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Intertemporal Dynamics of Corporate Voluntary Disclosures

ETI EINHORN* AND AMIR ZIV†

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ABSTRACT

While empirical evidence alludes to the intertemporal nature of corporate voluntary disclosures, most of the existing theory analyzes firms' voluntary disclosure decisions within single-period settings. Introducing a repeated, multiperiod, disclosure setting, we study the extent to which firms' strategic disclosure behavior in the past affects their prosperity to provide voluntary disclosures in the future. Our analysis demonstrates that by voluntarily disclosing private information firms make an implicit commitment to provide similar disclosures in the future, and therefore are less willing to voluntarily disclose information in the first place. This effect is expected to be of larger magnitude for firms (1) with a long history of absence of voluntary disclosures and an impressive past operating performance, or (2) that operate in a relatively stable and predictable business and information environment, or (3) whose managers have a long time horizon and a high degree of risk aversion.

*Faculty of Management, Tel Aviv University; †Graduate School of Business, Columbia University and The Arison School of Business, Interdisciplinary Center Herzliya. We would like to thank Gil Aharoni, Edwige Cheynel, Jonathan Glover, Richard Leftwich (the editor), Phillip Stocken, Varda Yaari, and especially an anonymous referee, for their helpful comments and suggestions. We also appreciate the helpful comments of participants in the European Accounting Association annual congress, the American Accounting Association annual meeting, and in seminars at Columbia University, the Hebrew University, Insead, the Interdisciplinary Center Herzliya, Technion—Israel Institute of Technology, and Tel Aviv University. We thank Gerda Kessler for expert editorial assistance. Eti Einhorn gratefully acknowledges financial support by the Henry Crown Institute of Business Research in Israel.

1. Introduction

Firms' incentives to voluntarily disclose private verifiable information have long been a widespread research interest in accounting, finance, and economics.[1] The theory is conceptually based on the seminal unraveling idea of Grossman and Hart [1980], Grossman [1981], and Milgrom [1981], who utilize Akerlof's [1970] adverse selection argument to show how withheld information is unraveled by the rational behavior of market participants. Rational investors interpret any piece of withheld information that can be credibly disclosed as conveying bad news, inducing firms to fully disclose their private information, however unfavorable it is, in order to distinguish themselves from firms possessing even worse information. Challenged by the unraveling idea, subsequent studies primarily aim at explaining the commonly observed propensity of firms to suppress private information from investors. The classical explanations include the costs associated with disclosure (see Verrecchia [1983]) and the uncertainty of investors about the firm's information endowment (see Dye [1985]).[2]

The above-mentioned earlier studies, as well as the extensive subsequent theoretical research on voluntary disclosure, analyze corporate disclosure choices within single-period frameworks. The empirical literature, however, alludes to the intertemporal nature of corporate voluntary disclosures, and specifically to the extent to which voluntary disclosure in one period affects the likelihood of disclosure occurrence in subsequent periods. Introducing a multiperiod disclosure setting, we shed light on the dynamics of corporate voluntary disclosures and explore the suppressing impact of intertemporal forces on the propensity of firms to voluntarily disclose information.

We combine the features of the single-period disclosure setups of Verrecchia [1983] and Dye [1985] and extend them to a repeated multiperiod setting. Our model describes a firm that is traded in a rational and risk-neutral capital market for an infinite number of successive periods, whose manager repeatedly exercises discretion over the credible disclosure of private information. In each period, with some probability, the firm's manager privately observes a signal that is relevant to the estimation of that period's uncertain forthcoming cash flows, but is subsumed by the end of the period when current period cash flows are realized and publicly observed. Similarly to Dye [1985] and Jung and Kwon [1988], investors are uncertain about the endowment of the manager with the information, and the manager cannot credibly claim to be uninformed. Upon receiving a private signal, however, its content can be voluntarily and credibly disclosed. Similarly to Verrecchia [1983], disclosure is costly. The manager's disclosure decision in each period is made in light of its rationally anticipated

[1] For surveys of the literature on corporate voluntary disclosure, see Dye [2001] and Verrecchia [2001].

[2] For other explanations, see Dye [1986], Nagar [1999], Fishman and Hagerty [2003], Einhorn [2007], Einhorn and Ziv [2007], and Suijs [2007].

impact on the firm's current market price, which, in turn, is determined by the investors' rational expectations about the firm's strategic disclosure behavior. Intertemporal dynamics occur because the firm's possession of information is assumed to be history dependent. This assumption reflects the perception that the business and the information environment of any firm is characterized by a certain degree of stability, and thus the availability of relevant information, the cost of acquiring such information, and the ability to credibly disclose it to outsiders are likely to be predictable.

We use our multiperiod model to demonstrate that intertemporal effects generate indirect disclosure costs that reduce the propensity of firms to provide voluntary disclosures to the capital market. In any period, by suppressing the current disclosure, the manager enhances the firm's reputation of being uninformed, which moderates the future adverse price reaction to the further absence of disclosures and thereby facilitates future withholding of information, thus saving on future disclosure costs. On the other hand, by providing the current disclosure, the manager alerts the market to the existence of information, and thereby increases the firm's implicit commitment to provide similar disclosures in the future. Investors rationally anticipate the enhancing impact of the current disclosure on future costly disclosures, and therefore the firm's current market price fully reflects the expected increment in future disclosure costs. This negative price reaction to disclosure introduces an endogenous indirect disclosure cost, which reduces the incentive of the manager to provide disclosure, even when she is myopic and interested only in maximizing the current market price. For a forward-looking manager, who cares not only about the current market price but also about future prices, disclosure is even more costly because it reduces the firm's future leeway in manipulating the investors' expectations by managing disclosure. When a forward-looking manager is also risk averse, disclosure is associated with another endogenous indirect cost, as it intensifies the dependence of the firm's future market price on the uncertain forthcoming information and thereby increases future price volatility.

While intertemporal forces have a suppressing impact on managerial incentives to provide voluntary disclosures regardless of the firm's history, the magnitude of this impact depends on the specific disclosure and operating history. A firm with a longer history of not providing disclosures has a better reputation of being uninformed, which is advantageous to current and future withholding of information, particularly when it is accompanied by impressive past operating performance. This is because past high operating outcome implies that any available past information was apparently too favorable to be withheld, convincing the market that it is more likely information was unavailable. That is, the longer the history of suppressing disclosure, and the better the corresponding past operating performance, the stronger the manager's reputation of being currently uninformed, and the easier it is for her to withhold private information. Once such a reputation is built up, refuting it with the current disclosure becomes more costly for the manager and further motivates her to suppress private information from the market.

The analysis predicts that the extent to which corporate voluntary disclosure strategies are subject to intertemporal forces depends on both firm-specific characteristics and managerial properties. In particular, intertemporal effects are expected to be larger in magnitude for firms that operate in a relatively stable business and information environment, where future information endowment and operating performance are predictable. In such environments, the disclosure and operating history of the firm is more informative to investors in assessing the current information status of the manager. The magnitude of intertemporal effects is also likely to be more salient for firms whose managers have a longer time horizon and a higher degree of risk aversion. Such managers care more about the distribution of the firm's future random price, and thus find the current disclosure more costly due to its decreasing effect on the expected future price and its increasing effect on the variation of the future price.

