

Endogenous Information Flows and the Clustering of

Announcements

by

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We consider the strategic timing of information releases. We develop a dynamic disclosure model in which a firm may privately receive information. Because investors don't know whether the firm is informed, the firm will not necessarily disclose immediately. We show that bad market news can trigger the immediate release of information by firms. Conversely, good market news can slow the release of information by firms. Thus, our model generates clustering of negative announcements. Surprisingly, this result holds only when firms can preempt the arrival of external information. These results have implications for conditional variance and skewness of stock returns.

(JEL D8, G3, M4)

One of the most important ingredients to the process of price discovery in financial markets is the flow of new information. The importance of information flow is perhaps most apparent during times of market “crisis,” when it often seems that bad news is being reported simultaneously from multiple sources. This clustering of news could occur because firms learn more during bad times, or because firms strategically time the release of information. Indeed, it has long been recognized in the literature that corporate news disclosures are controlled by self-interested agents, and a number of theoretical and empirical analyses have found support for the idea that given this discretion, managers may choose to delay the release of bad news.¹

As hinted above, in addition to delays in the release of information, casual observation suggests that disclosures of bad news are often clustered in bad times. While it is not surprising that firms' news are affected by market and sector conditions (given the correlation of their cash flows), the *timing* of the announcements is suggestive that these disclosure decisions are not made independently. Indeed, recent empirical work by Tse and Tucker (2007), who employ a

¹ See for example Dye (1990), Rajan (1994), Dye and Sridhar (1995), Genotte and Trueman (1996), Shin (2003), Burgstahler and Dichev (1997),. Empirical support can be found in Miller (2002) who compares voluntary disclosures by firms that enjoy strong earnings performance to firms that experience earnings declines. He finds an increase in voluntary disclosures during periods of increased earnings.

duration model to study whether managers “herd” in announcing earnings warnings, finds that earnings warnings within an industry are clustered and that firms speed up their warnings in response to poor market conditions. In contrast, they show that such clustering is asymmetric in that good news does not generate such clustering.

In this paper, we seek an endogenous explanation for this asymmetry in the clustering of disclosure of good and bad news. We study disclosure dynamics when a firm possesses information that is correlated with market conditions, and explore managers’ incentives to delay the disclosure of bad news, as opposed to good news, until market conditions worsen and become public knowledge. In particular, we examine a dynamic game in which a manager of a firm decides when to report information regarding the value of the firm he manages. The manager maximizes the present value of her expected compensation, where the rate of compensation at each point in time is proportional to the market value of the firm conditional on public information. Because investors are uncertain whether a manager has learned the information, in equilibrium only those firms that have sufficiently positive news will release their information. Firms with more negative information will prefer to keep their market value higher – at least temporarily – by claiming that they do not yet have any information to report.

We then extend the model by supposing that in addition to the disclosure by the manager there is an external public signal about market conditions that will arrive at a future date. As alluded to earlier, while the timing of firm’s information is uncorrelated with market conditions, we assume the value of the firm is correlated with this market news. Therefore, the public news announcement will affect the market value of the firm.

Our goal is to understand whether these interactions can lead to clustering in the *release* of information by firms even when the arrival of the underlying information is not clustered. To this end, we characterize the equilibrium conditions of this dynamic disclosure game and consider the resulting information release patterns. In Subsections I.C and III.A we prove a negative, benchmark result. We show that if the firm is unable to preempt the external news by releasing its own information *ex ante*, then the external news has no effect on the firm’s *ex-post* rate of disclosure. Thus, absent preemption there is no relation between the news announcement and the timing of disclosures.

One simple intuition for information clustering is the following: if the news about market conditions is bad, this will cause the market value of the firm to fall. This drop in value provides an incentive to release information if it is not as bad as the market now expects. That is, the release of negative external information lowers the threshold for disclosure, as the *relative* interpretation of the firm's news will become more favorable. However, the irrelevance results of Subsections I.C and III.A demonstrate that this simple intuition is not sufficient for the clustering of disclosures. This is because while negative news about market conditions does indeed lower the threshold for which the firm will disclose, it also lowers the posterior distribution of the firm's type. We show that generally, and somewhat remarkably, these effects perfectly cancel out and there is no clustering; that is, the probability that the firm will disclose is independent of the level of the public news about the economy.²

We begin our analysis in section I where we introduce a static framework which is the basis of our analysis. While our main contribution lies in the dynamic extension of the model, we provide a new characterization of the static equilibrium which is of independent interest. It is also useful in characterizing the equilibrium in a dynamic model.

In Section II we introduce a simple dynamic model and assume that the probability that the firm is informed is fixed. The manager is either informed at $t=0$ or not at all. This makes the model equivalent to a two period model but still enables us to demonstrate the main result. In contrast to the prior setting, we now allow the firm to release its information before the external news is announced. In the resulting dynamic disclosure game, because disclosure is irreversible, the firm faces a real options problem with regard to its disclosure decision: disclosing positive information may raise the stock price immediately, but gives up the option that the external public news would have had an even more positive impact on the stock price if the firm had not yet disclosed. In this case, we find that external market news can lead to an endogenous acceleration or deceleration in the rate of disclosure. In particular, in the main result of the paper -- we show that the release of negative information about the market accelerates the release of information by the firm. In this simple setup we find that negative public news triggers an immediate disclosure.

In Section III we consider a more realistic framework and assume that the firm learns its information at a random time so that the probability it is informed increases over time. We find that there will be an “information blackout” period prior to the news, when firms refrain from voluntary disclosures. When we consider the clustering effect which is the focus of our paper we find a stronger effect. The triggering of immediate disclosure following negative news is more pronounced. Also, in addition to negative public news “triggering” an immediate disclosure, positive public news announcements will slow the rate of disclosure at future dates.

Thus, the possibility of clustering emerges in our setting only if the firm has at least some likelihood of receiving its information prior to the arrival of external information and the opportunity to preempt the release of external information by disclosing its own signal first. The results of Sections II and III show that clustering arises in a dynamic setting due to the endogeneity of the ordering of the disclosure decision. The key is that in such a setting, the distribution of types who have not yet disclosed when the public news about the state of the economy comes out is an endogenous subset of the original support. We show that in this case the threshold effects outweigh the distributional effects of the public news, and clustering emerges. One intuition for this is that when market conditions are negative then it is likely that the firm’s news was also negative and it is more probable that it did not disclose this information beforehand. When market conditions are revealed to be negative the payoff upon non disclosure lowers and hence this firm has now more incentive to disclose.

A. Related Literature

Milgrom (1981) and Grossman (1981) were the first to examine disclosure of verifiable information and showed that if it is common knowledge that he is informed then all types will disclose. Dye (1985) and Jung and Kwon (1988) showed that when it is not common knowledge then there will be only partial disclosure; our model builds on this observation.

Dye and Sridhar (1995) is perhaps the most closely related paper as it considers a model with n firms, each of which may or may not have privately observed a signal. If a firm gets a signal it can disclose it in period 1 or 2. These features of their model are similar to ours. However, they assume that whether firms observe a signal or not is positively correlated, but the signals themselves are independent. This is exactly the dual of our assumption that signals are correlated but their arrival process is independent. As a result, in their model, it is more disclosures in

period 1 that leads to more disclosures in period 2 (since investors believe that non-disclosing firms have adverse information), whereas in our model, it is the nature of disclosure (good news or bad news) that delays or triggers disclosure by other firms. Hence, a key difference is that they assume the information arrival process is itself correlated. In contrast, in our model clustering of disclosures is due *only* to the strategic element and in particular not due to the correlated arrival of information. Another crucial difference between their results and ours is that in our model, clustering is not symmetric in quality of news. Specifically, when information arrival is correlated as in Dye and Sridhar, there is no difference in clustering of good news or bad news; in contrast, when information is correlated but not its arrival as in our model, there is clustering of bad news but not of good news.

