Voluntary Disclosure, Price Informativeness, and Efficient Investment*

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Abstract

I analyze a manager's decision to disclose private information when the stock market is a source of information for corporate investment-making. A manager with long-term incentives discloses her private information only if it *crowds-in* informed trading and increases the manager's ability to learn from the market. However, this ex-post disclosing behavior results in two *crowding-out* effects: First, it crowds-out informed trading in situations where the manager *withholds* her private information. Second, voluntary disclosure results in an ex-ante average decline in price informativeness. Paradoxically, ex-post voluntary disclosure aimed at stimulating informed trading distorts the market's feedback-providing role and restrains efficient investment-making. Long-term incentives induce this disclosing behavior and thus cause a novel form of investment inefficiency.

Keywords: Voluntary Disclosure, Price Informativeness, Investment Efficiency, Long-term incentives

JEL Codes: D82, G14, G31, M41

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1 Introduction

Financial markets are an important source of information. The trading process aggregates financial market participants' information into prices and reflects their views about the traded assets. A growing body of empirical work provides evidence that information aggregated by the financial market improves decision-making in firms (e.g., Luo [2005], Chen et al. [2007], Foucault and Frésard [2012], Williams and Xiao [2017], Edmans et al. [2017], and Dessaint et al. [2019]). Given the real economic implications, it is important to understand the determinants of price informativeness and how firms can stimulate the so-called feedback role of the market (Bond et al. [2012]). A firm's reporting activity shapes the public information environment and can be expected to influence private information acquisition and trading incentives of financial market investors. Therefore, public disclosure has the potential to drive price informativeness and thus the firm's ability to learn from the market.

In this paper, I propose a model to study how a firm's disclosing activities influence stock price informativeness and the associated real economic consequences, given the importance of market feedback for corporate decision-making. Importantly, I analyze a model where a firm manager makes the disclosure decision ex-post, that is, conditional on the specific piece of information learned privately inside the firm. In contrast, the literature that studies how disclosure affects the information content of prices focuses on ex-ante policies, which specify the structure of disclosure before the arrival of the manager's private information.[1]

The model applies to settings where the firm shares information relevant for future investment plans to gauge the market's view on those intended actions. Examples include announcements of early-stage merger and acquisition considerations, projections on research and development spending, capital expenditure forecasts, or strategy discussions during investor conference calls. All of these examples constitute *voluntary* disclosure settings where,

[1] See, for instance, Verrecchia [1982], Diamond [1985], and Gao and Liang [2013]. An excellent survey of the main economic forces identified in the literature is Goldstein and Yang [2017].

by its very nature, firms have control over which information they share with the public.[2,3] Therefore, it seems natural that firms consider the *content* of their private information when making voluntary disclosure decisions. By studying ex-post disclosure, I take the discretion firms have in their voluntary disclosures into account and highlight a nuanced way of how voluntary disclosure distorts the information aggregation role of prices. Paradoxically, voluntary ex-post disclosure aimed at stimulating informed trading limits market feedback from an ex-ante perspective, restraining efficient investment-making. Because price informativeness is relevant for corporate decision-making, I highlight critical financial and real economic implications being unique to modeling voluntary disclosure in an ex-post way. For instance, the manager's desire to learn from the market is driven by her incentives based on the firm's long-term profit. By inducing ex-post voluntary disclosure that distorts price informativeness, long-term incentives cause this novel form of investment inefficiency.

My model considers the ex-post disclosure technology introduced by Dye [1985] and Jung and Kwon [1988], where a firm manager decides whether to (truthfully) disclose or withhold private information. Departing from the standard setup, where the manager wants to maximize her firm's valuation in the market, I focus on a manager whose incentives are perfectly aligned with long-term shareholders' interests. The firm is known to have access to a new investment project which may succeed or fail in the future. Given her belief about the project's success probability, the manager chooses the profit-maximizing investment scale. A private signal informs the manager about the project's likelihood of success; however, it does not necessarily reveal its outcome entirely. The signal structure implies that even after

[2] To be in line with the model, the disclosure has to be informative about an intended action that can be revisited by the firm manager, rather than about a final decision. This requirement rules out mandatory reporting settings like the disclosure of a material event under Form 8-K (e.g., to be included in Item 1.01 of Form 8-K, the firm has to have entered a "material definitive agreement").

[3] The term *voluntary disclosure* is used ambiguously in the literature. On the one hand, it is used for ex-post disclosure policies (e.g., Dye [1985], Jung and Kwon [1988], or Verrecchia [1983]). In this paper, I follow the notion of this literature stream when referring to voluntary disclosure. In contrast, however, papers like Diamond [1985], Yang [2018], or Schneemeier [2019] use voluntary disclosure to refer to ex-ante state-independent disclosure policies. Usually, this implies that the disclosing party (e.g., the firm) commits to revealing its private information with some added random noise whereby the commitment to less noise is referred to as more or better voluntary disclosure.

receiving her private signal, the manager tries to utilize other information sources to make a better-informed investment decision. An information source the manager can influence is the financial market: The manager's decision to disclose or withhold her private signal shapes the public's assessment of the project's success probability and sets a sophisticated trader's incentives to costly acquire information about the project's payoff himself.[4] Because the investor trades on his private information in a Kyle [1985]-type market, the stock price partially reflects the trader's information. Therefore, the stock price represents a source of information the manager can influence with her disclosure decision.

As standard in Kyle-type trading models, the informed investor's trading gains are increasing in the information advantage he has over the uninformed market maker. Therefore, the higher the degree of *public uncertainty*, the stronger are the incentives for the trader to become informed in the first place. Because the price partially reflects the trader's information, stronger private information acquisition efforts help the manager learn more from the market. By that, the manager discloses her private information if it results in a high degree of public uncertainty and *crowds-in* the trader's private information acquisition. This crowding-in role of disclosure is in stark contrast to the literature's general notion that public disclosure crowds-out private information in prices.[5] If the disclosure of the manager's private information would induce only a small degree of information acquisition by the trader, she refrains from disclosure. Therefore, the disclosure equilibrium features partial disclo-

[4]The assumption that the trader can acquire information about the same random variable, i.e., the project's outcome, does not imply that the trader can access a "better" information technology than the manager. The model's qualitative results remain to hold for an arbitrary sizeable variable cost parameter, implying that the trader acquires only a small amount of information. Necessary for the analysis is that the manager can extract *some* additional information from the market and that the trader's *marginal* information acquisition depends on the disclosure outcome.

[5]The literature generally highlights a crowding-out role of ex-ante disclosure due to either of two assumptions: First, the asset value and the noise being normally distributed. Given this "normal-normal" specification, the asset fundamental's post-disclosure variance is always lower than the pre-disclosure variance (see, e.g., Verrecchia [1982]). Second, the manager's private information revealing the asset fundamental perfectly. In such a setting, disclosure always precludes investor's information acquisition (see, e.g., Gao and Liang [2013]). An exception of how disclosure can crowd-in informed trading in a normal-normal setting is when multiple dimensions of uncertainty are considered as in Bond and Goldstein [2015], Yang [2018], or Goldstein and Yang [2019]. Further discussions about the precise relation to the existing literature can be found in Section 2.

sure, where the manager discloses or conceals her private information depending on how her signal's communication influences price informativeness.

The manager's disclosure decision is maximizing her ability to learn from the market; however, does this imply that the resulting investment behavior maximizes firm profits? It is important to stress the timing difference between before (ex-ante) and after (ex-post) the manager has received a private signal realization. The manager's incentives are perfectly aligned with long-term shareholders' interests, and therefore the *investment decision* is profit-maximizing given the information she has after observing the stock price. Thus, the only source of ex-ante inefficiency is the manager's ex-post disclosure decision, which elicits a potentially inefficient degree of feedback from the market.

While the manager's disclosure decision is optimal ex-post, it creates an *information spillover effect* that influences the market's belief formation process after *nondisclosure*. Upon observing nondisclosure, the market rationally forms its belief by considering which signals the manager discloses or withholds in equilibrium. Therefore, *voluntary ex-post disclosure* affects the public's belief, market participants' behavior, and, ultimately, the stock price's degree of feedback indirectly also after *nondisclosure*. I show that the consequence of this informational spillover effect is generally negative: In an effort to increase feedback, voluntary ex-post disclosure *crowds-out* the trader's information acquisition efforts after nondisclosure. The intuition is as follows. In equilibrium, the manager discloses (withholds) signal realizations which result in high (low) degrees of public uncertainty. Thus, the public assesses the payoff uncertainty to be relatively low after nondisclosure, which results in small information acquisition efforts by the trader. Therefore, the manager's equilibrium voluntary disclosing behavior causes price informativeness to be high after disclosure but low after nondisclosure. Notably, *on average*, voluntary ex-post disclosure results in a decrease of price informativeness across all signals that the manager may receive from an ex-ante perspective.

