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Disclosure to a Credulous Audience: The Role of Limited Attention

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1 Introduction

In the classic models of voluntary disclosure of verifiable information, observers exhibit *extreme skepticism* about those who do not reveal what they know (see Grossman (1981) and Milgrom (1981)). This skepticism is the rational response of observers to the incentive of a party with adverse information to withhold it. In practice, observers do tend to be skeptical of those who fail to disclose. However, the further implication of these models that there will be full disclosure is in practice often violated, as evidenced by the fact that on occasion firms collapse when concealed adverse information comes to light.

Several extensions to the basic theory allow for the withholding of information.[1] Disclosure costs provide an innocent reason for non-disclosure, i.e., a reason other than the possession of an adverse signal. So disclosure costs make observers somewhat less skeptical of non-disclosure. Thus, an informed player with a sufficiently favorable signal discloses, whereas if his signal is below some cutoff he withholds it (see Jovanovic (1982), Verrecchia (1983)). However, in these models full disclosure is still approached as disclosure costs becomes small.[2]

In this paper, incomplete skepticism derives from the limited attention and cognitive processing power of observers. Limited attention sometimes causes observers to ignore useful signals. It can also cause observers to fail to take into account the implications of an absence of a signal— that an informed player has deliberately withheld relevant information. This lack of skepticism weakens the pressure on informed players to disclose. As a result, even when there are no exogenous costs of disclosure and the disclosing player surely is informed, in equilibrium disclosure is incomplete. On the other hand, a lack of attention to disclosed signals can encourage *greater* disclosure, by reducing the reputational penalty to low types of disclosing.

Our assumption of limited attention is intended to capture two stylized facts. First is the obvious fact that human information processing power is limited, which follows from the physical and design constraints of the human brain. A large literature in

[1]These include the models of Jovanovic (1982), Verrecchia (1983), Fishman and Hagerty (1989), Darrough and Stoughton (1990), and Teoh and Hwang (1991).

[2]Alternatively, Fishman and Hagerty (2003) examine a setting in which informed firms set prices and decide whether or not to disclose a signal about the quality of its product, and a subset of customers possess information complementary to the disclosed signal. This leads to differential updating by customers based upon the disclosed signal, and the possibility that in equilibrium firms do not disclose.

psychology studies limited attention, as discussed in Section 2. The second is that people often do not seem to be as skeptical of the motives of interested parties as rationality would seem to require. We will argue that such credulity is a natural consequence of limited attention. For examples and market evidence bearing upon limited attention and credulity, see Appendix A.

When cognitive resources are limited, an individual may fail to update adversely based upon observable events, and especially based upon non-events, such as the failure of an informed party to disclose. Drawing a correct inference from non-disclosure requires both focusing attention on this non-event, and paying enough attention to the disclosure game to reason out its strategic implications. An individual who does not direct his attention in this fashion may fail to update his prior belief at all.

In this paper we consider the equilibrium behavior of an informed player or players when the audience they face is subject to limited attention. We begin with a basic model with a single arena of possible information disclosure. The informed player understands that exogenous fractions of his audience ignore disclosed signals, a phenomenon we call *cue neglect*; and ignore the implications of non-disclosure, which we call *analytical failure*. As a result of analytical failure, in equilibrium there is a pool of non-disclosing types even though the cost of disclosure is zero. Perhap more surprisingly, cue neglect *encourages* disclosure, because the marginal type takes less of a reputational hit from disclosing.

The overall outcome is intuitive: owing to limited attention, in equilibrium there is only partial disclosure, and on average there is also excessive optimism about the quality of the informed player. However, the analysis shows that this finding does not derive from the raw fact of limited attention, but from a tendency for observers to attend more fully to disclosed signals than to a failure to disclose. We further explore the effects of government imposed disclosure regulation, and of variation in observer attention, on the precision and bias in observer perceptions.

Furthermore, we extend the basic model to a setting in which individuals can choose up front how carefully to attend to disclosed signals or toward the failure to disclose in an arena. We find that the main insights and specific results of the basic setting extend to a setting with endogenous allocation of attention.

We also examine a setting with two arenas of disclosure in which different informed players can compete for the attention (or to avoid the attention) of observers. This leads to effects which we call *cue competition*, and *analytical interference*. Cue competition is the tendency for observation of a disclosure in one arena to distract observers' attention from disclosure in the other arena. For example, the announcement of an acquisition may distract investors from the fact that a firm has just missed an earnings forecast.

Analytical interference is the tendency for disclosure in one arena to distract observers from taking into account appropriately the information implicit in the fact of non-disclosure in the other arena. For example, the announcement of large earnings surprises by firms in one industry may distract investor attention from a delay in the issuance of an earnings forecast by a firm in another industry.

We examine the implications of these effects for several further issues. First is whether regulation requiring disclosure in one arena causes the informed player in the other arena to disclose less frequently ('crowding out'). Second is whether requiring full disclosure in both arenas increases the accuracy of perceptions, and social welfare. Third is whether there is an optimal level of required disclosure that exceeds what informed players would voluntarily provide but which falls short of full disclosure. Fourth is the cross-arena contagion of news announcements on observer perceptions (or market prices) in other arenas. Last is the effect of disclosure regulation on observer welfare in different arenas.

Although our application of limited attention in this paper is to the theory of optimal disclosure, the simple modelling approach we provide is readily applicable to other problems in information economics. We describe some suggested further directions in which the approach can be taken in the concluding section of the paper.

Previous work on limited attention and economic decisions has focused mainly on the imperfect rationality of managers or other organizational decisionmakers (see, e.g., the early discussion of March and Simon (1958)). As Simon (1976) stated: "...the scarce resource is not information; it is processing capacity to attend to information." Several papers have analyzed the allocation of managerial attention across activities.[3] Our approach differs in focusing on a general audience of observers. In addition, we describe how to interpret our model assumptions in the context of a security market setting. Thus, our approach lends itself to the study of how limited attention affects the pricing of assets.

In concurrent work, Hirshleifer and Teoh (2002) examine the consequences of limited investor attention for financial reporting. Their analysis takes as given that all relevant information is publicly available (either through disclosure or spontaneously). They focus on the effects of additionally reporting information as part of earnings in a firm's financial statements. In contrast, our analysis focuses on the decision to disclose information which otherwise will not be publicly available.

[3] See Radner (1975), Radner and Rothschild (1975), Gifford (1992), and Gifford and Wilson (1995).

Perhaps the most closely related paper to this one is that of Milgrom and Roberts (1986). They show that the extreme skepticism results of past literature extend to a setting in which the informed player can disclose a set to which his signal belongs (rather than the precise value of the signal). If observers are rational, there is still full disclosure. However, if there are unsophisticated observers who are insufficiently skeptical, disclosure can be incomplete. Their paper also analyzes the conditions under which competition among self-interested informed parties in providing information can lead to accurate decisions (an issue we do not address).

A key difference in our approach from that of Milgrom and Roberts is that we analyze a specific source of unsophisticated behavior, limited attention. Thus, we model both incomplete skepticism about nondisclosure, and failure to incorporate disclosed signals.[4] A further difference in approach that derives from our focus on limited attention is that we analyze the carryover of disclosure between different informational arenas (as with the 'crowding out' effect), and how regulation in one arena affects disclosure, beliefs, and welfare in another. Thus, a distinctive aspect of our approach is our analysis of exclusionary effects wherein a salient disclosure attracts attention away from another disclosure; and of interference between attention to a disclosed signal in one arena and attention to the implications of a failure to disclose in another.

Some readers may question whether limited attention affects market prices. What is hard to contest is that both the public comments of policymakers and actual regulations reflect concerns about protecting investors with limited attention and processing power. For example, there are rules specifying not just that certain information items be revealed in a firm's financial statement, but *where* on the financial statement these items must be placed (as with rules on the reporting of comprehensive income; see Hirst and Hopkins (1998)). Furthermore, a bitter fight between regulators (including former SEC chair Arthur Levitt) and firms has concerned whether employee stock option compensation needs to be merely disclosed in a footnote, or should be integrated as part of reporting earnings (see, e.g., Mayer (2002)). Thus, at a minimum it seems useful to assess rigorously the implications of a view that forms part of the basis for existing policy.

The remainder of the paper is structured as follows. Section 2 discusses the psychology of limited attention and salience. Section 3 describes the basic setting with a

[4]The latter effect influences the nature of our results. Where in Milgrom and Roberts full disclosure in their basic model requires that the observer be smart enough to draw extreme skeptical inferences, in our setting there is full disclosure even when some observers are credulous, if inattention to disclosed signals is sufficiently strong.

single arena of disclosure. Section 4 describes equilibrium in the basic model. Section 5 analyzes a setting where observers attend to one of two arenas of information disclosure. Section 6 examines the effects of regulation on disclosure, beliefs, and welfare. Section 7 extends the basic setting to allow for an endogenous decision by observers of how much to attend to disclosed signals or to the fact of non-disclosure in an arena. Section 8 concludes.

2 Psychological Findings on Limited Attention

Limited attention is a necessary consequence of the vast amount of information available in the environment, and of limits to information processing power. In the face of cognitive constraints, attention must be selective and requires effort (substitution of cognitive resources from other tasks); see, e.g., Kahneman (1973). Several well-known decision biases are probably closely related to limits to attention, such as the phenomenon of narrow framing (as reviewed in Read, Loewenstein, and Rabin (1999)), which involves analyzing problems in too isolated a fashion.

Attention is required both for the *encoding* of environmental stimuli (such as a corporate information disclosure), and the *processing* of ideas in conscious thought (as in the analysis of a corporate disclosure or of a failure of a company to disclose). As discussed in Fiske (1995), the encoding process involves taking external information and representing it internally in a way that enables its use. Conscious thought involves a focus on particular ideas or memories to the exclusion of others. For example, if an individual is focused on understanding the implications of a disclosure by one firm, his ability to study another firm may be reduced.

Some stimuli tend to be perceived and encoded more easily or retrievably than others. The *salience* of a stimulus is its 'prominence,' tendency to 'stand out', or its degree of contrast with other stimuli in the environment. For example, an unusually large earnings surprise is highly salient for investors. The effects of salience are "robust and wide-ranging" (Fiske and Taylor (1991), ch.7), with influence on judgments about causality, importance of the stimulus, and how extreme it is. We reflect salience in our model as influencing the probability that a signal will be attended to, and the probability that an individual will analyze correctly the implications of a failure to disclose.

Reasonably enough, a stimulus is also more salient if it is goal-related; e.g., an individual in a group becomes more salient if you learn that she is to be your new boss. However, attention to stimuli can be misdirected in many ways, and this affects judgments. Seemingly trivial manipulations of salience have important effects on judgments (see, e.g., Taylor and Fiske (1978) Sect. IV). Attention is also drawn to vivid stimuli.[5] In contrast, people tend to underweight abstract, statistical, and base-rate information (see, e.g., Kahneman and Tversky (1973) and Nisbett and Ross (1980)). In view of these findings, in our model we do not assume that the amount of attention that observers direct toward a signal corresponds perfectly with its economic importance.

How attention is directed in conscious thought depends on the ease with which memories are accessed– what Tversky and Kahneman (1973) refer to as *availability*. For example, a disclosure by a firm that receives heavy play in the news media may, through emphasis and repetition, be more retrievable than a story that receives only a mention. In the availability heuristic individuals assess the frequency or likelihood of a phenomenon according to their ability to retrieve confirmatory examples from memory. To the extent that some ideas or facts contain hooks that make them more 'available' than others, attentional biases therefore induce biased beliefs.

These considerations suggest that in a corporate setting, disclosures by firms that are in the news a lot (larger firms or firms in 'fashionable' sectors), or are 'proximate' and affect-linked for observers who consume the firms' products (such as entertainment, sports, or automobile firms) may be particularly salient. Based on vividness, we would also expect more attention to simple disclosures than to those that are hard to process.

A literature in psychology has examined how subjects learn by observation over time to predict a variable that is stochastically related to multiple cues (see, e.g., Kruschke and Johansen (1999)). A pervasive finding is that animals and people do not achieve correct understanding of the correlation structure. Instead, *cue competition* occurs: salient cues weaken the effects of less salient ones, and the presence of irrelevant cues causes subjects to use relevant cues and base rates (unconditional frequencies) less. The presence of multiple cues also causes people to make analytical errors, such as 'learning' over time to use irrelevant cues.

3 The Economic Setting of the Basic Model

The Informed Player

The informed player observes a signal θ on the interval $[\underline{\theta}, \overline{\theta}]$. He decides either

[5]Vividness is greatest for concrete descriptions and scenarios, personal stories about individual experiences, information that falls into an easily summarized pattern, stimuli that trigger emotional responses, or which are more 'proximate in a sensory, temporal or spatial way' (Nisbett and Ross (1980), p. 45).

to disclose or withhold his signal; if he discloses he must be truthful. We follow the convention that a player who is indifferent always discloses.