I. A Static Model of Disclosure

We begin with a simple static model of disclosure which will form the basis for our dynamic model. The model is based on Dye (1985) and Jung and Kwon (1988), and builds on Grossman (1981) and Milgrom (1981). While our main contribution lies in the dynamic extension of the model, we also provide a new characterization of the static equilibrium which is of independent interest. In particular, we show that when the firm does not disclose information, investors' beliefs about the firm are the "worst possible" beliefs given any disclosure rule. Finally, we consider the impact of ex ante news announcements on disclosure, and establish an irrelevance result regarding the probability of disclosure that will provide an important contrast to our main result in the dynamic setting.

A. The Model

Consider a single firm whose manager may learn some information relevant to the firm's value. Let the manager's signal S be the value of the firm conditional on this new information.³ The manager learns this information with probability $p \in [0,1]$. Once the manager is informed, with probability q both the manager's signal and the fact that the manager is informed are private information. When privately informed, the manager has discretion regarding the release of the information: The manager may either disclose it or conceal it, but if it is disclosed it is verifiable

³ This assumption is essentially without loss of generality and is equivalent to assuming the manager learns information I and the firm's value is V , and then defining $S = E[V | I]$.

and cannot be manipulated.⁴ With probability $1-q$ the manager is “publicly” informed and so does not have discretion over the information’s release; in that case, the manager reports it immediately to the market.⁵ The distribution of the signal S is independent of whether the manager becomes informed or has discretion. For convenience, we assume that S is non-degenerate and continuously distributed on some (possibly unbounded) interval.

The manager’s objective is to maximize the firm’s market value, which is its value conditional on the information available to investors. Because the signal S is the firm’s expected value, if the manager discloses the signal the firm’s market value will simply be S . If the manager does not disclose, the firm’s market value will be based on the information contained in the fact that the manager did not disclose. Naturally, the manager is willing to disclose S if and only if it exceeds the value the firm would have without disclosing, and so the manager will disclose if

$$S \geq E[S \mid \text{nondisclosure}] \quad (1)$$

B. Equilibrium and Worst Case Beliefs

Equation (1) implies that only firms with a signal higher than some threshold x will disclose their information. Consider the case in which it is public knowledge that the manager is informed (i.e., $p = 1$ or $q = 0$), but investors do not know the manager’s information. In that case the manager would not disclose only if $S \leq x$, so that from (1) the equilibrium threshold satisfies

$$x^* = E[S \mid \text{nondisclosure}] = E[S \mid S \leq x^*] \quad (2)$$

This equation has the unique solution that x^* is the minimum of the support of S , and all information is disclosed. This result replicates the standard “unraveling” result – noted, e.g., by Ross (1979), Grossman (1981), Milgrom (1981) and others – that if the market knows for sure that a firm holds some information then in equilibrium the firm will disclose its information.

When $p < 1$ and $q > 0$, however, investors do not know if the manager is informed. In that case the payoff in the event of non-disclosure can be calculated as

⁴ This assumption of “verifiable reports” is common to the literature. See, for example, Shin (2003, 2006).

⁵ This case captures situations in which either (i) the information itself is public, (ii) the fact that the manager has learned the information is public (in which case immediate full disclosure will occur in equilibrium), or (iii) hiding the information would be too costly (perhaps due to legal concerns).

$$\begin{aligned}
E[S \mid \text{nondisclosure}] &= E \left[S \left(\begin{array}{l} \text{manager is} \\ \text{uninformed} \end{array} \right) \text{ or } \left(\begin{array}{l} \text{manager is informed, market} \\ \text{is uninformed, and } S \leq x \end{array} \right) \right] \\
&= \frac{(1-p)E[S] + pq \Pr(S \leq x) E[S \mid S \leq x]}{(1-p) + pq \Pr(S \leq x)}
\end{aligned}$$

Hence, letting $\rho \equiv \frac{pq}{1-p}$ be the relative likelihood that the manager is privately informed versus uninformed, we can write the equilibrium condition for the threshold x^* as

$$x^* = h_S(x^*, \rho) \equiv \frac{E[S] + \rho \Pr(S \leq x^*) E[S \mid S \leq x^*]}{1 + \rho \Pr(S \leq x^*)} \quad (3)$$

Note that the function $h_S(x, \rho)$ is decreasing in ρ , and is non-monotone in x , taking on its maximal value of $E[S]$ as $x \rightarrow \pm\infty$. Because S is continuously distributed, $h_S(x, \rho)$ is also differentiable.

Equation (3) expresses the equilibrium threshold as a fixed point of the function h . While the precise solution to (3) will depend on the distribution of S , we have the following useful characterization, which generalizes the intuition that in the absence of disclosure, investors will adopt the “worst case beliefs”:⁶

PROPOSITION 1. Equation (3) has a unique solution x^* which is the equilibrium disclosure threshold. This threshold is decreasing with ρ and satisfies

$$x^* = \min_x h_S(x, \rho) \quad (4)$$

The value of the firm in the event of non-disclosure is also equal to x , and this value is the lowest possible given any disclosure policy (threshold or not).

Equation (4) can be interpreted as generalization of the intuition from the standard full-disclosure equilibrium in (2): Investors interpret non-disclosure as pessimistically as possible, so that the equilibrium threshold is the one that leads to the lowest value for the firm in the event of non-disclosure. Not surprisingly, because h declines with ρ , the threshold for disclosure

⁶ See appendix for all proofs not in the text.

decreases with the likelihood that the manager is privately informed. Thus, conditional on the manager being privately informed, the probability of disclosure $\Pr(S > x^*)$ increases.

C. Ex Ante News: An Irrelevance Result

Suppose that prior to the firm's opportunity to disclose its information, investors and the manager observe public information that is correlated with the firm's value. This information may be from a public news source, or correspond to a disclosure of private information by another firm in the industry. We next consider the impact of such ex ante news on the likelihood of disclosure by the firm.

To capture this correlation between the news and the firm's signal, we denote the news announcement by the random variable Y , and suppose the firm's signal S and the news Y are jointly normally distributed with a positive correlation.⁷ Thus, without loss of generality we can write S as follows:

$$S = a + \beta Y + \varepsilon \tag{5}$$

where Y and ε are independent and normally distributed, $\beta > 0$, and ε has mean zero. The news announcement Y determines the conditional mean, and reduces the conditional variance, of investors' beliefs regarding the firm's value prior to any disclosure. How will this news affect the manager's disclosure decision?

First, the news announcement will have an immediate impact on the firm's stock price as investors revise their expectations. Because the manager will only disclose S in order to raise the stock price, holding fixed the manager's signal S , negative news will make it more likely that the manager will disclose this information. In other words, the equilibrium disclosure threshold will move with the quality of the news.

