is less likely that an informed manager was able to successfully withhold his private information. The investors deem it more likely that the manager is uninformed, and $P(\emptyset)$ approximates μ. Conversely, for a low likelihood π, it is reasonable to assume that a strategic manager is able to hide his private information. The price $P(\emptyset)$ therefore moves towards $E(y)$, which implies a lower no-information price. We thus identify a *concealment effect*. The no-information price $P(\emptyset)$ increases with π, which provides incentives for the manager to withhold his private information.

Proposition 3. *The disclosure-minimizing likelihood $\pi^\dagger$ is increasing in the informativeness of leaks, i.e., $d\pi^\dagger/d\psi > 0$. In particular, we find that*

(i) $\pi^\dagger\big|_{\psi=1} = 1$*, i.e., the threshold y is strictly increasing in π for perfect leaks, and*

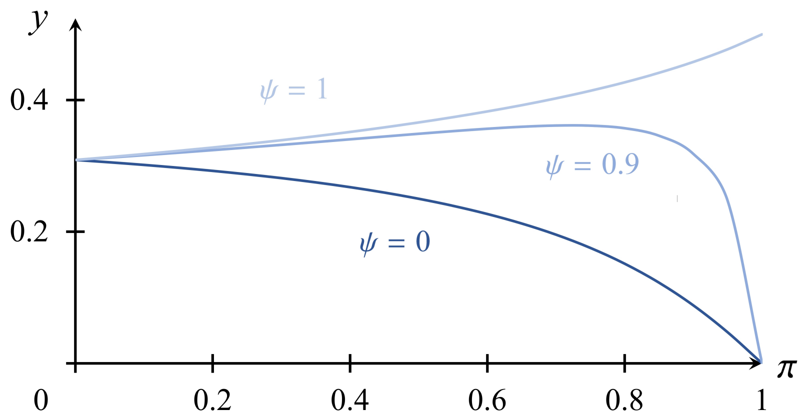
(ii) $\pi^\dagger\big|_{\psi=0} = 0$*, i.e., the threshold y is strictly decreasing in π for uninformative leaks.*

According to Proposition 3, the critical probability $\pi^\dagger$ increases as leaks become more informative. It approaches 1 if all leaks are perfect. In this case, increases of the likelihood π generally reduce the amount of voluntary disclosure. If leaks are uninformative with probability 1 and only reveal the manager's information endowment, the opposite is true. There is generally more voluntary disclosure if the likelihood of leakage increases.

Proposition 3 shows that the total effect of higher likelihood π on the disclosure threshold depends on the informativeness ψ of information leaks, which can be explained by the revelation effect. If leaks tend to reveal only the manager's information endowment, there is a higher risk of being underpriced and a marginal type faces strong incentives to separate himself from lower types. In contrast, the risk of adverse market reactions is negligible if information leaks tend to reveal the firm value. Thus, the revelation effect is attenuated by increasing informativeness ψ. In contrast, the concealment effect relies on the no-information price, $P(\emptyset)$, which does not directly depend on ψ. In line with this reasoning, Proposition 3 shows that the revelation effect dominates the concealment effect for $\psi = 0$. In this case, a higher likelihood of leakage generally increases the manager's willingness to share his information. Conversely, for $\psi = 1$, leaks do not create market discipline. An increasing likelihood π implies higher no-information prices, $P(\emptyset)$, and hence strictly decreases disclosure incentives.

We conclude the analysis with a numerical illustration for a uniformly distributed firm value, $\tilde{x} \sim U[0,1]$. Figure 2 depicts the disclosure threshold as a function of the likelihood of information leakage π. The shaded graphs represent three cases that differ with regard to the informativeness of leaks, $\psi \in \{0, 0.9, 1\}$. In line with Proposition 1, the disclosure threshold y is increasing in the informativeness ψ. If information leaks are perfect with probability 1 (i.e., $\psi = 1$), the disclosure threshold is strictly increasing in π. In contrast, if leaks only reveal the manager's information endowment ($\psi = 0$), a higher likelihood of leakage fosters voluntary disclosure. For $\psi = 0.9$, the disclosure threshold is increasing up to a likelihood of $\pi^\dagger = 0.72$ with a maximum value of $y = 0.36$.

FIGURE 2
The likelihood of leaks and voluntary disclosure ($\tilde{x} \sim U[0,1]$, $p = 0.8$, $\lambda = 1$)



Disclosure revision and managerial time horizon

Next, we extend our analysis to setting in which the manager is not completely myopic ($\lambda \leq 1$). Lemma 3 characterizes the equilibrium strategies at the disclosure revision stage and the initial disclosure stage.

Lemma 3. *Equilibrium of the dynamic disclosure game*

a) *At the revision stage, the manager reveals the firm value in response to uninformative leaks, i.e., $d^r(x, \hat{x}) = x$, and remains silent in the absence of leaks, i.e., $d^r(x, \emptyset) = \emptyset$.*

b) *At the initial stage, there is a disclosure threshold $y \in (\underline{x}, \mu)$ such that $d(x) = x$ if and only if $x \geq y$. The threshold level y satisfies the condition*

$$y = \frac{\pi(1-\psi^\dagger)}{1-\pi\psi^\dagger} E(y) + \frac{1-\pi}{1-\pi\psi^\dagger} P(\emptyset), \qquad (EC)$$

with $\psi^\dagger \equiv 1-(1-\psi)\lambda$ and $P(\emptyset)$ as given in Lemma 1.

Suppose that the price P at the initial disclosure stage has been realized, and the manager can react by revising his earlier decision. Disclosure revisions could be useful if an informed manager withheld his information in the first place and there is either an uninformative leak ($\Omega_I = \hat{x}$) or no information leak ($\Omega_I = \emptyset$).[18] Consider the case that

[18] The disclosure revision stage is irrelevant if the firm value has already been revealed either by

the investors encounter an uninformative leak, $\Omega_I = \hat{x}$. Thus, the manager can no longer pretend to be uninformed. A marginal type who observes the firm value y is pooled with all lower types $x \leq y$. He uses the opportunity to separate himself by sharing his information at the disclosure revision stage. Following the logic of the unraveling result (Grossman 1981; Milgrom 1981), all types must disclose their information in equilibrium. We can conclude that the disclosure game collapses to the case in which both perfect and uninformative leaks imply full revelation.

If the manager withholds his private information at the initial disclosure stage, and his strategic behavior is not detected ($\Omega_I = \emptyset$), he can either revise his initial decision or continue to pool with uninformed types. He shares his information whenever the disclosure price $P^r_D(x) = x$ exceeds the non-disclosure price $P^r_{ND} = P^r(\emptyset)$. According to Lemma 3 a), this case cannot occur in equilibrium. The argument relies on the fact that i) the expected non-disclosure price at the initial stage is lower than the non-disclosure price at the revision stage, i.e., $P_{ND} < P^r_{ND}$, and ii) the manager has not disclosed his information at the initial stage, i.e., $x < P_{ND}$.

At the initial disclosure stage, we identify a unique disclosure equilibrium. The equilibrium condition (EC) is structurally identical to the condition (EC^M) with a completely myopic manager. It differs only in the (effective) informativeness parameter $\psi^\dagger \in [\psi, 1]$, which weakly exceeds ψ and is decreasing in managerial myopia, λ. We can conclude that a longer time horizon has the same effect as higher informativeness of leaks. For $\lambda = 1$, the manager does not benefit from the opportunity to revise his initial decision. He is fully exposed to the pricing implications of uninformative leaks and increases his voluntary disclosures to preempt adverse market reactions. With increasing time horizon, the manager assigns more weight to the market price after the disclosure revision. For $\lambda \to 0$, he only cares about P^r, and information leaks lose their disciplining effects.