Uninformed Observers

There is a continuum of uninformed observers. Limited attention has two effects. First, fraction $\alpha^W \in [0,1]$ of the observers are rationally skeptical about the motives of a non-disclosing (**W**ithholding) informed player, with the remaining fraction $1-\alpha^W$ inattentive (analytical failure). An individual who is inattentive in this fashion does not update his beliefs. This may occur because he simply does no cognitive processing. Alternatively, he may note the fact that information was withheld, but fail to take the further cognitive step of attributing this withholding to the strategic incentives of the informed party–credulous behavior. Under either interpretation, the inattentive observer's belief remains at his prior.

We do not by any means wish to imply that accounting for the possibility of strategic behavior by an informed party is a profoundly difficult conceptual leap for most people. When attending carefully, most people are adept in recognizing such possibilities. However, even intelligent people will sometimes neglect fairly obvious points in any given arena of action. Time and cognitive resources are limited and the universe of possible signals and considerations to attend to is large.[6]

The second effect of limited attention in the model is that a fraction $\alpha^D \in [0,1]$ attend to information that is disclosed; the remaining fraction $1-\alpha^D$ of observers fail to attend to the disclosure (cue neglect). We assume that $\alpha^D \geq \alpha^W$, based on the notion that disclosure is salient, and therefore calls attention to itself more strongly than a failure to disclose. This is consistent with psychological evidence that people tend to be more influenced by the information reflected in the occurrence of an event than the non-occurrence (see, e.g., Newman, Wolff, and Hearst (1980), and Nisbett and Ross (1980)).

The shared prior belief of observers about the informed player's type has density $f(\theta)$ and distribution function $F(\theta)$. The public information set ϕ is equal either to (D,θ) (knowledge that information was disclosed, and that the revealed value was θ) or else to W (knowledge that information was not disclosed).

The average population belief about the type of the informed player is the average

[6]Broadly supportive of this argument (though not specifically a test of it) is evidence that people tend to underweight the probabilities of event contingencies that are not explicitly available for consideration. For example, people tend to understimate the probability of 'other causes' in a list of possible causes of an event (Fischoff, Slovic, and Lichtenstein (1978)).

of the credulous/inattentive and the rational beliefs,

$$\begin{aligned}\hat{\theta}^D &\equiv (1-\alpha^D)E[\theta]+\alpha^D\theta \\ \hat{\theta}^W &\equiv (1-\alpha^W)E[\theta]+\alpha^W\hat{\theta}^\rho(W),\end{aligned} \tag{1}$$

where a hat denotes an average observer perception, and a ρ superscript indicates an attentive belief.[7]

The informed player's objective in deciding whether or not to disclose is to achieve the highest possible average perception among observers. For example, in a corporate disclosure context, this would amount to maximizing the current stock price. As has been found in several models of market equilibrium when some investors have imperfectly rational beliefs and others have rational beliefs, equilibrium stock prices reflect a weighted average of the beliefs of both groups of traders (see, e.g., Daniel, Hirshleifer, and Subrahmanyam (2001)), where the weights reflect the relative numbers, risk tolerances, and perceived risks of individuals with different beliefs.

4 Equilibrium in the Basic Model

4.1 Characterizing the Equilibrium

As is standard in several disclosure models, the behavior of the information recipients can be viewed in a very simple way. We assign the informed player the objective of making the average beliefs of observers be as favorable as possible.[8]We propose a threshold equilibrium in which there is a critical signal value θ^* such that an informed player discloses if and only if his type $\theta \geq \theta^*$.

If the firm does not disclose, then the average expectation among the audience of the informed player's signal is a weighted average of the inattentive/credulous expectation $E[\theta]$, and the rational expectation $\hat{\theta}^\rho(W) = E[\theta|\theta < \theta^*]$. So the average perceptions

[7]Equation (1) has two possible interpretations. One is that different individuals by nature have different degrees of attentiveness towards different information signals available in the environment and to the opportunities of the informed player to engage in strategic disclosure behavior. The other is that observers are ex ante identical, but each has a probability of being inattentive or attentive toward environmental information and toward the strategic incentives of others.

[8]This can be viewed as a reduced form of a setting in which observers take actions based upon their beliefs that affect the informed player. For example, in a corporate disclosure setting, investors would use incorrect beliefs in their security trading decisions. The resulting stock price would be of concern to the informed player (a corporate manager).

given that the informed player withholds, or that he discloses his type θ, are

$$\hat{\theta}^D = (1-\alpha^D)E[\theta] + \alpha^D\theta = \theta - (1-\alpha^D)(\theta - E[\theta]) \quad (2)$$

$$\hat{\theta}^W = (1-\alpha^W)E[\theta] + \alpha^W E[\theta|\theta < \theta^*]. \quad (3)$$

When an above-average type discloses, limited attention detracts from his reputation (the subtracted term on the RHS), whereas limited attention enhances the reputation of a disclosing below-average type.

The equilibrium threshold value θ^* makes the informed player just willing to disclose,

$$(1-\alpha^D)E[\theta] + \alpha^D\theta^* = (1-\alpha^W)E[\theta] + \alpha^W E[\theta|\theta < \theta^*], \quad \text{or} \quad (4)$$

$$\theta^* = \gamma E[\theta] + (1-\gamma)E[\theta|\theta < \theta^*], \quad (5)$$

where

$$\gamma \equiv \frac{\alpha^D - \alpha^W}{\alpha^D}. \quad (6)$$

The parameter γ can be viewed as a measure of the excess attention paid to an arena when a signal is disclosed rather than withheld. We describe the possible equilibria as follows.

Proposition 1 *For all parameter values, an equilibrium exists.*

1. *If $\alpha^W \geq \alpha^D > 0$, the unique equilibrium entails full disclosure.*

2. *If $0 < \alpha^W < \alpha^D$, then in equilibrium there exists a threshold value θ^*, $\underline{\theta} < \theta^* < E[\theta]$, such that the informed player discloses if his signal $\theta \geq \theta^*$, and withholds if $\theta < \theta^*$.*

To prove this, we will establish, for a given inference by attentive observers about the implications of non-disclosure, increasing monotonicity of the gain to an informed player of disclosing as a function of θ. By (3) and (2), the difference

$$\hat{\theta}^D - \hat{\theta}^W = \alpha^D\theta + (\alpha^W - \alpha^D)E[\theta] - \alpha^W E^\rho[\theta|W] \quad (7)$$

increases monotonically with θ. Thus, there are up to three possible types of equilibrium: 1. All types disclose; 2. No types disclose; and 3. A player discloses if and only if his type equals or exceeds a critical value θ^*, $\underline{\theta} < \theta^* \leq \overline{\theta}$. In a proposed equilibrium with no disclosure (2.), the perception of a type that withheld would be $E[\theta]$, so any type $\theta > E[\theta]$ would prefer to disclose. This breaks the proposed equilibrium, so only (1.) and (3.) are viable equilibrium candidates.

If $\alpha^W = \alpha^D$, then $\gamma = 0$, and there is full disclosure (1.), because equation (5) can only be satisfied by $\theta^* = \underline{\theta}$. If $\alpha^W > \alpha^D$, then $\gamma < 0$, and there is no θ^* satisfying (5); the informed player always prefers to disclose. It remains to be shown that if $\alpha^W < \alpha^D$, full disclosure (1.) is not an equilibrium, so that only possibility (3.) remains, and that equilibrium exists. The proof is in Appendix B. Intuitively, when $\alpha^W < \alpha^D$, the expected reputational penalty on a low type for failing to disclose is so small that such a type strictly prefers to withhold its signal. Finally, the critical value $\theta^* < E[\theta]$, because an above-average type would always prefer to disclose in the hope of being attended to, rather than being viewed as being below the threshold (and therefore, on average below $E[\theta]$).

This threshold equilibrium is analogous to those described in the models of Jovanovic (1982) and Verrecchia (1983). In their models, threshold behavior derives from a transaction cost of disclosure. Here, as in Milgrom and Roberts (1986), possible non-disclosure of low types arises not from a cost, but from the failure of some observers to draw sufficiently skeptical inferences.

4.2 Comparative Statics on the Amount of Disclosure

Attention by observers to the withholding of information, α^W, and attention to disclosure, α^D, have opposing effects on the incentive of the informed player to disclose. Attention to a failure to disclose encourages disclosure because of the increased skepticism toward the informed player who withholds. In contrast, attention to disclosure discourages disclosure by the marginal type. Since $\theta^* < E[\theta]$ (Proposition 1 Part 2), the marginal type is reevaluated adversely when observers attend to his disclosure.

Intuitively, the threshold value θ^* should decrease with α^W or increase with γ; less attention to withholding should accommodate more non-disclosure. Introducing some inattentiveness toward withholding creates a pool of non-disclosing types, and as $\alpha^W \to 0$, the pool of non-disclosing types eventually includes all below-average types (so $\theta^* = E[\theta]$).

To understand the effect of varying α^D, consider the critical type θ^*. Higher α^D increases the fraction of observers who, when he discloses, perceive his type as $\theta^* < E[\theta]$ instead of the prior $E[\theta]$. This discourages disclosure, implying higher θ^*. This reasoning is consistent with (8).

To derive these results formally, note that by (6),

$$\frac{d\gamma}{d\alpha^W} < 0, \qquad \frac{d\gamma}{d\alpha^D} > 0. \tag{8}$$

Applying (3) and (2), let

$$G(t,\gamma) \equiv \frac{\hat{\theta}^D - \hat{\theta}^W}{\alpha^D} = t - \gamma E[\theta] - (1-\gamma)E[\theta|\theta < t]. \tag{9}$$

An equilibrium threshold θ^* satisfies $G(\theta^*, \gamma) = 0$. For a stable equilibrium, $G_1(\theta^*, \gamma) > 0$, so that a marginal increase in the threshold encourages disclosure by the marginal type. Under the market perceptions associated with such a marginal increase, the firm then prefers to disclosure at a critical threshold below the increased threshold. Since $G(\underline{\theta}, \gamma) < 0$ for a given $\gamma \in [0, 1]$ and $G(\overline{\theta}, \gamma) > 0$, there exists at least one stable equilibrium in the interval $[\underline{\theta}, \overline{\theta}]$.

To derive comparative statics of θ^* with respect to γ in the neighborhood of a stable equilibrium, we differentiate both sides of $G(\theta^*(\gamma), \gamma) \equiv 0$ with respect to γ:

$$\begin{aligned} 0 &= G_1(\theta^*, \gamma)\frac{d\theta^*}{d\gamma} + G_2(\theta^*, \gamma) \\ &= G_1(\theta^*, \gamma)\frac{d\theta^*}{d\gamma} - E[\theta] + E[\theta|\theta < \theta^*], \quad \text{so} \\ \frac{d\theta^*}{d\gamma} &= \frac{E[\theta] - E[\theta|\theta < \theta^*]}{G_1(\theta^*, \gamma)} > 0. \end{aligned} \tag{10}$$

The last inequality holds for stable equilibria ($G_1(\theta^*, \gamma) > 0$) since $E[\theta] > E[\theta|\theta < \theta^*]$. For example, under the uniform distribution $f(\theta) = 1/(\overline{\theta} - \underline{\theta})$, by (5),

$$\theta^* = \frac{\gamma\overline{\theta} + \underline{\theta}}{\gamma + 1}, \tag{11}$$

which is increasing in γ since $\overline{\theta} > \underline{\theta}$. It follows by the chain rule and (8) that $d\theta^*/d\alpha^W < 0$, and $d\theta^*/d\alpha^D > 0$.

Proposition 2 *Under the assumptions of the basic model, in the neighborhood of a stable equilibrium:*

1. *The amount of disclosure increases uniformly with the fraction of observers who are attentive about the withholding of information α^W;*

2. *The amount of disclosure decreases uniformly with the fraction of observers who attend to disclosure α^D.*

4.3 Accuracy of Observer Perceptions

We now examine how attention affects the accuracy (bias and mean squared error) of observers' average perception.

4.3.1 Optimism

Observers on average tend to be optimistic about the quality of the informed party ($E[\hat{\theta}] > E[\theta]$). On the one hand, for a given threshold θ^*, credulity about non-disclosure increases the average perception— inattentive individuals perceive the type of a non-disclosing informed player as on average $E[\theta]$ instead of $\theta < \theta^*$. On the other hand, inattention to disclosure tends to decrease average perception— inattentive individuals perceive the type of a non-disclosing informed player as on average $E[\theta]$ instead of the disclosed $\theta > \theta^*$, which on average must be greater than $E[\theta]$. However, so long as $\alpha^W < \alpha^D$, the first effect dominates (see Appendix B). We therefore have:

Proposition 3 *If disclosure is incomplete and if $\alpha^D > \alpha^W$, then observers are on average overoptimistic about the informed signal ($E[\hat{\theta}] > E[\theta]$). If $\alpha^D = \alpha^W$, then observers on average correctly assess the quality of the informed player.*

Although there is an average tendency toward optimism, owing to cue neglect average investor perceptions are too pessimistic when θ is sufficiently high.