Additional empirical implications of our analysis concern the impact of a firm's disclosure level on its cost of capital. While economic theory suggests that a commitment by a firm to an increased level of disclosure should lower the information asymmetry component of the firm's cost of capital (see Diamond and Verrecchia [1991], Baiman and Verrecchia [1996], Easley and O'Hara [2004]), empirical results have been mixed (see, e.g., Botosan [1997], Botosan and Plumlee [2002]). Leuz and Verrecchia [2000] ascribe the mixed empirical findings to the use of disclosure ratings that represent analysts' perceptions of voluntary disclosures as a proxy for the level of disclosure. They argue that the relation between the cost of capital and an ex ante commitment to disclose should be stronger than the relation between the cost of capital and an ex post decision to provide voluntary disclosure, because under a commitment information is disclosed regardless of its content. Our analysis indicates circumstances where an ex post decision to provide disclosure, based on observing the disclosed content, can properly proxy for such an ex ante commitment. In particular, the analysis identifies three categories of firms for which voluntary disclosure might better serve as a commitment to disclose in the future. The first includes firms with a long history of avoiding voluntary disclosures and impressive corresponding past operating performance. The second consists of firms that operate in a relatively stable and predictable business and information environment. The last contains firms whose managers have a long time horizon (e.g., new mangers) or a high degree of risk aversion. We predict that empirical tests of the relation between rating on voluntary disclosures and cost of capital might provide stronger results for firms that belong to these three categories.

The paper proceeds as follows. A description of the model is provided in the next section and a definition of the equilibrium is given in section 3. In section 4, we derive and analyze the equilibrium, exploring the reliance of the manager's optimal disclosure strategy on past and future considerations. In section 5, we extend the analysis to consider a richer set of managerial preferences. The final section summarizes and offers concluding remarks. Highlights of the proofs appear in the appendix.

2. Model

Our model describes a firm traded in a rational and risk-neutral capital market for an infinite number of periods. In each period, the firm's manager, who serves in that role for only one period, exercises discretion over the credible disclosure of private information. The model is a multiperiod replication of the single-period disclosure setup of Dye [1985] combined with that of Verrecchia [1983], where subsequent periods are linked via the history-dependent nature of the information environment. In this section, we detail the parameters and assumptions of the model, which are all common knowledge, unless otherwise indicated.

We start by describing a representative period in our model. In the representative period, the firm's operations generate uncertain cash flows, represented by a normally distributed random variable CF with mean μ and variance σ^2. Before the realization of the cash flows, with some probability, the firm's manager privately observes a signal, S, that is relevant in assessing the forthcoming cash flows. Specifically, the private signal S, if received, takes the form $S = CF + \varepsilon$, where ε is an independent normally distributed noise term with zero mean and variance σ_ε^2. As in Dye [1985] and Jung and Kwon [1988], investors are uncertain whether the manager is endowed with the private signal and the manager cannot credibly attest to being uninformed. Upon receiving the signal, however, its content can be credibly disclosed.[3] Similarly to Verrecchia [1983], we assume that disclosure of the private signal is associated with a positive cost c. Hence, the manager, if informed, can either truthfully disclose her private signal to investors at a cost c or keep quiet. The set of the manager's two disclosure alternatives is represented by $\mathrm{A} = \{dis, nd\}$, where *dis* describes the alternative of disclosing the private signal and *nd* describes the alternative of not disclosing it. We assume that the manager makes her disclosure decision in order to maximize the firm's current market price.

Figure 1 illustrates the sequence of events within a representative period. At the beginning of the period, the prior beliefs of all players are determined and a new manager joins the firm. Then, with some probability, the manager

[3] Several multiperiod models of cheap-talk (e.g., Gigler and Hemmer [1998], Stocken [2000], Lundholm [2003]) focus on the role of intertemporal forces in endogenously enabling credible communication between firms and investors. In these models, voluntary disclosures cannot be credibly communicated, but verifiable mandatory disclosures create an environment that enables firms to credibly convey their more value-relevant voluntary disclosures. In order to explore other intertemporal effects of corporate voluntary disclosures, we adopt a different tack, assuming that there exist exogenous means to make the reporting credible. This assumption ties our model more closely to the standard models of voluntary disclosure, enabling us to isolate and emphasize the incremental impact of intertemporal forces beyond the equilibrium outcomes derived in earlier research.

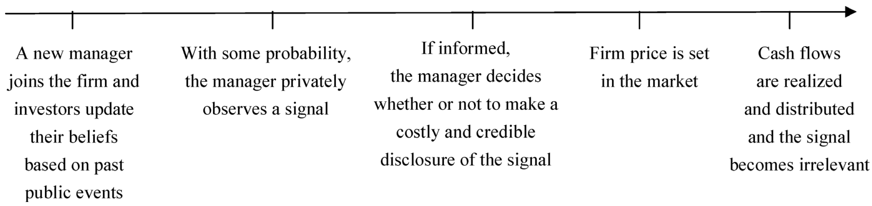

FIG. 1.—Timeline per period.

privately observes the signal S. Conditioned on possessing the private signal and based on its content, the manager decides whether or not to credibly disclose it, at a cost c. Now, based on all available public information, the firm's price is set in the market. Finally, at the end of the period, the cash flows, CF, are realized and distributed as a dividend to the shareholders and therefore become commonly known.

Next, we replicate the representative period into a multiperiod model with an infinite number of successive identical periods.[4] For simplicity, we assume that all parameters are stationary.[5] We preclude any correlation of cash flows across periods and view the firm's uncertain future cash flows as an infinite sequence of uncorrelated random variables, drawn from an identical normal distribution and discounted by the market using a discount factor r ($0 < r < 1$).[6] The private signals that the firm might receive across the different periods are similarly represented by an infinite sequence of uncorrelated random variables, drawn from an identical normal distribution. Moreover, the firm's private signal in each period is relevant only during that period, because cash flows become publicly observable at the end of the period.[7] The model also assumes away managerial time dependencies. The firm's

[4] Under the assumption of an infinite number of periods, any period is followed by an identical infinite future horizon, so the history is the only determinant of the firm's disclosure strategy in each period. Hence, by neutralizing other factors of secondary importance, the assumption of an infinite horizon draws attention to the role of the firm's history in shaping its disclosure strategy. Nevertheless, the proofs as they appear in the appendix pertain to both finite and infinite horizons of the firm.

[5] This assumption significantly simplifies the notation and streamlines the presentation and the analysis. However, the results could be easily generalized to the case of nonstationary parameters.

[6] The discount factor r can also be interpreted as the probability that the firm continues to operate in future periods. Hence, although we assume an infinite horizon for the firm, we allow the possibility of a finite probabilistic horizon.

[7] This assumption is applicable to many real-world situations where disclosure becomes irrelevant over time as more information arrives in the market. It could apply, in particular, to disclosures of management predictions of future input prices, management forecasts of future earnings, results of a market analysis regarding the introduction of a new product, loan-loss reserves, or bad-debt estimates. It also distinguishes our model from that of Cosimano, Jorgensen, and Ramanan [2004], where intertemporal dynamics arise because disclosure in any period is relevant in estimating the profits of future periods and never subsumed by new public information.

manager in each period is myopic and interested only in maximizing the firm's current market price.[8]

Subsequent periods in our model are linked through the history dependence of the information endowment. We model the dynamics of the information endowment over time as a two-state stochastic process, where the set $\Omega = \{inf, ui\}$ includes the two possible random states in each period. The notation *inf* stands for an informed state where the manager possesses the private signal, and *ui* stands for an uninformed state where the manager does not possess the private signal. Following Cosimano, Jorgensen, and Ramanan [2004], we assume that the stochastic process of the information states is a Markov chain, so that the probability of the manager being informed in each period depends on the information state in the previous period.[9] We assume an intertemporal positive correlation for the private information arriving, so that the probability of the manager being informed in any given period is higher when information was available in the previous period than when information was previously unavailable.[10] This assumption reflects the perception that the availability of relevant information, the cost of acquiring such information, and the ability to credibly disclose it to outsiders remain relatively stable over time. Formally, the probability of the manager being informed in any given period is π if the manager was informed in the previous period and $\pi - \delta$ if she was uninformed, where $0 < \delta < \pi < 1$.[11] Our initial condition is such that the probability of the manager being informed in the first period is π. The parameter δ measures the magnitude of the history dependence in the information endowment, and therefore captures the level of stability in the firm's information environment.