Proposition 4. *If uninformative leaks occur with positive probability (i.e., if $\pi > 0$ and $\psi < 1$), increasing managerial myopia motivates more disclosure, $dy/d\lambda < 0$.*

Managerial myopia strengthens the disciplining effect of uninformative leaks. More myopic managers are exposed to the threat of adverse market reactions and tend to preempts leaks. This follows from Proposition 1 and the fact that $\psi^\dagger$ decreases in λ.

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disclosure or by a perfect leak. We therefore focus on the case that an informed manager withholds his information at the initial stage, and the firm value is not revealed by a perfect leak.

IV. Proprietary costs

In the previous analysis, we have assumed that firm disclosures provide useful information to investors but do not affect the firm value. In many practical settings, sharing proprietary information is associated with considerable costs. For instance, information about a firm's product portfolio or its contractual relationships can be used by rivals to gain a competitive advantage or by suppliers and (retail) customers to improve their positions in contract negotiations. If firms expect costs of information sharing, prior research suggests that they adjust their disclosure behavior accordingly (e.g., Jovanovic 1982; Verrecchia 1983; Darrough and Stoughton 1990; Wagenhofer 1990).

We extend our model to study the consequences of proprietary costs in the presence of information leaks. A revelation of information at the initial disclosure stage is costly. More specifically, the firm incurs a cost $\kappa(\Omega_I)$, which depends on the available information Ω_I (e.g., Verrecchia 1983; Heinle et al. 2020; Cheynel and Ziv 2021). Accordingly, the market price at the initial disclosure stage is $P(\Omega_I) = E[\tilde{x}|\Omega_I] - \kappa(\Omega_I)$. Disclosures at the revision stage come too late to be used against the firm and do not cause any costs.[19]

Let $\kappa(x) = c > 0$ and $\kappa(\hat{x}) = \delta c$ denote the costs of perfect and uninformative leaks, respectively, where $\delta \in [0, 1]$. If investors do not receive any information, we normalize the costs to zero, $\kappa(\emptyset) = 0$. Our assumptions ensure that $\kappa(x) \geq \kappa(\hat{x}) \geq \kappa(\emptyset)$, which is descriptive of settings in which more precise public information causes higher proprietary costs. This seems reasonable because more precise information allows third parties to tailor their potentially harmful actions to the actual economic conditions. In case of an uninformative leak, outsiders learn that the manager has decided not to share his signal. This information helps them narrow down the region of possible firm values. The factor $\delta \in [0, 1]$ measures the relative size of the proprietary costs caused by such uninformative leaks. For $\delta = 0$, the information conveyed by uninformative leaks cannot be used against the firm. For $\delta = 1$, uninformative leaks and perfect leaks are equally harmful and cause identical costs c. To avoid uninteresting cases in which managers generally withhold their private information, we limit the maximum disclosure costs assuming $c < \overline{x} - \mu$.

We follow the procedure in the main analysis and first study a setting with a completely myopic manager, i.e., $\lambda = 1$. With the same arguments as above, there is a

[19] Intuitively, a timelier disclosure causes higher proprietary costs. We obtain similar results if disclosures at the revision stage are accompanied by costs that do not exceed the costs at the initial stage.

unique equilibrium characterized by a threshold $y \in (\underline{x}, \overline{x})$. The price reactions to perfect and uninformative leaks are $P(x) = x - c$ and $P(\hat{x}) = E(y) - \delta c$, respectively. As in the main analysis, the equilibrium is characterized by the indifference condition for a marginal type who observes the firm value y:

$$\begin{aligned} & y = \pi[\psi(y-c) + (1-\psi)(E(y) - \delta c)] + (1-\pi)P(\emptyset) \\ \Leftrightarrow \quad & y - C = \frac{\pi(1-\psi)}{1-\pi\psi}E(y) + \frac{1-\pi}{1-\pi\psi}P(\emptyset), \end{aligned} \tag{EC^{MC}}$$

where $C \equiv \left(1 - \frac{\pi(1-\psi)\delta}{1-\pi\psi}\right)c \in [0, c]$. A comparison with the equilibrium condition (EC^M) shows that the effect of proprietary costs can be summarized in the effective cost term C. Higher effective costs, C, imply a higher threshold y and hinder voluntary disclosure. Proposition 5 summarizes the direct effects of disclosure costs.

Proposition 5. *Suppose that the manager is completely myopic, $\lambda = 1$. Increasing costs of revealing the firm value hinder disclosure, i.e., $dy/dc > 0$. In contrast, increasing costs of uninformative leaks foster disclosure, i.e., $dy/d\delta < 0$.*

In our setting, the manager cannot avoid disclosure costs by withholding his private information. Even if he remains silent, there is a risk that leaks reveals information and triggers proprietary costs. Any increase in the disclosure costs c therefore affects both the disclosure price $P_D(x)$ and the expected non-disclosure price $P_{ND}(x)$. Note however that the effect on the non-disclosure price is weaker. If c increases by 1, $P_D(x)$ decreases by 1 while $P_{ND}(x)$ decreases by only $\pi(\psi + (1-\psi)\delta) \leq 1$. Hence, higher costs c penalize disclosure rather than strategic withholding, and the disclosure threshold y increases in c. Proposition 5 shows that increasing the costs of uninformative leaks has a countervailing effect. The reason is that higher levels of δ do not affect the disclosure price $P_D(x)$ but only penalizes non-disclosure. Consequently, increasing costs following uninformative leaks reduce the threshold level y and provide additional disclosure incentives.

Interestingly, the size of the effective costs C also depends on the likelihood and informativeness of information leaks. It is not obvious whether the presence of proprietary costs changes the comparative statics with regard to π and ψ. We therefore revisit the results of the previous section in Proposition 6.

Proposition 6. *Effects of π and ψ with a completely myopic manager (i.e., $\lambda = 1$)*

a) *Increasing informativeness ψ reduces disclosure, i.e., $dy/d\psi > 0$ for $\pi > 0$.*

b) *There is $\pi^{\ddagger} \in [0, 1]$ such that y increases in π for $\pi < \pi^{\ddagger}$ and decreases for $\pi > \pi^{\ddagger}$. The value $\pi^{\ddagger}$ weakly decreases in δ. It may increase or decrease in c.*

The effective disclosure costs C are increasing in the informativeness of information leaks ψ. Thus, higher levels of ψ not only reduce market discipline (see Proposition 1) but also raise the effective disclosure costs. In line with our previous analysis, a higher informativeness of leaks reduces voluntary disclosure.

An increasing likelihood of leakage reduces the effective costs, $dC/d\pi < 0$. This effect can amplify or countervail the forces identified in Proposition 2. Our results show that the comparative statics results of Proposition 2 are robust to the consideration of proprietary costs. A higher likelihood of leaks hinders disclosure if leaks are rare events, i.e., for $\pi \in [0, \pi^{\ddagger}]$, and fosters disclosure if leaks are sufficiently probable, i.e., for $\pi \in [\pi^{\ddagger}, 1)$. Intuitively, the region $\pi \in [\pi^{\ddagger}, 1)$ where information leaks foster voluntary disclosure is increasing in the costs of uninformative leaks. Recall that higher δ strengthens disclosure incentives. This effect is amplified by a higher probability π of leakage. Given that the proprietary costs c affect both the disclosure price and the non-disclosure price, the effects on the critical value $\pi^{\ddagger}$ can go either way.