However, while the impact of the news on the disclosure threshold affects the probability of disclosure of a given type S , the distribution of the manager's type is also affected by the news. Specifically, the worse the news, the lower the likelihood that the manager's information S will

⁷ As long as the correlation is non-zero, making it positive is without loss of generality as we can always redefine the news. For simplicity, we assume that firm's signal S is a sufficient statistic for the firm's value (and the manager's payoff) given the news Y . For a more general setting in which Y may also have an effect on the manager's payoff, see Subsection IV.B

exceed a given threshold. Indeed, as the following result demonstrates, this second effect completely offsets the first so that despite the change in the disclosure threshold, the probability of disclosure is independent of the news Y .

PROPOSITION 2. Given the ex ante news announcement Y , the equilibrium disclosure threshold for the firm is given by

$$x^*(Y) = a + \beta Y + \sigma_\varepsilon z^* \quad (6)$$

where $z^* < 0$ is the disclosure threshold that solves (4) given a standard normal signal. The probability that the firm discloses is independent of the news Y and is identical to the firm's disclosure probability if the news Y were not revealed.

Proof of PROPOSITION 2: The equilibrium condition becomes

$$x^*(Y) = h_{S|Y}(x^*(Y), \rho) \quad (7)$$

where “ $S|Y$ ” denotes that the expectations in (3) are with respect to the conditional distribution of S . Because S is conditionally normally distributed given Y , we can write $S = \mu(Y) + \sigma(Y) Z$, where Z is standard normal. Then, using **PROPOSITION 1** and the fact that the function h is a conditional expectation and thus a linear operator, the equilibrium threshold $x^* = h_{S|Y}(x^*, \rho) = \min_z h_{S|Y}(\mu + \sigma z, \rho) = \mu + \sigma \min_z h_Z(z, \rho) = \mu + \sigma z^*$, which implies (6). Moreover, the probability S exceeds the threshold is $\Pr(S > x^*) = \Pr(\mu + \sigma Z > \mu + \sigma z^*) = \Pr(Z > z^*)$, which is independent of the conditional mean and volatility of the signal. \(\text{qed}\)

Thus, **PROPOSITION 2** implies that ex ante news announcements should have no impact on disclosure rates. Voluntary disclosures should be observed with a similar frequency after good or bad public news. As we will show in the next section, this symmetry will no longer hold in a setting in which firms have the opportunity to disclose both before and after the public news is revealed.

Remark. While **PROPOSITION 2** is for a setting with joint normality, the proof shows that the realization of Y will have no effect on the disclosure rate as long as the posterior distribution of S can be expressed as $S = \mu(Y) + \sigma(Y) \varepsilon$, where the distribution of ε is arbitrary. Thus, for example, S can be conditionally log-normal, or conditionally uniform, with an arbitrary distribution for Y .

II. Dynamic Disclosure: Delay and Downward Clustering

We now consider a simple dynamic version of the disclosure game, in which the manager has the opportunity to disclose his information either before or after the external news is revealed. By giving the manager discretion over the timing of the disclosure, two effects emerge. First, a manager with a sufficiently high signal will choose to preempt the news announcement and disclose immediately. However, a manager with a more intermediate signal may choose to delay disclosure, and wait to see if good external news will raise the stock price above his signal. If the external news is poor, however, the manager will then disclose his information immediately after the news announcement. Thus, relative to the static model, disclosures are delayed prior to the news, and disclosures tend to cluster just after negative news announcements.

A. Basic Dynamic Model

As before, the manager learns the firm's value S at date 0 with probability p , and with probability q the manager has discretion regarding whether to disclose his information to the market. Now, the manager can disclose his information at any time $t \in [0, T]$, after which the value becomes public information. At an interim date $t_1 \in (0, T)$, the news Y is announced.⁸

Let I_t be the information that is public at time t . Then, given risk neutral investors and normalizing the interest rate to zero, the market value of the firm on date t is given by $\hat{s}_t = E[S | I_t]$. We assume the manager's payoff is increasing in the market value of the firm at any moment in time. The exact form of this payoff will not affect the qualitative results, and for simplicity we represent the payoff to the manager of the firm as

$$\int_{t=0}^T \lambda(t) u(\hat{s}_t) dt \quad (8)$$

where u is increasing and the weights $\lambda(t) \in (0, \bar{\lambda})$ may reflect, e.g., discounting or fluctuations in the sensitivity of the manager's wage to the share price.

⁸ For simplicity we assume in this section that the manager learns his information at date 0 if at all, and the timing of the news announcement is known. We consider the case in which the manager may learn his information and the news may arrive at any time in Section XXX.

B. Ex-Post Disclosure and Clustering

Given our timing assumptions, information is only learned at date 0 and at the time of the news announcement. Thus, in equilibrium disclosure will occur, if at all, at date 0 or t_1 . Let's consider the optimal disclosure policy at date t_1 , once the public news Y is revealed.

Suppose types $S > x_0$ disclose at date 0. As in the static model, at date t_1 a manager who has not yet disclosed will choose to do so only if his signal exceeds the firm's share price absent disclosure. Let $x_1(Y)$ be the disclosure threshold at date t_1 given Y . Then

$$x_1(Y) = E[S \mid \text{nondisclosure}, Y] = h_{s|Y}(\min(x_0, x_1(Y)), \rho) \quad (9)$$

Note that in (9), we calculate the expected value of the firm given nondisclosure by recognizing that an informed manager with type $S > \min(x_0, x_1(Y))$ would have disclosed, either initially or after the news. As long as $x_1(Y) \leq x_0$, condition (9) is the same fixed point condition as in the static model (see (7)), and thus the characterization in **PROPOSITION 2** applies. But if $x_1(Y) > x_0$, then a manager with type $S \in [x_0, x_1(Y))$ will have disclosed his type initially but will regret that decision once the public news is revealed. Because the static equilibrium minimizes the firm's nondisclosure share price (**PROPOSITION 1**), this "excessive" disclosure relative to the static case will raise the firm's nondisclosure share price relative to the static equilibrium. Thus, if we define y_0 such that

$$x_0 \equiv a + \beta y_0 + \sigma_\varepsilon z^* = x^*(y_0), \quad (10)$$

then we have the following characterization of the post-news disclosure threshold:

PROPOSITION 3. Suppose the date 0 disclosure threshold x_0 is given by (10). Then the optimal disclosure threshold at date t_1 once the news Y is revealed is given by

$$x_1(Y) = x^*(Y) + k\left([Y - y_0]^+\right) \quad (11)$$

where k is continuous and strictly increasing with $k(0) = 0$.

Proof: Suppose $Y \leq y_0$. Then $x_1(Y) = a + \beta Y + \sigma_\varepsilon z^* \leq x_0$, and so (9) holds. For $Y > y_0$,

$$\begin{aligned}
x_1(Y) &= h_{S|Y}(x_0, \rho) \\
&= a + \beta Y + \sigma_\varepsilon h_Z \left(\frac{x_0 - a - \beta Y}{\sigma_\varepsilon}, \rho \right) \\
&= a + \beta Y + \sigma_\varepsilon z^* + \sigma_\varepsilon \left[h_Z \left(\frac{x_0 - a - \beta Y}{\sigma_\varepsilon}, \rho \right) - h_Z(z^*, \rho) \right] \\
&= a + \beta Y + \sigma_\varepsilon z^* + \sigma_\varepsilon \left[h_Z(z^* - \beta \sigma_\varepsilon^{-1}(Y - y_0), \rho) - h_Z(z^*, \rho) \right] \\
&\equiv a + \beta Y + \sigma_\varepsilon z^* + k(Y - y_0)
\end{aligned}$$

Because z^* is a unique local minimum of h_Z , k is positive and strictly increasing in Y . \qed

Note that firms who have not disclosed at date 0 will choose to once Y is revealed at date t_1 only if the ex-post threshold is sufficiently low so that $x_1(Y) < x_0$, or equivalently $Y < y_0$. Thus, we have the result that disclosures are likely to cluster immediately following negative news announcements, as summarized in the corollary to **PROPOSITION 3** below:

THEOREM I. When the manager learns the private information at date 0 (if at all), then the manager will either disclose the information immediately at date 0, or just after the news announcement at date 1. A post news announcement will only occur if $Y \leq y_0$, with the likelihood of such an announcement higher if the news Y is lower.