The model I present uncovers a paradox of voluntary disclosure: Ex-post voluntary disclosure aimed at stimulating market feedback distorts the manager's ex-ante ability to learn from the market. Therefore, the manager makes on average worse-informed investment decisions resulting in a novel form of ex-ante inefficient investment-making.

Jayaraman and Wu [2019b] analyze an highly relevant empirical setting of my theory: voluntary capital expenditure (CAPEX) forecast disclosures. Forecast announcements that lead to high measures of informed trading are associated with CAPEX adjustments, indicating that the manager learned from the market. Market feedback improves firm performance, which corroborates the interpretation that the manager used voluntary CAPEX disclosure to stimulate her ability to learn from prices. The findings of Jayaraman and Wu [2019b] are in line with the crowding-in role of ex-post voluntary disclosure in my model. However, my model further predicts that such voluntary disclosing activities crowds-out price informativeness for nondisclosing firms and limits the market's ex-ante average feedback-providing role.

In addition to several empirical predictions regarding post-disclosure market outcomes (see Section 7 for details), my model generates three novel theoretical implications. First, because the manager's ex-post disclosure decision aims to improve her ability to learn from prices, this disclosing behavior would be induced by incentives based on the investment project's profit. Thus, incentives that rely on the long-term growth option's outcome create the ex-post optimal, but ex-ante inefficient disclosure policy. While long-term incentives relax standard agency issues (e.g., Stein [1989]), I highlight an associated feedback solicitation cost. Also, the model shows that any incentive contract has real efficiency implications beyond investment distortions arising from agency conflicts. Because incentive contracts influence the manager's ex-post disclosing behavior, they indirectly matter for price informativeness and, thus, the manager's ability to learn from the market. For instance, take short-term incentives where the manager tries to maximize the firm's valuation in the market.[6] Under some conditions, I show that the voluntary disclosure policy based on short-term incentives results in a less distorted degree of price informativeness. Thus, while short-term

[6]This model variation coincides with Dye [1985], Jung and Kwon [1988], Acharya et al. [2011], and Frenkel et al. [2020].

incentives may lead to standard agency-based *investment distortions*, short-term incentives may dominate long-term incentives in terms of the manager's ex-ante ability to learn from the market.

Second, improving the manager's ability to learn inside the firm may backfire and reduce investment efficiency. In the model, the internal information technology is captured by the probability that the manager receives a private signal, and the associated signal distribution function. Increasing the likelihood that the manager receives private information has a direct positive effect on her investment decision. In addition, an increase in the probability of receiving private signals leads to more voluntarily ex-post disclosure in equilibrium. Given that, the distortions in price informativeness caused by voluntary disclosure increase, which reduces the manager's ex-ante average ability to learn from the market. If strong enough, this indirect effect can dominate and reduce investment efficiency, as the manager is more likely to receive internal information.

The last implication of the model is related to the distinction between real and market efficiency. The former efficiency notion refers to ex-ante expected investment efficiency by the firm and the latter to market participants' ability to forecast the firm's cash flow conditional on the firm's disclosure and the information contained in the stock price. Whenever *ex-ante* disclosure is taken into account, real and market efficiency tend to move in opposite directions.[7] However, the full relationship between the two efficiency measures is more nuanced when we consider *ex-post* disclosure. Voluntary ex-post disclosure distorts the allocation of price informativeness toward states for which the manager chose to disclose her information. Real efficiency critically depends on the manager's private information combined with the additional information the market provides, which itself is influenced by the manager's disclosure decision. Thus, the model implies that the association between real and market efficiency is rather nuanced, when considering voluntary ex-post disclosure, and

[7] Indeed, when public uncertainty is maximized, the trader maximizes his effort to acquire private information and thus maximizes the manager's ability to learn from the price. Because the trader's information is only *partially* reflected in the stock price, maximizing public uncertainty with a disclosure policy minimizes market efficiency.

cautions researchers and policymakers to use market efficiency as a proxy for real efficiency.

I structure the paper as follows. In the next section, I discuss the relation to the existing theoretical literature. Section 3 describes the economic environment, the players, and potential strategies. In Section 4, I solve for the equilibrium of the trading stage and the investment subgame. In Section 5, I study the resulting ex-post optimal disclosure strategy if the manager faces long-term incentives. I describe the real and market efficiency implications of the equilibrium disclosure policy in Section 6. In Section 7, I discuss empirical implications of the analysis, and Section 8 concludes the findings.

2 Related theoretical literature

This work is related to the extensive literature on voluntary ex-post disclosure going back to, e.g., Grossman and Hart [1980], Milgrom [1981], Grossman [1981], Jovanovic [1982], Verrecchia [1983], and Dye [1985]. However, while the more recent literature considers ex-post disclosure in various contexts,[8] to the best of my knowledge, this paper is the first studying ex-post disclosure when the stock market is an endogenous source of information for the manager.

Probably the most related paper is Langberg and Sivaramakrishnan [2010], which studies the interplay of voluntary ex-post disclosure, analyst feedback, and the resulting efficiency gains through better-informed decision-making by the manager. In their model, a disclosing manager triggers analyst feedback about long-term efficient investment strategies but may be perceived as incompetent, which in turn may decrease short-term stock prices. I consider market feedback even in the case of nondisclosure, which Langberg and Sivaramakrishnan [2010] rule out. Thus, as there is no feedback after nondisclosure in Langberg and Sivaramakrishnan [2010], voluntary disclosure does not result in distortions in price informativeness

[8]Just to name a few, Acharya et al. [2011] focus on the timing of disclosures, Fu and Trigilia [2019] study ex-post disclosure in a dynamic agency model, Bond and Zeng [2019] consider disclosure when the sender is uncertain about the audience preferences, and Frenkel et al. [2020] focus on the interplay of voluntary disclosure by a firm and an analyst.

which is at the heart of my model.

My paper adds to the growing literature on how markets affect real decisions and how these real effects themselves depend on public information disclosure (see the surveys by Bond et al. [2012] and Goldstein and Yang [2015], respectively). While more informative stock prices can have multiple benefits (e.g., acting as a better monitoring devices as in Fishman and Hagerty [1989]), my paper belongs to the literature that studies an enhanced learning opportunity for managers similar to Gao and Liang [2013], Yang [2018], Goldstein and Yang [2019], Schneemeier [2019], and Smith [2020]. All of these papers assume that the information provider (in the case of my model, the manager) can commit to a disclosure policy before any information is received. By studying ex-ante disclosure policies, all of these papers do not capture the strategic nature of voluntary ex-post disclosure. In particular, the information spillover effect unique to my paper can only arise in ex-post disclosure settings, which these papers do not study.

Relatedly, it is worth commenting on the crowding-in or crowding-out role of disclosure. Disclosure crowds-in or crowds-out private information acquisition and trading efforts if it complements or substitutes the trader's information, respectively.[9] While substitute information disclosure decreases the trader's information advantage over the uninformed, complement information disclosure increases it (Boot and Thakor [2001]). Implicit in most models of the literature is that this notion is equivalent to whether the disclosure is about the same or a different random variable the trader is informed about.[10] As the models in Verrecchia [1982], Diamond [1985], and Gao and Liang [2013] feature a single asset fundamental being the only source of uncertainty, disclosure is a substitute to trader's information

[9] Boot and Thakor [2001] differentiate between i) substitute information: disclosure reveals part of the information only known to the informed trader, ii) to-be-processed complementary information: disclosure that complements the information available only to some traders, and iii) pre-processed complementary information: disclosure that complements the information of all investors. While substitute information disclosure (i) weakens private information acquisition incentives, complementary information disclosure (ii and iii) strengthens private information acquisition efforts.