Next, we study the effects of managerial myopia and allow for $\lambda \leq 1$. An informed manager maximizes the weighted sum of the initial price P and the revised price P^r.

Lemma 4. *Equilibrium of the dynamic disclosure game*

a) *At the revision stage, the manager reveals the firm value in response to uninformative leaks, i.e., $d^r(x, \hat{x}) = x$. If no information is leaked, there is a threshold $y^r \in (\underline{x}, y]$ such that an informed manager discloses his information if and only if $x \geq y^r$.*

b) *At the initial stage, there is a threshold $y \in (\underline{x}, \overline{x})$ such that $d(x) = x$ if and only if $x \geq y$. We identify a level of myopia $\lambda^{\ddagger} \in (0, 1]$ such that y satisfies the condition*

$$y - C^{\ddagger} = \frac{\pi(1 - \psi^{\dagger})}{1 - \pi\psi^{\dagger}} E(y) + \frac{1 - \pi}{1 - \pi\psi^{\ddagger}} P(\emptyset), \qquad (EC^C)$$

with $P(\emptyset)$ as defined in Lemma 1,

$$C^{\ddagger} \equiv \begin{cases} \frac{1-\pi(\psi+(1-\psi)\delta)}{(1-\pi\psi)\lambda} c & \text{if } \lambda < \lambda^{\ddagger} \\ \frac{1-\pi(\psi+(1-\psi)\delta)}{1-\pi\psi^{\ddagger}} c & \text{else} \end{cases}, \text{ and } \psi^{\ddagger} \equiv \begin{cases} \psi & \text{if } \lambda < \lambda^{\ddagger} \\ 1 - (1-\psi)\lambda & \text{else} \end{cases}.$$

Lemma 4 shows that proprietary costs do not considerably change the structure of the equilibrium. Again, an informed manager reacts to uninformative leaks by disclosing his private information. As in our main analysis, this has implications for the disclosure decision at the initial disclosure stage. However, disclosure costs have an additional effect in our dynamic setting. Some managers remain silent at the initial disclosure stage and instead share their information at a later point in time to avoid proprietary costs.

In line with this argument, we identify cases where a manager revises an earlier non-disclosure decision even though he is not exposed by a perfect or uninformative leak. A necessary condition for this result is that the manager is not too myopic, i.e., $\lambda < \lambda^{\ddagger}$ for a critical level $\lambda^{\ddagger} \in (0, 1]$. In this case, some managers delay their disclosure decision to the disclosure revision stage to avoid the proprietary costs. There is a threshold $y^r < y$ such that a manager who observes $x \in [y^r, y)$ remains silent at the initial stage but shares his information at the revision stage. In contrast, a more myopic manager, $\lambda \geq \lambda^{\ddagger}$, has a higher interest in the short-term market price. He therefore accepts the disclosure costs in order to be able to influence the price P at the initial stage. Such managers never delay the disclosure decision to the revision stage, i.e., $y^r = y$.

We can conclude that the manager's motive to avoid disclosure costs reinforces the effects identified in our main analysis. In line with Proposition 4, higher managerial myopia fosters voluntary disclosures at the initial disclosure stage. Corollary 2 shows that this result even holds in the absence of uninformative leaks as long as there are positive proprietary costs. This underpins the robustness of our findings.

Corollary 2. *Assume that there are proprietary costs $c > 0$. Even in the absence of uninformative leaks ($\psi = 0$), increasing managerial myopia motivates more disclosure, i.e., $dy/d\lambda < 0$ for $\lambda < \lambda^{\ddagger}$ and $dy/d\lambda = 0$ for $\lambda \geq \lambda^{\ddagger}$.*

V. Robustness results

Leakage of noisy signals

Thus far, we have considered informativeness as the conditional probability distribution over extreme types of leaks. This simplifying assumption ensures the tractability of the model. In this section, we consider an alternative notion of informativeness to show the robustness of our main results.

For simplicity, we focus on a uniformly distributed firm value, $\tilde{x} \sim U[\underline{x}, \overline{x}]$, and a completely myopic manager, $\lambda = 1$. The manager observes the realization x with probability $p \in [0, 1]$, and information is leaked with probability $\pi \in [0, 1)$. In contrast to our main analysis, all leaks have the same structure: The investors observe a noisy signal $\tilde{s}$ about the firm value, which is uniformly distributed with support $[x - \epsilon, x + \epsilon]$. The length of this interval is a natural measure for the informativeness of the leaked information. We therefore define informativeness as $\overline{\psi} = 1/\epsilon$. For $\epsilon = 0$, information leaks reveal the inside information with probability 1, which corresponds to the case $\psi = 1$ in our main analysis. For $\epsilon > \overline{x} - \underline{x}$, information leaks do not directly convey any information about the firm value. This corresponds to the case $\psi = 0$ in our main analysis. We restrict the analysis to threshold equilibria with a disclosure threshold $y \in [\underline{x}, \overline{x}]$ such that $d(x) = x$ for $x \geq y$ and $d(x) = ND$ for $x < y$.

When making his disclosure decision, an informed manager must compare the expected price reactions upon disclosure and non-disclosure. If he discloses his private information, the market price is $P_D(x) = x$. If he keeps quiet, the investors may receive a signal $s \in [x - \epsilon, x + \epsilon]$ and price the firm based on their beliefs about the manager's disclosure strategy. A marginal type who observes $x = y$ must be indifferent between disclosure and non-disclosure, i.e.,

$$y = \pi \cdot P(\ell, y) + (1 - \pi) \cdot P(\emptyset), \tag{3}$$

where $P(\ell, x) = E_s[E[\tilde{x}|s, y]|x]$ denotes the expected price reaction to an information leak for a given firm value x. As in the main model, the no-information price is

$$P(\emptyset) = \frac{1 - p}{1 - p + p \cdot (1 - \pi) \cdot \frac{y - \underline{x}}{\overline{x} - \underline{x}}} \cdot \mu + \frac{p \cdot (1 - \pi) \cdot \frac{y - \underline{x}}{\overline{x} - \underline{x}}}{1 - p + p \cdot (1 - \pi) \cdot \frac{y - \underline{x}}{\overline{x} - \underline{x}}} \cdot \frac{\underline{x} + y}{2}. \tag{4}$$

Condition (3) is similar to the equilibrium condition in our main analysis. The only difference is that the expected price reaction to an information leak, which was previously $\psi \cdot y + (1 - \psi) \cdot E(y)$, is now replaced by $P(\ell, y)$.

Lemma 5. *For given market beliefs about the disclosure threshold y, a manager who observes $x = y$ expects the following market price in response to an information leak:*

$$P(\ell, y) = \begin{cases} y - \dfrac{1}{2\overline{\psi}} & if\ y \geq 2\epsilon + \underline{x} \\ \dfrac{\underline{x} + y}{2} + \dfrac{(y - \underline{x})^2}{8}\overline{\psi} & else \end{cases}.$$

Note that $P(\ell, y)$ is increasing in the informativeness $\overline{\psi}$ of potential leaks.