In each period, the investors' prior beliefs regarding the firm's current information state are partially determined by previously observed information. Because disclosure unequivocally reveals the manager's (Markovian) information state, all public events that occurred prior to the firm's last past disclosure are irrelevant. The relevant history thus includes the timing of the firm's last disclosure and all cash flow realizations since that time. Investors could use past cash realizations to imperfectly infer the past information state by estimating the likelihood of information being withheld.

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[8] In section 5 we analyze an extension to our model where the manager values more than one period.

[9] In general, a Markov chain is a special type of a stochastic process, in which the probability of being in a given state at any given time depends only on the previous state. When only a finite number, n, of states is possible at any time and the probability of moving from any given state to another is stationary, it is convenient to describe the Markov chain by an $n \times n$ transition matrix, where the (i, j) element is the probability of being in state i given that the previous state was j.

[10] In a different setting, Dye and Sridhar [1995] similarly assume a positive correlation for managers being privately informed across firms in the same industry.

[11] That is, the Markov chain of information states can be described by the 2×2 transition matrix $\begin{pmatrix} \pi & \pi-\delta \\ 1-\pi & 1-(\pi-\delta) \end{pmatrix}$, where *inf* is defined as the first state and *ui* as the second state.

Note, however, that while disclosure unambiguously reveals that the manager was informed, the cash history provides only a noisy indication about the information state. The manager in each period could have superior information about the firm's history, beyond the available public information, but any such superior information is irrelevant in choosing the current strategy. Formally, the relevant history can be summarized by a vector $h = (n, cf_1, cf_2, \ldots, cf_n)$, where $n \in \mathrm{N}$ describes the disclosure history and $(cf_1, cf_2, \ldots, cf_n) \in \Re^n$ describes the operating history. Explicitly, the component n of the vector h represents the number of periods without disclosure since the most recent past disclosure, while the components $cf_1, cf_2, \ldots, cf_n$ of the vector h represent the cash realizations in these n periods. Starting with (0) in the first period, the history evolves with time, so that if it is $(n, cf_1, cf_2, \ldots, cf_n)$ in a certain period, then it is either reset to (0) in the next period (given current disclosure) or becomes $(n+1, cf_1, cf_2, \ldots, cf_n, cf_{n+1})$ (given no disclosure and a current cash realization of cf_{n+1}). We use the notation H to denote the set $\{(n, cf_1, cf_2, \ldots, cf_n) \mid n \in \mathrm{N}, (cf_1, cf_2, \ldots, cf_n) \in \Re^n\}$ of all possible histories.

3. Equilibrium Definition

We look for a Bayesian equilibrium. In equilibrium, in every period the firm's manager chooses the disclosure strategy in light of its rationally anticipated impact on the firm's current market price, which, in turn, is determined by the investors' rational expectations about the disclosure strategies of the firm in the past, present, and future. As the equilibrium analysis of each period applies to the same set of stationary parameters and to an identical infinite future horizon of the firm, differences in the equilibrium outcomes of different periods might be due only to differences in the preceding history. Hence, the firm's history is the only determinant that distinguishes the equilibrium outcomes of different periods. Accordingly, we represent the manager's equilibrium disclosure strategy by the function $D : \mathrm{H} \times \Omega \times \Re \rightarrow \mathrm{A}$, where $D(h, i, s) \in \mathrm{A}$ is the manager's binary disclosure decision in any period with a history $h \in \mathrm{H}$, given that the information state in that period is $i \in \Omega$ and the realization of the private signal, if received, is $s \in \Re$. The equilibrium market pricing rule is represented by the function $P : \mathrm{H} \times \mathrm{A} \times \Re \rightarrow \Re$, where $P(h, d, s) \in \Re$ is the market price of the firm in any period with a history $h \in \mathrm{H}$, given that $d \in \mathrm{A}$ is the manager's disclosure decision in that period and $s \in \Re$ is the realization of the private signal (if available and disclosed). We also use the function $\hat{D} : \mathrm{H} \times \Omega \times \Re \rightarrow \mathrm{A}$ to describe the market expectations about the manager's disclosure strategy D and the function $\hat{P} : \mathrm{H} \times \mathrm{A} \times \Re \rightarrow \Re$ to describe the manager's expectations about the market pricing rule, P.

Equilibrium is formally defined as a vector $(D, \hat{D} : \mathrm{H} \times \Omega \times \Re \rightarrow \mathrm{A}, P, \hat{P} : \mathrm{H} \times \mathrm{A} \times \Re \rightarrow \Re)$, which satisfies the following three conditions. The first equilibrium condition pertains to the manager's disclosure strategy, requiring that $D(h, ui, s) = nd$ and $D(h, inf, s) \in \arg\max_{d \in \mathrm{A}} \hat{P}(h, d, s)$

for any $h \in \mathrm{H}$ and $s \in \Re$. That is, in each period, an informed manager chooses the disclosure alternative that maximizes the firm's market price in that period, whereas an uninformed manager obviously does not provide any disclosure. The second equilibrium condition describes the market pricing rule. According to the pricing condition, the firm's market price in each period satisfies $P(h, dis, s) = \mathrm{E}[CF \mid S = s] + \sum_{t=1}^{\infty} r^t \mu - c - \psi^{dis}$ and $P(h, nd, s) = \frac{\varphi(h)(1-\tau(h))}{1-\varphi(h)\tau(h)} E[CF \mid \hat{D}(h, inf, S) = nd] + \frac{1-\varphi(h)}{1-\varphi(h)\tau(h)}\mu + \sum_{t=1}^{\infty} r^t \mu - \psi^{nd}(h)$ for any $h \in \mathrm{H}$ and $s \in \Re$, where $\varphi(h)$, $\tau(h)$, ψ^{dis}, and $\psi^{nd}(h)$ are defined below. We define $\varphi(h)$ as the investors' estimate of the probability that the manager is currently informed, given a history h. We define $\tau(h) \equiv prob(\hat{D}(h, inf, S) = dis)$ as the investors' estimate of the probability of disclosure occurrence given a history h and conditioned on the manager being currently informed. The term ψ^{dis} represents the market estimate of the discounted disclosure costs that are expected to be incurred by the firm in the future when disclosure occurs currently, whereas $\psi^{nd}(h)$ represents the market estimate of the discounted future disclosure costs that are expected in the absence of a current disclosure and given a history h. The pricing rule reflects the investors' risk neutrality by setting the market price in each period to be the expected value of the firm, conditional on all publicly available information. At any point in time, investors determine the expected value of the firm by aggregating the firm's expected future cash flows from its operations and subtracting the expected future disclosure-associated costs, employing a discount factor r. The investors' information set in each period includes the realization of the manager's signal, if disclosed, or a history-based Bayesian update on the distribution of the manager's information state and her private signal otherwise. Lastly, the third equilibrium condition imposes $\hat{D}(h, i, s) = D(h, i, s)$ and $\hat{P}(h, d, s) = P(h, d, s)$ for any $h \in \mathrm{H}$, $i \in \Omega$, $d \in \mathrm{A}$, and $s \in \Re$, implying that both the manager and the investors have rational expectations regarding each other's behavior.