C. *Ex-Ante Disclosure and Delay*

Now that we have characterized the optimal disclosure policy for the firm once the news Y has been released at date 1, we consider next the equilibrium level of preemptive disclosure at date 0. In our prior analysis, we used the equilibrium condition that the manager would disclose if the signal S exceeded the firm's market value. In the case of preemptive disclosure, however, a real option problem emerges. If a firm with signal S discloses at date 0, then the market value of the firm will equal S from that point onward. If it does not disclose at date 0, there is a chance that the news Y will be sufficiently positive that its market value will exceed S for some time if it delays disclosure. Disclosing at date 0 forfeits this option. Thus, the firm will not disclose at date 0 unless its immediate gain from disclosing exceeds that value of this option.

If the manager discloses if and only if the signal S exceeds a threshold x_0 , then from the analysis in Section I the firm's market value is given by $h_S(x_0, \rho)$. In that case, the immediate

gain from disclosing at date 0 given signal S is $u(S) - u(h_S(x_0, \rho))$. Because the market value of a non-disclosing firm on date $t \geq 1$ is $x_1(Y)$, the potential gain from not disclosing at date t is $(u(x_1(Y)) - u(S))^+$. Then, from (8), a firm with signal S prefers to disclose if

$$\int_0^1 \lambda(t) [u(S) - u(h_S(x_0, \rho))] dt > E \left[\int_1^\infty \lambda(t) [u(x_1(Y)) - u(S)]^+ dt \mid S \right] \quad (12)$$

If we let $\alpha \equiv \int_1^\infty \lambda(t) dt / \int_0^1 \lambda(t) dt$, then the equilibrium disclosure threshold satisfies⁹

$$u(x_0) = u(h_S(x_0, \rho)) + \alpha E \left[(u(x_1(Y)) - u(S))^+ \mid S = x_0 \right] \quad (13)$$

The real option component thus implies the following result for the firm's ex-ante disclosure policy:

PROPOSITION 4. The ex-ante disclosure threshold x_0 exceeds the firm's non-disclosure share price $h_S(x_0, \rho)$, which exceeds the static disclosure threshold absent news x^* . That is,

$$x_0 > h_S(x_0, \rho) > x^*$$

Thus, the ex-post news announcement delays disclosure relative to the setting without news.

Proof: The first inequality follows immediately from (13) and the fact that $\alpha > 0$, u is strictly increasing, and $Pr(x_1(Y) > S) > 0$. The second inequality follows directly from the characterization of x^* in **PROPOSITION 1**. \qed

III. Stochastic Information Arrival

In the basic dynamic model in Section II, the manager learns the signal S at date $t = 0$ or not at all. As a result, disclosures only occurred at date 0 or immediately after sufficiently negative public news. In this section we examine the case where the *date* at which the manager may learn

⁹ **Guaranteeing** the optimal strategy is indeed a threshold strategy requires showing that if (12) holds for S , then it holds for all $S' > S$. In the appendix we provide a weak sufficient condition for this result, but as a practical matter, we can solve for $x(0)$ assuming a threshold exists, and then verify that it is optimal (which is the case for all examples we have considered).

the signal S is itself stochastic, and thus the manager may learn the firm's type at any time. Specifically, we let $p(t)$ denote the cumulative probability that the firm is informed by date t , and assume that $p(t)$ is weakly increasing and converges to 1 (so the manager eventually learns the firm's type). In this case, disclosures can occur at any time. We will show that two new effects that arise when there is an external news announcement: (i) there will be an "information blackout" period prior to the news, when firms refrain from voluntary disclosures; and (ii) in addition to negative public news "triggering" an immediate disclosure, positive public news announcements will slow the rate of disclosure.

A. The No Preemption Benchmark

As a useful benchmark, we begin by examining the case in which the public news announcement occurs at date 0, so there is no possibility for the firm to preempt the news. Recall that in the static model in Section I, we established that in this case the public news has no impact on the probability of disclosure. Here we characterize the equilibrium and extend that result to the dynamic setting when $p(t)$ increases over time.

Recall from the static model in Section I that the disclosure threshold is decreasing in ρ , the relatively likelihood that the manager is privately informed. When $p(t)$ increases over time, the relevant likelihood is given by

$$\rho(t) \equiv \frac{p(t)q}{1-p(t)}. \quad (14)$$

As $\rho(t)$ increases, the fact that the manager has not disclosed is more likely due to the manager's unwillingness to disclose rather than his ignorance. Thus, we would expect investors' valuation of the firm, conditional on nondisclosure, to decline over time. Absent future news, this anticipated price decline implies that there is no option value to waiting to disclose, and the optimal disclosure decision is again the myopic one: The manager will disclose if and when his signal exceeds the share price in the event of nondisclosure. As a result, we have the following natural extension of our prior characterization of the equilibrium disclosure threshold:

PROPOSITION 5. Suppose the public news Y is revealed at date 0 and the probability $p(t)$ that the manager is informed increases over time. Then the decreasing disclosure threshold,

$$x_{np}^*(Y, t) = \min_x h_{S|Y}(x, \rho(t)) \quad (15)$$

is the unique equilibrium of the dynamic disclosure game.

Again, $x_{np}^*(Y, t)$ decreases over time as it becomes clearer that the reason for nondisclosure is that the firm's type is low. In the limit as $p(t)$ approaches one, all types would disclose and $x_{np}^*(Y, t)$ drops to $-\infty$. When the news and the manager's signal are joint normal, following

PROPOSITION 2 we have

$$x_{np}^*(Y, t) = a + \beta Y + \sigma z^*(t) \quad (16)$$

where $z^*(t)$ is the equilibrium threshold at date t when the signal is standard normal. We can similarly characterize the equilibrium when there is no news at all based on the unconditional distribution of S :

$$x_{np}^*(t) = \mu_S + \sigma_S z^*(t) \quad (17)$$

Hence, as before, the firm's disclosure threshold is affected by the prior news announcement. Bad news (i.e., news such that $\beta Y < 0$) will lower the threshold. Thus, *for a given signal S* , the firm will disclose more quickly in the event of bad news. Still, as in Section I, the probability of disclosure is unaffected by Y :

COROLLARY. When the public news is announced at date 0, the probability of disclosure over any time interval is independent of the realization of the news Y , and coincides with the no news case.

B. Dynamic Model with Preemption

We now examine the case where the public news is revealed at date t_1 so a firm can preempt the news by disclosing its signal beforehand. We let $x(t)$ denote the threshold for disclosure for $t < t_1$ before the public news is revealed, and $x(Y, t)$ denote the post-news disclosure threshold for $t > t_1$.

Given the firm's equilibrium disclosure strategy, absent disclosure the firm's market value will be its expected value given that it has not yet disclosed, which we denote in this case by $v(t)$.