Lemma 5 shows that a decreasing informativeness of leaks motivates an adverse market reaction. That is, the investors discount the observed signal realization s. This is comparable to our main analysis. As investors receive less precise information about the inside information, the market price $P(\ell, y)$ increasingly reflects the fact that the manager withholds bad news. Based on Lemma 5, we show that there is a unique threshold equilibrium and confirm the results of our main analysis.

Proposition 7. *There exists a unique threshold equilibrium with equilibrium threshold $y \in [\underline{x}, \overline{x}]$ such that $d(x) = x$ for $x \geq y$ and $d(x) = ND$ for $x < y$. We find that:*

(i) There is less voluntary disclosure if leaks become more informative, i.e., $dy/d\overline{\psi} > 0$.

(ii) There is a critical value $\pi^{\ddagger} \in [0, 1]$ such that the threshold y increases in π for $\pi < \pi^{\ddagger}$ and decreases in π for $\pi > \pi^{\ddagger}$, i.e., $\pi^{\ddagger}$ minimizes voluntary disclosure.

(iii) The disclosure-minimizing likelihood, $\pi^{\ddagger}$, is increasing in the informativeness of leaks, i.e., $d\pi^{\ddagger}/d\overline{\psi} > 0$.

Proposition 7 confirms the results of our main analysis and illustrates that our findings are robust with respect to the model of informativeness.

VI. Conclusion

This study addresses the effects of information leakage on managers' decisions to provide voluntary disclosure to the capital market. In contrast to external information sources, leaks generally reveal that the management is endowed with private information but has decided not to share it. This has a considerable impact on managers' strategic disclosure decisions. Depending on the informativeness and likelihood of information leaks, managers might decrease or increase voluntary disclosure.

If leaks are not perfectly informative about the private information, managers face the threat of adverse market reactions. They increase voluntary disclosures to preempt information leaks and to avoid the risk of underpricing. This disciplining effect vanishes as information leakage becomes more informative about the firm value. Increasing the likelihood of leakage amplifies the revelation effect while causing a countervailing concealment effect. The reason is that uninformed investors assign higher market prices as they deem it less likely that managers successfully withhold their private information. This provides incentives to withhold more information and undermines market discipline. The total effect of a higher likelihood of leaks depends on their informativeness about the private information. If leaks are sufficiently informative, a higher likelihood of leaks reduces voluntary disclosure. Otherwise, a higher likelihood of leakage fosters disclosure.

Moreover, we show that the disciplining effect of information leakage is particularly strong if managers are myopic and interested in short-term price reactions. In this case, they are particularly vulnerable to adverse market reactions and cannot undo the avoid underpricing by additional disclosures. Our results therefore predict that managerial myopia fosters voluntary disclosure.

These findings offer novel empirical predictions. Our results suggest that the effect of a higher likelihood of leakage depends on the information content of potential leaks. If the economic consequences of leaked information are difficult to understand for outsiders, which is particularly the case in industries with complex business models and innovative products, information leaks foster voluntary disclosure. In contrast, if leaks clearly reveals the corresponding value implications, we expect that a higher likelihood of leakage reduces voluntary disclosure. Moreover, we expect that possibility of information leaks motivates voluntary disclosures if managers' benefit from short-term price reactions and cannot react to information leaks in a very timely manner.

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Proof of Lemma 1

An informed manager makes his decision to maximize the expected market price, P. If he discloses the firm value x, the market reaction is $P_D(x) = x$. If he withholds his information, the expected market price is given by

$$P_{ND}(x) = \pi[\psi P(x) + (1-\psi)P(\hat{x})] + (1-\pi)P(\emptyset). \tag{5}$$

Disclosure is optimal if

$$P_D(x) \geq P_{ND}(x) \quad \Leftrightarrow \quad x \geq \frac{\pi(1-\psi)}{1-\pi\psi}P(\hat{x}) + \frac{1-\pi}{1-\pi\psi}P(\emptyset), \tag{6}$$

where $P(\hat{x})$ and $P(\emptyset)$ do not depend on x. As the left-hand side of (6) is strictly increasing in x, the manager discloses his information whenever x exceeds a threshold value y determined by the investors' beliefs. This observation helps us to specify the equilibrium market prices $P(\hat{x})$ and $P(\emptyset)$:

$$P(\hat{x}) = E(y), \quad P(\emptyset) = \mathrm{pr}[\Omega_M = \emptyset \,|\, \Omega_I = \emptyset]\mu + (1 - \mathrm{pr}[\Omega_M = \emptyset \,|\, \Omega_I = \emptyset])E(y), \tag{7}$$

where

$$\mathrm{pr}[\Omega_M = \emptyset \,|\, \Omega_I = \emptyset] = \frac{\mathrm{pr}[\Omega_M = \Omega_I = \emptyset]}{\mathrm{pr}[\Omega_I = \emptyset]} = \frac{1-p}{1-p+p(1-\pi)F(y)}. \tag{8}$$

A manager who observes the firm value $x = y$ must be indifferent between disclosing and withholding his information. This yields the equilibrium condition $P_D(y) = P_{ND}(y)$. Substituting (5) and (7) yields the following condition:

$$y = \underbrace{\pi[\psi y + (1-\psi)E(y)] + (1-\pi)P(\emptyset)}_{=P_{ND}(y)}. \tag{9}$$

For $y = \underline{x}$, the right-hand side becomes $\pi\underline{x} + (1-\pi)\mu$ and strictly exceeds the left-hand side, $\underline{x}$. For $y = \mu$, the left-hand side equals μ, which exceeds the weighted average of μ and $E(\mu)$ on the right-hand side. Due to continuity, there exists $y \in (\underline{x}, \mu)$ that satisfies the equilibrium condition. Rearranging (9) yields the condition (EC^M).

Next, we prove uniqueness. It is sufficient to show that $P_D(y)$ is increasing in y at a higher rate than $P_{ND}(y)$. This is the case if

$$\frac{dP_{ND}}{dy} < \frac{dP_D}{dy} = 1. \tag{10}$$

Rearranging yields

$$P_{ND}(y) = y - (1-\pi)(y - P(\emptyset)) - \pi(1-\psi)(y - E(y)). \tag{11}$$

We can therefore conclude that

$$\frac{dP_{ND}}{dy} = 1 - (1-\pi)\left(1 - \frac{dP(\emptyset)}{dy}\right) - \pi(1-\psi)\left(1 - \frac{dE(y)}{dy}\right). \tag{12}$$

We know that $dE(y)/dy < 1$ given log-concavity of the distribution. To prove the inequality in (10), it is sufficient to show that $dP(\emptyset)/dy < 1$. Using the representation in equation (7), we find that

$$\frac{dP(\emptyset)}{dy} = \frac{p(1-p)(1-\pi)f(y)}{(1-p+p(1-\pi)F(y))^2}\underbrace{(E(y)-\mu)}_{<0} + \underbrace{\frac{p(1-\pi)F(y)}{1-p+p(1-\pi)F(y)}}_{<1}\underbrace{\frac{dE(y)}{dy}}_{<1}. \tag{13}$$