[10] A different set of models features complement information disclosure where the trader's information has little or no value unless a public disclosure occurs (see, e.g. Kim and Verrecchia [1994], McNichols and Trueman [1994], Boot and Thakor [2001], and Cheynel and Levine [2020]).

and results in a crowding-out effect.[11] In contrast, Bond and Goldstein [2015], Yang [2018], and Goldstein and Yang [2019] consider multiple dimensions of uncertainty. In these papers, disclosure results in a crowding-out (crowding-in) effect in the same (other) information dimension. To some extent, my model captures both information substitutes and complements within a single dimension of uncertainty. Because the manager's and trader's information are about the same variable (the project's success probability), they are substitutes from an ex-ante perspective: Any form of disclosure reduces ex-ante *average* information acquisition of the trader. However, given my information structure with a binary payoff and a non-perfectly revealing signal, the manager's ex-post signal disclosure may increase or decrease the trader's gains from being informed. Thus, ex-post, the manager's disclosure may substitute or complement the trader's information depending on the impact the manager's information revelation has on public uncertainty.[12]

The inefficiency in my model arises, as a commitment to implement an ex-ante efficient disclosure policy is assumed to be not feasible. The finding that a lack of commitment power leads to inefficient disclosure is not new in the literature. However, the mechanisms of how the inefficiency arises is quite different. Darrough [1993], Clinch and Verrecchia [1997], Arya et al. [2010] show that in a duopoly product market, the ex-ante efficient disclosure policy generally does not realize when the manager has discretion to disclose ex-post. Guay and Verrecchia [2017] study valuation distortions arising from voluntary disclosure. Ben-Porath et al. [2018] highlight that the option to disclose good project outcomes but to conceal bad ones results in excessive ex-ante risk-taking by the manager. While the cited papers highlight how a lack of commitment power may result in various inefficiencies, the insight that it results in inefficient feedback solicitation is new.

[11] Schneemeier [2019] also considers a single dimension of uncertainty and documents a crowding-out effect of more precise public disclosure. However, a higher ex-ante commitment to more precise disclosure signals high managerial ability and, thus, on average higher firm value to investors incentivizing information acquisition.

[12] Smith [2020] considers a setting where the disclosure is informative only about the riskiness of the firm's investment. Like the outcome in my model, high (low) risk disclosure results in strong (weak) efforts to acquire information for the trader.

This paper also contributes to the literature on managerial short-termism. Among others, Narayanan [1985], Stein [1989], and, Bebchuk and Stole [1993] study the inefficiencies arising from exogenously set short-term incentives. Another part of the literature features optimal contracts that include short-term incentives (e.g., Bolton et al. [2006], Laux [2012], Peng and Röell [2014], and Piccolo [2018]). The main difference from my model is that the literature focuses on classical agency issues, while I assume no conflict of interest between shareholders and the manager. Even if not incentivized directly, the manager invests in a profit-maximizing way conditional on her information. The friction of my model is a commitment problem: Committing to an efficient ex-ante disclosure policy is not feasible, which results in inefficient disclosure. Therefore, while long-term incentives may relax standard *agency issues*, I show that there is an associated *feedback solicitation* cost. In addition, I highlight the importance of incentive contracts in determining the manager's ex-post disclosing behavior. Because the structure of the disclosure policy matters for price informativeness, incentives have real implications, as they matter for the manager's ability to learn from the market. To the best of my knowledge, this insight is new to the "short-termism" literature.

Finally, this paper contributes to the literature distinguishing market and real efficiency (see the survey by Bond et al. [2012]), given the feedback-providing role of financial markets. Most notably, the review of Goldstein and Yang [2017] discusses various real and financial market implications of pre-committed information disclosure. A general result is that better public information provision discourages private information acquisition of traders. Thus, the stock price contains less private information of traders and has negative real implications if the manager tries to learn from the price. Therefore, real and market efficiency measures tend to move in opposite directions.[13] A similar assertion also holds in my setting as a policy of full nondisclosure (full disclosure) minimizes (maximizes) market efficiency but maximizes

[13]Better public information provision always leads to less private information being aggregated by the price, which leads to a decrease of real efficiency. The implications for market efficiency, however, depend on whether the crowding-out happens on the intensive or extensive margin of private information acquisition. In cases where the crowding-out occurs on the intensive margin, better disclosure leads to higher market efficiency. See the explanations in Goldstein and Yang [2017] of Figure 3 for more details.

(minimizes) the ex-ante average degree of information acquisition by the trader.[14] In addition, this paper adds the novel perspective that the distinction between real and market efficiency is even more nuanced when taking into account voluntary ex-post disclosure.

3 Model Setup

I study an economy that consists of a single publicly traded firm, a manager (she), a market maker, a sophisticated trader (he), and a liquidity trader. There are four time periods. The firm has assets in place that yield a random payoff V in $t = 4$. The payoff may be either high $V = 1$ (with $Pr(V = 1) = \mu_0 \in (0, 1)$) or low $V = 0$. In $t = 1$, the manager has the opportunity to disclose privately learned information to the public. After the financial market has closed in $t = 2$, the firm may invest in a growth opportunity whose return is correlated with the "firm fundamental" V. The details of the disclosure stage, the financial market, the investment decision, and the payoffs of all parties are described below. All parties are assumed to be risk-neutral, and the risk-free interest rate is zero.

Essentially, my model combines a voluntary disclosure stage à la Dye [1985] and Jung and Kwon [1988], followed by a financial market similar to Kyle [1985] with endogenous information acquisition, with a standard investment choice by the manager. The trading process aggregates information from market participants and therefore provides the manager with a noisy signal about the informed trader's information.

The timeline in Figure 1 summarizes how the game unfolds:

$t = 1$**, Disclosure Subgame:**

The manager's role in this paper is to choose a disclosure strategy in $t = 1$ and to invest in a growth option in $t = 3$, based on her total information regarding the firm fundamental

[14] However, a full nondisclosure does not maximize ex-ante real efficiency. What matters for real efficiency is not the average amount of feedback provided by the stock market but the probability-weighted marginal value of feedback taking into account the manager's internal information and the probability that the manager ends up in said information state.

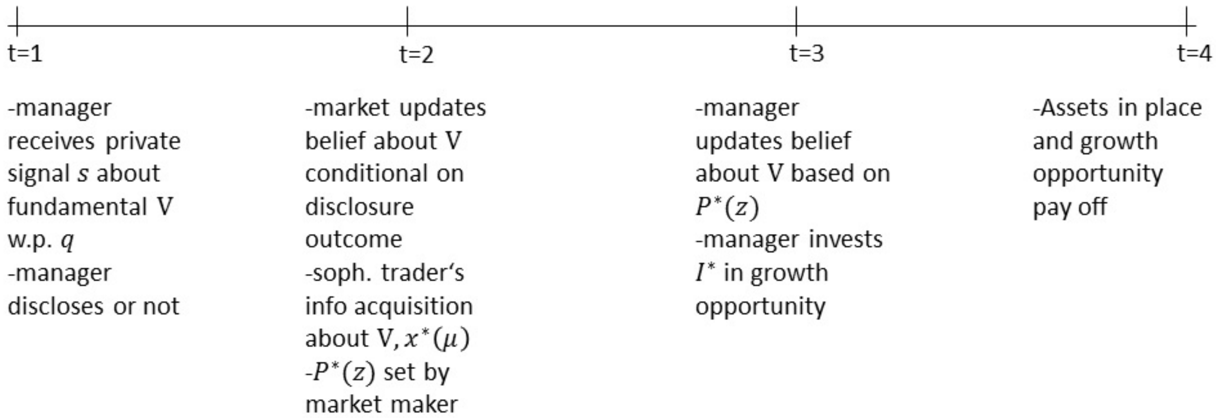


Figure 1: Timeline

V. While the majority of the theoretical literature focuses on frictions inherent in the investment process, I abstract away from any standard agency friction. I assume that the manager always invests in line with shareholders' interests in $t = 3$, conditional on her total information.[15] Thus, in this model, the degree of efficient investment is purely driven by the manager's information endowment. In turn, the manager's information at $t = 3$ depends on the information contained in the price, which the manager can influence by her disclosure decision. Thus, the sole source of potential investment distortions is a disclosure strategy that elicits an inefficient amount of information from markets.

The disclosure game is modeled as follows. With probability $q \in (0, 1]$, the manager receives a verifiable signal $s \in S = [0, 1]$, providing her with additional information about V. Both the arrival and the content of this information is assumed to be private and captures the extent to which a manager may learn about the firm's fundamental in the course of her employment. Let $\mathbb{E}[V|s] = s$, which implies that the updated belief of the fundamental is simply the signal s.[16] With probability $1 - q$, the manager does not observe any signal,

[15]Clearly, in the absence of any standard *investment* friction, including an infinitesimal weight on the return on the growth opportunity is sufficient to induce the manager to choose the profit-maximizing investment scale. In order to focus on the pure feedback production role of the contract terms, I assume that the manager's investment decision maximizes expected profits when she is indifferent.

[16]Given common risk-neutrality, this assumption is without loss of generality. It is equivalent to assuming the manager learns the signal s' and then defining $s = \mathbb{E}[V|s']$.

hence her belief about V stays at the prior μ_0. Denote the continuous pdf and cdf with full support over S as $f(s)$ and $F(s)$, respectively. I will refer to the privately informed manager who received signal s as type s.