Then a firm with signal S will benefit from disclosing at date $\tau < t_1$ rather than wait until after the news announcement only if

$$\int_{\tau}^{t_1} \lambda(t) [u(S) - u(v(t))] dt > E \left[\int_{t_1}^{\infty} \lambda(t) [u(x^*(Y, t)) - u(S)]^+ dt \mid S \right] \quad (18)$$

By the same real option argument as in Section II, the disclosure threshold exceeds the nondisclosure share price, which exceeds the no preemption threshold: $x(t) > v(t) > x_{np}^*(t)$. Now, while the right-hand side of (18) is strictly positive and independent of τ , the left-hand side of (18) tends to 0 as τ approaches 1. Therefore, for any signal, there is a point in time such that the firm would rather wait for the release of the public news before deciding whether to disclose its information. Intuitively, the option value of waiting exceeds the benefit of increasing its stock price for a very short interval of time.

This observation implies that the equilibrium threshold strategy, $x(t)$, prior to the release of public news satisfies $x(t) \rightarrow \infty$ as $t \rightarrow t_1$. We refer to this as an *information blackout*, as it states that voluntary disclosures should be very rare just prior to public news announcements whose timing is known.¹⁰

Turning to the post-news strategy, recall from Section II that the post-news disclosure threshold will coincide with the no preemption case when it is below the pre-news disclosure threshold. We can extend this result to case with stochastic news arrival as follows:

PROPOSITION 6. Let $x_{\min} \equiv \min\{x(t) \mid t < t_1\}$ be the lowest ex-ante disclosure threshold.

Then the equilibrium ex post disclosure threshold can be characterized as follows:

$$x(Y, t) = x_{np}^*(Y, t) + K(Y, t) \quad (19)$$

where $K(Y, t) = 0$ if $x_{np}^*(Y, t) \leq x_{\min}$, and otherwise, $K(Y, t)$ is strictly increasing in Y .

We illustrate **PROPOSITION 6** in Figure 1 below. Note that prior to the news announcement at date t_1 , $x(t)$ exceeds the threshold in the no preemption/no news case due to the real option effect. This effect grows as t_1 becomes near. Once the public news is revealed, the threshold

¹⁰ We note that in this case the equilibrium disclosure threshold is likely to be non-monotonic on $[0, 1]$. For t near 0, the disclosure threshold may fall as $p(t)$ increases, and then rise as t approaches 1 and the option value of delaying dominates.

coincides with the no preemption case when it is below x_{min} . Above x_{min} , the threshold is elevated due to the possibility that firm's below the threshold may have disclosed early.

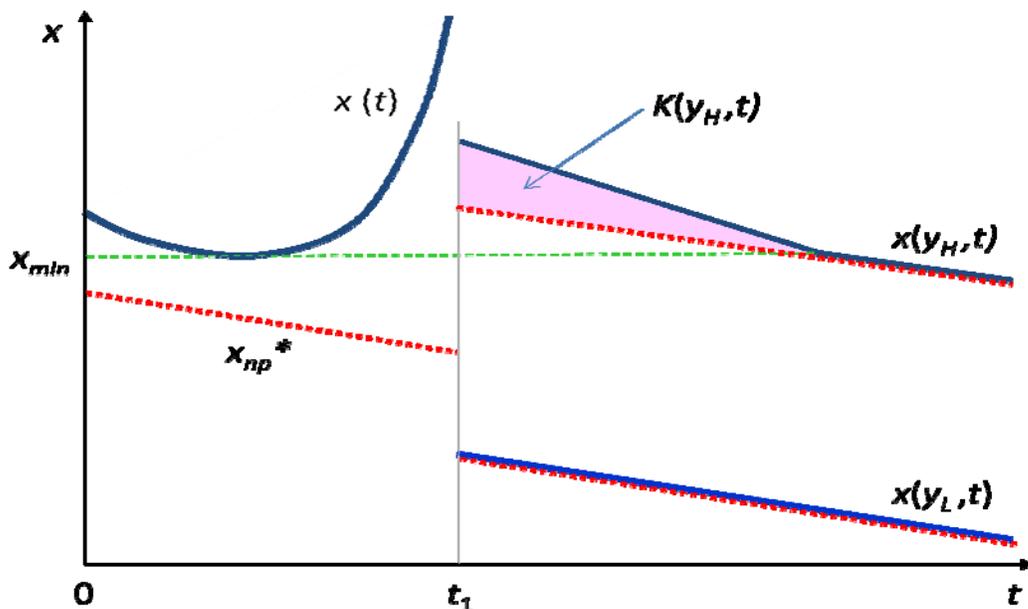


Figure 1: Ex-ante and Ex-post Disclosure Thresholds with Stochastic Information Arrival

Given this characterization of the disclosure threshold, we have the following implications. First, because of the “information blackout” effect, the disclosure threshold will drop once the news is released. Thus we have the following generalization of the clustering effect in Section II:

THEOREM II. There is a positive probability of an immediate disclosure at date t_1 when the public news is released. This probability strictly decreases with the quality of the news Y .

There is a second, new effect which arises in this case. Because $p(t)$ is increasing, there is a positive probability of disclosure after date t_1 . This probability is independent of Y , if $x(Y, t) < x_{min}$. But for Y such that $x(Y, t) > x_{min}$, because $K(Y, t)$ increases with Y , the probability of disclosure decreases with Y . Hence, positive public news will slow the rate of ex-post disclosure:

THEOREM III. For $t > s > t_1$ with $p(t) > p(s)$, there is a positive probability of disclosure in the interval (s, t) , and that probability decreases in Y if $x(Y, s) > x_{min}$.

IV. Additional Extensions

A. Multiple firms

A natural extension is a model with no external signal but with multiple firms. For simplicity suppose there are two symmetric firms: A and B whose signals are given by S^A and S^B . As we shall see the equilibrium is similar to the equilibrium of stochastic news arrival that we have just examined. However, the construction of the equilibrium presents a significant computational challenge.

The key observation is the fact that from firm A's perspective, B's signal is an external signal. Let $\gamma^B(t | S^B)$ denote the equilibrium arrival density of B's disclosure conditional on B's signal, so that the probability that B will disclose in the interval between t and $t + dt$, given that it has not yet disclosed, is $\gamma^B(t | S^B)dt$.

Consider firm A's decision whether to preempt and release its information at time t as compared to the alternative of waiting until $t + dt$. A's decision to disclose is similar to the case of stochastic arrival of an external signal:

$$x^*(t) = u^{-1} \left(u(v(t)) + \lambda(t)^{-1} E \left[\gamma^B(t | S^B) \int_t^\infty \lambda(\tau) \left[u(x^*(S^B, \tau)) - u(S) \right]^+ d\tau \mid S^A = x^*(t) \right] \right)$$

Once the threshold $x^*(t)$ is determined, it will then determine the arrival density of A's announcement, $\gamma^A(t | S^A)$. A symmetric equilibrium then requires the solution of the additional fixed point problem ($\gamma^A = \gamma^B$), which is computationally quite challenging. In such a setting, we conjecture that our qualitative results regarding immediate disclosure would continue to apply and would lead to the clustering of news announcements by firms, with clustering more likely the more negative the news.