□

Proof of Lemma 2

Consider the equilibrium threshold y as a function of p, i.e., $y = y(p)$. The equilibrium condition (**??**) is equivalent to

$$y - P_{ND}(y, p) = 0, \tag{14}$$

where $P_{ND}(y, p)$ is a continuously differentiable function of y and p. By use of the implicit function theorem, we find that

$$\frac{dy}{dp} = \frac{\partial P_{ND}/\partial p}{1 - dP_{ND}/dy}. \tag{15}$$

In the proof od Lemma 1, we have established that $dP_{ND}/dy < 1$. Hence, the sign of dy/dp equals to the sign of

$$\begin{aligned}\frac{\partial P_{ND}}{\partial p} &= (1-\pi)\frac{\partial P(\emptyset)}{\partial p} \\ &= -\frac{(1-\pi)^2 F(y)}{(1-p+p(1-\pi)F(y))^2}(\mu - E(y)) < 0. \end{aligned} \tag{16}$$

□

Proof of Proposition 1

Applying the implicit function theorem to the equilibrium condition (9) yields

$$\frac{dy}{d\psi} = \frac{\partial P_{ND}/\partial\psi}{1 - dP_{ND}/dy}. \tag{17}$$

We know from the proof of Lemma 1 that $\partial P_{ND}/\partial y < 1$. Hence, the sign of $dy/d\psi$ is identical to the sign of

$$\frac{\partial P_{ND}}{\partial \psi} = \pi(y - E(y)), \tag{18}$$

which is strictly positive for $\pi > 0$.

□

Proof of Corollary 1

Using integration by parts, the price $P(\emptyset)$ as characterized in Lemma 1 can be stated as

$$P(\emptyset) = \frac{(1-p)\mu + p(1-\pi)\left(F(y)y - \int_{\underline{x}}^{y} F(x)dx\right)}{1-p+p(1-\pi)F(y)}. \tag{19}$$

Differentiation with regard to y yields

$$\frac{dP(\emptyset)}{dy} = 0 \quad \Leftrightarrow \quad y_{\min} = \mu - \frac{p(1-\pi)}{1-p}\int_{\underline{x}}^{y} F(x)dx. \tag{20}$$

It is easy to see that $y_{\min}$ minimizes $P(\emptyset)$. Next, evaluate the condition (9) for $\psi = 1$:

$$y = \pi\, y + (1-\pi)P(\emptyset) \quad \Leftrightarrow \quad y = y_{\min}. \tag{21}$$

Thus, the result of the Corollary follows directly from Proposition 1.

□

Proof of Proposition 2

Applying the implicit function theorem to the equilibrium condition (9) yields

$$\frac{dy}{d\pi} = \frac{\partial P_{ND}/\partial \pi}{1 - dP_{ND}/dy} \tag{22}$$

with $dP_{ND}/dy < 1$. The sign of $dy/d\pi$ therefore corresponds to the sign of

$$\frac{\partial P_{ND}}{\partial \pi} = -\underbrace{\frac{(1-p)^2(\mu - E(y))}{(1-p+p(1-\pi)F(y))^2}}_{\equiv A} + \underbrace{\psi(y - E(y))}_{\equiv B}. \tag{23}$$

We first consider the special cases $\psi = 0$ and $\psi = 1$. For $\psi = 0$, equation (23) yields

$$\left.\frac{\partial P_{ND}}{\partial \pi}\right|_{\psi=0} = -\frac{(1-p)^2(\mu - E(y))}{(1-p+p(1-\pi)F(y))^2} < 0, \tag{24}$$

i.e., we can conclude that $\pi^\dagger|_{\psi=0} = 0$. For $\psi = 1$, condition (9) can be rearranged to

$$y - E(y) = \frac{1-p}{1-p+p(1-\pi)F(y)}(\mu - E(y)). \tag{25}$$

Substitution into (23) yields:

$$\left.\frac{\partial P_{ND}}{\partial \pi}\right|_{\psi=1} = \frac{(1-p)(\mu - E(y))}{1-p+p(1-\pi)F(y)}\left(1 - \frac{1-p}{1-p+p(1-\pi)F(y)}\right) > 0, \tag{26}$$

and find $\pi^\dagger|_{\psi=1} = 1$. Finally, we turn to the case $\psi \in (0,1)$. For $\pi \to 1$, condition (9) yields $y \to E(y)$ which can only be satisfied if y approaches $\underline{x}$. We therefore find that

$$\lim_{\pi \to 1} \frac{\partial P_{ND}}{\partial \pi} = -(\mu - \underline{x}) < 0. \tag{27}$$

Due to continuity, there is a $\underline{\pi} < 1$ such that P_{ND} is decreasing in $\pi \in [\underline{\pi}, 1]$. Define

$$\pi^\dagger = \inf\left\{\underline{\pi} \in [0,1] \;\middle|\; \frac{\partial P_{ND}}{\partial \pi} < 0 \text{ for all } \pi \in [\underline{\pi}, 1)\right\}. \tag{28}$$

It remains to show that $\partial P_{ND}/\partial\pi \geq 0$ for $\pi \in [0, \pi^\dagger)$. For $\pi^\dagger = 0$, there is nothing left to prove. Consider the case $\pi^\dagger > 0$. Due to continuity, we can conclude that

$$\left.\frac{\partial P_{ND}}{\partial \pi}\right|_{\pi=\pi^\dagger} = 0. \tag{29}$$

Assume that there is $\pi^* \in [0, \pi^\dagger)$ with $\partial P_{ND}/\partial\pi|_{\pi=\pi^*} < 0$. Due to continuity, there must be a $\overline{\pi} \in (\pi^*, \pi^\dagger)$ and $\partial P_{ND}/\partial\pi|_{\pi=\overline{\pi}} = 0$ such that

$$\frac{\partial P_{ND}}{\partial \pi} \leq 0 \qquad \text{for all } \pi \in [\pi^*, \overline{\pi}]. \tag{30}$$

According to (22), y must be weakly decreasing in $\pi \in [\pi^*, \overline{\pi}]$. This observation helps us to make inferences on the slope of A and B as defined in equation (23). Note that A is strictly decreasing in y and increasing in π whereas B is increasing in y. Altogether, we can conclude that (i) $\partial P_{ND}/\partial\pi|_{\pi=\overline{\pi}} = 0$ and (ii) $\partial P_{ND}/\partial\pi$ is strictly decreasing in the range $\pi \in [\pi^*, \overline{\pi}]$. As a consequence, we have

$$\frac{\partial P_{ND}}{\partial \pi} > 0 \qquad \text{for all } \pi \in [\pi^*, \overline{\pi}), \tag{31}$$

which contradicts (30).