Similar points may apply more broadly in settings where an informed player has some discretion in what he tells an observer with limited attention. Psychologists have found that individuals on average tend to exhibit unrealistic optimism about the likelihood of experiencing favorable personal outcomes.[9] Unrealistic optimism may result in part from limited attention. Life events are substantially influenced by the strategic revelation policies of interested, informed parties. Participants in business and personal relationships often conceal their lack of commitment; as a result, all too often people are shocked when they lose their jobs or life partners 'out of the blue.' Our analysis suggests that credulity about the strategic incentives of others may be a source of unrealistic optimism.[10,11]

[9] Adam Smith (1776), in regard to "the greater part of mankind," referred to "Their absurd presumption in their own good fortune..." See also the experimental work of Weinstein (1980, 1982).

[10] Kennedy and Dimick (1987) find that 48% of college athletes in revenue-producing sports expect to play professionally, while the actual figure is 2%. Colleges may have an incentive to allow athletes to believe they have a real shot at going professional, rather than disclosing adverse information about likelihood of success.

[11] To give a conjectural hint about how such an issue could be modelled, consider a social exchange setting in which two individuals play a repeated Prisoners' Dilemma over an infinite number of periods. In such a setting there may be a trigger strategy equilibrium enforcing cooperation (C) as opposed to defection (D). However, in round t one party I receives private information about the value of an external option that will become available in round $t + k$, where $k > 0$ is known to all. To exploit the external option he must, at time $t + k$, abandon the existing relationship, i.e., he must play D at round $t + k$ and at all later rounds. If the external option is sufficiently favorable, it pays for him to do

Differentiating the average optimism (49) with respect to α^W and α^D, it is not hard to verify that more attention to disclosed signals discourages disclosure, and thereby increases optimism; and greater attention to non-disclosure decreases optimism.

Proposition 4 *In the neighborhood of a stable equilibrium, average optimism* $E[\hat{\theta}]-E[\theta]$ *increases as attention to disclosure increases (*$dE[\hat{\theta}-\theta]/d\alpha^D > 0$*) and decreases with attention to non-disclosure (*$dE[\hat{\theta}-\theta]/d\alpha^W < 0$*) .*

In addition, greater uncertainty by observers about the informed player's information increases optimism. It is not hard to show that if the density of θ is horizontally stretched by a factor of K, then average optimism is also multiplied by K.

4.3.2 Mean Squared Error

The mean squared deviation of the average perception of the informed type from the actual type,

$$\begin{aligned} E[(\hat{\theta}-\theta)^2] &= \int_{\underline{\theta}}^{\theta^*} \left\{(1-\alpha^W)E[\theta]+\alpha^W E[\theta|\theta<\theta^*]-\theta\right\}^2 f(\theta)d\theta \\ &+ \int_{\theta^*}^{\overline{\theta}} \left\{(1-\alpha^D)E[\theta]+\alpha^D\theta-\theta\right\}^2 f(\theta)d\theta, \end{aligned} \tag{12}$$

is a measure of the inaccuracy of observer perceptions.

Proposition 5 *If there is a higher probability that observers attend to disclosed information than that they attend to the fact that information is withheld,* $\alpha^D > \alpha^W$, *then in the neighborhood of a stable equilibrium:*

1. *The mean squared error of the average observer perceptions as an estimate of the true type is decreasing in* α^W.

2. *The mean squared error of the average observer perceptions as an estimate of the true type can either increase or decrease as* α^D *increases.*

so. I's signal provides him with superior information in round t about whether he will later abandon the current relationship. If the uninformed party U infers that I is sufficiently likely to abandon, then the trigger strategy equilibrium breaks down and U defects immediately as well. Such breakdown of cooperation is costly to I, who prefers to reap the rewards of the old relationship longer. Thus, under limited attention, I may benefit from concealing favorable external options, thereby encouraging U to be optimistic about I's commitment to the relationship.

The proof is contained in Appendix B.

Intuitively, by Proposition 2, the more attentive observers are about non-disclosure, the more disclosure occurs. Greater disclosure makes beliefs on average more accurate, implying a lower mean squared error. It is true that perceptions are sometimes inaccurate even after disclosure so long as $\alpha^D < 1$. However, since $\alpha^D > \alpha^W$, the frequency of inaccurate perceptions is lower when the informed player discloses than when he does not disclose. Furthermore, when investors are rationally skeptical, the inference drawn from nondisclosure, $E[\theta|\theta < \theta^*]$, is a less precise estimate of θ than the inference that can be drawn from rationally attending to disclosure, the actual value of θ.

In contrast, the comparative statics with respect to α^D is ambiguous even in the uniform case. Intuitively, the more attentive observers are to disclosure, the less disclosure occurs (for reasons described earlier). The marginal type finds disclosure less attractive if this disclosure is noticed, as his type is below average. For reasons discussed in the preceding paragraph, less disclosure tends to increase the mean squared error of the average investor perception if $\alpha^D > \alpha^W$. However, a countervailing force is that higher α^D increases the probability that an individual incorporates the disclosed information into his beliefs.

5 Competing Attentional Demands and Salience

When individuals have limited cognitive capacity it is impossible to attend to all decision-relevant information of different forms and derived from different sources. The allocation of attention across signals or strategic considerations will in general be biased by the salience of different aspects of the decision environment. As discussed in Section 2, there is extensive evidence from the psychology literature that people attend more to some stimuli than others, often in ways that do not correspond to differences in the informativeness or usefulness of the different signals. We now explore a setting in which disclosure or non-disclosure in each arena influences perceptions and disclosure behavior in the other.

In this setting there are two arenas of disclosure, $i = A$ or B. The informed player in arena i observes a signal θ_i, where $\underline{\theta}_i \leq \theta_i \leq \overline{\theta}_i$. Disclosure decisions in each arena are taken simultaneously. An observer who attends to disclosure or to non-disclosure in a given arena updates his belief rationally, whereas an observer who fails to attend to arena i holds to his prior about θ_i.

We consider a very simple form of limited attention: individuals can attend to one or the other arena, but not both. This specification captures the notion of information overload in a simple way. Borrowing from the literature in experimental psychology on multiple cue learning (see Section 2), we call the tendency for an information disclosure in one arena to distract observers from attending to a disclosure in the other arena *cue competition*. We call the tendency for an information disclosure in one arena to distract observers from inferring the reason for an action or failure to act in another arena *analytical interference*.

5.1 The Basic Model with Competing Information Sources

For each arena A and B, we will first show that an equilibrium of the sort described in the preceding section applies. Limited attention determines the fraction of the observers who are credulous with respect to each arena, α_A^W, α_A^D, α_B^W and α_B^D, endogenously.

If the individual is faced with no disclosure in either arena, we assume that he attends to one or the other arena with equal probability. If there is disclosure about one arena but not another, then the effect of the disclosure on attention to the other arena is assumed to be related to the *salience* of the information disclosure.

We allow different arenas of disclosure to have different levels of salience or vividness (see Section 2). For simplicity the amount of attentional interference between arenas depends only on whether disclosure occurred, not on the signal realization. The saliences of arenas A and B, denoted s_A or s_B, help determine the probability that individuals will attend to each arena.

In the absence of any attention-grabbing events, the probability of an individual attending to A versus B would be .5. If the arena A signal is withheld the arena B, signal is disclosed, arena B is likely to capture a greater share of observer attention. To reflect the higher salience of occurrence than non-occurrence of an event, we assume that the probability that an individual attends to arena A or to B is

$$\begin{aligned} \alpha_A(W_A, D_B) &= .5(1 - s_B) \\ \alpha_B(W_A, D_B) &= .5(1 + s_B). \end{aligned} \tag{13}$$

Thus, as the salience of disclosure in arena B increases, it robs more attention from the non-disclosing arena A. If the salience of the disclosed information is 0 this effect vanishes (B gets only its 50:50 share of attention). However, as salience rises to 1 the probability of attending to A diminishes to zero. Symmetrically, we assume that

$$\begin{aligned}\alpha_A(D_A, W_B) &= .5(1+s_A)\\ \alpha_B(D_A, W_B) &= .5(1-s_A). \end{aligned} \tag{14}$$

If there is disclosure in both arenas, then it is assumed that the probability that an individual attends to A or to B is

$$\begin{aligned}\alpha_A(D_A, D_B) &= .5(1+s_A-s_B)\\ \alpha_B(D_A, D_B) &= .5(1-s_A+s_B). \end{aligned} \tag{15}$$

There is a greater tendency to attend to the more salient arena, and if the difference in salience between the two arenas is maximal $(1-0=1)$, then an observer attends to the more salient disclosure with certainty.

In equilibrium, the informed player in arena i takes the strategy of the other informed player (i.e., player i''s threshold value $\theta^*_{i'}$) as given. Each informed player therefore treats the fraction of observers who will attend to disclosure, α_i^D, or to non-disclosure, α_i^W, in his arena as given. Thus, we can apply the equilibrium of the previous section to each of the arenas, to derive the threshold value in arena i, θ^*_i, as a funciton of the porposed critical value in the other arena i', $\theta^*_{i'}$. Given critical value θ^*_B, the probability that an observer attends to the fact that information is withheld in arena A is

$$\begin{aligned}\alpha_A^W &= .5Pr(W_B) + .5(1-s_B)Pr(D_B)\\ &= .5[Pr(\theta_B < \theta^*_B)] + .5(1-s_B)[Pr(\theta_B > \theta^*_B)]\\ &= .5[1-s_B+s_BF(\theta^*_B)]. \end{aligned} \tag{16}$$

Similarly, for arena B,

$$\alpha_B^W = .5[1-s_A+s_AF(\theta^*_A)]. \tag{17}$$

Given a proposed threshold in arena B, θ^*_B, the probability that a given observer attends to disclosure in arena A is

$$\begin{aligned}\alpha_A^D &= \alpha_A(D_A, W_B)Pr(W_B) + \alpha_A(D_A, D_B)Pr(D_B)\\ &= .5(1+s_A)F_B(\theta^*_B) + .5(1-s_B+s_A)[1-F_B(\theta^*_B)]\\ &= .5(1+s_A-s_B[1-F_B(\theta^*_B)]). \end{aligned} \tag{18}$$

The probability that an observer is attentive to disclosure in B is derived similarly:

$$\alpha_B^D = .5(1+s_B-s_A[1-F_A(\theta^*_A)]). \tag{19}$$

From (16)-(19), $\alpha_i^D > \alpha_i^W$ when $s_i > 0$. We propose an equilibrium in which each informed player follows a threshold disclosure rule, with cutoffs θ_A^* and θ_B^*. We determine the equilibrium in each arena taking the cutoff in the other arena as given. We seek a set of self-confirming cutoff values that satisfy the basic model equilibrium conditions together with (16)-(19).

However, in general there may be multiple equilibria. Even if ex ante the arenas are symmetric, there may be asymmetric equilibria. High disclosure in one arena can distract from the other, leading to lower disclosure in the other. Later we will show uniqueness by direct calculation in the case of a uniform distribution of types; and in the case of equal saliences, we will solve for a symmetric equilibrium.

The equilibrium condition for informed player i to be just willing to disclose, as in (5), is that

$$\theta_i^* = \gamma_i E[\theta] + (1-\gamma_i)E[\theta|\theta < \theta_i^*], \quad \text{where} \tag{20}$$

$$\gamma_i \equiv \frac{\alpha_i^D - \alpha_i^W}{\alpha_i^D}, \qquad i = A \text{ or } B, \tag{21}$$

and where α_i^W, α_i^D are the probabilities that individuals attend to either the withholding of information, or the disclosure of information, in arena i.

Equations (20) and (21) describe θ_A^* in terms of α_A^W and α_A^D. But these in turn are both functions of θ_B^*. Thus, we can solve for a reaction curve $\theta_A^*(\theta_B^*)$. Similarly, we can solve for the reaction curve $\theta_A^*(\theta_B^*)$. Together these reaction curves determine equilibrium values for the two disclosure thresholds.