4. *Equilibrium Analysis*

We now turn to deriving the equilibrium and analyzing its properties. Throughout the analysis, we highlight the dependence of the manager's disclosure strategy on past and future considerations. As a benchmark, denoted by the superscript B, we consider the case $\delta = 0$, an extremely volatile environment, where the information endowment is unpredictable. Here, each period can be viewed as a single-period setting with a time-independent disclosure strategy. Based on Verrecchia [1983], Dye [1985], and Jung and Kwon [1988], Observation 1 establishes the existence and uniqueness of the benchmark equilibrium and characterizes its basic form.

OBSERVATION 1. *In the benchmark case of $\delta = 0$, there exists a unique equilibrium, where the disclosure strategy $D^B : \mathrm{H} \times \Omega \times \Re \to \mathrm{A}$ of each period is characterized* *by a history-independent threshold* $s^B \in \Re$, *such that for any* $h \in \mathrm{H}$, $i \in \Omega$, *and* $s \in \Re$:

$$D^B(h, i, s) = \begin{cases} dis & if\,(i = inf)\, and\,(s \geq s^B) \\ nd & otherwise. \end{cases}$$

Observation 1 yields a standard upper-tailed disclosure strategy in each period, where an informed manager chooses to disclose her private signal if and only if its realization is sufficiently favorable and exceeds the history-independent threshold level s^B.[12] Proposition 1 characterizes the form that the equilibrium takes when moving from the benchmark case of $\delta = 0$ to environments where $\delta > 0$.

PROPOSITION 1. *There exists a unique equilibrium for any* $\delta > 0$. *In equilibrium, the disclosure strategy* $D : \mathrm{H} \times \Omega \times \Re \rightarrow \mathrm{A}$ *of each period is characterized by a threshold function* $s^* : \mathrm{H} \rightarrow \Re$, *such that for any* $h \in \mathrm{H}$, $i \in \Omega$, *and* $s \in \Re$*:*

$$D(h, i, s) = \begin{cases} dis & if\,(i = inf)\, and\,(s \geq s^*(h)) \\ nd & otherwise. \end{cases}$$

Proposition 1 establishes the existence and uniqueness of the equilibrium, indicating that the upper-tailed structure of the disclosure strategy continues to hold for any $\delta > 0$. Unlike the benchmark case, however, the disclosure threshold now becomes history dependent. Proposition 2 compares the history-dependent disclosure threshold $s^*(h)$ to the benchmark history-independent disclosure threshold s^B.

PROPOSITION 2. *In equilibrium, for any* $h \in \mathrm{H}$, $s^*(h) > s^B$.

Proposition 2 indicates that the disclosure threshold $s^*(h)$ is strictly above the benchmark level s^B for any history h, implying that intertemporal dynamics reduce managerial incentives to provide voluntary disclosures. Intuitively, in any period, regardless of the firm's history, suppressing current disclosure contributes to establishing a reputation of being uninformed, which facilitates future information withholding. On the other hand, providing voluntary disclosure augments the market's awareness of the existence of information, and thereby strengthens the implicit commitment of the firm to provide similar disclosures in the future.[13] The current disclosure, therefore, works to enhance future costly disclosures. The expected incremental future disclosure cost due to the current disclosure, $\psi^{dis} - \psi^{nd}(h)$, denoted $\lambda(h)$, is rationally anticipated by investors and thus fully incorporated in the current market price. This adverse price reaction to disclosure introduces an endogenous indirect disclosure cost, which reduces the incentive

[12] Most models of voluntary disclosure result in an upper-tailed disclosure strategy with a history-independent threshold. However, a few models (e.g., Kirschenheiter [1997], Einhorn [2005], Pae [2005]) derive a history-independent threshold that depends on private information the firm possesses in addition to the information that underlies its disclosure decision.

[13] Our analysis provides a possible explanation for the role of voluntary disclosure in imposing a commitment on the part of the firm to further disclose. Trueman [1997] provides an alternative explanation, based on legal liability considerations.

of the manager to provide disclosure, even though she is myopic and interested only in maximizing the current market price. That is, when $\delta > 0$, intertemporal dynamics emerge and, endogenously, generate a positive indirect disclosure cost of $\lambda(h)$, in addition to the already existing direct disclosure cost, c. As a result, the disclosure threshold $s^*(h)$ moves upward above the benchmark level of s^B, for any history h. We emphasize that this result applies, in particular, to the shortest possible history (0), where disclosure has just occurred in the previous period and the manager has no past reputation to protect (because the current period is used by the manager to initiate reputation buildup). Though the suppressing effect of intertemporal dynamics on managerial incentives to provide voluntary disclosures exists for any firm's history $h = (n, cf_1, cf_2, \ldots, cf_n)$, its magnitude depends on the specific history, both the disclosure history, n, and the operating cash flow history, $(cf_1, cf_2, \ldots, cf_n)$.

Focusing first on the disclosure history, n, two past public events are of importance: the last past disclosure (which occured n periods ago and revealed that the manager was informed in that period) and the absence of disclosure since that time. The first-mentioned event causes an upward revision of $\varphi(h)$, the investors' estimate of the probability that the manager is currently informed, to the maximal possible level of π, making all prior disclosure decisions irrelevant. The second has an opposite, downward, impact on the probability $\varphi(h)$. The cumulative downward impact on the probability $\varphi(h)$ is increasing with the number n of periods that have elapsed since the last disclosure. Hence, a longer history of suppressing disclosures results in a lower $\varphi(h)$, providing the firm with a better reputation of being uninformed, which moderates the adverse price reaction to the absence of disclosures in the next periods and facilitates the current and future withholding of information, thus saving on disclosure costs. Once this valuable reputation has been built up, its collapse by the current disclosure is costly to the firm. That is, not only does a longer history of avoiding disclosures endow the manager with a more valuable reputation of being currently uninformed, it also makes the destruction of this reputation by the current disclosure more costly. Thus, a longer history of not providing disclosures reduces the incentives of the manager to provide disclosure by implying a lower probability $\varphi(h)$ of the investors perceiving the manager as being currently informed, as well as a higher indirect disclosure cost, $\lambda(h)$. Hence, as formally stated in Proposition 3, the longer the history of suppressing disclosure, the lower is the propensity of the manager to make the current disclosure.[14]

[14] Cosimano, Jorgensen, and Ramanan [2004] demonstrate scenarios where the opposite could occur. Unlike our model, their model depicts situations where disclosure is not subsumed over time by new information that arrives in the market. Using a simulation analysis, they demonstrate that the uncertainty of the market about the firm is built up over time in the absence of voluntary disclosure, increasing the pressure for disclosure and the likelihood of its occurrence.

PROPOSITION 3. *In equilibrium, for any* $(n, cf_1, cf_2, \ldots, cf_n) \in \mathrm{H}$*, such that* $n \geq 1$, $s^*(n, cf_1, cf_2, \ldots, cf_n) > s^*(n-1, cf_2, \ldots, cf_n)$.

Proposition 3 implies that, by augmenting the market's awareness of the existence of information, voluntary disclosures provided by firms in the past endogenously augment their implicit commitment to provide similar disclosures in the future.[15] This provides some support to empirical tests of the relation between the level of voluntary disclosure and the cost of capital, which usually use ex post voluntary disclosure decisions as a proxy for an ex ante commitment to disclose in the future. Our analysis proceeds by identifying circumstances where corporate voluntary disclosures are subject to more salient intertemporal effects, so that past voluntary disclosure serves to indicate a stronger commitment to future disclosures.