□

Proof of Proposition 3

In the proof of Proposition 2, we have already established that $\pi^\dagger|_{\psi=0} = 0$ and $\pi^\dagger|_{\psi=1} = 1$. We therefore turn to the case $\psi \in (0, 1)$. Consider $\pi^\dagger$ as a function of ψ, i.e., $\pi^\dagger = \pi^\dagger(\psi)$. Moreover, let $y(\pi, \psi)$ denote the disclosure threshold as a function of π and ψ. The critical likelihood $\pi^\dagger$ is characterized by the condition

$$F(\pi^\dagger(\psi), \psi) \equiv \frac{\partial P_{ND}}{\partial \pi}(y(\pi^\dagger(\psi), \psi), \pi^\dagger(\psi), \psi) = 0. \tag{32}$$

By use of the implicit function theorem, we obtain

$$\frac{d\pi^\dagger(\psi)}{d\psi} = -\frac{\frac{\partial F(\pi^\dagger(\psi),\psi)}{\partial\psi}}{\frac{\partial F(\pi^\dagger(\psi),\psi)}{\partial\pi}}. \tag{33}$$

We find

$$\frac{\partial F(\pi^{\dagger}(\psi),\psi)}{\partial \psi} = \underbrace{\frac{\partial^2 P_{ND}}{\partial \pi \partial y}}_{>0} \underbrace{\frac{\partial y}{\partial \psi}}_{>0} + \underbrace{\frac{\partial^2 P_{ND}}{\partial \pi \partial \psi}}_{>0} > 0 \tag{34}$$

and

$$\frac{\partial F(\pi^{\dagger}(\psi),\psi)}{\partial \pi} = \underbrace{\frac{\partial^2 P_{ND}}{\partial \pi \partial y}}_{>0} \underbrace{\frac{\partial y}{\partial \pi}}_{=0} + \underbrace{\frac{\partial^2 P_{ND}}{\partial \pi^2}}_{<0} < 0. \tag{35}$$

The sign of the components can be easily confirmed using the expression in (23) as well as Proposition 1 and the fact that $\partial y/\partial\pi(\pi^{\dagger}(\psi),\psi) = 0$.

□

Proof of Lemma 3

First, consider the equilibrium at the disclosure revision stage. If an informed manager faces an uninformative leak, i.e., $(\Omega_M, \Omega_I) = (x, 0)$, the investors know the manager's information endowment. Thus, the unraveling result applies and all informed managers truthfully disclose their information. Next, consider the case that a manager's strategic behavior has not been uncovered by a leak, $(\Omega_M, \Omega_I) = (x, \emptyset)$. Assume that there is an equilibrium, where some managers revise there initial non-disclosure decision and share their information. This necessarily implies that there is less strategic withholding than at the initial disclosure stage. As a consequence, the no-information prices at the initial and revised disclosure stages satisfy the ordering $P^r(\emptyset) > P(\emptyset)$. However, if a manager of type x found it optimal to remain silent in the first place, it must hold that $x \leq P_{ND}(x) < P(\emptyset)$. This implies $x < P^r(\emptyset)$. The manager has no incentive to revise his initial non-disclosure decision. This contradicts the our assumption and completes the proof of a).

In his initial disclosure decision, an informed manager anticipates future disclosure revisions. He compares his utility from disclosure, $\lambda P(x) + (1-\lambda)P^r(x) = x$, with the expected utility from non-disclosure,

$$\lambda P_{ND}(x) + (1-\lambda)E[P^r(x)\,|\,d(x) = ND], \tag{36}$$

with $P_{ND}(x)$ according to (2), and

$$E[P^r(x) \,|\, d(x) = ND] = \pi x + (1-\pi)P(\emptyset). \tag{37}$$

With the same arguments as above, there is a unique threshold equilibrium. The threshold $y \in (\underline{x}, \mu)$ satisfies the indifference condition

$$y = \lambda P_{ND}(y) + (1-\lambda)[\pi y + (1-\pi)P(\emptyset)]. \tag{38}$$

Simplifying the right-hand side yields the condition in b).

□

Proof of Proposition 4

Apparently, $\psi^\dagger$ is decreasing in λ because $d\psi^\dagger/d\lambda = -(1-\psi) < 0$. Thus, higher myopia has the same effect as a decreasing informativeness of information leaks. According to Proposition 1, this is accompanied by more voluntary disclosure.

□

Proof of Proposition 5

With the same arguments as in the proof of Lemma 1, we establish that there is a unique disclosure equilibrium with threshold $y \in (\underline{x}, \overline{x})$. A manager who observes the firm value x compares the disclosure price $P_D(x) = x - c$ with the expected non-disclosure price

$$P_{ND}(x) = \pi[\psi(x-c) + (1-\psi)(E(y) - \delta c)] + (1-\pi)P(\emptyset), \tag{39}$$

with $P(\emptyset)$ according to Lemma 1. The threshold y is characterized by the indifference condition $P_D(y) = P_{ND}(y)$ and can be rearranged to

$$y - C = \frac{\pi(1-\psi)}{1-\pi\psi}E(y) + \frac{1-\pi}{1-\pi\psi}P(\emptyset), \tag{40}$$

where $C \equiv \left(1 - \frac{\pi(1-\psi)\delta}{1-\pi\psi}\right)c$. For $y = \underline{x}$, the right-hand side of this condition exceeds the left-hand side. The slope of the left-hand side is steeper than that of the right-hand side. Thus, increasing levels of C imply higher threshold values y. The results follow from

$$\frac{dC}{dc} = 1 - \frac{\pi(1-\psi)\delta}{1-\pi\psi} > 0 \text{ and } \frac{dC}{d\delta} = -\frac{\pi(1-\psi)c}{1-\pi\psi} < 0. \tag{41}$$

Note that the disclosure threshold y is maximized for $\delta = 0$ and $\psi = 1$. Even in this case, the assumption $c < \overline{x} - \mu$ ensures that $y < \overline{x}$. That is, there are always some managers with sufficiently high firm values who disclose their private information.

□

Proof of Proposition 6

First, we study the comparative statics of y with regard to π. As shown in the proof of Proposition 2, the sign of $dy/d\pi$ is identical to the sign of $\partial P_{ND}/\partial\pi$. Based on the expression in equation (39), we obtain

$$\frac{\partial P_{ND}}{\partial \pi} = -\frac{(1-p)^2(\mu - E(y))}{(1-p+p(1-\pi)F(y))^2} + \psi(y - E(y) - (1-\delta)c) - \delta c. \tag{42}$$

We use the same arguments as in the proof of Proposition 2 to show that there is $\pi^{\ddagger} \in [0,1]$ such that $\partial P_{ND}/\partial\pi > 0$ for $\pi < \pi^{\ddagger}$ and $\partial P_{ND}/\partial\pi < 0$ for $\pi > \pi^{\ddagger}$. The critical value $\pi^{\ddagger}$ is either a boundary value, i.e., $\pi^{\ddagger} \in \{0,1\}$, or it is characterized by the condition

$$G(\delta, \pi, y(\delta,\pi)) \equiv \frac{\partial P_{ND}}{\partial \pi}(\delta, \pi, y(\delta,\pi)) = 0 \tag{43}$$

for all $\delta \in [0,1]$. Differentiating this equation for δ and rearranging yields

$$\frac{d\pi^{\ddagger}}{d\delta} = -\frac{\left.\frac{\partial G}{\partial \delta}\right|_{\pi=\pi^{\ddagger}} + \left.\frac{\partial G}{\partial y}\right|_{\pi=\pi^{\ddagger}} \left.\frac{dy}{d\delta}\right|_{\pi=\pi^{\ddagger}}}{\left.\frac{\partial G}{\partial \pi}\right|_{\pi=\pi^{\ddagger}}}. \tag{44}$$

We know that $\pi^{\dagger}$ maximizes the disclosure threshold y, i.e.,

$$\left.\frac{\partial G}{\partial \pi}\right|_{\pi=\pi^{\ddagger}} < 0. \tag{45}$$

Proposition 5 shows that $dy/d\delta < 0$. Moreover, it is straightforward to see that

$$\left.\frac{\partial G}{\partial \delta}\right|_{\pi=\pi^{\ddagger}} = -(1-\psi)c < 0 \text{ and } \left.\frac{\partial G}{\partial y}\right|_{\pi=\pi^{\ddagger}} > 0 \tag{46}$$

In line with the Proposition, we can conclude that $d\pi^{\ddagger}/d\delta < 0$. Numerical examples show that the comparative statics of $\pi^{\ddagger}$ with regard to c are ambiguous.