We consider the case of uniform distributions, and without loss of generality set $\underline{\theta}_A = \underline{\theta}_B = 0$, and $\overline{\theta}_A = \overline{\theta}_B = 1$ (a rescaling and translation). By (6) and (11),

$$\theta_i^*(\alpha_i^W, \alpha_i^D) = \frac{\alpha_i^D - \alpha_i^W}{2\alpha_i^D - \alpha_i^W}, \qquad i = A, B. \tag{22}$$

We now solve for the attention parameters in arena A (the α's) in terms of the tendency for disclosure in arena B, as measured by the threshold in that arena, θ_B^*. By (17), this gives the reaction curve for the informed player in arena A, and a similar derivation gives the curve for arena B:

$$\theta_A^*(\theta_B^*) = \frac{s_A}{1 + 2s_A - s_B + s_B\theta_B^*} \tag{23}$$

$$\theta_B^*(\theta_A^*) = \frac{s_B}{1 + 2s_B - s_A + s_A\theta_A^*}. \tag{24}$$

Figure 1 shows reaction curves for different parameter values, and the equilibria determined by the intersections of these curves.

Insert Figure 1 Here

Combining equations (23) and (24) gives the equilibrium disclosure threshold θ_A^* as a root of the quadratic equation

$$s_A(1+2s_A-s_B){\theta_A^*}^2+[(1+2s_A-s_B)(1+2s_B-s_A)+{s_B}^2-{s_A}^2]\theta_A^*-s_A(1+2s_B-s_A)=0. \quad (25)$$

This equation has only one root between 0 and 1. Since $0<\theta_A^*<1$, by (24), θ_B^* is also between 0 and 1. We therefore have:

Proposition 6 *If the types of the informed players in two arenas are distributed uniformly on* $[0,1]$*, then there is a unique equilibrium. In this equilibrium, there is partial disclosure.*

Example: We solve for the equilibrium when salience is symmetric ($s \equiv s_A = s_B$) and types are uniform on $[0,1]$. Let the common threshold value be θ^*, and let salience be s. If $s=0$, then (25) reduces to a linear equation with solution $\theta^*=0$, implying full disclosure. Intuitively, $s=0$ causes $\alpha^D=\alpha^W=.5$, so that the advantage to a very low type of withholding in the hope of not being attended to is just offset by the advantage to disclosing in the hope of not being attended to. For $s>0$, θ^* is the positive solution to (25),

$$\theta^*=\frac{-(1+s)+\sqrt{(1+s)^2+4s^2}}{2s}. \quad (26)$$

For all $s>0$, $\theta^*>0$, implying partial disclosure. If $s=1$, $\theta^*=-1+\sqrt{2}\approx .414$. $\|$

By (23), $d\theta_A^*/d\theta_B^*<0$, so the reaction curves are downward sloping. In other words, disclosures in the two arenas are strategic substitutes. It follows that regulation that forces more disclosure in one arena than would have occurred in equilibrium crowds out disclosure in the other arena. Intuitively, reduced attention to B reduces the pressure on a marginal B player to disclose.

Proposition 7 *Suppose that the probability distributions of types of the informed players in the two arenas are uniform on* $[0,1]$*. Then regulation that forces greater disclosure in one arena (by reducing* θ_i^* *in arena* i*) causes the informed player in the other arena to disclose less information (i.e., in arena* $\sim i$ *the disclosure threshold* $\theta_{\sim i}^*$ *increases).*

5.2 Cross-Arena Contagion of News Announcements

This subsection examines the effect of disclosure versus non-disclosure in arena A on the expected perception by observers of the signal value in a fundamentally-unrelated arena B. Applied in a stock market setting, the results we derive describe how an announcement about one stock, such as an earnings forecast or dividend announcement, affects the price of another stock.

Thus, we calculate $E[\hat{\theta}_B|D_A, \theta]$ and $E[\hat{\theta}_B|W_A]$, where the expectation is taken with respect to the possible outcome for θ_B. The average perception in arena B if the informed player in arena B withholds, $\hat{\theta}_B^W$, is, in analogy to equation (3),

$$(1-\alpha_B^W)E[\theta_B] + \alpha_B^W E[\theta_B|\theta_B < \theta_B^*] = (1-\alpha_B^W)E[\theta_B] + \alpha_B^W \int_{\underline{\theta}_B}^{\theta_B^*} \theta_B \frac{f(\theta_B)}{F(\theta_B^*)} d\theta_B. \quad (27)$$

If he discloses, then the average perception is

$$\hat{\theta}_B^D = (1-\alpha_B^D)E[\theta_B] + \alpha_B^D \theta_B. \quad (28)$$

Taking expectations over the possible values of θ_B, we find the expected perception by observers of the informed player in arena B conditional on the behavior of the informed player in arena A. Recalling our notation $\phi = W$ or (D, θ), this is

$$\begin{aligned} E[\hat{\theta}_B|\phi_A] &= F(\theta_B^*) \left\{ (1-\alpha_B^W)E[\theta_B] + \alpha_B^W \int_{\underline{\theta}_B}^{\theta_B^*} \theta_B \frac{f(\theta_B)}{F(\theta_B^*)} d\theta_B \right\} \\ &\quad + \int_{\theta_B^*}^{\overline{\theta}_B} \left\{ (1-\alpha_B^D)E[\theta_B] + \alpha_B^D \theta_B \right\} f(\theta_B) d\theta_B. \\ &= (\alpha_B^D - \alpha_B^W) \int_{\underline{\theta}_B}^{\theta_B^*} \{E[\theta_B] - \theta_B\} f(\theta_B) d\theta_B + E[\theta_B]. \end{aligned} \quad (29)$$

The effect of ϕ_A on perceptions in arena B comes from ϕ_A's effect on α_B^W, α_B^D, and thereby on θ_B^*; attention in arena B depends on the disclosure choice and outcome in arena A. To condition on D_A, we substitute α_B^W from (17) and α_B^D from (19) when $\theta_A^* = \underline{\theta}$ (implying certainty of disclosure in arena A). This yields

$$\begin{aligned} \alpha_B^W(D_A) &= .5(1-s_A) \\ \alpha_B^D(D_A) &= .5(1+s_B-s_A). \end{aligned} \quad (30)$$

Similarly, to condition on W_A, we substitute α_B^W from (17) and α_B^D from (19) when $\theta_A^* = \overline{\theta}$ (implying no disclosure in arena A). This yields

$$\begin{aligned} \alpha_B^W(W_A) &= .5 \\ \alpha_B^D(W_A) &= .5(1+s_B). \end{aligned} \quad (31)$$

Comparing $E[\hat{\theta}_B|D_A]$ with $E[\hat{\theta}_B|W_A]$, we obtain:

Proposition 8 *Disclosure in one arena causes the expected perception of the type in the other arena to increase.*

The two arenas have no fundamental relationship (θ_A and θ_B are independent). Cross-effects here are induced by the attentional relationship between the two arenas. More generally, if there are many arenas, disclosure in any single arena may have little effect on another arena unless there is some kind of attentional linkage between the two. The attentional linkage could derive from a fundamental relationship, or could be entirely superficial (as with two firms with similar-sounding names).[12]

When there are many arenas, the cross effect between attentionally related ones is probably positive. Instead of distracting, disclosure in a given arena probably calls further attention to a few attentionally related arenas, while distracting slightly from a large number of more distantly related arenas. Thus, although we regard the implication derived here regarding the contagion effects of news announcements as having conceptual interest, empirical predictions relevant for stock market contagion will probably require analysis of at least three arenas.

6 Effects of Regulation on Belief Accuracy and Welfare

We examine here how disclosure regulation affects the accuracy of investor perceptions, the degree of optimism, and welfare. If government simply mandates disclosure and that mandate is always obeyed, in effect the disclosure threshold is set below $\underline{\theta}$. However, often a more realistic description of the legal/regulatory environment is that only partial disclosure is enforced, implying a threshold at an intermediate value between $\underline{\theta}$ and $\overline{\theta}$. The threat of liability for the failure to disclose can encourage a firm to do so (see, e.g., Skinner (1994)), but may not enforce complete disclosure. Even when disclosure is clearly mandated, firms may balance the risk of liability against possible benefits of withholding bad news from the market. A firm may intentionally choose to violate a disclosure rule. In some cases there may be legal uncertainty as to whether disclosure of the information item is mandatory. Firms will be pressured to disclose more bad news when there is a higher probability of legal liability for non-disclosure, and when the

[12]Rashes (2001) provides evidence of stock market pricing errors based upon investors being confused by similarities in names and ticker symbols of different stocks, a clear symptom that limited attention causes inappropriate contagion across arenas.

expected penalties are higher. Thus, the legal/regulatory environment involves different effects which can be viewed as adjusting the level of the threshold indirectly.

We assume that welfare is measured by the accuracy of investor perceptions. If there is only a single arena, we define welfare as the negative of the mean squared error,

$$W \equiv -E[(\hat{\theta} - \theta)^2], \tag{32}$$

where $\hat{\theta}$ is the average perception of type conditional on the disclosure decision.

When there are multiple arenas, the value of belief accuracy will generally vary depending on the arena's size and characteristics.[13] We therefore consider a social welfare function that allows for unequal weights on perception errors between arenas A and B,

$$W \equiv -\lambda E[(\hat{\theta}_A - \theta_A)^2] - (1 - \lambda)E[(\hat{\theta}_B - \theta_B)^2], \tag{33}$$

where $\hat{\theta}_A$ and $\hat{\theta}_B$ are the average perceptions of type in the two arenas conditional on the disclosure decision, and λ measures the relative importance of the two arenas.

We begin by describing the effects of regulation when there is only a single arena.

Proposition 9 *Under the assumptions of the basic model, if there is a higher probability that observers attend to the disclosed information than that they attend to the fact that information is withheld, $\alpha^D > \alpha^W$, then:*

1. *Suppose that θ^* is imposed by regulation (instead of satisfying the indifference condition (5)). Then the mean squared error of the average observer perception as an estimate of the true type decreases, and social welfare increases with the amount of required disclosure, i.e., the mean squared error increases with θ^*.*

2. *An exogenous decrease in the disclosure threshold reduces optimism when $\theta^* < E[\theta]$.*

So long as regulation takes the form of encouraging disclosure (perhaps by imposing a risk of liability on a non-disclosing firm), the condition $\theta^* < E[\theta]$ holds (by Proposition 1), because this condition holds even when there is no regulation.

[13]For example, one arena may have greater payoff variability than the other, so that the benefits of accurate information differs across arenas. The validity of investor perceptions of the paper clip industry may matter less than perceptions of the steel industry. Also, an incorrect perception of a state of the world that is not very relevant for the observer's actions may matter less than a highly action-relevant state of the world. Alternatively, the informed player's 'type' in our model could be viewed as a noisy indicator of value, where the noise variance can differ across arenas. Other things equal, the social value of accurate communication of a noisier signal is smaller than communication of a more accurate one. Also, the qualitative nature of the information disclosed is important for welfare; see, e.g., the analysis of Boot and Thakor (2001).

The accuracy of observers' beliefs increases with the amount of disclosure. Consider now a regulation that imposes a level of disclosure θ^*. Intuitively, higher θ^* (a weaker disclosure requirement) increases the probability that observers hold to their prior beliefs (since $\alpha^D > \alpha^W$) instead of updating appropriately. It also tends to make even fully rational inferences of type more noisy by increasing the set of types that are not revealed (see Appendix B, Proof of Proposition 9, Part 1).

When there are multiple arenas, we can examine the effects of a change in the disclosure rule in one of the arenas, or in both simultaneously.

Proposition 10 *1. If there is disclosure in two arenas, then an exogenous increase in the disclosure threshold (implying a lower probability of disclosure) in one arena causes average beliefs to be more accurate (lower mean-squared-error) in the other arena in the neighborhood of a stable equilibrium.*

2. An exogenous increase in the disclosure threshold in one arena reduces optimism in the other arena in the neighborhood of a stable equilibrium.

3. Forced disclosure in one arena can reduce welfare by discouraging disclosure in the other arena.

4. If there is disclosure in two arenas, then a simultaneous exogenous increase in the disclosure threshold in both arenas ($\theta^* = \theta^*_A = \theta^*_B$) can cause average beliefs in each area to become either more or less accurate, i.e., $\partial E[(\hat{\theta} - \theta)^2]/\partial\theta^*$ can be negative or positive. Thus, even though there are no costs of disclosure, forced disclosure in both arenas can reduce welfare.

The proof of Parts 1, 2, and 3 are in Appendix B. Intuitively, there is a crowding out effect of disclosure. For example, if regulators impose higher disclosure in arena A, then this distracts observers from arena B. The lower attention to either disclosure or non-disclosure in arena B makes beliefs in arena B less accurate, which can reduce welfare, especially if arena B is more important than arena A.

This suggests an important limitation to disclosure policy. It is impossible to regulate disclosure in all arenas. Even if high disclosure were required of all firms, there is private information in other parts of economic and social life. The effect of imposing disclosure requirements in some arenas but not others may be redirecting attention rather than improving the accuracy of perceptions overall. This suggests that a relevant input for regulatory decisions is the importance of different arenas for the decisions of observers.