B. Alternative Payoffs and Relative Performance

We have assumed so far that the manager's payoff depends only upon the expected value of the firm conditional on the manager's information. To see why this might be the case, suppose the manager is compensated based on some increasing function of his perceived ability α , and let

$S = \alpha + \eta$, where α and η are joint normal. Suppose also that $Y = S + \theta$, where the noise θ is independent of (α, η) . Then the signal S is a sufficient statistic for the manager's ability, and $E[\alpha | S, Y]$, is a linear function of S . Thus, the manager's objective of maximizing utility over his expected compensation is equivalent to maximizing an increasing function of the market value of the firm.

In the previous example the manager's ability affects the firm's absolute performance. A natural alternative to consider is one in which the manager's ability determines the firm's relative performance. We argue that the qualitative conclusions of our model will continue to apply. To see why, consider for example the extreme case in which $S = Y + \alpha$, where Y and α are independent and joint normal.

Suppose first that Y is revealed at $t = 0$ and there is no possibility of preemption. Because $\alpha = S - Y$, we can reinterpret the manager's signal as α and it is immediate that the disclosure threshold $\alpha^*(t)$ and therefore the disclosure rate will not depend on Y . Thus, our results in Subsection I.C carry through as before.

Now suppose that Y is realized at $t = 1$ so that S can be disclosed before Y is revealed. Then the equilibrium will be similar to our analysis in Section II.C. The disclosure threshold $x^*(0)$ at date 0 will reflect a real option premium (i.e., $x^*(0) > v(0)$), as the agent with type $S = v(0)$ would regret disclosing if Y is sufficiently high (specifically, if $S - Y < \alpha^*(1)$). As in our current model, at date $t = 1$ there will be a positive probability of immediate disclosure if the market news Y is sufficiently low (so that $Y + \alpha^*(1) < x^*(0)$). On the other hand, if Y is high, disclosure will be delayed. Thus, all of the qualitative conclusions of our model continue to hold if the agent is compensated based on relative rather than absolute performance.

C. Stochastic News Arrival

Until now we assumed the arrival date of the public news is common knowledge. This is often the case, for example, for government news releases and other forms of aggregate data. A natural question is how our results would change if the timing of the public news is random.

Suppose, for example, the arrival date of the public news has an exponential distribution with arrival rate γ , so that the probability that the news will arrive in the interval between t and $t + dt$, given that it has not yet arrived, is γdt .

Consider a firm's decision whether to preempt the external information and release its information at time t as compared to the alternative of waiting until $t + dt$. The gain from preempting at time t is given by

$$\lambda(t)[u(S) - u(v(t))]dt$$

The potential loss is that the public news is released between t and $t + dt$ and is sufficiently positive that the firm regrets having disclosed its signal. The expected loss is given by:

$$\gamma dt E \left[\int_{t+dt}^{\infty} \lambda(\tau) [u(x^*(Y, \tau)) - u(S)]^+ d\tau \mid S \right]$$

The equilibrium disclosure threshold should therefore satisfy

$$x^*(t) = u^{-1} \left(u(v(t)) + \gamma \lambda(t)^{-1} E \left[\int_t^{\infty} \lambda(\tau) [u(x^*(Y, \tau)) - u(S)]^+ d\tau \mid S = x^*(t) \right] \right)$$

This equation is nearly identical to the equation we obtained in (18). Hence, the equilibrium behavior is essentially the same as in the case we examined. If, for example, the weights λ correspond to standard exponential discounting, then the only change over time comes from the increase in $p(t)$. In that case, the disclosure threshold $x^*(t)$ would gradually decline as $p(t)$ increased prior to the public news release.

V. Implications for Asset Pricing

An important implication of our results is that with strategic timing of disclosures by managers, the process of information arrival to markets is different from the process of information arrival to firms and managers. For instance, the underlying information process may have constant variability over time and no skewness, but this need not be true of the process describing disclosed information. Below, we discuss the specific implications of our dynamic disclosure model for the skewness and volatility of observed stock returns.

Return Skewness. The basic model of strategic delay developed in Section III of the paper implies that individual stock returns will tend to exhibit positive skewness, as firms release good news but delay the disclosure of bad news. The average positive skewness in individual stock returns was documented early by Beedles (1979) and is reproduced for more recent data in Figure 1. Such positive skewness should disappear in our model at the point that $p(t) = 1$, and full disclosure occurs. This pattern is consistent with McNichols (1988), who finds less positive skewness in earnings announcement periods (when disclosures are likely to be involuntary) compared to non-announcement periods (when disclosures are more likely to be strategic).

While this effect of disclosure timing on average positive skewness of individual stock returns has been suggested elsewhere (for example, in Damodaran, 1985), our model with public news in Section II.C implies an important, additional *conditional* pattern. In periods without public news, stock returns will be positively skewed as the firm voluntarily releases good news. When public news is announced, however, returns will be negatively skewed. The reason is that when the public news is good, it is more likely that the firm would have preemptively released good news, mitigating the effect of the news on the stock price. When the public news is bad, however, the firm is less likely to have previously disclosed its information, in which case the stock's return will respond to the public news fully.

Conditional Correlation (Beta). This asymmetry in the response of disclosures to the nature of public news implies that individual stock returns will be more sensitive to aggregate market news when the market news is negative. This implication also finds empirical support. Ang and Chen (2002) document that correlations between U.S. stocks and the aggregate U.S. market are much greater for downside moves, especially for extreme downside moves, than for upside moves, and that these correlations differ from the conditional correlations implied by a normal

distribution. Interestingly, they find that the downside correlation is stronger for small stocks, where managerial ability to strategically time disclosures may be greater due to investor inattention, and for past loser stocks, where there may be greater adverse information that is being delayed for release until market news arrives.

Further, the asymmetry in response to public news and the resulting downside correlation of firm returns helps explain the empirical result that while individual stock returns tend to be positively skewed on average, stock market indices tend to have negatively skewed returns (Alles and Kling, 1994, and also see Figure 1 for recent evidence regarding index returns). The existing literature has found it hard to reconcile the differential nature of skewness in firm-level and market-level stock returns, and in fact, often interpreted the difference as lack of consensus on evidence of skewness. In contrast, this differential pattern of skewness in returns arises naturally in our model.

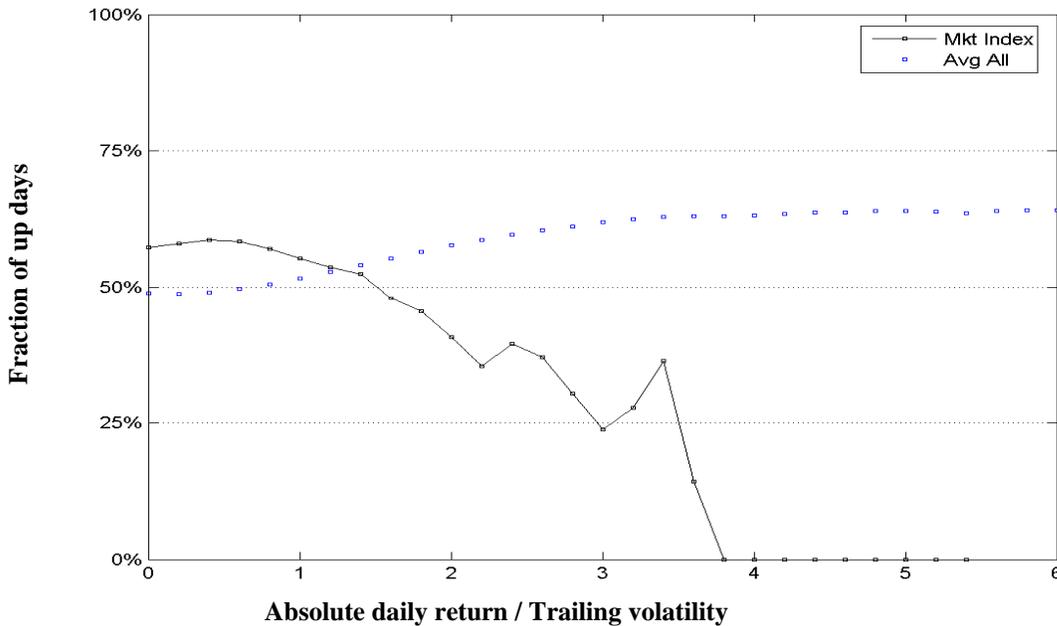


Figure 1: Positive skewness of individual stock returns and negative skewness of index returns