Next, we study the comparative statics of y with regard to ψ. As shown in the proof of Proposition 1, the sign of $dy/d\psi$ is identical to the sign of $\partial P_{ND}/\partial\psi$. Based on the expression in equation (39), we obtain

$$\frac{\partial P_{ND}}{\partial \psi} = \pi(y - E(y) - (1-\delta)c). \tag{47}$$

This expression is positive if and only if $y - E(y) > (1-\delta)c$, where $y - E(y)$ is increasing in y. The comparative statics analysis with regard to π shows that the threshold y is minimized either by $\pi = 0$ or for $\pi \to 1$. For $\pi \to 1$, the equilibrium condition yields $\lim_{\pi \to 1} y - E(y) = (1-\delta)c$. For $\pi = 0$, we find that

$$y - E(y) = c + \frac{1-p}{1-p+pF(y)}(\mu - E(y)) > (1-\delta)c. \tag{48}$$

We can conclude that the derivative (47) is strictly positive for $\pi > 0$.

□

Proof of Lemma 4

Note that disclosures do not cause any proprietary costs at the revision stage. Hence, if a strategic manager experiences an uninformative leak, unraveling ensures that he shares his private information, i.e., $d^r(x, 0) = x$.

Next, consider an informed manager who withholds his private information at the initial stage and is not exposed by a leak. Because the manager remains silent at the initial stage, we know that he has observed unfavorable information, $x < y$. At the revision stage, the manager compares the disclosure price x with the non-disclosure price $P^r(\emptyset)$. Any equilibrium must be a threshold equilibrium. The equilibrium threshold y^r satisfies the condition $y^r = \min\{y^*, y\}$, where $y^* \in [\underline{x}, \overline{x}]$ satisfies the indifference condition

$$y^* = P^r(\emptyset) = \frac{1-p}{1-p+p(1-\pi)F(y^*)}\mu + \frac{p(1-\pi)F(y^*)}{1-p+p(1-\pi)F(y^*)}E(y^*). \tag{49}$$

For $y^* \geq y$, we have $y^r = y$, i.e., the manager does not revise his non-disclosure decision at the revision stage. For $y^* < y$, there is a region of firm values $y \in [y^r, y)$, which are not disclosed at the initial stage but revealed at the revision stage even in the absence of leaks.

We first consider an equilibrium that satisfies $y^* < y$. The equilibrium threshold y at the initial disclosure stage is given by the indifference condition of a marginal type who observes the firm value $x = y$. If he discloses his information, the firm's market price in both periods is $y - c$. If he remains silent, the non-disclosure price $P_{ND}(y)$ at the initial stage is given by equation (2). The price at the revision stage is $y - c$ or $y - \delta c$ if a perfect or an uninformative leak occurs. If there is no leak, the marginal type discloses his information at the revision stage because we have assumed $y^* < y$. The market price is y. Hence, the indifference condition of the marginal manager is

$$y = \lambda P_{ND}(y) + (1-\lambda)E[\tilde{P}^r(y) \,|\, d(y) = ND], \tag{50}$$

where $E[\tilde{P}^r(y) \,|\, d(y) = ND] = \pi(\psi(y-c) + (1-\psi)(y-\delta c)) + (1-\pi)y$. Rearranging this condition yields

$$y - C^\ddagger = \left(1 - \frac{1-\pi}{1-\pi\psi}\right)E(y) + \frac{1-\pi}{1-\pi\psi}P(\emptyset), \tag{51}$$

with $P(\emptyset)$ according to Lemma 1 and $C^\ddagger = \frac{1-\pi(\psi+(1-\psi)\delta)}{(1-\pi\psi)\lambda}c$. Note that $C^\ddagger$ is decreasing in λ and $C^\ddagger \to \infty$ for $\lambda \to 0$. Thus, the assumption $y^* < y$ is satisfied for low levels of myopia, $\lambda < \lambda^\ddagger$. For reasons of continuity, $\lambda^\ddagger$ is given by the condition $y = y^*$ or equivalently

$$\lambda^\ddagger = \frac{1-\pi(\psi+(1-\psi)\delta)}{\pi(1-\psi)}\frac{1-p+p(1-\pi)F(y^*)}{1-p}\frac{c}{\mu - E(y^*)} > 0. \tag{52}$$

Next, consider an equilibrium where $y^* \geq y$, i.e., in the absence of information leakage, the manager does not revise his earlier non-disclosure decision. A manager who withholds his information at the initial stage anticipates that he will also remain silent at the revision stage if no leak occurs. We therefore find $E[\tilde{P}^r(y) \,|\, d(y) = ND] = \pi(\psi(y-c) + (1-\psi)(y-\delta c)) + (1-\pi)P(\emptyset)$, which yields the equilibrium condition

$$y - C^\ddagger = \left(1 - \frac{1-\pi}{1-\pi\psi^\ddagger}\right)E(y) + \frac{1-\pi}{1-\pi\psi^\ddagger}P(\emptyset), \tag{53}$$

with $C^\ddagger = \frac{1-\pi(\psi+(1-\psi)\delta)}{1-\pi\psi^\ddagger}c$ and $\psi^\ddagger = 1-(1-\psi)\lambda$. It is easy to see that y is decreasing in λ, i.e., the assumption $y^* \geq y$ is satisfied for sufficiently high levels of myopia. Again, the critical level of λ is given by the condition $y = y^*$, which yields the same expression as in equation (52).

□

Proof of Corollary 2

Consider the equilibrium threshold y according to Lemma 4 for $\psi = 1$. Apparently, y is decreasing in λ for $\lambda < \lambda^\ddagger$ because $C^\ddagger$ is decreasing. For $\lambda > \lambda^\ddagger$, the y is independent of λ. Moreover, it is easy to see that y is continuous at $\lambda = \lambda^\ddagger$, which completes the proof.

□

Proof of Lemma 5

Consider the disclosure decision of a marginal type, $x = y$. When determining the expected market price in response to a leak, we must distinguish two cases. First assume that $y - \underline{x} < 2\epsilon$. In this case, we have

$$\begin{aligned} E_s[E[\tilde{x}|s,y]|x=y] &= \frac{1}{2\epsilon}\left(\int_{y-\epsilon}^{\underline{x}+\epsilon} \frac{\underline{x}+y}{2} ds + \int_{\underline{x}+\epsilon}^{y+\epsilon} \frac{s-\epsilon+y}{2} ds\right) \\ &= \frac{4\epsilon(\underline{x}+y) + (\underline{x}-y)^2}{8\epsilon}. \end{aligned} \tag{54}$$

The first integrals represents all cases with $s - \epsilon < \underline{x}$ and the second integral the cases with $s - \epsilon > \underline{x}$. Because of $y - \underline{x} < 2\epsilon$, both cases are possible: Given $x = y$, the lowest possible signal is $y - \epsilon$. Given a signal realization $s = y - \epsilon$, the lowest possible value of x is $s - \epsilon = y - 2\epsilon$. For $y - \underline{x} \geq 2\epsilon$, we have

$$E_s[E[\tilde{x}|s,y]|x=y] = \frac{1}{2\epsilon}\int_{y-\epsilon}^{y+\epsilon} \frac{s-\epsilon+y}{2} ds = y - \frac{\epsilon}{2}. \tag{55}$$

If we combine both cases and substitute $\overline{\psi} = 1/\epsilon$, we obtain the market price $P(\ell, y)$ according to the Lemma. Apparently, both (54) and (55) are increasing in the informativeness $\overline{\psi}$.