While the absence of past disclosures contributes to establishing a reputation of being uninformed, the process is faster when the history of not providing disclosures goes along with an impressive past operating performance. This is because a high operating outcome in the past implies that any available information was apparently too favorable to be withheld, convincing the market that it is more likely information was unavailable. Described differently, when the firm exhibits higher cash flows from its operations in the past, the market is more likely to attribute the absence of past disclosures to the unavailability of information rather than to its unfavorable content. Therefore, for any given number n of past periods without disclosure, the better the corresponding past cash realizations, $(cf_1, cf_2, \ldots, cf_n)$, the better is the manager's reputation of being currently uninformed and the more costly for the manager is the collapse of this reputation by the current disclosure. Hence, as suggested by Proposition 4, the propensity of the manager to make the current disclosure is negatively related to the cash realizations since the last past disclosure.

PROPOSITION 4. *In equilibrium, for any* $(n, cf_1, cf_2, \ldots, cf_n) \in \mathrm{H}$*, such that* $n \geq 1$, $s^*(n, cf_1, cf_2, \ldots, cf_n)$ *is increasing in* $cf_1, cf_2, \ldots, cf_n$.

Propositions 3 and 4 suggest that an ex post voluntary disclosure decision can serve as a relatively good proxy for an ex ante commitment to continue disclosing in the future for firms with a long history of not providing voluntary disclosures and an impressive corresponding past operating performance. Supplementing the empirical implications emanating from Proposition 3, it seems that empirical tests of the relation between the level of voluntary disclosure and the cost of capital, if applied to such a subset of firms, may provide stronger results.

Another category for which past voluntary disclosures might be a good proxy for a commitment to disclose in the future consists of firms that operate in a relatively stable and predictable environment. In a stable business

[15] For empirical evidence that supports this prediction, see Lang and Lundholm [1993] and Botosan and Harris [2000].

and information environment, captured in our model by a high δ, a past information endowment serves as a good indicator of a similar subsequent information endowment, and thus the intertemporal dynamics of corporate voluntary disclosures are expected to be stronger. Similarly, intertemporal considerations are likely to be more salient for firms that operate in a less risky business environment, where the future operating results are more predictable. In pricing such firms, investors employ a higher discount factor, r, assigning a higher weight to the expected future cash flows in determining the firm's current market price, hence enhancing the extent to which the manager values the future implications of her disclosure choices. That is, while the parameters δ and r have no effect on the benchmark disclosure strategy, they play an important role in shaping the manager's disclosure choice in the presence of intertemporal dynamics. In particular, Proposition 5 suggests that the suppressing impact of intertemporal forces on managerial incentives to provide voluntary disclosure is positively related to the parameters δ and r.

PROPOSITION 5. *In equilibrium, for any* $h \in \mathrm{H}$, $s^*(h)$ *is increasing in* δ *and in* r, *while* s^B *is independent of* δ *and* r.

We illustrate our multiperiod analysis with a numerical example. Assume $\mu = 100$, $\sigma = 20$, $\sigma_\varepsilon = 10$, $\pi = 0.8$, $\delta = 0.4$, $c = 10$, and $r = 0.9$. Table 1 presents selected equilibrium outcomes for this example. In the benchmark case of $\delta = 0$, our example yields a probability $\tau^B = prob(S \geq s^B) = 49\%$ of disclosure occurrence, conditioned on the manager being informed. Consistent with Proposition 2, with $\delta = 0.4 > 0$, the probability that an informed manager provides voluntary disclosure is below the benchmark level of $\tau^B = 49\%$ for any history $(n, cf_1, cf_2, \ldots, cf_n)$ presented in table 1. As suggested by Proposition 3, for any given sequence of past cash realizations, the equilibrium probability of disclosure occurrence, conditioned on possessing the information, is decreasing in the number of past periods without disclosure. For example, in panel B, where all past cash realizations coincide with 100, as n increases, the probability that an informed manager provides disclosure decreases from 44% (for $n = 0$) through 38% (for $n = 1$) to 37%

TABLE 1

Numerical Example

Panel A		**Panel B**		**Panel C**	
h	$\tau(h)$	h	$\tau(h)$	h	$\tau(h)$
(0)	0.44	(0)	0.44	(0)	0.44
(1,80)	0.40	(1,100)	0.38	(1,120)	0.31
(2,80,80)	0.38	(2,100,100)	0.37	(2,120,120)	0.31
(3,80,80,80)	0.37	(3,100,100,100)	0.36	(3,120,120,120)	0.31

Relating to a numerical example where $\mu = 100$, $\sigma = 20$, $\sigma_\varepsilon = 10$, $\pi = 0.8$, $\delta = 0.4$, $c = 10$, and $r = 0.9$, the table presents the equilibrium probability $\tau(h)$ of disclosure occurrence, conditioned on the manager being informed, for a sample of histories of the form $h = (n, cf, cf, \ldots, cf)$, such that $n = 0, 1, 2, 3$ and $cf = 80, 100, 120$.

(for $n = 2$) and to 36% (for $n = 3$). Furthermore, as implied by Proposition 4, for any fixed number n of past periods without disclosure, the probability that an informed manager provides voluntary disclosure is negatively related to the cash realizations in the preceding n periods. For example, consider the case of $n = 1$, where the history of nondisclosure includes only the previous period (see the second row in panels A, B, and C). Here, the probability that an informed manager provides disclosure is 40% when the cash realization of the previous period is 80, but it decreases to 38% when the cash realization of the previous period is 100, and it further decreases to 31% when the cash realization of the previous period is even higher, at 120.

5. *Extension*

In this section, we incorporate into the model a richer set of managerial time and risk preferences to explore how managerial properties affect disclosure choices in the presence of intertemporal dynamics. We extend the base model described in section 2 by assuming the manager's time horizon includes not only the current period but also one additional future period. That is, while the base model assumes that the manager is myopic and interested only in maximizing the firm's current period market price, the extended model considers the case of a forward-looking manager who also cares about the price during a subsequent period. When the manager is forward looking, her degree of risk aversion becomes relevant, because future prices are uncertain. We allow for a continuum of risk-aversion degrees, including the case of risk neutrality. To facilitate the analysis, we assume the manager in each period has a mean-variance utility function of the form $E[x] - \gamma VAR[x]$, where x is a linear combination that assigns a weight 1 to the current market price of the firm and a weight ω to the price in the subsequent period, where $0 \leq \omega \leq 1$ and $\gamma \geq 0$.[16] The parameter ω represents the strength of the manager's future preferences. The special case of $\omega = 0$ coincides with the base model, describing a myopic manager, who cares only about the current market price of the firm. The parameter γ represents the manager's degree of risk aversion, where $\gamma = 0$ captures risk neutrality.[17] We first note that the results drawn from the base model can be generalized to the extended model, adding robustness to our discussion.

[16] For the sake of simplicity, and since the risk preferences of the manager are not our main focus, we assume mean-variance preferences, as is common in the literature. It is well known that such preferences can be derived endogenously under a negative exponential utility function that applies to a normally distributed variable. Jorgensen and Kirschenheiter [2002] extend this observation to a truncated-normal distribution. We note, however, that none of these results applies to our setting, where the upper-tailed structure of the disclosure strategy implies a truncated-normal distribution of the future uncertain price conditioned on disclosure, while the unconditional distribution of the future price conforms to neither a normal nor a truncated-normal distribution.