The figure shows the fraction of up (positive stock return) days as a function of absolute stock return divided by the trailing volatility of stock returns (computed as the standard deviation of returns over the prior 100 days). The dotted line shows the fraction of up days for each stock on the New York Stock Exchange over the period 1998-2007 and averaged across all stocks. The solid line plots the fraction calculated for a value-weighted index of stock

returns over the same period. Note that the majority of large moves for individual stocks tend to be positive, whereas large moves in the index tend to be negative.

Volatility and the Leverage Effect. Finally, our result regarding the acceleration of disclosure after bad market news implies that return volatility will increase after negative shocks. This is consistent with the so-called “leverage effect” (Black, 1976) that conditional on negative returns, return volatility is higher. In most striking evidence of this effect, Officer (1973) and Schwert (1989, 1990) document that stock market’s return variability has been unusually high during downturns such as the Great Depression of 1929-33 and the stock market crash of 1987. They contend that the amplitude of the fluctuations in aggregate stock volatility is difficult to explain using simple models of stock valuation, especially during downturns. Furthermore, the feature that stock return volatility is stochastic and negatively correlated with the level of returns, is now considered essential in explaining observed option prices. For example, Heston (1993) shows that a stochastic volatility model where shocks to volatility are negatively correlated to shocks to returns can fit index option prices well in that it can explain the (Black-Scholes model-based) implied volatility “skew” in index option prices.¹¹

Our model provides a potential explanation for these findings since the arrival of adverse public news during market downturns should accelerate the disclosure of information by firms and result in greater volatility. To stress, our model treats the disclosure of information by firms as an endogenous response to market downturns which causes volatility to rise. An alternative explanation of these effects is the “volatility feedback”, formalized by Campbell and Hentschel (1992), which assumes that it is market volatility - rather than the market return - which receives exogenous, permanent shocks, that in turn, cause expected market return to rise, producing a contemporaneous negative return on the market. A differentiating feature of our explanation relative to the volatility feedback channel is that we can *simultaneously* explain the positive skewness of individual stock returns (as explained above) and the negative skewness of market returns. In contrast, the volatility feedback implies negative skewness of market returns and lower negative skewness of individual stock returns: individual stock volatility also

¹¹ Implied volatility “skew” in index option prices is used to describe the pattern that volatility numbers to be put into the Black-Scholes model to fit observed index option prices exhibit a declining relationship with the option strike price. This is now universally considered to be a violation of the Black-Scholes assumption that stock return volatility is constant over time or is deterministic.

consists of idiosyncratic risk which does not command a risk premium, and hence, as Campbell and Hentschel note, is less affected by rise in market volatility.

To summarize, skewness and volatility related patterns observed in stock returns are consistent with the dynamics of disclosures by firms and the incentives of managers who have discretion over disclosure timing. In contrast to the existing literature which has often treated such patterns as a statistical artifact of data, our model provides a common information-theoretic foundation for their existence.¹²

VI. Conclusion

In this paper, we provided a dynamic disclosure model in which the announcement of bad news hastens the disclosure of information by firms, resulting in bunching of disclosures. Since positive correlation of public news and firms' private information is a critical factor driving this result, our model implies that disclosures should be more clustered within industries and geographies, as empirically found by Tse and Tucker (2007) and Kedia and Rajgopal (2007), respectively.

We assumed throughout our analysis that delaying disclosure is costless for firms. In practice, non-disclosure might entail real costs since the firm would have to bypass observable activities warranted by this information, for example, continue to make investment even in response to adverse information about its prospects.¹³ Another possibility is that there may be litigation risk associated with delay in releasing information. Some researchers (Skinner, 1994, Trueman, 1997) have argued that litigation risk can explain why firms voluntarily disclose bad news.¹⁴ Conversely, there might also be strategic benefits to a firm from not disclosing

¹² Shin (2003, 2006), discussed in the related literature section, represent contributions that share this theme. Both papers consider single-firm (one-time) disclosure models with verifiable reports where a manager attempts to maximize the current share price and the markets rationally anticipate manager's disclosure policy. The models generate implications such as the appearance of short-run momentum and long-run reversal in returns and the higher return variance following a poor disclosed outcome. Rogers, Schrand and Verrecchia (2007), cited above, find evidence for some of the implications of Shin's models for firm-level and market-level return and return volatility.

¹³ Rajan (1994) examines coordination and strategic delay in the recognition of bad loans by banks. He assumes that in order to hide bad loans, banks must continue lending or make new loans to the defaulted borrowers, which is costly in real terms. He shows that when bank loan portfolios are correlated, strategic delay in recognition of bad loans can induce a low-frequency cycle in the real sector, characterized by excessive extension of credit in good times.

¹⁴ Such effects are captured to some extent in a reduced-form fashion in our model by the parameter q , which represents the likelihood with which the firm has no discretion over the release of its information.

information when such information has not yet reached its competitors or the market as a whole. Dierker (2002) analyzes a dynamic disclosure model with such considerations. Modeling more explicitly the cost or benefits of non-disclosure within our framework could potentially lead to further empirical predictions. We leave such an extension for future work.

An alternative motive for delayed disclosure that has been proposed is managerial short-termism. While our model of the manager's objective is general enough to include such features, it is interesting to note that in our setting the impact of short-termism is ambiguous. For example, decreasing the weight $\lambda(t)$ that the manager puts on the stock price after the public announcement ($t > 1$) will reduce the real option effect of delay and lead to greater disclosure in period 0.

Finally, we believe our dynamic disclosure game has interesting asset-pricing implications for skewness and volatility of firm-level and market-wide stock returns. Fully establishing the empirical link between strategic timing of disclosures and these features of stock returns appears to be a promising line of enquiry for further work.

Appendix

Proof of **PROPOSITION 1**: First note that $h_S(x, \rho) < E[S]$ for x in the interior of the support of S , and that $h_S(x, \rho) \rightarrow E[S]$ as $x \rightarrow \pm \infty$. Therefore h_S has a minimum in the interior of the support of S . Suppose that x^* satisfies $h_S(x^*, \rho) = x^*$; then x^* represents the average type in a pool of types who were either uninformed, or privately informed with a signal lower than x^* .