If the manager has received a signal s, she can decide whether to disclose or conceal it. If disclosure takes place, it has to be truthful. Therefore, denote $d = \{s, \varnothing\}$ as the disclosure decision made by the manager with private signal s, where $\varnothing$ refers to the manager not disclosing her signal. If the manager did not receive a private signal, she has no option but to stay silent. In addition, the manager cannot credibly disclose the arrival of the signal (without disclosing the signal itself) or the lack thereof.

Because the manager wants to maximize profits with the investment decision, she wants to learn as much as possible from her own stock price. Therefore, the disclosure decision intends to maximize stock price informativeness and thus enhance the manager's information, which is the basis for her investment decision. Before further describing the disclosure strategy, I have to characterize trading in the stock market and the resulting price informativeness first.

$t = 2$**, Trading Subgame:**

The trading stage follows a simple version of Kyle [1985], with endogenous information acquisition. The financial market involves a competitive market maker, a liquidity trader, and a sophisticated trader. At some cost, the sophisticated trader can produce information about V. In particular, the trader chooses $x \in [0, 1]$, the probability of perfectly learning V.[17] With probability $1 - x$ the sophisticated trader receives no information whatsoever. The cost of acquiring information is captured by the cost function $\frac{k}{2}x^2$. In terms of the cost parameter k, I impose the following assumption:

Assumption 1 *The sophisticated trader's marginal cost of information acquisition is* $k \geq 1/4$.

[17] It does not matter that the trader has access to a *perfectly revealing* learning technology. The same qualitative results obtain if the trader can costly choose the precision of his private signal.

To avoid discussing various corner solutions, Assumption 1 ensures that the intensity of information acquisition is an interior value in equilibrium.

After potentially receiving information, the sophisticated trader demands y units of the asset.

The liquidity trader's order quantity is independent from the fundamental value V and arises stochastically: With equal probabilities, the liquidity trader chooses the demand $u = \{-1, 1\}$, where $u = -1(1)$ represents selling (buying) one unit of the asset.

The risk-neutral market maker sets the stock price P equal to the expectation of V, given the observed order flow $z = u + y$ and public disclosure or the lack thereof. If the orders result in a nonzero net order flow, the market maker absorbs it from his own inventory.

$t = 3$, Firm's Investment Subgame:

The manager updates her belief of V given the observed stock price P and her private information, if she has received any. She has the opportunity to invest in a project whose return is related to the true firm fundamental V. Specifically, the manager chooses the scale I of the investment opportunity by $\max_I \mathbb{E}[VI - 1/2I^2|\mathcal{I}]$ with $\mathcal{I} = \{\{s, P\}, \{P\}\}$ denoting the potential information sets of the manager that consist of the observed price P from $t = 2$ and potentially the private information s. I assume that the investment in the growth option is separate from the assets in place, is non-tradable, and is financed from retained earnings.[18] In addition, it is common knowledge that the firm has *access* to an investment project. This implies that voluntary disclosure cannot be used as a way to signal the existence about an investment project, but rather only to shape the public's belief about the project's profitability (through V).[19]

[18] The assumption of non-tradability of the growth project makes the model more tractable. Otherwise, the strategic trader would have to condition his information acquisition and trading decision on the post-trade price informativeness, which induces the manager's profit-maximizing investment decision and thus feeds back into the profit that the trader can earn (see also Subrahmanyam and Titman [1999], Foucault and Gehrig [2008], and Goldstein and Yang [2017]). As I want to focus on the pure feedback generation role of the manager's disclosure decision, I abstract away from the signaling effect a securities issuance could have here (see also Gao and Liang [2013]).

[19] Given the separation of the assets in place and the growth option, this assumption is not necessary.

$t = 4$**, Asset value realization:** V is realized, which determines the payoffs from the assets in place and the growth opportunity. All contractual payments are made.

The equilibrium solution concept is Perfect Bayesian Equilibrium, which is characterized by: 1) The informed manager's choice to disclose her private signal or not, $d^* = \{s, \varnothing\}$, which maximizes the profitability of the growth opportunity; 2) the strategic trader's choice of the intensity of information acquisition x^*, which maximizes his expected trading profit net of information acquisition costs; 3) a pricing rule $P^*(z)$ such that the market maker breaks even on average; 4) the strategic investor's expected profit maximizing trade y^*; 5) the manager's profit-maximizing investment $I^*(\mathcal{I})$ in the growth opportunity; and 6) all the players' beliefs satisfying Bayes' rule wherever they are well-defined. I denote the equilibrium values of all variables with a *.

Before solving the model, it is useful to specify commonly used terminology in my setting. The main point of the paper is how the absence of power to commit to a disclosure policy results in inefficient feedback solicitation and investment distortions. In what follows, I will use the term *optimal* to describe the ex-post equilibrium disclosure strategy by the manager, given her incentives to maximize the profits of the growth option and conditional on her potentially privately held information. In contrast, I will use the term *efficient* when evaluating disclosure policies in terms of their *real efficiency*, which I define as the ex-ante expected firm profits (in Section 6, I make the definition of *real efficiency* and *market efficiency* more explicit). Therefore, whereas *optimal* will be used in combination with *ex-post*, that is, after the manager has received private information, the notion of *efficiency* will be reserved for efficiency from an ex-ante perspective. In addition, as there are no standard agency frictions, the manager's investment decision is not subject to any standard inefficiencies. Therefore,

Because financial market participants only care about the value of assets in place, their behavior is independent of the existence of a growth option. However, this assumption would be important in a model where the growth option is part of the traded firm value.

whenever I refer to the ex-post profit-maximizing *investment decision* I refrain from using the notion of *efficient investment* used in the literature.

In addition, a more detailed comment on the model's main assumptions is due. First, in terms of the information structure, I assume the asset payoff V is binary and the manager receives a signal, that specifies a posterior belief $s = Pr(V = 1|s) \in [0, 1]$. The information structure implies that disclosure of the manager's signal may increase or decrease the uncertainty about the asset's payoff, depending on whether s is closer to $1/2$ than the prior belief. This property of my signal structure has strong empirical support, as Neururer et al. [2016] and Hann et al. [2019] find that measures of uncertainty may either increase or decrease after disclosure. In contrast, a common assumption in the literature is a normally distributed fundamental alongside some normal noise. In a "normal-normal" model where the manager receives a noisy version of the fundamental, the disclosure of such a signal reduces the posterior variance of the fundamental unambiguously across all signal realizations. Thus, while it seems intuitive that disclosure *always* reduces uncertainty, it is, in fact, a specific property of the normal distribution[20] and not supported empirically.

Second, in this paper, I highlight how voluntary ex-post disclosure distorts price informativeness and thus result in ex-ante inefficient investment-making. In modeling disclosure, I use the canonical verifiable disclosure model by Dye [1985] and Jung and Kwon [1988]. The highlighted inefficiency, however, is not specific to the verifiable disclosure technology used here but would also arise with other ex-post communication technologies. Take, for instance, the *earnings manipulation* modeling approach initiated by Stein [1989] and used in similar forms, among others by Fischer and Stocken [2004], Strobl [2013], and Gao and Zhang [2019]. Suppose the manager can "manage" his privately received signal and release a report with a literal meaning, that is, a report indicating a specified posterior belief. In this setting, all manager types would like to induce a posterior of $1/2$ with their report, as this maximizes feedback from the financial market. The resulting equilibrium, however, is

[20]See, for instance, Casella and Berger [2002] Chapter 4.2.

a standard signal-jamming equilibrium where all manager types publish a report indicating a posterior of 1/2, which is ultimately ignored by market participants. Therefore, all manager types will receive feedback given the prior belief independent of the marginal value of feedback. Similar to the outcome of my model, the disclosure or reporting strategy of an informed manager with signal s creates an information spillover effect influencing all other informed manager types. In equilibrium, manager type s does not take into account this spillover effect, which results in a real inefficiency. The inefficiency is thus caused by the lack of commitment power and not specific to the disclosure model I am using in this paper.