[17] Note that in the case of a myopic manager, $\omega = 0$, the degree of risk aversion is irrelevant, because the current market price of the firm is predictable, with no variance.

Moreover, the extension we analyze enables us to draw additional insights, in particular to identify further intertemporal considerations underlying corporate disclosure choices.

In section 4, we demonstrate that intertemporal forces generate indirect disclosure costs because of the impact of the current disclosure in augmenting the occurrence of similar future costly disclosures. Since the expected increment in future disclosure costs due to the current disclosure is rationally anticipated by investors and therefore fully conveyed by the current market price, the current disclosure becomes costly even to a myopic manager ($\omega = 0$) who cares only about the current price. Two additional indirect disclosure costs emerge when the manager is forward looking so that she also cares about the future random price of the firm. First, current disclosure makes it more difficult for the firm to avoid unfavorable disclosures in the future and therefore diminishes the firm's ability to manage future market expectations. Hence, current disclosure reduces the expected value of the future random price, generating another indirect disclosure cost for a forward-looking manager, which is increasing in her time horizon, ω. Second, if the manager is also risk averse, the current disclosure is even more costly, because it also intensifies the dependence of the future price on the future unknown information, and thereby increases its volatility.[18] The increase in the volatility of the future price introduces another kind of indirect disclosure cost, which is increasing in both the manager's time horizon, ω, and her degree of risk aversion, γ. In summary, three kinds of indirect disclosure costs that suppress the incentives to provide voluntary disclosure arise due to intertemporal forces. The two identified in this section are associated with managerial characteristics and result in a negative relation between the propensity of an informed manager to provide voluntary disclosure and her time horizon and degree of risk aversion. Formally,

PROPOSITION 6. *In the extended model, Observation 1 and Propositions 1–5 hold. Also, in equilibrium, for any* $h \in \mathrm{H}$, $s^*(h)$ *is increasing in* ω *and* γ, *while* s^B *is independent of* ω *and* γ.

Complementing Propositions 3, 4, and 5, Proposition 6 identifies an additional category of firms for which past voluntary disclosures might serve as a good proxy for a commitment to disclose in the future. Specifically, Proposition 6 suggests that the extent to which voluntary disclosures are subject to intertemporal forces is expected to be large for the category of firms whose managers have a relatively long time horizon and a high degree of risk aversion. In this category of firms, therefore, empirical tests of the relation between the level of voluntary disclosure and the cost of capital may be more valid.

[18] In a different setting, Nagar [1999] demonstrates that risk-averse managers face disclosure costs due to the risk of not knowing how the market will interpret their disclosure.

6. *Summary and Conclusions*

Though the empirical evidence indicates the intertemporal nature of corporate voluntary disclosures, existing theory largely analyzes disclosure choices within single-period frameworks. In this paper, using a repeated multiperiod setting, we shed light on the intertemporal dynamics of disclosure choices, demonstrating that a firm's voluntary disclosure strategy is not time isolated, but is rather an integral part of its past and future strategic disclosure behavior.

We demonstrate that by augmenting the market's awareness of the existence of information, voluntary disclosure generates an implicit commitment on the part of the firm to provide similar disclosures in the future. This outcome of disclosure is the source of various indirect disclosure costs that reduce the managerial propensity to provide voluntary disclosures. The analysis also indicates circumstances where the intertemporal nature of corporate voluntary disclosures is especially salient. Such circumstances are likely to occur when firms have a long history of absence of disclosures and an impressive corresponding past operating performance, when they operate in a relatively stable and predictable business and information environment, and when their managers have a long time horizon and a high degree of risk aversion. These predictions offer guidance for empirical work, instances where firms' ex post voluntary disclosure decisions might serve in empirical tests to proxy their ex ante commitment to disclose in the future.

Obviously, in our model we capture only a small part of the rich array of intertemporal considerations underlying corporate discretionary disclosure strategies. While we highlight the history dependence of information endowment as a possible source of the intertemporal dynamics of corporate voluntary disclosures, we believe that there is much potential for future research in exploring many other sources. Examples include the history dependence of disclosure costs, the history dependence of information quality, and the endowment with private relevant information about subsequent periods.

APPENDIX

The appendix presents the highlights of the proofs and describes the overall logic that underlies them. To streamline the presentation of the proofs, all the technical details are taken away into a set of Lemmata stated at the end of the appendix, whose proofs are available from the authors upon request. We start by deriving the system of equilibrium equations, which is in the basis of all the proofs, and then provide the outline of each proof.

For any period with a history $h \in \mathrm{H}$, it is easy to show, as is done elsewhere (e.g., Verrecchia [1983], Dye [1985]), that due to the positive correlation between the signal and the cash flow, the signal (if available to the manager) is disclosed if and only if it exceeds some threshold $s^*(h)$. Recall that $\varphi(h)$ is the investors' estimate of the probability that the manager is currently informed, and observe that $\tau(h) = prob(S \geq s^*(h))$ is the investors' estimate of the probability that an informed manager provides disclosure. Hence, similarly to Jung and Kwon [1988], conditioned on the absence of disclosure in a period with a history $h \in \mathrm{H}$, $\frac{1-\varphi(h)}{1-\varphi(h)\tau(h)}$ is the probability that the manager is uninformed, while $\frac{\varphi(h)(1-\tau(h))}{1-\varphi(h)\tau(h)}$ is the probability that the manager is informed and chooses to withhold her information. Thus, in any period with a history $h \in \mathrm{H}$, given a realization $s \in \Re$ of the signal S, the market's expectation about the cash flow CF is $E[CF \mid S = s]$ upon disclosure of the signal and $\frac{\varphi(h)(1-\tau(h))}{1-\varphi(h)\tau(h)} E[CF \mid S \leq s^*(h)] + \frac{1-\varphi(h)}{1-\varphi(h)\tau(h)} \mu$ in the absence of disclosure. Accordingly, for any $h \in \mathrm{H}$ and $s \in \Re$, the difference $P(h, dis, s) - P(h, nd, s)$, when taking into account the direct and indirect disclosure costs $c + \lambda(h)$, is

$$E[CF \mid S = s] - \left(\frac{\varphi(h)(1-\tau(h))}{1-\varphi(h)\tau(h)} E[CF \mid S \leq s^*(h)] + \frac{1-\varphi(h)}{1-\varphi(h)\tau(h)} \mu \right) - c - \lambda(h)$$

or

$$E[CF \mid S = s] - E[CF \mid S \leq s^*(h)] - \frac{1-\varphi(h)}{1-\varphi(h) prob(S \geq s^*(h))} \times (\mu - E[CF \mid S \leq s^*(h)]) - c - \lambda(h).$$

Given a history $h \in \mathrm{H}$, when the realization s of the signal equals the threshold $s^*(h)$, the manager is indifferent between disclosing the signal and withholding it. Thus, for any $h \in \mathrm{H}$, $P(h, dis, s^*(h)) - P(h, nd, s^*(h)) = 0$. This implies that the disclosure thresholds in the set $\{s^*(h) \mid h \in \mathrm{H}\}$ satisfy the following system of equations:

$$\forall h \in \mathrm{H} : F(\varphi(h), s^*(h)) = c + \lambda(h) \tag{A1}$$

where $F(\alpha, x) = E[CF \mid S = x] - E[CF \mid S \leq x] - \frac{1-\alpha}{1-\alpha prob(S \geq x)} (\mu - E[CF \mid S \leq x])$ for any $\alpha \in (0, 1)$ and $x \in \Re$.