To prove Part 4, we consider the case of symmetric salience and calculate the mean squared error of beliefs as a function of the common cutoff θ^*. When the θ_i's are distributed uniformly on $[0,1]$, by direct calculation the mean squared error can increase or decrease with the common cutoff θ^*. For example, when $s_A = s_B = 0.99$ and $\theta^* = 0.4$, $\partial E[(\hat{\theta}-\theta)^2]/\partial\theta^* \approx -0.021$, but when $s_A = s_B = 0.1$, the derivative is positive (≈ 0.025).

Part 3 indicates that disclosure in a less important arena may distract so much from disclosure in the important arena that welfare declines. Consider the symmetric case where $s_A = s_B = s$. Using the attention probabilities given in equations (16)-(19), we can differentiate welfare with respect to the disclosure threshold for A (holding constant θ_B^*); details are provided in Appendix B, proof of Part 3. Using the symmetric solution given in (26), $\partial W/\partial\theta_A^*$ as a function of s and λ is shown in Figure 2.

Insert Figure 2 Here

As seen in Figure 2, $\partial W/\partial\theta_A^*$ is positive when the salience s is high and the weight on arena A is low. Forced disclosure in arena A (lower θ_A^*) can decrease welfare when the importance of arena B is high (lower λ) and the salience is high. A high salience of disclosure in arena A, combined with greater disclosure in A, makes withholding more attractive in arena B. Therefore, forced disclosure in A can have a negative overall effect by discouraging disclosure in the more important arena.

In Part 4 there are countervailing effects. On the one hand, greater disclosure in one arena has a direct tendency to increase the precision of observer beliefs in that arena. On the other hand, it distracts attention from the other arena, which tends to reduce precision there. Overall, jointly forcing increased disclosure can reduce belief precisions and therefore welfare, as illustrated in Figure 3.

Letting $\theta_A^* = \theta_B^* \equiv \theta^*$, in Figure 3 $\partial W/\partial\theta^*$ is positive for high values of s and negative for low values of s (calculations in Appendix B).

Insert Figure 3 Here

Intuitively, although forcing disclosure in both arenas directly increases the amount of information available, it also makes people less attentive to a given datum. If salience is high enough, the second effect (lower attention) can outweigh the first (more information/disclosure).

7 Optimal Allocation of Attention

Even boundedly rational observers may, through effort, try especially hard to attend to those signals that offer high return to attention.[14] This section generalizes the basic single-arena model of Section 3 to allow individuals to decide *ex ante* how much attention to devote to either disclosed information or the strategic implications of non-disclosure. We examine whether the equilibrium in a setting with endogenous allocation of attention has implications similar to those of the basic model.

The focus of the analysis here is on the first arena A, but we include a second arena B to give individuals an opportunity cost of attending to arena A. Individuals ex ante also have a choice within in arena A as to how much attention to devote to disclosed information versus the failure of information to be disclosed.

There are two stages in the model. In the first stage identical observers choose attention probabilities α_A^W, α_A^D, as defined earlier, and the probability of attending to a second independent arena B, α_B. This choice is not observable to the informed player, although in equilibrium he knows what the choice will be.

In the second stage, attention outcomes are realized, so each observer either attends or does not attend to each arena and forms beliefs accordingly. The informed player observes his private signal about arena A, and decides whether or not to disclose. At this point, the decision problem of the informed player is identical to that of the informed player in the basic model. So the disclosure threshold θ_A^* is determined as in the basic model as a function of α_A^W and α_A^D.

Also at the second stage, each observer makes a project choice based on his beliefs at that time. Thus, at the first stage the individual allocates attention so as to increase the quality of his later project choice. Let θ_A be an observer's net payoff from adopting the arena A project. We assume that if he is indifferent, he adopts the project. Thus, he would like to adopt if and only if $\theta_A \geq 0$. For algebraic simplicity, we assume that $E[\theta_A] = 0$, so that an individual who ends up not attending to arena A is just willing to undertake the project. Similar results apply more generally.

Also for simplicity, we assume that there is no disclosure game in arena B. Instead, an information signal becomes public spontaneously and with certainty. We therefore assume that the B component of the observers' objective is equal to $\alpha_B K$, where $K > 0$ is a constant.[15]

[14] Conlisk (1996) considers the decision of a boundedly rational decisionmaker of how carefully to deliberate when making correct decisions is costly.

[15] It is easy to derive this if there is an investment project related to arena B with net value $k\theta_B$, where

From the analysis of the basic model, $\theta_A^* < E[\theta_A] = 0$. When an individual attends to a disclosure in arena A, he adopts the project if and only if $\theta_A > 0$. When he attends to a failure to disclosure, he rejects the project since $E[\theta_A|\theta_A < \theta_A^*] < 0$. As discussed above, whenever an individual fails to attend (either to a disclosure or to a failure to disclose), he adopts. Thus, his expected payoff from his arena A project choices given his attention probabilities α_A^D and α_A^W is

$$\begin{aligned}
\Pi_A &= (1-\alpha_A^D)Pr(\theta_A > \theta_A^*)E[\theta_A|\theta_A > \theta_A^*] \\
&+ \alpha_A^D Pr(\theta_A > 0)E[\theta_A|\theta_A > 0] + (1-\alpha_A^W)Pr(\theta_A < \theta_A^*)E[\theta_A|\theta_A < \theta_A^*] + \alpha_A^W \cdot (0) \\
&= (1-\alpha_A^D)\int_{\theta_{A*}}^{\bar{\theta}_A} \theta_A f(\theta_A)d\theta_A + \alpha_A^D \int_0^{\bar{\theta}_A} \theta_A f(\theta_A)d\theta_A + (1-\alpha_A^W)\int_{\underline{\theta_A}}^{\theta_A^*} \theta_A f(\theta_A)d\theta_A \\
&= \int_{\theta_{A*}}^{\bar{\theta}_A} \theta_A f(\theta_A)d\theta_A - \alpha_A^D \int_{\theta_A^*}^{0} \theta_A f(\theta_A)d\theta_A + (1-\alpha_A^W)\int_{\underline{\theta}_A}^{\theta_A^*} \theta_A f(\theta_A)d\theta_A \qquad (34)
\end{aligned}$$

Adding to this the expected profit from the arena B project, an observer's overall first stage optimization problem is

$$\max_{\alpha_A^W,\alpha_A^D,\alpha_B} \int_{\theta_{A*}}^{\bar{\theta}_A} \theta_A f(\theta_A)d\theta_A - \alpha_A^D \int_{\theta_A^*}^{0} \theta_A f(\theta_A)d\theta_A + (1-\alpha_A^W)\int_{\underline{\theta}_A}^{\theta_A^*} \theta_A f(\theta_A)d\theta_A + \alpha_B K,$$

subject to the attention allocation constraint

$$G(\alpha_A^W, \alpha_A^D, \alpha_B) \leq 1, \qquad (35)$$

where $G(\cdot,\cdot,\cdot)$ is weakly increasing in each of its arguments. If arena A is complex and non-salient, a relatively large reduction in α_B may be required to maintain given levels of the α_A's. If the individual has good control over his attention, the α's may be highly substitutable. On the other hand, if vividness and salience grab people's attention without conscious volition, the different α's may be highly complementary in G, so that a given increase in one of the α's requires a relatively large decrease in one or more of the others.

We consider a tractable functional form for G,

$$G(\alpha_A^W, \alpha_A^D, \alpha_B) = \sigma^W(\alpha_A^W)^2 + \sigma^D(\alpha_A^D)^2 + \alpha_B, \qquad (36)$$

$E[\theta_B] = 0$ and $k > 0$. Attending to B allows an observer to obtain on average $kE[\theta_B|\theta_B \geq 0]$ by investing when doing so is profitable, instead of always investing for an average payoff of 0. In this setting, arena B contributes $\alpha_B kE[\theta_B|\theta_B \geq 0]$ to the observer's expected profits, so that $K = kE[\theta_B|\theta_B \geq 0]$.

where σ^W, σ^D, and σ_B are exogenous parameters which measure the opportunity cost of directing attention to a particular target. Substituting out

$$\alpha_B = 1 - \sigma^W (\alpha_A^W)^2 - \sigma^D (\alpha_A^D)^2,$$

we write the first order conditions of the optimization with respect to α_A^W and α_A^D, supressing A subscripts, as

$$\begin{aligned} 0 &= \int_{\theta^*}^{0} (-\theta) f(\theta) d\theta - 2K\sigma^D \alpha^D \\ 0 &= \int_{\underline{\theta}}^{\theta^*} (-\theta) f(\theta) d\theta - 2K\sigma^W \alpha^W, \end{aligned}$$

so that

$$\begin{aligned} \alpha^D &= \frac{1}{2K\sigma^D} \int_{\theta^*}^{0} (-\theta) f(\theta) d\theta \\ \alpha^W &= \frac{1}{2K\sigma^W} \int_{\underline{\theta}}^{\theta^*} (-\theta) f(\theta) d\theta. \end{aligned} \tag{37}$$

The disclosure threshold is determined by equations (5) and (6) of the basic model applied to arena A. From (37), the ratio α^W/α^D does not depend on K. Therefore, we can ensure that $\alpha_B > 0$ by selecting K sufficiently large without affecting the equilibrium disclosure level. Also, for appropriate values of parameters σ^W and σ^D, $\alpha^D > \alpha^W$, ensuring that the equilibrium involves only partial disclosure.

Differentiating (37) with respect to σ^W and σ^D respectively:

$$\begin{aligned} \frac{d\alpha^D}{d\sigma^W} &= \frac{\theta^* f(\theta^*)}{2K\sigma^D} \frac{d\theta^*}{d\sigma^W} \\ \frac{d\alpha^W}{d\sigma^D} &= -\frac{\theta^* f(\theta^*)}{2K\sigma^W} \frac{d\theta^*}{d\sigma^D}. \end{aligned}$$

Since $\theta^* < 0$,

$$\begin{aligned} sign\left(\frac{d\alpha^D}{d\sigma^W}\right) &= -sign\left(\frac{d\theta^*}{d\sigma^W}\right) \\ sign\left(\frac{d\alpha^W}{d\sigma^D}\right) &= sign\left(\frac{d\theta^*}{d\sigma^D}\right). \end{aligned} \tag{38}$$

The threshold value for disclosure depends on the attention levels, $\theta^* = \theta^*(\alpha^W, \alpha^D)$, where by (6) and (10),

$$\frac{\partial \theta^*}{\partial \alpha^D} > 0, \quad \frac{\partial \theta^*}{\partial \alpha^W} < 0. \tag{39}$$

Taking the total derivative of θ^* with respect to the exogenous parameters σ^W and σ^D,

$$\begin{aligned}\frac{d\theta^*}{d\sigma^W} &= \frac{\partial\theta^*}{\partial\alpha^D}\frac{d\alpha^D}{d\sigma^W} + \frac{\partial\theta^*}{\partial\alpha^W}\frac{d\alpha^W}{d\sigma^W} \\ \frac{d\theta^*}{d\sigma^D} &= \frac{\partial\theta^*}{\partial\alpha^D}\frac{d\alpha^D}{d\sigma^D} + \frac{\partial\theta^*}{\partial\alpha^W}\frac{d\alpha^W}{d\sigma^D} \qquad (40)\end{aligned}$$

$$(41)$$

From (38)-(41),

$$\begin{aligned}sign\left(\frac{d\alpha^D}{d\sigma^W}\right) &= -sign\left(\frac{d\theta^*}{d\sigma^W}\right) = sign\left(\frac{d\alpha^W}{d\sigma^W}\right) \\ sign\left(\frac{d\alpha^W}{d\sigma^D}\right) &= sign\left(\frac{d\theta^*}{d\sigma^D}\right) = sign\left(\frac{d\alpha^D}{d\sigma^D}\right) \qquad (42)\end{aligned}$$

Differentiating (37) with respect to σ^W and σ^D respectively:

$$\begin{aligned}\frac{d\alpha^W}{d\sigma^W} &= \frac{1}{2K(\sigma^W)^2}\int_{\underline{\theta}}^{\theta^*}\theta f(\theta)d\theta - \frac{\theta^* f(\theta^*)}{2K\sigma^W}\frac{d\theta^*}{d\sigma^W} \qquad (43) \\ \frac{d\alpha^D}{d\sigma^D} &= \frac{1}{2K(\sigma^D)^2}\int_{\theta^*}^{0}\theta f(\theta)d\theta + \frac{\theta^* f(\theta^*)}{2K\sigma^D}\frac{d\theta^*}{d\sigma^D}.\end{aligned}$$

Since $\theta^* < 0$, $\int_{\theta^*}^0 \theta f(\theta)d\theta < 0$ and $\int_{\underline{\theta}}^{\theta^*} \theta f(\theta)d\theta < 0$, (42) and (43) imply that

$$\frac{d\theta^*}{d\sigma^D} < 0, \quad \frac{d\theta^*}{d\sigma^W} > 0.$$

Thus, the comparative statics when individuals have an allocation choice are similar to those with exogenous α's, as described in Section 4.2, Proposition 2. Since an increase in σ^D increases the opportunity cost of attending to disclosure, it causes less attention to disclosure, and a lower threshold (more disclosure). An increase in σ^W makes attending to non-disclosure more costly, which reduces attention to withholding, and thereby increases the disclosure threshold (less disclosure). Thus, variation in the cost of attending to different arenas (the σ's) leads to comparative statics on the amount of disclosure essentially identical to those in the basic model varying the α's.