Finally, as in Subrahmanyam and Titman [1999], Foucault and Gehrig [2008], and Goldstein and Yang [2017], I assume that the firm shares are claims on the cash flows of the assets in place but not on the cash flows of the growth opportunity. This assumption is made for tractability and to generate closed-form solutions. In the model, the investment in the growth option depends on the information contained in the stock price. If the stock would be a claim on the growth option, the price would consist of the manager's investment in the growth option and therefore on both the investor's information conveyed through prices and the information the manager holds privately. In particular, when the manager chooses to conceal her signal, this feedback loop (the stock price affecting investment that, in turn, affects the stock price) creates a fixed-point problem that depends in a nonlinear way on the belief induced by nondisclosure and precludes closed-form solutions. By assuming that the shares are claims on the assets in place only, the share price is simply a linear function of the belief induced by disclosure or the lack thereof and thus simplifies the analysis tremendously. The main insight of the paper that the strategic nature of disclosure results in feedback externalities and thus creates real inefficiencies, however, should also hold in a setting where the shares represent claims on the growth option's payoff.[21]

[21] In the model, the trader's information acquisition effort is only a function of the asset value's variance. Given the binary asset payoff, this implies that the trader's information acquisition is inverse U-shaped in the public belief about V. Thus, the manager's incentive to disclose/withhold is symmetric around a signal of $s = \frac{1}{2}$. Incorporating the growth opportunity's pay-off would create an asymmetric trading and information acquisition behavior by the trader as highlighted by Edmans et al. [2015]. Thus, I conjecture that the resulting disclosure equilibrium also features asymmetry in terms of the types disclosing/withholding their

4 Investment and Trading Subgame

Before analyzing the disclosure strategy of the manager, let us consider the equilibrium outcomes in the investment and trading subgame.

4.1 $t = 3$ Investment Subgame Equilbrium

The information set $\mathcal{I}$ of the manager at this stage includes the observed stock price P in $t = 2$, which I describe in detail in section 4.2, and potentially her private information s. Therefore, she chooses the scale I of the investment opportunity as

$$\max_I \mathbb{E}[VI - 1/2I^2|\mathcal{I}], \tag{1}$$

with the profit-maximizing investment of $I^* = \mathbb{E}[V|\mathcal{I}]$. Given that the return on the growth option is convex in the manager's updated belief, $\mathbb{E}[G|\mathcal{I}] = \frac{1}{2}\mathbb{E}[V|\mathcal{I}]^2$, the manager wants her information about V to be as precise as possible.[22]

4.2 $t = 2$ Trading Subgame Equilibrium

For now, let's suppose the belief $Pr(V = 1) = \mu$ is exogenously given; in Section 5, I discuss how the belief $\mu(d^*)$ is driven by the outcome of the disclosure stage. The next lemma describes the equilibrium in the trading subgame.

Lemma 1 (Trading Subgame Equilibrium) *For $\mu \in (0, 1)$, the unique subgame equilibrium in the trading stage is as follows:*

1) Information acquisition: The strategic trader chooses the intensity of information acquisition of $x^*(\mu) = \frac{\mu(1-\mu)}{k}$.

2) Strategic trader's demand: The informed strategic trader who learned $V = 1$ ($V = 0$)

signal.

[22]For any prior $\mu_0 \in (0, 1)$, the manager strictly prefers any second-order stochastically dominated distribution.

trades $y^* = 1$ ($y^* = -1$) and the uninformed strategic trader chooses $y^* = 0$;

3) Price setting: The market maker sets prices as a function of observed order flow z: $P^*(2) = 1$, $P^*(-2) = 0$, and $P^*(z) = \mu$ for $z \in \{-1, 0, 1\}$.

All proofs can be found in Appendix A.

The trading subgame equilibrium is intuitive. Whenever the strategic trader receives positive or negative information, he buys or sells, respectively. As is standard in Kyle-type models, uninformed trades generate a loss on average. Thus, the strategic trader does not trade if uninformed. After observing $z = 2$ ($z = -2$), the market maker infers that the strategic trader has received conclusive evidence that $V = 1$ ($V = 0$) and sets $P(2) = 1$ ($P(-2) = 0$). After $z = \{-1, 1\}$ the market maker infers that the strategic trader is not active in the market and therefore sets the price according to his prior belief μ. Equivalently, whenever the market maker observes one buy and one sell order, either of the trades may be coming from the informed trader, and therefore the updated expectation about V stays at μ.

The intensity of information acquisition x^* is linearly increasing in the payoff variance $\mu(1-\mu)$. The gains in the trading game are related to the information asymmetry between the strategic trader and the uninformed market maker. As the asset payoff is Bernoulli-distributed, the belief that imposes the highest variance of the asset payoff is $\mu = 1/2$. Thus, at $\mu = 1/2$, the information rents that an informed trader can earn are maximized, which induces the sophisticated trader to maximize the intensity of information production. As the trading game does not feature any frictions that would result in asymmetric trading behavior (e.g., short-selling constraints), it is intuitive that x^* is symmetric around $1/2$. Furthermore, x^* is decreasing in the marginal cost of information acquisition k.

5 Disclosure Subgame

As stated in Section 4, given the manager's $t = 3$ profit-maximizing investment decision, the expected return of the growth option is $\frac{1}{2}\mathbb{E}[V|\mathcal{I}]^2$. At the disclosure stage in $t = 1$, the manager takes into account the impact of her disclosure decision d on market prices and the information she can extract from them. Thus, the manager sets her disclosure policy such that $\Psi(s, \mu(d)) \equiv \mathbb{E}_d[\frac{1}{2}\mathbb{E}[V|\mathcal{I}]^2|s]$ is maximized. As highlighted in Lemma 1, the strategic trader's information acquisition strategy depends on the market belief prior to trading. The disclosure decision d of the manager indirectly shapes price informativeness by defining the incentives of the strategic trader to acquire information. Given the informative role of the stock price, the expected return on the growth option is a function of s, the manager's private information, and the market belief $\mu(d) = \mu_d$ induced by the manager's disclosure decision.

The belief μ_d matters for the manager, as it influences her ability to learn from prices and thus for the investment decision. In particular, a manager who holds a belief of μ and induces a market belief of μ_d with her disclosure decision expects the following profit of the growth opportunity:

$$\Psi(\mu, \mu_d) = \frac{1}{2}\sum_z Pr(z|\mu)\mathbb{E}[V|\mu, P(z)]^2 = \frac{1}{2}\left(\mu^2 + \frac{1}{2}x^*(\mu_d)(\mu - \mu^2)\right). \tag{2}$$

Obviously, the expected return on the growth option is increasing in the manager's belief μ and benefits from a more informative stock price, which is captured by the sophisticated trader's intensity of information acquisition. The belief that a disclosure decision induces matters for the manager only through the intensity of information acquisition $x^*(\mu_d)$. In particular, by disclosing her signal s, the manager induces informed trading of $x^*(s)$, while nondisclosure results in feedback of the form of $x^*(\mu_\varnothing)$.

Because the manager wants to extract as much information as possible from prices, she discloses her private information s only if it induces more-informed trading than after nondisclosure. If the manager is indifferent to disclosing or not, I assume she does not disclose.[23] As standard in Dye-type disclosure models, the equilibrium is pinned down by an indifferent manager type.

Clearly, whenever the manager disclosed her private signal, the market's updated belief is also $\mathbb{E}[V|s] = s$. In contrast, whenever the manager does not disclose her signal, the market belief is (almost surely) not equal to s. Remember, the disclosure technology permits the manager to disclose or conceal her signal s. Thus after nondisclosure, all types s that chose $d^* = \varnothing$ are pooled with the manager type who did not receive any private information, which has occurred with probability $1 - q$. Therefore, the market belief after nondisclosure is characterized by

$$\mu_{\varnothing} = \frac{(1-q)\mu_0 + qPr(s \in \Omega)\mathbb{E}[V|s \in \Omega]}{1 - q + qPr(s \in \Omega)}, \tag{3}$$

with $\Omega \subseteq [0, 1]$ being an arbitrary set of manager types s who conceal their signal.

As Lemma 1 shows, the sophisticated trader's degree of information acquisition x^* is linearly increasing in the payoff variance implied by the public belief μ_d. Because the public's perceived variance of the binary distributed asset V is $\mu_d(1 - \mu_d)$, the types s and $1 - s$ will induce the same degree of information acquisition by disclosing or withholding their signals. Therefore, the disclosure equilibrium features two symmetric thresholds, as Proposition 1 describes.

Proposition 1 (Disclosure Subgame Equilibrium) *For $q \in (0, 1)$, there exists a unique equilibrium in the disclosure subgame, which is characterized by two thresholds s_1^* and s_2^*.*

[23]The indifference assumption only matters for realizations of S with zero measure. I will discuss this in detail once I solve for the disclosure equilibrium in Proposition 1.