The system of equilibrium equations (A1) is the basis of all proofs. Once solved, it implies the set of equilibrium disclosure thresholds. In solving this system of equations we rely on the fact that $F(\alpha, x)$ is a continuous and increasing function of both α and x (Lemma 1). It should also be noted that although the disclosure threshold $s^*(h)$ for any given history $h \in \mathrm{H}$ seemingly appears only in one equation, it cannot be derived without simultaneously solving the other equations in the system (A1). This is true because the terms $\varphi(h)$ and $\lambda(h)$ for any given history $h \in \mathrm{H}$ depend on the disclosure thresholds of other histories. This is the main difference between our analysis and that provided by prior studies (see Verrecchia [1983], Dye [1985], Jung and Kwon [1988]), where there is only one history-independent threshold that is simply derived as the solution of a single equation. The system (A1) is reduced to a single equation, as in prior literature, only in the benchmark case of $\delta = 0$.

Proof of Observation 1. Under the benchmark case $\delta = 0$, so we can substitute $\varphi(h) = \pi$ and $\lambda(h) = 0$ for any history $h \in \mathrm{H}$. Hence, each period can be analyzed as an independent single-period model. Consequently, the disclosure threshold s^B is history independent and the system (A1) is reduced to the following single equation:

$$F(\pi, s^B) = c. \tag{A2}$$

The history-independent disclosure threshold s^B is the solution of equation (A2), which is a straightforward extension of prior literature. Since the left side of equation (A2) is continuous and increasing in s^B from $-\infty$ to $+\infty$, whereas the right side of the equation is independent of s^B, there exists a unique solution, s^B, which constitutes the unique equilibrium for the benchmark case of $\delta = 0$. ■

Proof of Proposition 1. When $\delta > 0$, the history-dependent disclosure thresholds $\{s^*(h) \mid h \in \mathrm{H}\}$ are obtained as the solution of the system (A1). To establish their existence and uniqueness, we first truncate the number of periods in the model to a finite number, denoted N. Using an induction on N, we establish the existence and uniqueness of equilibrium in a model with N periods. The proof holds for any N, as large as we wish. The proof of Proposition 1 is then obtained by showing the sequence of equilibria of the finite models converges to a limit when N approaches infinity.

In a model with an infinite number of periods, any period is followed by an identical infinite future horizon, so the disclosure threshold depends only on the history. On the other hand, in a model with a finite number of periods, the future horizon also varies and is an additional determinant of the disclosure strategy. We define the future horizon of each period as the number of subsequent periods and denote it by a non-negative integer f. In an N-period model, the set $\Omega^N = \{(h, f) \mid h = (n, cf_1, cf_2, \ldots, cf_n) \in \mathrm{H}, f \in \{0, 1, 2, 3 \ldots, N-1\} n + f + 1 \le N\}$ includes all possible pairs of a history h and a future horizon f. For any such pair, we denote the probability of the manager being currently informed by $\varphi(h, f)$, the indirect disclosure costs by $\lambda(h, f)$, and the disclosure threshold by $s^*(h, f)$.

We recursively present $\varphi(h, f)$ as follows (Lemma 2):

$$\varphi(h, f) = \begin{cases} \pi & \textit{if } h = (0) \\ \pi - \dfrac{1 - \varphi(h^-, f+1)}{1 - \varphi(h^-, f+1)\mathit{prob}(S \ge s^*(h^-, f+1) \mid CF = cf_n)}\delta & \textit{otherwise}, \end{cases} \tag{A3}$$

where $h^- = (n-1, cf_1, cf_2, \ldots, cf_{n-1})$.

We recursively present $\lambda(h, f)$ as follows (Lemma 3):

$$\lambda(h, f) = \begin{cases} 0 & \textit{if } f = 0 \\ r \cdot E_{CF}[(a-b)\cdot c + (1-b)\cdot \lambda(h^{+}, f-1) - (1-a)\cdot \lambda((0), f-1)] & \textit{otherwise}, \end{cases} \tag{A4}$$

where $h^{+} = (n+1, cf_1, cf_2, \ldots, cf_n, CF)$, $a = \pi \cdot prob(S \geq s^{*}((0), f-1))$ and $b = \varphi(h^{+}, f-1) \cdot prob(S \geq s^{*}(h^{+}, f-1))$.

The system of equilibrium equations can now be generalized to the N-period model, so that instead of the system (A1) we get the following system:

$$\forall (h, f) \in \Omega^{N} : F(\varphi(h, f), s^{*}(h, f)) = c + \lambda(h, f). \tag{A5}$$

To solve the equations in the system (A5) and derive the equilibrium disclosure thresholds $s^{*}(h, f)$ for any $(h, f) \in \Omega^{N}$, we use an induction on the number of periods in the model, N. Besides showing the existence and uniqueness of the equilibrium disclosure thresholds, it is necessary for the induction process to also show their negative relationship with the initial probability π of being informed (although it is not a part of Proposition 1).

Starting with $N = 1$, the system of equations (A5) is reduced to a single equation similar to equation (A2), which yields a unique disclosure threshold. As the left side of the equation is increasing in the initial probability π of being informed, the resulting disclosure threshold is decreasing in π.

We proceed by considering a model with N periods, such that $N \geq 2$. Here, we apply the induction assumption to the submodel that includes the $N-1$ last periods. We do so under two alternative scenarios. Under the first one, disclosure has occurred in the first period, so the initial probability of being informed in the submodel is $\varphi((0), N-2) = \pi$. Under the second scenario, disclosure has not occurred in the first period, so the initial probability of being informed in this submodel is $\varphi((1, cf_1), N-2)$, where cf_1 is the cash flow of the first period. Note, in particular, that unlike the first scenario, the disclosure thresholds in the $N-1$ submodel under the second scenario depend on the threshold of the first period because of its effect on the initial probability $\varphi((1, cf_1), N-2)$. Specifically, the disclosure thresholds in the submodel under the second scenario are decreasing in the initial probability $\varphi((1, cf_1), N-2)$ by the induction assumption, and the probability $\varphi((1, cf_1), N-2)$ is increasing in the first-period disclosure threshold by the recursive formula (A3), so the disclosure thresholds in the last $N-1$ periods under the second scenario are decreasing in the first-period disclosure threshold.

By the induction assumption, for any disclosure threshold in the first period, there exists a unique set of disclosure thresholds in the submodel of the last $N-1$ periods. The disclosure thresholds for the last $N-1$ periods are decreasing in π. From the induction assumption, these thresholds are decreasing in the initial probability of being informed in the submodel, which is increasing in π, under both scenarios (see formula (A3)). This completes the proof for all equilibrium disclosure thresholds, except for that of the first period. That is, all we need to show is the existence and uniqueness of the disclosure threshold $s^*((0), N-1)$ in the first period (where the history is (0) and the future horizon is $N-1$) and its negative relationship with π.