To analysis matches that of the basic model even more closely in the extreme special case of perfect complementarity between both arenas of attention, and between withholding and disclosing:

$$G(\alpha_A^W, \alpha_A^D, \alpha_B) = max[\sigma^W(\alpha_A^W)^2, \sigma^D(\alpha_A^D)^2, \sigma_B\alpha_B]. \qquad (44)$$

Under perfect complementarity, it is optimal to allocate attention so as to equate the three components in the maximization,

$$\sigma^W(\alpha_A^W)^2 = \sigma^D(\alpha_A^D)^2 = \sigma_B\alpha_B = 1;$$

reallocating attention by decreasing one of these components would not lead to any corresponding increase in the other components, it would merely throw away attentional resources. Thus, the optimal attention levels are

$$\alpha^W = \frac{1}{\sqrt{\sigma^W}}, \quad \alpha^D = \frac{1}{\sqrt{\sigma^D}}. \tag{45}$$

Each of the α's in (45) is a function only of its corresponding exogenous σ. It follows that all propositions of the model with exogenous attention levels are consistent with the perfect complementarity case, with comparative statics on α's interpreted as corresponding variations in σ's as in (45).

8 Conclusion

In this paper we have modelled limited attention as incomplete usage of publicly available information. Informed players decide whether or not to disclose information to an audience of observers who sometime neglect either disclosed signals or the implications of non-disclosure. In equilibrium, we found that observers are unrealistically optimistic, disclosure is incomplete, neglect of disclosed signals increases disclosure, and neglect of a failure to disclose reduces disclosure. We also found that these insights extend to a setting in which observers choose ex ante how to allocate their limited attention. In a setting with multiple arenas of disclosure, we found that disclosure in one arena affects perceptions in fundamentally unrelated arenas, owing to cue competition, salience, and analytical interference; and that disclosure in one arena can crowd out disclosure in another.

We have also considered the implications of limited attention and the resulting credulity of investors for disclosure regulation. Law and regulation in the U.S. require firms to reveal information in financial reports, and to disclose other relevant information. This contrasts with the appealingly simple policy implication of the classic models of disclosure. In these models, rational observers, through appropriate skepticism, induce full disclosure, and full disclosure is a good thing. In extensions with costly disclosure, the recommendation is almost as simple: force additional disclosure only if the social benefits exceed the costs.

In contrast, limited attention suggests that the balance of considerations is more complex, even if disclosure is costless. On the one hand, informed parties may conceal information in the hope of exploiting the inattention and credulity of observers. This puts regulation of disclosure on the table. However, we find, paradoxically, that regulations designed to force greater disclosure can make perceptions less accurate. For example, we find that forced disclosure in one arena can crowd out disclosure in another, and thereby can reduce welfare. Thus, even if forced disclosure in one arena creates benefits to observers in that arena, there is no presumption that forced disclosure is socially desirable.

Furthermore, forcing simultaneous disclosure in multiple arenas can also reduce welfare, for at least two reasons. First, greater forced disclosure can increase what we call analytical interference, wherein a disclosed signal in one arena distracts observers from analyzing the reasons for a failure of a player to disclose in the other arena. Second, and this point applies even if *complete* disclosure is enforced in both arenas, greater disclosure can cause greater cue competition between disclosures— observers have trouble paying attention to both signals. Even though more information is publicly available, observer perceptions may on average be less accurate.

Thus, to determine whether forcing greater disclosure in one or in many arenas will improve welfare, policymakers have a challenging task. Evaluating such a policy requires an assessment of the relative importance of the different arenas, the precision of the information that might be disclosed, and the salience of the different arenas.

At least three significant considerations not captured in our model deserve further exploration. First, salience here depends only on the arena of disclosure. In practice, extreme signals may be more salient. This effect may further discourage disclosure, as the critical minimum type to disclose is by definition at a noticeable lower extreme if he discloses.

Second, the analysis of many arenas (more than two) when there are fundamental as well as attentional relationships between arenas may offer insights into contagion in evaluations of different securities, product categories, or political ideas.

Finally, an informed party may misrepresent his information by 'disclosing' an incorrect value for his information signal. This issue is highlighted by recent U.S. corporate accounting scandals such as those involving Enron and WorldCom. Limits to investor attention presumably affect the incentives for firms to engage in fraud or milder shading of the truth. An interesting further direction would be to analyze how different regulatory policies influence the incentives for firms to exploit inattentive observers through misrepresentation as well as simply not disclosing.

Owing to the simplicity of our modelling approach, it can easily be adapted to analyze the effects of limited attention in other settings involving strategic behavior and asymmetric information. Possible applications include equilibrium in signalling games, adverse selection in markets, and the design of optimal contracts between a principal and an agent. We believe that such a program for research is analytically tractable; whether it will be empirically validated remains to be seen.

We close by emphasizing that the general approach to limited attention offered here may be applicable to a wide range of human transactions. As argued in Appendix A, there are various interactions in which informed players seem to take advantage of inattention to manipulate the perceptions of others. Some possible directions that merit further exploration include the reporting of firms' financial condition to investors, the advertising of products to consumers, the presentation of information by political activists, and the presentation of personal information by individuals in their everyday lives. The approach described here—in which observers are limited in their ability to attend to signals or features of the strategic environment, salience parameters influence which signals or environmental features are attended to more, and occurence of an event is more salient than non-occurence—may be helpful in capturing minimally the effects of limited attention in these and other contexts.

Appendix A: Do Limited Attention and Credulity Affect Markets?

Casual observation suggests that limited attention and credulity are important. Rather than focusing on detailed, careful analysis of issues, politicians and political pressure groups invest heavily in 'sound bites' or 'photo ops' designed to underscore a simple, vivid message. Relatedly, the idea 'rational ignorance' of voters is consistent with limits to attention and processing power. Many product advertisements are designed to engage viewers' attention and emotions, rather than to present a strong documentary case in support of claims about quality and price.[16] Despite the evident possibility of interested motives, con artists recurrently seduce the foolish with get-rich-quick scams. So at a minimum there is an extreme tail of credulous individuals.

Experimental studies have provided strong evidence that subjects frequently fail to discount adequately for the motives of interested parties. Subjects fail to adjust properly for adverse selection problems even after numerous repetitions.[17] In a product market experiment, Lynch et al (1991) find some evidence of seller misrepresentation, and that inexperienced buyers overpay. Some buyers offer a high price to the same seller immediately after being 'ripped off' by a low quality product. However, since the sellers choose to produce almost entirely low-quality products, buyer naivete is eliminated through experience.

Especially germane for the current paper is evidence that individuals are insufficiently skeptical about firms' motives for refraining from disclosing information. In the experiments of Forsythe, Isaac, and Palfrey (1989) and King and Wallin (1991), the seller of an asset can choose whether or not to disclose the asset's value; any disclosure must be truthful. Forsythe, Isaac and Palfrey find that in early experiments buyers overpay in the 'blind bid' auctions that result from a seller choosing not to disclose; and that sellers profitably exploited this buyer naivete. With many repetitions there was gradual unravelling toward fuller disclosure. However, in the version of the King and Wallin (1991) experiments in which the rational equilibrium entails full disclosure, neither full disclosure nor extreme skepticism was closely approached.

[16] Hanson and Kysar (1999) review evidence from the consumer marketing and consumer psychology literatures, which, they claim, indicates that sellers successfully manipulate consumer perceptions of their products.

[17] For an excellent review of this evidence, see Kagel and Levin (2002) ch.1.D. For example, buyers do not adjust properly for the winner's curse in bilateral bargaining games (Samuelson and Bazerman (1985), Ball, Bazerman, and Caroll (1991), and Holt and Sherman (1995)). Ball, Bazerman and Caroll find that very few subjects learn through experience to adjust properly.

Forsythe, Lundholm, and Rietz (1999) find in an experimental asset market that when there is no communication, buyers pay more for the asset than the value of the lowest-quality asset, an apparent failure of buyers to take adverse selection fully into account. Furthermore, when the rules (known to all) allow sellers to engage in "cheap talk" (fraudulent claims) about the quality of the security, buyers often overpay. Under the "antifraud" regime in which sellers can disclose a set of qualities that includes the true quality, outcomes are closer to the full disclosure equilibrium, but buyers are still sometimes insufficiently skeptical.

There is also evidence of limited attention in practice. Mathios (2000) examined the effect of the Nutrition Labeling and Education Act on purchases of salad dressing. This legislation mandated the labelling of information about fat content. He found that even though there was voluntary labeling (mostly of low-fat brands) prior to the regulation, after disclosure was mandated fattier dressings lost market share. If consumers had been highly attentive and skeptical, without regulation they would have already inferred a high fat content among non-disclosing products.

There is evidence that the *re*announced gains from debt-equity swaps in quarterly earnings announcements were significantly related to mean abnormal returns (Hand (1990)). Amir (1993) found that footnote disclosure of post-retirement benefits was underweighted by investors until the policy discussions leading up to SFAS 106, which made the long-term costs of these benefits more salient. In Aboody (1996), stock prices in the oil and gas industry weighted write-down information more heavily when it was explicitly recognized as part of earnings than when it was merely disclosed to investors separately. Schrand and Walther (2000) provide evidence that managers select the form of the prior-period earnings benchmark when announcing earnings. Prior period gains were more likely to be announced than prior period losses in the sample, apparently to lower the benchmark for current-period evaluation.

Financial markets also provide indirect evidence of limited attention and excessive credulity. Investors make trades based upon anonymous internet chat, so that cheap talk appears to move prices.[18] Rational investors should understand that anonymous internet chat comments may be designed to mislead others in order to move prices. Shiller

[18]This creates opportunities for 'pump and dump' manipulation strategies wherein an individual buys the stock, starts rumors to drive up the price, and then sells. In one recent case a 14-year-old spread favorable rumors about thinly trading stocks using numerous fictitious names, and immediately sold the stocks (*Bloomberg*, 9/21/00). The SEC alleged that he made $272,826 in illegal profits on stocks he touted and sold, though his total gains were several times larger.

(2000) describes several episodes indicative of investor naivete.[19] A body of evidence reviewed in Daniel, Hirshleifer, and Teoh (2002) suggests that credulity of investors about the motives of firms, analysts, and brokers explains several general patterns in investor trading and capital market prices.[20] Such evidence is surprising since mispricing in securities markets offers potential profit opportunities to smart traders. Some have argued that inattention to information about deferred executive stock option compensation contributed to the internet bubble of the 1990s.[21]

Also indicative of limited attention is evidence that the stock market reacts to re-publication of news that is already publicly available (see Ho and Michaely (1988), Huberman and Regev (2001)), and to corporate name changes (Cooper, Dimitrov, and Rau (2001)); and reacts more strongly to public news announcements if the outlet is *The New York Times* (Klibanoff, Lamont, and Wizman (1999)). Grinblatt, Masulis, and Titman (1984) propose an investor attention hypothesis to explain the positive average market price reaction to stock splits (seemingly an irrelevant change in units). Individuals participate in only a subset of stocks, which may be a consequence of limited attention. Consistent with investors forming imperfectly diversified portfolios, there is a market premium for security-specific risk (see Bessembinder (1992) and Malkiel and Xu (2000)). Finally, Barber and Odean (2001) find that individual investors tend to be purchasers of stock on 'high attention days'– days in which abnormal news about a firm is announced, days following extreme price moves, and days in which a stock has high abnormal trading volume.

Appendix B: Proofs

Proof of Proposition 1: We now show that if $\alpha^W < \alpha^D$ there is no equilibrium with full disclosure. The most skeptical inference in any equilibrium that could be drawn

[19]These include the bizarre claims and self-promotion methods used by the financial forecaster Joseph Granville, whose pronouncements caused large movements in the Dow Jones Industrial Average. Shiller describes the history of Ponzi schemes, such as the 1996-7 episode in Albania, which led to rioting and the resignation of the Prime Minister and his cabinet. More broadly, Shiller argues that shifts in the focus of public attention cause stock market booms and overshooting.