An informed manager withholds her signal s, if and only if, $s \in \Omega^*$, with

$$\Omega^* = \begin{cases} [0, s_1^*] \cup [1 - s_1^*, 1], & \text{for } \mu_0 < 1/2 \\ [0, 1], & \text{for } \mu_0 = 1/2 \\ [0, 1 - s_2^*] \cup [s_2^*, 1], & \text{for } \mu_0 > 1/2. \end{cases}$$

The disclosure thresholds are given by the solutions to the following conditions:

$$\begin{aligned} s_1^* &= \frac{(1-q)\mu_0 + q(\int_0^{s_1^*} sf(s)ds + \int_{1-s_1^*}^1 sf(s)ds)}{(1-q) + q(\int_0^{s_1^*} f(s)ds + \int_{1-s_1^*}^1 f(s)ds)} < \mu_0 \\ s_2^* &= \frac{(1-q)\mu_0 + q(\int_0^{1-s_2^*} sf(s)ds + \int_{s_2^*}^1 sf(s)ds)}{(1-q) + q(\int_0^{1-s_2^*} f(s)ds + \int_{s_2^*}^1 f(s)ds)} > \mu_0 \end{aligned} \tag{4}$$

The corner types $s = \{0, 1\}$ are indifferent and, by assumption, do not disclose.

For $q = 1$ there exists an equilibrium that has the same structure as above iff $f(1) > 0$ for $\mu_0 < 1/2$ ($f(0) > 0$ for $\mu_0 > 1/2$).

The black dashed line in Figure 2 illustrates the degree of information acquisition of the strategic trader x^* as a function of any belief in $[0, 1]$. The preference of the manager is to maximize the profit of the growth option and thus to elicit as much market feedback as possible. Feedback is maximized at an induced belief of $1/2$ and symmetrically declines, with an increasing distance to $1/2$. Clearly, after receiving $s = 1/2$, disclosure is an optimal strategy for the manager, as it results in highest degree of feedback possible.

The equilibrium is pinned down by the type that is indifferent between disclosing and not, that is, the type that induces the same belief after disclosure and nondisclosure. Suppose $\mu_0 > \frac{1}{2}$, which by Proposition 1 implies that the indifferent manager type is $s_2^* > \mu_0$. Every type $s \in (1 - s_2^*, s_2^*)$ induces more uncertainty into the market by disclosure than with nondisclosure. For types $s \notin (1 - s_2^*, s_2^*)$, the converse is true. All types that by disclosure would induce a more certain belief, that is, types that are closer to the extremes than $1 - s_2^*$

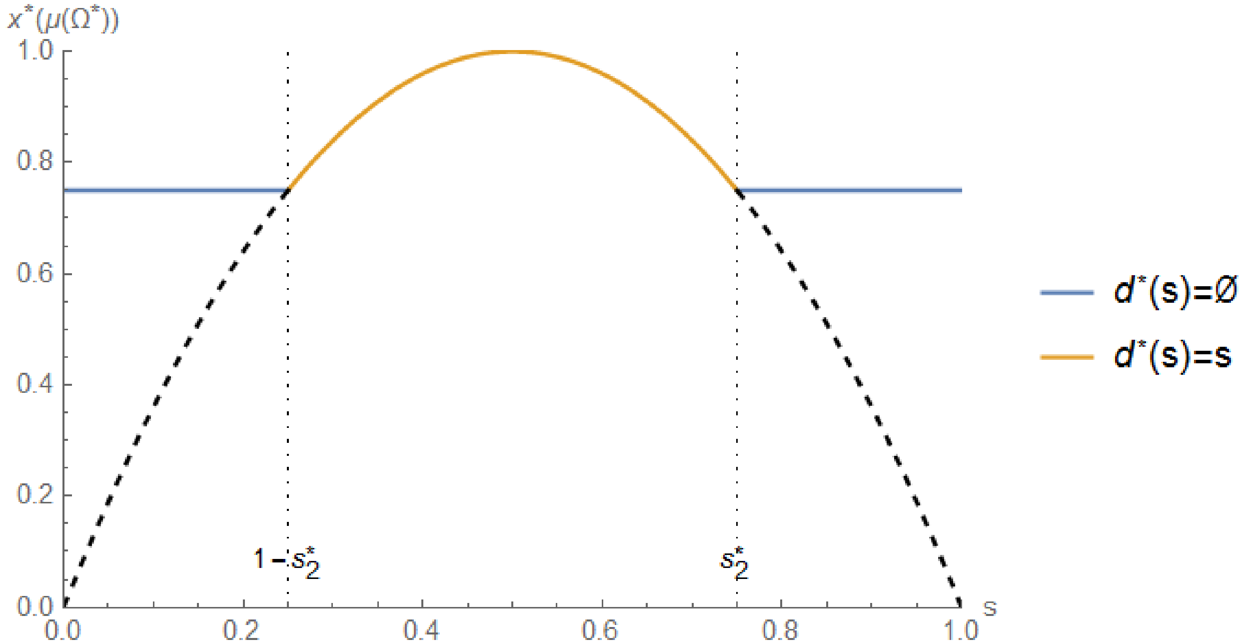


Figure 2: Equilibrium-induced informed trading
The figure shows the degree of information acquisition of the strategic trader after the disclosure equilibrium materialized. In terms of parameters, I used $q = 4/5$ and $k = 1/4$. For the internal signal distribution, I assumed $f(s) = 2s$. Together, these assumptions result in $s_2^* = 3/4$.

or s_2^*, are better off withholding and inducing the more uncertain belief of $\mu_\varnothing^*$. Given that, the equilibrium is characterized by disclosure of types $s \in (1 - s_2^*, s_2^*)$ and nondisclosure by the remaining types. Figure 2 visualizes the degree of feedback disclosing (orange line) and nondisclosing (blue line) manager types induce in equilibrium.

Note that the equilibrium structure prevails also for $q = 1$, given the distributional properties of $f(s)$ outlined in Proposition 1.[24] In those instances, the fixed-point problem in equation 4 has an interior solution, which implies that the symmetric threshold property of the equilibrium continues to hold.

[24]Naturally, for $q = 1$, there always exists an unraveling equilibrium. For an appropriately specified off-equilibrium belief (e.g., $\mu_\varnothing = 0$), all types are better off disclosing their signal. However, in contrast to most models of strategic communication, in my model there also exists an equilibrium featuring nondisclosure - without using the common assumptions of costly disclosure (Grossman and Hart [1980] and Jovanovic [1982]) or the impossibility of disclosure for some types (Dye [1985]). The reason is that the sender's payoff from disclosing/nondisclosing is not monotone in the induced posterior (see Lemma 3). Okuno-Fujiwara et al. [1990] study sender payoff monotonicity and the implications for unravelling. Relatedly, Bond and Zeng [2019] show another way how "silence" can be part of the disclosure equilibrium. If the sender is risk-averse and uncertain about the receiver's preferences over her messages, the sender is safest not to communicate at all.

If a manager type is indifferent to disclosing or not, I assume that the manager withholds her information. When changing the tie-breaking assumption, the equilibrium from Proposition 1 changes only for a measure zero set of types. The types that are indifferent are the corner types of $s \in \{0, 1\}$, and the threshold manager types $s \in \{1 - s_2^*, s_2^*\}$ (for $\mu_0 > \frac{1}{2}$). Indeed, with the new assumption on the behavior of indifferent types, the equilibrium changes to $\Omega^* = (0, 1 - s_2^*) \cup (s_2^*, 1)$.

It is crucial to keep in mind that the disclosure choice of the manager is optimal conditional on her individual signal realization and on the equilibrium disclosure strategies of all other manager types. Thus, while the disclosure choice of manager type s is optimal for her, it indirectly also has an impact on all other manager types because it influences the updating process of investors after nondisclosure according to Equation 3. The optimal disclosure choice of s results, in some sense, in an *information spillover* effect influencing all other potential manager types that could have been realized. This *information spillover* is at the heart of the paper. In fact, it turns out that the types choosing to disclose in equilibrium *reduce* the degree of market feedback, nondisclosing types are able to receive. The next proposition formalizes this finding.

Proposition 2 (Negative Information Spillover) *In an equilibrium that features partial disclosure (i.e., $\Omega^* \notin \{\{\}, [0, 1]\}$),*

i) voluntary disclosure results in a negative information spillover harming price informativeness after nondisclosure: $x^*(\mu_\varnothing^*) < x^*(\mu_0)$;

ii) the negative information spillover effect gets more severe for an increase in q: $\frac{dx^*(\mu_\varnothing^*)}{dq} < 0$; and

iii) the ex-ante expected degree of market feedback following the disclosure equilibrium Ω^* is lower than under a full nondisclosure policy.