The equation in the system (A5), which corresponds to the disclosure threshold of the first period, is $F(\pi, s^*((0), N-1)) = c + \lambda((0), N-1)$, which can be written as $F(\pi, s^*((0), N-1)) - \lambda((0), N-1) = c$. The first-period indirect disclosure cost in the left side of the equation, $\lambda((0), N-1)$, is the discounted incremental disclosure costs in the $N-1$ last periods due to the first-period disclosure. So, it follows from the recursive formula (A4) that $\lambda((0), N-1)$ is decreasing in the disclosure thresholds of the $N-1$ last periods under the first scenario and increasing in the disclosure thresholds of the $N-1$ last periods under the second scenario. Recall, however, that the disclosure thresholds of the $N-1$ last periods under the second scenario are decreasing in the first-period disclosure threshold. Hence, $\lambda((0), N-1)$ is also decreasing in the first-period disclosure threshold, $s^*((0), N-1)$. Since $F(\pi, s^*((0), N-1))$ is increasing in $s^*((0), N-1)$ from $-\infty$ to $+\infty$ and $\lambda((0), N-1)$ is bounded and decreasing in $s^*((0), N-1)$, the left side of the equation $F(\pi, s^*((0), N-1)) - \lambda((0), N-1) = c$ is increasing in $s^*((0), N-1)$ from $-\infty$ to $+\infty$, while the right side in independent of $s^*((0), N-1)$. Hence, there exists a unique solution, $s^*((0), N-1)$, to the equation. This solution is decreasing in π, because $F(\pi, s^*((0), N-1))$ is increasing in π.

We establish above the existence and uniqueness of equilibrium in a model with N periods, for any N, as large as we wish. We now move to the analysis of a model with an infinite number of periods, by converging N to infinity. Here, any period is followed by an identical infinite future horizon. It follows from $0 < r < 1$ and the recursive formula (A4) that, for any given history $h \in \mathrm{H}$, the sequence $\{\lambda(h, f)\}_{f=0}^{\infty}$ converges to a limit point. Thus, using the recursive formula (A3) together with the system (A5), for any given history $h \in \mathrm{H}$, the sequences $\{\varphi(h, f)\}_{f=0}^{\infty}$ and $\{s^*(h, f)\}_{f=0}^{\infty}$ also converge into a limit point. For any history $h \in \mathrm{H}$, the limit point $s^*(h) = \lim_{f\to\infty} s^*(h, f)$ is the unique equilibrium disclosure threshold in a model with an infinite number of periods. ■

Proof of Propositions 2, 3, 4, 5, and 6. The proofs of Propositions 2, 3, 4, 5, and 6 are based on the observation that, for any history $h \in \mathrm{H}$ and future horizon $f \geq 0$, the left side of the corresponding equation in the system (A5) is increasing in $\varphi(h, f)$, and the right side of the equation is increasing in $\lambda(h, f)$. So, the solution $s^*(h, f)$ to the equation is decreasing in the probability $\varphi(h, f)$ of the manager being informed and increasing in the indirect cost $\lambda(h, f)$ of disclosure.

Building on the above finding, and drawing the inequalities $\varphi(h, f) \leq \pi$ and $\lambda(h, f) > 0$ for any $h \in \mathrm{H}$ and $f \geq 0$ from the recursive formulas

(A3) and (A4), we get that the solution s^B to equation (A2) is lower than the solution $s^*(h, f)$ to the corresponding equation in the system (A5) and thus also lower than $s^*(h) = \lim_{f\to\infty} s^*(h, f)$. This completes the proof of Proposition 2.

To establish the proof of Propositions 3–5, we use the recursive formulas (A3) and (A4) to show, by an induction on n, that $\varphi(h, f)$ is decreasing in n, $cf_1, cf_2, \ldots, cf_n$ and δ (Lemmata 4, 5, and 6), and to show, by an induction on f, that $\lambda(h, f)$ is decreasing in $\varphi(h, f)$ and increasing in r (Lemmata 7 and 8), and thus $\lambda(h)$ is increasing in n, $cf_1, cf_2, \ldots, cf_n$, δ and r. This implies that $s^*(h, f)$ is increasing in n, $cf_1, cf_2, \ldots, cf_n$, δ, and r, and so is $s^*(h) = \lim_{f\to\infty} s^*(h, f)$.

Lastly, for the proof of Propositions 6, the definition of $\lambda(h, f)$ needs to be extended to reflect the manager's long time horizon and risk aversion. Using the extended definition, it can be shown that $\lambda(h, f)$ is increasing in ω and γ (Lemma 9), whereas $\varphi(h, f)$ is independent of ω and γ. This implies that $s^*(h, f)$ is increasing in ω and γ, and so is $s^*(h) = \lim_{f\to\infty} s^*(h, f)$. ■

To complete the proofs, Lemmata 1–9 stated below need to be proven. Proofs of the Lemmata are available from the authors upon request.

LEMMA 1. *Let* $F(\alpha, x) = E[CF \mid S = x] - E[CF \mid S \le x] - \frac{1-\alpha}{1-\alpha prob(S \ge x)}(\mu - E[CF \mid S \le x])$ *for any* $\alpha \in (0, 1)$ *and* $x \in \Re$. *Then,* $F(\alpha, x)$ *is increasing in* x *and in* α, *where* $\lim_{x\to-\infty} F(\alpha, x) = -\infty$ *and* $\lim_{x\to\infty} F(\alpha, x) = \infty$ *for any* $\alpha \in (0, 1)$.

LEMMA 2. *For any* $h = (n, cf_1, cf_2, \ldots, cf_n) \in \mathrm{H}$ *and* $f \ge 0$, $\varphi(h, f)$ *satisfies the following recursive formula:*

$$\varphi(h, f) = \begin{cases} \pi & \text{if } h = (0) \\ \pi - \dfrac{1 - \varphi(h^-, f+1)}{1 - \varphi(h^-, f+1) prob(S \ge s^*(h^-, f+1) \mid CF = cf_n)}\delta & \text{otherwise,} \end{cases}$$

where $h^- = (n-1, cf_1, cf_2, \ldots, cf_{n-1})$.

LEMMA 3. *For any* $h = (n, cf_1, cf_2, \ldots, cf_n) \in \mathrm{H}$ *and* $f \ge 0$, $\lambda(h, f)$ *satisfies the following recursive formula:*

$$\lambda(h, f) = \begin{cases} 0 & \text{if } f = 0 \\ r \cdot E_{CF}[(a-b)\cdot c + (1-b)\cdot\lambda(h^+, f-1) - (1-a)\cdot\lambda((0), f-1)] & \text{otherwise,} \end{cases}$$

where $h^+ = (n+1, cf_1, cf_2, \ldots, cf_n, CF)$, $a = \pi \cdot prob(S \ge s^*((0), f-1))$ *and* $b = \varphi(h^+, f-1) \cdot prob(S \ge s^*(h^+, f-1))$.

LEMMA 4. *For any* $(n, cf_1, cf_2, \ldots, cf_n) \in \mathrm{H}$ *and* $f \ge 0$, *such that* $n \ge 1$, $\varphi((n, cf_1, cf_2, \ldots, cf_n), f) < \varphi((n-1, cf_2, \ldots, cf_n), f)$.

LEMMA 5. *For any* $(n, cf_1, cf_2, \ldots, cf_n) \in \mathrm{H}$ *and* $f \geq 0$*, such that* $n \geq 1$*,* $\varphi((n, cf_1, cf_2, \ldots, cf_n), f)$ *is decreasing in* $cf_1, cf_2, \ldots, cf_n$*.*

LEMMA 6. *For any* $h \in \mathrm{H}$ *and* $f \geq 0$*,* $\varphi(h, f)$ *is decreasing in* δ*.*

LEMMA 7. *For any* $h \in \mathrm{H}$ *and* $f > 0$*,* $\lambda(h, f)$ *is decreasing in* $\varphi(h, f)$*.*

LEMMA 8. *For any* $h \in \mathrm{H}$ *and* $f \geq 0$*,* $\lambda(h, f)$ *is increasing in* r*.*

LEMMA 9. *In the extended model, for any* $h \in \mathrm{H}$ *and* $f \geq 0$*,* $\lambda(h, f)$ *is increasing in* ω *and* γ*.*

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