[20]These patterns include a failure of market prices to discount adequately for incentives of firms to manage earnings (see, e.g., Sloan (1996), Teoh, Welch, and Wong (1998)), and the apparent failure of the market to discount fully for the incentive of firms with private information to sell shares when these shares are overvalued by the market (see Loughran and Ritter (1995)), and to buy shares when shares are undervalued (see Ikenberry, Lakonishok, and Vermaelen (1995)).

[21]There is evidence that market prices fail to discount sufficiently for the dilution in value implicit in outstanding managerial stock options. The publicly available information that a firm has a large overhang of executive stock option compensation is a negative predictor of subsequent abnormal stock returns (Garvey and Milbourn (2001)). This illustrates both limited attention, and also perhaps credulity on the part of investors about the incentive of managers to manage earnings upward.

about non-disclosure would be $\hat{\theta} = \underline{\theta}$. Thus, observers' perception of a withholding player satisfies

$$\hat{\theta}^W \geq (1-\alpha^W)E[\theta] + \alpha^W \underline{\theta}. \tag{46}$$

The perception upon disclosing for a type $\theta = \underline{\theta} + \epsilon$ is

$$\hat{\theta}^D = (1-\alpha^D)E[\theta] + \alpha^D(\underline{\theta} + \epsilon). \tag{47}$$

Thus,

$$\begin{aligned} \hat{\theta}^W - \hat{\theta}^D &\geq (\alpha^D - \alpha^W)\left(E[\theta] - \underline{\theta}\right) - \alpha^D \epsilon \\ &> 0, \end{aligned} \tag{48}$$

where the last inequality holds, for given α^W and α^D, by choosing ϵ to satisfy

$$0 < \epsilon < \frac{(\alpha^D - \alpha^W)(E[\theta] - \underline{\theta})}{\alpha^D}.$$

Thus, in any equilibrium there exists a set of types with $\theta < \underline{\theta} + \epsilon$, ϵ small that prefer not to disclose. Furthermore, so long as $\gamma < 1$, $\theta^* < E[\theta]$. Otherwise, there would be an above-average type ($\theta > E[\theta]$) who prefers not to disclose. This is impossible; if he does not disclose, the average perception of his type is below $E[\theta]$, by (3), whereas if he does disclose, he is correctly perceived as having information $\theta > E[\theta]$. $\|$

Proof of Proposition 3:

$$\begin{aligned} E[\hat{\theta} - \theta] &= \int_{\underline{\theta}}^{\theta^*} \{(1-\alpha^W)E[\theta] + \alpha^W E[\theta|\theta < \theta^*] - \theta\} f(\theta) d\theta + \int_{\theta^*}^{\overline{\theta}} \{(1-\alpha^D)E[\theta] + \alpha^D \theta - \theta\} f(\theta) d\theta \\ &= \{(1-\alpha^W)E[\theta] + \alpha^W E[\theta|\theta < \theta^*]\} F(\theta^*) - \int_{\underline{\theta}}^{\theta^*} \theta f(\theta) d\theta \\ &\quad + (1-\alpha^D)E[\theta][1 - F(\theta^*)] - (1-\alpha^D)\left(E[\theta] - \int_{\underline{\theta}}^{\theta^*} \theta f(\theta) d\theta\right) \\ &= \{(1-\alpha^W)E[\theta] + \alpha^W E[\theta|\theta < \theta^*]\} F(\theta^*) - E[\theta|\theta < \theta^*] F(\theta^*) \\ &\quad + (1-\alpha^D)E[\theta][1 - F(\theta^*)] - (1-\alpha^D)\left\{E[\theta] - E[\theta|\theta < \theta^*] F(\theta^*)\right\} \\ &= (\alpha^D - \alpha^W) F(\theta^*) \left(E[\theta] - E[\theta|\theta < \theta^*]\right). \end{aligned} \tag{49}$$

Since $\alpha^D > \alpha^W$ and $E[\theta] > E[\theta|\theta < \theta^*]$, $E[\hat{\theta} - \theta] > 0$.

Proof of Proposition 4:

$$\begin{aligned} \frac{dE[\hat{\theta} - \theta]}{d\alpha^W} &= -(E[\theta] - E[\theta|\theta < \theta^*]) F(\theta^*) + (\alpha^D - \alpha^W) f(\theta^*)(E[\theta] - \theta^*) \frac{d\theta^*}{d\alpha^W} \\ \frac{dE[\hat{\theta} - \theta]}{d\alpha^D} &= (E[\theta] - E[\theta|\theta < \theta^*]) F(\theta^*) + (\alpha^D - \alpha^W) f(\theta^*)(E[\theta] - \theta^*) \frac{d\theta^*}{d\alpha^D}. \end{aligned}$$

Since $E[\theta] > E[\theta|\theta < \theta^*]$, $\alpha^D > \alpha^W$, $E[\theta] > \theta^*$, $d\theta^*/d\alpha^W < 0$ and $d\theta^*/d\alpha^D > 0$, $E[\hat{\theta} - \theta]/d\alpha^W < 0$ and $E[\hat{\theta} - \theta]/d\alpha^D > 0$ ‖

Proof of Proposition 5: By (3)–(4), we can rewrite the MSE as

$$\begin{aligned} E[(\hat{\theta} - \theta)^2] &= \int_{\underline{\theta}}^{\theta^*} \left\{(1 - \alpha^D)E[\theta] + \alpha^D\theta^* - \theta\right\}^2 f(\theta)d\theta \\ &+ \int_{\theta^*}^{\overline{\theta}} \left\{(1 - \alpha^D)\left(E[\theta] - \theta\right)\right\}^2 f(\theta)d\theta. \end{aligned} \tag{50}$$

Since α^W affects $E[(\hat{\theta} - \theta)^2]$ only through θ^*,

$$\frac{dE[(\hat{\theta} - \theta)^2]}{d\alpha^W} = \frac{dE[(\hat{\theta} - \theta)^2]}{d\theta^*}\frac{d\theta^*}{d\alpha^W}, \tag{51}$$

where

$$\begin{aligned} \frac{dE[(\hat{\theta} - \theta)^2]}{d\theta^*} &= 2\alpha^D F(\theta^*)\left\{\alpha^D\theta^* + (1 - \alpha^D)E[\theta] - E[\theta|\theta < \theta^*]\right\} \\ &> 0. \end{aligned} \tag{52}$$

Thus,

$$Sign\left(\frac{dE[(\hat{\theta} - \theta)^2]}{d\alpha^W}\right) = Sign\left(\frac{d\theta^*}{d\alpha^W}\right).$$

By (6) and (10),

$$\frac{d\theta^*}{d\alpha^W} = -\frac{d\theta^*/d\gamma}{\alpha^D} < 0$$

for a stable equilibrium.

To see how the mean squared error varies with α^D, substitute θ^* of the uniform $[0, 1]$ distribution case from (11) into the MSE formula, (12), and differentiating with respect to α^D. This yields

$$\begin{aligned} \frac{dE[(\hat{\theta} - \theta)^2]}{d\alpha^D} &\equiv \left[\frac{\alpha^D}{6(2\alpha^D - \alpha^W)^4}\right]\left\{8(1 - \alpha^D)^4 - 3(\alpha^W)^2(1 - \alpha^W)^2 - 8(1 - \alpha^D)^3(3 - 2\alpha^W)\right. \\ &+ \left. 4(1 - \alpha^D)^2\left[6 - 8\alpha^W + 3(\alpha^W)^2\right] - (1 - \alpha^D)\left[8 - 16\alpha^W + 21(\alpha^W)^2 - 6(\alpha^W)^3\right]\right\}, \end{aligned}$$

which can be either positive or negative: $dE[(\hat{\theta} - \theta)^2]/d\alpha^D = -0.0354938$ when $(\alpha^W, \alpha^D) = (0.4, 0.5)$, and $dE[(\hat{\theta} - \theta)^2]/d\alpha^D = 0.000708395$ when $(\alpha^W, \alpha^D) = (0.4, 0.95)$. ‖

Proof of Proposition 8: By Proposition 1, $E[\theta_B] > \theta_B^* > 0$. Therefore, if $\theta_B < \theta_B^*$, $E[\theta_B] - \theta_B > 0$, which implies that the integral on the RHS of the final equation in (29) is increasing with θ_B^*. Furthermore, by (30) and (31), the coefficient on this integral,

$$\alpha_B^D(D_A) - \alpha_B^W(D_A) = \alpha_B^D(W_A) - \alpha_B^W(W_A) = .5s_B,$$

does not depend on ϕ_A. Thus, substituting $\phi_A = W_A$ or D_A into (29), we see that $E[\hat{\theta}_B|D_A] > E[\hat{\theta}_B|W_A]$ if and only if $\theta^*_B(D_A) > \theta^*_B(W_A)$. Let $\gamma_B = (\alpha^D_B - \alpha^W_B)/(\alpha^D_B)$. Since

$$\gamma_B(D_A) = s_B/(1 + s_B - s_A) > s_B/(1 + s_B) = \gamma_B(W_A),$$

$\theta^*_B(D_A) > \theta^*_B(W_A)$. Thus $E[\hat{\theta}_B|D_A] > E[\hat{\theta}_B|W_A]$. $\|$

Proof of Proposition 9:

Part 1:

$$E[(\hat{\theta} - \theta)^2]$$

$$\begin{aligned}
&= \int_{\underline{\theta}}^{\theta^*} \left\{(1-\alpha^W)E[\theta] + \alpha^W E[\theta|\theta < \theta^*] - \theta\right\}^2 f(\theta)d\theta + \int_{\theta^*}^{\overline{\theta}} \left\{(1-\alpha^D)\left(E[\theta] - \theta\right)\right\}^2 f(\theta)d\theta \\
&= \left\{(1-\alpha^W)E[\theta] + \alpha^W E[\theta|\theta < \theta^*]\right\}^2 \int_{\underline{\theta}}^{\theta^*} f(\theta)d\theta - 2\left\{(1-\alpha^W)E[\theta] + \alpha^W E[\theta|\theta < \theta^*]\right\} \int_{\underline{\theta}}^{\theta^*} \theta f(\theta)d\theta \\
&+ \int_{\underline{\theta}}^{\theta^*} \theta^2 f(\theta)d\theta + \int_{\theta^*}^{\overline{\theta}} \left\{(1-\alpha^D)\left(E[\theta] - \theta\right)\right\}^2 f(\theta)d\theta. \qquad (53)
\end{aligned}$$

$$\begin{aligned}
\frac{\partial E[(\hat{\theta} - \theta)^2]}{\partial \theta^*} &= 2\left\{(1-\alpha^W)E[\theta] + \alpha^W E[\theta|\theta < \theta^*]\right\} \alpha^W \frac{\partial E[\theta|\theta < \theta^*]}{\partial \theta^*} F(\theta^*) \\
&+ \left\{(1-\alpha^W)E[\theta] + \alpha^W E[\theta|\theta < \theta^*]\right\}^2 f(\theta^*) - 2\alpha^W \frac{\partial E[\theta|\theta < \theta^*]}{\partial \theta^*} \int_{\underline{\theta}}^{\theta^*} \theta f(\theta)d\theta \\
&- 2\left\{(1-\alpha^W)E[\theta] + \alpha^W E[\theta|\theta < \theta^*]\right\} \theta^* f(\theta^*) \\
&+ (\theta^*)^2 f(\theta^*) - \left\{(1-\alpha^D)\left(E[\theta] - \theta^*\right)\right\}^2 f(\theta^*). \qquad (54)
\end{aligned}$$

Since $\alpha^W < \alpha^D$, by

$$\begin{aligned}
\frac{\partial E[\theta|\theta < \theta^*]}{\partial \theta^*} &= \frac{f(\theta^*)}{F(\theta^*)}(\theta^* - E[\theta|\theta < \theta^*]) \quad \text{and} \\
\int_{\underline{\theta}}^{\theta^*} \theta f(\theta)d\theta &= E[\theta|\theta < \theta^*]F(\theta^*),
\end{aligned}$$

$$\frac{\partial E[(\hat{\theta} - \theta)^2]}{\partial \theta^*} = f(\theta^*)\left\{[1 - (1-\alpha^W)^2](\theta^* - E[\theta|\theta < \theta^*])^2 + [(1-\alpha^W)^2 - (1-\alpha^D)^2](\theta^* - E[\theta])^2\right\} > 0.$$