Remember, in equilibrium, the manager discloses signal realizations which result in high posterior variance estimates about V and thus in high information acquisition efforts by the trader. In contrast, the manager chooses to withhold signals that would result only in a small degree of public uncertainty after disclosure. Clearly, the public rationally takes into account which signals the manager discloses or withholds in equilibrium. Therefore, voluntary disclosure of types $s \in \{1 - s_2^*, s_2^*\}$ (for $\mu_0 > \frac{1}{2}$) creates an informational spillover effect influencing the feedback nondisclosing manager types can receive. Given that managers with signals that would induce a high posterior variance will disclose in equilibrium, the public assesses the payoff variance to be relatively low after observing nondisclosure. The consequence of the informational spillover effect is thus negative for nondisclosing types: The degree of feedback after nondisclosure in equilibrium ($x^*(\mu_\varnothing^*)$) is lower compared to the degree of feedback given a policy of full nondisclosure ($x^*(\mu_0)$). Thus, voluntary disclosure *crowds-out* private information acquisition efforts upon *nondisclosure*.

The negative consequence of the information spillover effect worsens if the manager is more likely to be informed. Note, the nondisclosure belief $\mu_\varnothing$ is a mixture of the prior belief μ_0 and the average type of withholding managers. Intuitively, as the probability that the manager has received private information increases, the nondisclosure belief is more sensitive to the strategic behavior of the informed manager types. Thus, more manager types find it optimal to disclose in equilibrium, which depresses even further the degree of feedback after nondisclosure.

Voluntary disclosure of some manager types does not only have an adverse effect of the degree of feedback that nondisclosing types can achieve it also depresses the ex-ante average intensity of information acquisition by the strategic trader. The last property of Proposition 2 shows that the average degree of feedback is reduced compared to a policy of full nondisclosure. This property is similar in flavor to the prominent crowding-out effect of public information provision on private information acquisition efforts shown in the literature (see Goldstein and Yang [2017] for a review). However, in a setting of *voluntary ex-post* disclosure the channel how crowding-out occurs is more nuanced. Here, ex-post disclosure results in crowding-in of information acquisition by the strategic trader. Intuitively, if disclosure would not result in higher market feedback, the manager would not care to disclose her signal. Therefore, in a voluntary disclosure setting, disclosure crowds-in private information from an ex-post perspective. A side effect of this crowding-in from disclosing manager types is the described information spillover diminishing feedback after nondisclosure. In addition, from an ex-ante perspective, voluntary ex-post disclosure reduces the average degree of information acquisition by the trader. Therefore, from an ex-ante perspective voluntary (ex-post) disclosure also features an average crowding-out effect.

A policy of full nondisclosure maximizes the ex-ante expected intensity of informed trading and thus provides on average the highest degree of feedback. Does this mean that such a policy results in the highest expected firm value? Not necessarily. Equation 2 highlights that the marginal benefit is not constant across manager types. Therefore, ex-ante firm profits are a function of: i) the degree of feedback a manager type receives, ii) the marginal benefit this feedback provides in terms of more efficient decision-making, and iii) the probability that the manager ends up in this information state.

In particular, the firm's ex-ante profit given any disclosure policy Ω can be written as

$$\zeta(\Omega) \equiv (1-q)\Psi(\mu_0, \mu_\varnothing) + q\left(\int_\Omega \Psi(s, \mu_\varnothing) f(s) ds + \int_{\Omega^C} \Psi(s, s) f(s) ds\right), \tag{5}$$

with $\Omega^C = [0,1] \setminus \Omega$ being the set of states that are disclosed.

The manager receives no private information with probability $1-q$, and thus $d^* = \varnothing$ mechanically. In this case, however, the manager still is able to learn from the stock price, so the induced market belief of $\mu_\varnothing$ matters. With probability q, the manager receives private information in form of the signal realization s and the feedback induced by either s or $\mu_\varnothing$, depending on whether type s discloses or not.

In the next section, I analyze efficiency implications of the equilibrium and compare it to alternative disclosure policies.

6 Efficiency Implications

The discussion in the previous section shows that any disclosure policy matters for ex-ante profits in terms of how the feedback of the market is distributed across manager types. A central role plays the internal signal distribution function $f(s)$. Therefore, in order to study efficiency implications of the equilibrium disclosure policy, more structure on the function is necessary.

In particular, I make the following assumption on the internal signal distribution:

Assumption 2 *The manager's private signal s is distributed according to $f(s) = 2s$. Thus, $\mu_0 = \frac{2}{3}$.*

Given Proposition 1, $s_2^* > \mu_0 = \frac{2}{3}$. For brevity, in what follows I will define the threshold $s_2^* = s^*$.

Assumption 2 confines the distribution of internal signals to be a simple linear function of s. The distributional assumption does not matter qualitatively for the results of the paper, however, allow me to present more results in closed form. In Appendix B, I provide affirmative numerical and, whenever possible, analytical results given alternative distributions of the internal signal.

In order to study the implications of a disclosure policy Ω, I focus on two widely used measures of efficiency.

Definition 1 (Efficiency Measures) *Real and market efficiency of a disclosure policy Ω are defined as*

1. *Real efficiency:* $RE(\Omega) \equiv \zeta(\Omega)$
2. *Market efficiency:* $ME(\Omega) \equiv -\mathbb{E}_\Omega \left[\frac{Var(V|P,d)}{Var(V)}\right]$.

I define real efficiency (RE) as the ex-ante expected profit of the growth option. As Equations 5 and 3 show, the disclosure policy specifies which privately informed manager types receive feedback as a function of their privately held belief s and which types receive feedback as a function of the induced nondisclosure belief $\mu_{\varnothing}$. Thus, the policy Ω has two implications on RE. First, Ω determines which nondisclosure belief $\mu_{\varnothing}$ is induced and therefore determines the intensity of informed trading for all nondisclosure states, including the situation where the manager did not receive any internal information. Second, Ω defines which private information states s are concealed in order to induce said $\mu_{\varnothing}$. Given this dual role of Ω, RE is maximized if feedback from financial markets is spread efficiently among the information states at which the manager may end up.

The definition of market efficiency (ME) captures the informational content of public information to predict the firm fundamental V. In particular, the measure is calculated as the negative fundamental variance conditional on the stock price and the disclosure outcome $Var(V|P,d)$, scaled by the unconditional fundamental variance. Ω influences market beliefs in terms of the price-setting behavior of the market maker as well as the information acquisition and trading decisions of the strategic trader. However, in contrast to RE, ME does not take into account a potentially received private signal of the manager.

To put the efficiency aspects of the disclosure equilibrium in perspective, consider two natural disclosure benchmarks. First, full disclosure $\Omega_{FD} \equiv \{\}$ where the manager mechanically discloses her signal, $d(s) = s \ \forall s \in S$, and full nondisclosure $\Omega_{ND} \equiv [0,1]$ where all signals are withheld.

I start with the analysis of real efficiency implications of the different disclosure policies Ω.

6.1 Real Efficiency

Note that both under full disclosure Ω_{FD} and full nondisclosure Ω_{ND} the observation of $d = \varnothing$ is not informative any more as all manager types behave in the same way. Therefore, $\mu_{\varnothing} = \mu_0 = 2/3$ for both Ω_{FD} and Ω_{ND}.

The next proposition ranks the two benchmark disclosure policies - full disclosure and full nondisclosure - and the equilibrium disclosure outcome in terms of real efficiency.

Proposition 3 (RE of Equilibrium, Full Disclosure, and Full Nondisclosure) *The disclosure policies can be ranked in terms of real efficiency as:* $\zeta(\Omega_{FD}) \leq \zeta(\Omega^*) \leq \zeta(\Omega_{ND})$.

Given distributional Assumption 2, full nondisclosure results in higher RE than full disclosure for any q.[25] As already outlined, the nondisclosure belief for Ω_{FD} and Ω_{ND} in both cases is $\mu_\varnothing = 2/3$. Thus, after nondisclosure, all managerial types s receive feedback of the form of $x^*(2/3)$ while all types after disclosure receive $x^*(s)$.

Comparing the two benchmark policies, all types $s \in (1/3, 2/3)$ would strictly benefit from disclosure compared to nondisclosure. In addition, these types with relatively uncertain private signals benefit more from a marginal increase in feedback compared to the types $s \notin (1/3, 2/3)$ with more certain private information (see Equation 2). Given the distributional assumption 2, however, the types in the middle region have a relatively low probability-mass compared to the types $s \notin (1/3, 2/3)$.[26] From an ex-ante real efficiency point of view, the high probability that the types in $s \notin (1/3, 2/3)$ occur dominates the effect that the types in $s \in (1/3, 2/3)$ have a higher marginal value of feedback. By that, a full nondisclosure policy dominates the full disclosure benchmark in terms of RE.