□

Proof of Proposition 7

First, note that the market price $P(\ell, y)$ according to Lemma 5 is continuously differentiable and satisfies $\frac{\partial}{\partial y}P(\ell, y) \leq 1$. As a consequence, the equilibrium condition (3) has a unique solution y. We have to show that this is in fact an equilibrium. That is, all managers observing $x \leq y$ have an incentive not to disclose, and all managers with $x > y$ will disclose. The difficulty is that the expected price reaction to a leak $P(\ell, x)$ is a function of the observed firm value x. A manager of type x will disclose if and only if

$$x > \pi P(\ell, x) + (1-\pi)P(\emptyset). \tag{56}$$

For $\overline{x} - \underline{x} \leq 2\epsilon$, it is easy to see that

$$P(\ell, x) = \frac{1}{2\epsilon}\left(\int_{x-\epsilon}^{\overline{x}-\epsilon} \frac{\underline{x} + s + \epsilon}{2}\, ds + \int_{\overline{x}-\epsilon}^{\underline{x}-\epsilon} \frac{\underline{x} + \overline{x}}{2}\, ds + \int_{\underline{x}+\epsilon}^{x+\epsilon} \frac{s - \epsilon + \overline{x}}{2}\, ds\right)$$
$$= \frac{2x(\overline{x} - \underline{x}) - (\overline{x} + \underline{x})(\overline{x} - \underline{x} - 4\epsilon)}{8\epsilon}. \tag{57}$$

As a consequence, we establish $\frac{\partial}{\partial x}P(\ell, x) = \frac{\overline{x}-\underline{x}}{4\epsilon} \leq 1$. Next, we consider the case $2\epsilon < \overline{x} - \underline{x} \leq 4\epsilon$. Here, we consider three sub-cases.
For $\overline{x} - x \leq 2\epsilon$ and $x - \underline{x} \leq 2\epsilon$, we find

$$P(\ell, x) = \frac{1}{2\epsilon}\left(\int_{x-\epsilon}^{\underline{x}+\epsilon} \frac{\underline{x} + s + \epsilon}{2}\, ds + \int_{\underline{x}+\epsilon}^{\overline{x}-\epsilon} s\, ds + \int_{\overline{x}-\epsilon}^{x+\epsilon} \frac{s - \epsilon + \overline{x}}{2}\, ds\right)$$
$$= \frac{2x(\overline{x} - \underline{x}) - (\overline{x} + \underline{x})(\overline{x} - \underline{x} - 4\epsilon)}{8\epsilon}. \tag{58}$$

It follows that $\frac{\partial}{\partial x}P(\ell, x) = \frac{\overline{x}-\underline{x}}{4\epsilon} \leq 1$. For $\overline{x} - x \leq 2\epsilon$ and $x - \underline{x} \geq 2\epsilon$, we find

$$P(\ell, x) = \frac{1}{2\epsilon}\left(\int_{x-\epsilon}^{\overline{x}-\epsilon} s\, ds + \int_{\overline{x}-\epsilon}^{x+\epsilon} \frac{s - \epsilon + \overline{x}}{2}\, ds\right)$$
$$= \frac{2x(\overline{x} + 2\epsilon) - (\overline{x} - 2\epsilon)^2 - x^2}{8\epsilon}. \tag{59}$$

Again, it follows that $\frac{\partial}{\partial x}P(\ell, x) \leq 1$. For $\overline{x} - x \geq 2\epsilon$ and $x - \underline{x} \leq 2\epsilon$, we have

$$P(\ell, x) = \frac{1}{2\epsilon}\left(\int_{x-\epsilon}^{\underline{x}+\epsilon} \frac{\underline{x} + s + \epsilon}{2}\, ds + \int_{\underline{x}+\epsilon}^{x+\epsilon} s\, ds\right)$$
$$= \frac{(x - \underline{x})^2 + 4(x + \underline{x})\epsilon + 4\epsilon^2}{8\epsilon}. \tag{60}$$

It is easy to see that $\frac{\partial}{\partial x}P(\ell, x) \leq 1$.

It remains to consider the case $4\epsilon < \overline{x}$, which again requires the analysis of three sub-cases. The analysis of these sub-cases is analogous to the prior derivations. We therefore omit a detailed analysis. We generally find that $\frac{\partial}{\partial x}P(\ell, x) \leq 1$.

These results show that a manager who observes $x \leq y$ never finds it optimal to disclose his information. It remains to show that all managers who observe $x > y$ have an incentive to disclose. Apparently, Bayesian updating is not possible for signal realizations $s > y + \epsilon$ because this observation is not consistent with the equilibrium. For such signal realizations, we assume the most pessimistic belief $s - \epsilon$. This assumption is consistent with the concept of a perfect Bayesian equilibrium. We only consider the case $y - \underline{x} \geq 2\epsilon$. The case $y - \underline{x} < 2\epsilon$ is analogous. Given this assumption, we find for $x \leq y + 2\epsilon$ that

$$P(\ell, x) = \frac{1}{2\epsilon}\left(\int_{x-\epsilon}^{y+\epsilon} \frac{s - \epsilon + y}{2}\, ds + \int_{y+\epsilon}^{s-\epsilon} (s - \epsilon)\, ds\right)$$

$$= \frac{(x-y)^2 + 4(x+y)\epsilon - 4\epsilon^2}{8\epsilon}. \tag{61}$$

Again, we confirm $\frac{\partial}{\partial x}P(\ell, x) \leq 1$. This also holds for $x > y + 2\epsilon$. In this case, we obtain $P(\ell, x) = x - \epsilon$.

As in our main analysis, we are interested in the comparative statics of $y(\pi, \overline{\psi})$ with respect to q and $\overline{\psi}$. First, it can easily be established that $y(\pi, \overline{\psi})$ is increasing in $\overline{\psi}$. The proof is analogous to the proof of Proposition 1. Key here is that the equilibrium condition (3) depends on $\overline{\psi}$ only via the market price $P(\ell, y)$. Therefore, we can conclude that

$$\frac{\partial P_{ND}}{\partial \overline{\psi}}(y) = \pi \frac{\partial}{\partial \overline{\psi}} P(\ell, y), \tag{62}$$

and the comparative static result follows from the comparative statics of $P(\ell, y)$.

Next, we study the comparative statics with respect to π. It is important to find an analogue to equation (23). As in the main analysis, it can be shown that

$$\frac{\partial P_{ND}}{\partial \pi}(y(\pi), \pi) = -\underbrace{\frac{(1-p)^2(\mu - E(y))}{(1 - p + p(1-\pi)F(y))^2}}_{\equiv A} + \underbrace{P(\ell, y) - E(y)}_{\equiv B}. \tag{63}$$

The expression A is exactly the same as in (23). Furthermore, the expression B has the same properties as in (23). For example, $P(\ell, y)$ is non-decreasing in y. Using this result, it is easy to show that $y(\pi)$ has an inverted U-shape.

□