Now consider $h_S(x, \rho)$, with $x > x^*$. In this case, relative to the pool of types corresponding to $h_S(x^*, \rho)$, we have to include new types in the pool that are informed and exceed x^* . This must raise the quality of average type above x^* . Thus, $h_S(x, \rho) > h_S(x^*, \rho)$. Next consider $h_S(x, \rho)$, with $x < x^*$. In this case, relative to the pool of types corresponding to $h_S(x^*, \rho)$, we have to exclude types from the pool that are informed but below x^* . Since we are eliminating some types that are lower than the average quality of pool, this must also raise the quality of average type above x^* . Thus again, $h_S(x, \rho) > h_S(x^*, \rho)$. Therefore, the equilibrium threshold $x^* = h_S(x^*, \rho)$ occurs at the unique minimum of the function h_S .

To see that threshold strategies lead to the worst possible beliefs, consider any disclosure strategy Γ (threshold or not) and let $v = E[S \mid \text{nondisclosure given } \Gamma]$. Then given these beliefs, the optimal policy Γ' for the manager is to disclose if $S > v$ and not disclose if $S \leq v$. Unless the two policies coincide almost surely, then under Γ' some above average types are removed from the pool of non-disclosers, and some below average types are added, so that $E[S \mid \text{nondisclosure given } \Gamma'] < v$.

Finally, because h_S decreases with ρ , so does the threshold. \qed

Proof of **PROPOSITION 5**: Because the payoff from non-disclosure does not depend on the firm's true type, it is immediate that the optimal strategy can be expressed as a threshold. Because $p(t)$ is increasing, the optimal threshold in (15) is decreasing with t . As a result, only the current threshold is relevant in determining the firm's market value absent disclosure, which is given by $v_t = h_S(x^*(t), \rho(t))$. Finally, because $v(t)$ also declines with t , it is optimal for the firm to disclose if and only if S exceeds $v(t)$, and so $x^*(t)$ is indeed an equilibrium threshold.

To see that the equilibrium is unique, note that by the same reasoning as in the static case, any equilibrium must involve a threshold strategy (the gain from disclosure is increasing in type). Let $x(t)$ be some other disclosure policy, and let $v(t)$ be the market value of the firm in the event of non-disclosure under this policy. Note first that if $x(t)$ is an equilibrium, and if $t' > t$, then

$$x(t) \geq v(t) \geq x^*(t) \geq x^*(t'). \quad (20)$$

The first inequality follows because the manager would not disclose if it would lower the current share price. The second follows because, from **PROPOSITION 1**, the share price $x^*(t)$ is the lowest possible share price under any beliefs regarding the manager's disclosure policy. Finally, the last follows because $x^*(t)$ is weakly decreasing.

Next we claim that

$$x(t) = v(t) \text{ if and only if } x(t) = x^*(t). \quad (21)$$

To see why, note with this disclosure threshold at date t , because $x(t) = x^*(t) < x(s)$ for all $s < t$ from (20), the set of non-disclosing firms is precisely the same as the set that is privately informed with $S < x^*(t)$, and thus $x^*(t) = h(x^*(t), \rho(t)) = v(t)$. The “only if” follows because, as in the static case, this fixed point is unique (lowering the threshold from any fixed point must raise the share price).

Finally, note that if $x(t) > v(t)$, it must be that $v(t^*) = \sup\{v(t') : t' > t\} > x(t)$ (it pays to delay disclosure only if a higher price can be obtained in the future from not disclosing). But then because $x(t^*) = v(t^*)$ (there is no reason to delay at t^*), we have from (20) and (21) that $v(t^*) = x^*(t^*) \leq x(t)$, a contradiction.

\qed

Proof that a threshold strategy is optimal prior to news announcement (Subsection II.C):

Here we provide a justification for a threshold strategy prior to the public news announcement. To simplify the analysis, here we assume that the manager's payoff function u is linear. Given this assumption, it is sufficient to analyze the case $u(v) = v$.

Consider the condition(12). We need to show that if this condition holds for some type S , it holds for all higher types. Now, the left hand side of (12) clearly increases with S . Thus, it is enough to show that the right hand side of (12) weakly decreases with S . Without loss of generality normalize S so that $a = 0$ and note that we can write $Y = \frac{\beta}{\beta^2 + \sigma^2} S + \eta$ where S and

$\eta \sim N\left(0, \frac{\sigma^2}{\beta^2 + \sigma^2}\right)$ are independent. Therefore,

$$\begin{aligned} x^*(Y, t) - S &= \beta Y + \sigma z^*(t) + k(Y, t) - S \\ &= \eta + \sigma z^*(t) + k\left(\frac{\beta}{\beta^2 + \sigma^2} S + \eta, t\right) - \frac{\sigma^2}{\beta^2 + \sigma^2} S \end{aligned}$$

and so the result follows if

$$\frac{\beta}{\beta^2 + \sigma^2} k'(Y, t) - \frac{\sigma^2}{\beta^2 + \sigma^2} \leq 0 \quad \text{or equivalently} \quad k'(Y, t) \leq \frac{\sigma^2}{\beta} \quad (22)$$

This condition obviously holds if $Y \leq y_0(t)$, since then $k' = 0$. Consider the case $Y = y > y_0(t)$ and therefore $x^*(y, t) > x_0^*$. Using the expression for k in

Error! Reference source not found., we can write (22) as

$$\frac{\partial}{\partial x_0} h^*(x_0^*, y) \geq -\frac{\sigma^2}{\beta^2} \quad (23)$$

Now, from **Error! Reference source not found.**,

$$\frac{\partial}{\partial x_0} h^*(x_0^*, y) = \frac{\partial}{\partial x_0} h(x^*(y, t), x_0^*, y) = \frac{\rho_0 n \left(\frac{x_0^* - \beta y}{\sigma}\right) \left(\frac{x_0^* - h(x^*(y, t), x_0^*, y)}{\sigma}\right)}{1 + \rho_0 N\left(\frac{x_0^* - \beta y}{\sigma}\right) + \rho_t N\left(\frac{x^*(y, t) - \beta y}{\sigma}\right)} \quad (24)$$

Because $x_0^* < h(x^*(y, t), x_0^*, y) = x^*(y, t)$, and because h decreases with ρ_t , the magnitude of (24) decreases with ρ_t . Thus, it is sufficient to establish (23) for the case $\rho_t = 0$. Also, because

with $\rho_t = 0$, $h(x^*(y, t), x_0^*, y) = \beta y + \sigma h_e\left(\frac{x_0^* - \beta y}{\sigma}, \rho_0\right)$, we can substitute $z = \frac{x_0^* - \beta y}{\sigma}$ in (24) and

so a sufficient condition for (24) is

$$\frac{\rho_0 n(z)(z - h_\varepsilon(z, \rho_0))}{1 + \rho_0 N(z)} = \frac{\partial}{\partial z} h_\varepsilon(z, \rho_0) \geq -\frac{\sigma^2}{\beta^2} \text{ for all } z. \quad (25)$$

Because $h_\varepsilon < 0$,

$$\frac{\rho_0 n(z)(z - h_\varepsilon(z, \rho_0))}{1 + \rho_0 N(z)} > -\rho_0 |n(z)z| \geq -\rho_0 n(1) > -\frac{\rho_0}{4} \quad (26)$$

a very weak sufficient condition for a threshold strategy to be optimal is that $\sigma > \frac{1}{2}\beta\sqrt{\rho_0}$.

This condition is extremely weak, in part because we have required monotonicity of the right hand side of (12) state-by-state, rather than in expectation. Indeed, in the extreme alternative case $\sigma = 0$, it is easy to see that a threshold strategy is optimal: Y is then a perfect signal of S , and the option value of waiting disappears. \qed

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