Part 2:

$$\begin{aligned}
E[\hat{\theta} - \theta] &= (\alpha^D - \alpha^W)F(\theta^*)(E[\theta] - E[\theta|\theta < \theta^*]) \\
\frac{\partial E[\hat{\theta} - \theta]}{\partial \theta^*} &= (\alpha^D - \alpha^W)f(\theta^*)(E[\theta] - \theta^*) > 0, \text{ when } E[\theta] > \theta^*. \qquad (55)
\end{aligned}$$

||

Proof of Proposition 10, Part 1: The mean squared error in arena i is

$$E[(\hat{\theta}_i - \theta_i)^2] = \int_{\underline{\theta}_i}^{\theta_i^*} \left\{(1-\alpha_i^W)E[\theta_i] + \alpha_i^W E[\theta_i|\theta_i < \theta_i^*] - \theta_i\right\}^2 f(\theta_i)d\theta_i$$
$$+ \int_{\theta_i^*}^{\overline{\theta}_i} \left\{(1-\alpha_i^D)\left(E[\theta_i] - \theta_i\right)\right\}^2 f(\theta_i)d\theta_i, \quad (56)$$

where α_i^W, α_i^D, and θ_i^* are functions of $\theta_{\sim i}^*$, the critical value in the other arena. The derivative of mean squared error in arena i with respect to $\theta_{\sim i}^*$ can be written as:

$$\frac{\partial E[(\hat{\theta}_i - \theta_i)^2]}{\partial \theta_{\sim i}^*} = -2\frac{\partial \alpha_i^W}{\partial \theta_{\sim i}^*}(1-\alpha_i^W)(E[\theta_i] - E[\theta_i|\theta_i < \theta_i^*])^2 Pr[\theta_i < \theta_i^*]$$
$$- 2\frac{\partial \alpha_i^D}{\partial \theta_{\sim i}^*}(1-\alpha_i^D)\int_{\theta_i^*}^{\overline{\theta}_i} (E[\theta_i] - \theta_i)^2 f(\theta_i)d\theta_i$$
$$+ \frac{\partial \theta_i^*}{\partial \theta_{\sim i}^*} f(\theta_i^*)\alpha_i^W(2-\alpha_i^W)(\theta_i^* - E[\theta_i|\theta_i < \theta_i^*])^2$$
$$+ \frac{\partial \theta_i^*}{\partial \theta_{\sim i}^*} f(\theta_i^*)(\alpha_i^D - \alpha_i^W)(2-\alpha_i^D-\alpha_i^W)(\theta_i^* - E[\theta_i])^2. \quad (57)$$

By inspection of equations (16)-(19), the derivatives of α_i^W and α_i^D with respect to $\theta_{\sim i}^*$ are

$$\frac{\partial \alpha_i^W}{\partial \theta_{\sim i}^*} = \frac{\partial \alpha_i^D}{\partial \theta_{\sim i}^*} = 0.5 s_{\sim i} f(\theta_{\sim i}^*) > 0. \quad (58)$$

Also,

$$\frac{\partial \theta_i^*}{\partial \theta_{\sim i}^*} = \frac{\partial \theta_i^*}{\partial \gamma_i}\frac{\partial \gamma_i}{\partial \theta_{\sim i}^*} = \frac{\partial \theta_i^*}{\partial \gamma_i}\left[-0.5 s_{\sim i} f(\theta_{\sim i}^*)\frac{\alpha_i^D - \alpha_i^W}{(\alpha_i^D)^2}\right] < 0. \quad (59)$$

Therefore, in the neighborhood of a stable equilibrium ($\partial\theta_i^*/\partial\gamma_i > 0$), the mean squared error of arena i decreases with the threshold of the other arena $\sim i$,

$$\frac{\partial E[(\hat{\theta}_i - \theta_i)^2]}{\partial \theta_{\sim i}^*} < 0.$$

||

Proof of Proposition 10, Part 2:

$$\frac{\partial E[\hat{\theta}_i - \theta_i]}{\partial \theta_{\sim i}^*} = \left(\frac{\partial \alpha_i^D}{\partial \theta_{\sim i}^*} - \frac{\partial \alpha_i^W}{\partial \theta_{\sim i}^*}\right) F(\theta_i^*)(E[\theta_i] - E[\theta_i|\theta_i < \theta_i^*])$$
$$+(\alpha_i^D - \alpha_i^W) f(\theta_i^*)(E[\theta_i] - \theta_i^*)\frac{\partial \theta_i^*}{\partial \theta_{\sim i}^*}$$
$$= (\alpha_i^D - \alpha_i^W) f(\theta_i^*)(E[\theta_i] - \theta_i^*)\frac{\partial \theta_i^*}{\partial \theta_{\sim i}^*} < 0 \quad (60)$$

The last line follows from equations (58) and (59). $\|$

Proof of Proposition 10, Part 3: To prove Part 3, we differentiate the welfare function with respect to θ_A^* when θ_A and θ_B are distributed uniformly over $[0,1]$. The attention probabilities are given in equations (16)-(19).

$$\begin{aligned}
\frac{\partial W}{\partial \theta_A^*} &= \frac{1}{48}(-9\lambda(\theta_A^*)^2 \\
&- 2s\left\{-1+(\theta_B^*)^3+\lambda\left[4-12\theta_A^*-(\theta_B^*)^3+9(\theta_A^*)^2+3(\theta_A^*)^2\theta_B^*\right]\right\} \\
&+ s^2\{2(\theta_B^*-1)[3(\theta_B^*-1)\theta_B^*+\theta_A^*+\theta_A^*\theta_B^*+\theta_A^*(\theta_B^*)^2] \\
&+ \lambda[-3+12(\theta_B^*)^2-6(\theta_B^*)^3-9(\theta_A^*)^2+18(\theta_A^2)^2\theta_B^* \\
&+ 3(\theta_A^2)^2(\theta_B^*)^2+14\theta_A^*-24\theta_A^*\theta_B^*-2\theta_A^*(\theta_B^*)^3]\}). \qquad (61)
\end{aligned}$$

Using the symmetric solution given in (26), $\partial W/\partial\theta_A^* = 0.02244$ when $(s,\lambda)=(0.8,0.2)$, and it becomes -0.01663 when $(s,\lambda)=(0.8,0.9)$. $\|$

Calculations Underlying Figure 3: We differentiate the welfare W with respect to the common threshold θ^* where θ_A and θ_B are distributed uniformly over $[0,1]$

$$\frac{\partial W}{\partial \theta^*} = \frac{1}{48}\left\{-9\theta^{*2}-2s[2-12\theta^*+9(\theta^*)^2+4(\theta^*)^3]+s^2[-3+22\theta^*-45(\theta^*)^2+24(\theta^*)^3+5(\theta^*)^4]\right\}.$$

The derivative $\partial W/\partial\theta^*$ is positive for high value and negative for low values of s. For example, $\partial W/\partial\theta^* = 0.0114$ when $s=0.8$, and $\partial W/\partial\theta^* = -0.0079$ when $s=0.2$. $\|$

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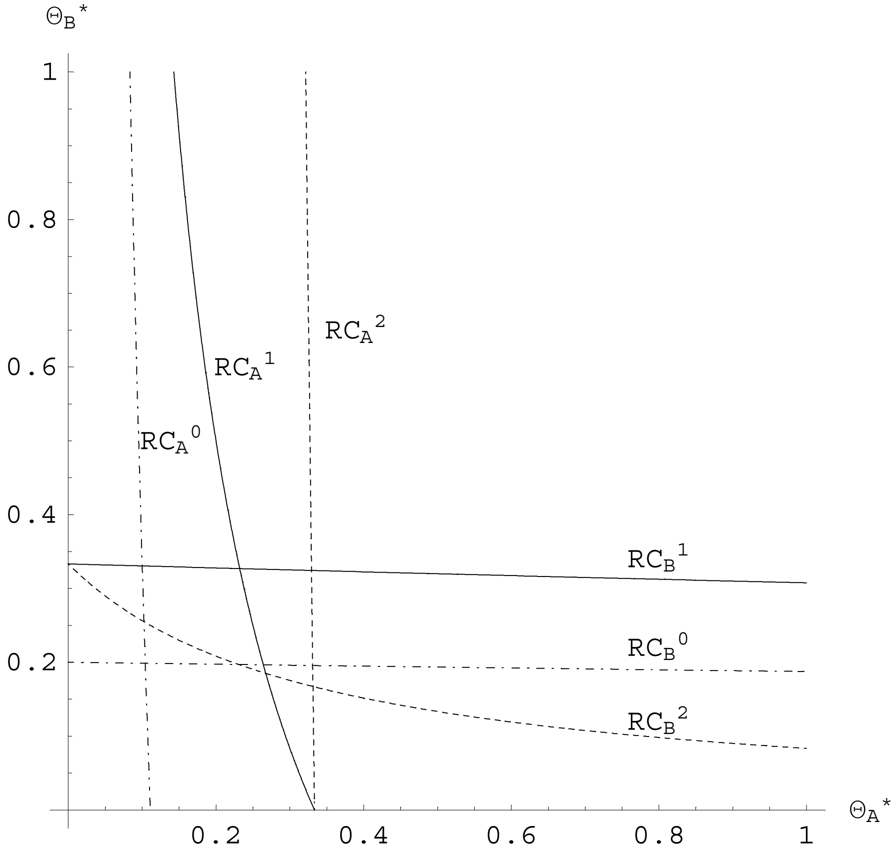

Figure 1: Reaction Curves for Disclosure in Arenas *A* and *B*

RC_A^0 and RC_B^0 are reaction curves for disclosure in arenas A and B when $(s_A, s_B) = (0.1, 0.3)$. RC_A^1 and RC_B^1 are the reaction curves when $(s_A, s_B) = (0.2, 0.8)$, and RC_A^2 and RC_B^2 are the reaction curves when $(s_A, s_B) = (0.9, 0.1)$.

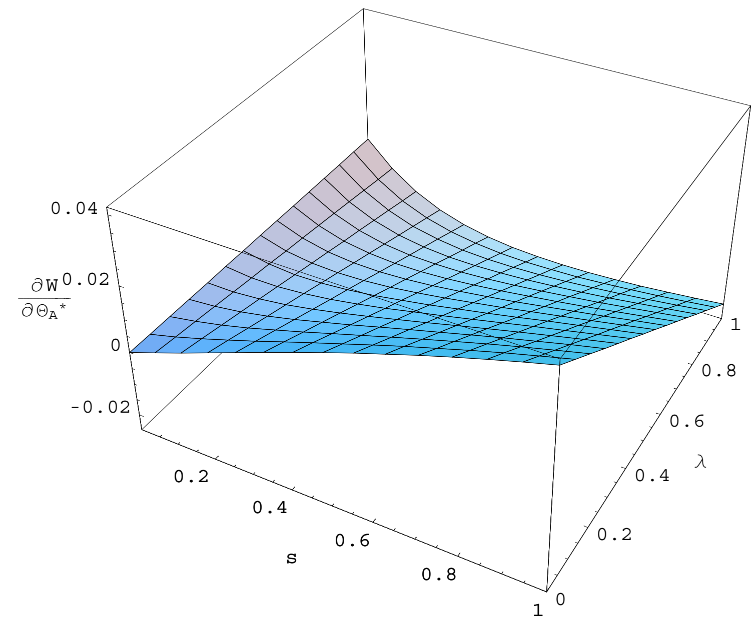

Figure 2: Welfare effect of exogenous increase in the disclosure threshold in arena A

The graph shows the derivative of welfare with respect to an exogenous increase in the disclosure threshold in arena A, as a function of the common salience of disclosure s, and the weight λ on arena A in the social welfare function.

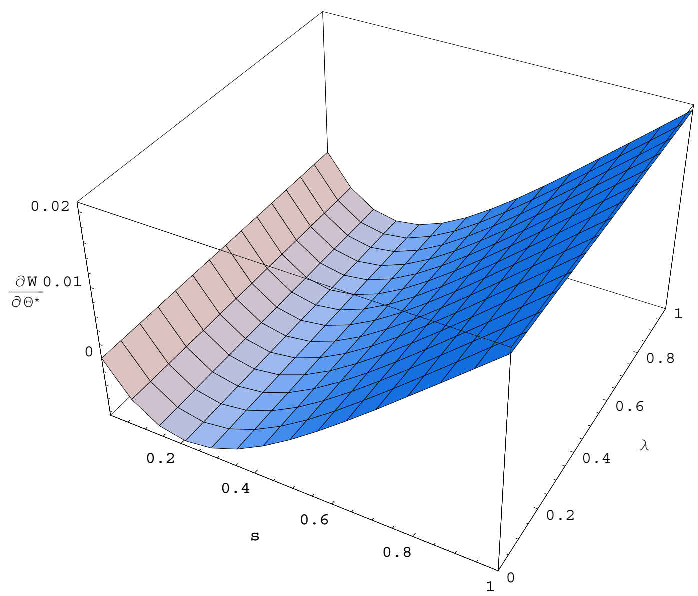

Figure 3: Welfare effect of exogenous increase in the common disclosure threshold in arenas A and B

The graph shows the derivative of welfare with respect to an exogenous increase in the common disclosure threshold for arenas A and B, as a function of the common salience of disclosure s, and the weight λ on arena A in the social welfare function.