As the comparison between Ω_{ND} and Ω_{ND} shows, in order to determine the real efficiency of a disclosure policy, we have to keep in mind the marginal benefit of the induced feedback for every manager type and the probability that such manager type is realized.

The same reasoning applies to real efficiency of the equilibrium disclosure policy. As already outlined above, all types $s \in (1 - s^*, s^*)$ prefer to disclose, as these types receive higher feedback after disclosure than after nondisclosure. From an ex-ante perspective, the voluntary disclosure of these types harms real efficiency, however, as they have an adverse

[25] Without Assumption 2, there exist $\mu_0 \in (0, \epsilon) \cup (1 - \epsilon, 1)$ for small $\epsilon > 0$, for which $\zeta(\Omega_{FD}) > \zeta(\Omega_{ND})$. Indeed, as shown in Appendix B.2, for sufficiently extreme priors, $\zeta(\Omega^{FD}) > \zeta(\Omega^{ND})$. Intuitively, for very certain priors, that is μ_0 close to 0 or 1, the degree of feedback conditional on nondisclosure is negligible. In this situation, it is preferable to always disclose the private signal distribution s, as this ensures a higher intensity of informed trading for most of the state realizations. Another way to see that $\zeta(\Omega_{FD}) > \zeta(\Omega_{ND})$ may occur is that the expected profit given a disclosed private signal s is proportional to $s^2(1 - s)^2$ which is convex near the corner realization of s while concave otherwise.

[26] Indeed, the types preferring disclosure occur with probability $\int_{1/3}^{2/3} 2s ds = 1/3$ while the types preferring nondisclosure have a probability of 2/3 of occurring.

impact on the nondisclosure belief $\mu_{\varnothing}$. In particular, the disclosure by types $s \in (1-s^*, s^*)$ pushes the equilibrium nondisclosure belief further away from 1/2 which in turn, reduces the degree of feedback all nondisclosing types can achieve. Again, as the realization of types in $s \notin (1-s^*, s^*)$ is relatively likely, the efficiency losses incurred by the nondisclosing types outweighs the efficiency gains from the disclosing types.

Surprisingly, the distortions occurring in equilibrium can even result in situations where an increase in q, the probability that the manager receives firm-inside information, reduces ex-ante firm profits and thus real efficiency.

6.1.1 Implications of Better-Informed Manager

An increase of the probability that the manager receives internal information has two effects on real efficiency. First, - holding constant the equilibrium disclosure policy which ensures the same degree of feedback for every manager type - it has the direct benefit that the manager bases her investment, on average, on better internal information. Second, an increase in q changes the disclosure equilibrium and thus the distribution of market feedback across manager types. I will refer to the first effect as the direct effect and to the latter as the indirect effect.

As the next proposition highlights, the direct effect of an increase in q is positive while the indirect effect is negative. Interestingly, the indirect negative effect can dominate which implies that an increase in q can lead to a reduction in real efficiency.

Proposition 4 (Lower RE with better-informed manager) *An increase in q always results in a positive direct effect and a negative indirect effect on real efficiency:*[27]

$$\frac{d\zeta(q;s^*)}{dq} = \underbrace{\frac{\partial \zeta}{\partial q}}_{\textit{direct effect}>0} + \underbrace{\frac{\partial \zeta}{\partial s^*}\frac{\partial s^*}{\partial q}}_{\textit{indirect effect}<0} .$$

[27]Note, the ex-ante profit function here is characterized as $\zeta(q;s^*)$ instead of $\zeta(\Omega^*)$ as in the main text. In fact, the precise formulation of ex-ante profits is $\zeta(q;\Omega^*(q,s^*), s^*(q,\Omega^*))$.

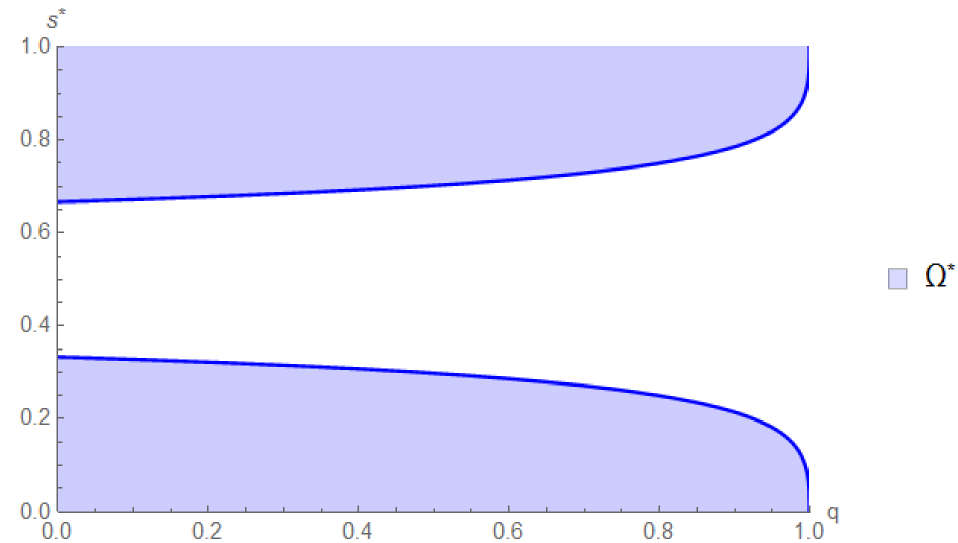


Figure 3: Equilibrium nondisclosure beliefs and regions
The blue curves represent the nondisclosure belief thresholds $1 - s^*$ and s^*. The shaded region represents the equilibrium nondisclosure region Ω^*.

Combined, real efficiency decreases in q, $\frac{d\zeta(q;s^*)}{dq} < 0$*, iff* $q \in (\bar{q}, 1)$ *and* $k \in [\frac{1}{4}, \bar{k})$.

Intuitively, holding constant the disclosure equilibrium s^*, an increase of q results in the manager being more likely to receive private information according to the internal signal technology described by $f(s)$. Thus, on average, the manager bases her investment decision on more internal information, while the amount of information from the market is kept constant. Given that the profit of the growth option in convex in the manager's belief, this increases ex-ante profits and thus real efficiency.

Whenever the manager discloses her information optimally, that is, as in Proposition 1, an increase in q changes the disclosure equilibrium. In particular, as implied by Proposition 2 part ii), the manager type that is indifferent between disclosing or not is pushed away from $\frac{1}{2}$. Ultimately, this leads to a reduction of the degree of feedback all nondisclosing manager types receive. In effect, the newly disclosing types strengthen the negative information spillover effect. Therefore, as Proposition 4 shows, an increase in q leads to a negative indirect effect.

Figure 3 displays the the disclosure equilibrium along q. The nondisclosure region Ω^* is decreasing while the nondisclosure belief $s^* > 1/2$ is increasing in q in line with Proposition

2 ii). The indirect effect is driven by the extent of how q changes the nondisclosure belief $\mu_\varnothing = s^*$. Especially for high q, the equilibrium nondisclosure belief s^* changes dramatically. The result is a large negative indirect effect as the information the manager can extract from the market is distorted to a large extent. Thus, if the feedback-providing role of the market is sufficiently important for the manager, the negative indirect effect may outweigh the positive direct effect of an increase in q. Indeed, for k not too large, the market is sufficiently informative which, in combination with a sufficiently high q, results in decreasing real efficiency along q.

Another potential counter-intuitive result that follows from the inability to commit to a disclosure policy relates to the implication different incentives have on real efficiency. In fact, the next section shows that a disclosure policy based on short-term incentives can dominate the equilibrium disclosure policy in terms of real efficiency.

6.1.2 Comparison with short-term incentives

Neither the manager, nor shareholders have power to commit to a disclosure policy. However, in the model, shareholders have two means of incentivizing the manager which drive equilbrium disclosure choices and therefore real efficiency. First, the stock price that realizes at the end of $t = 2$ and second the profit from the scale investment realized in $t = 4$.[28] In the following, I will refer to the first as *short-term* and to the latter as *long-term* incentives.[29]

Essentially, the disclosure equilibrium I have characterized in Section 5 results from long-term incentives. Conditional on having received an internal signal s, the manager discloses

[28] The manager has no means of influencing the payoff from the assets in place. Thus, it does not make sense to use these payoffs in incentivizing the manager.

[29] The term *long-term* incentive needs some discussion in my model. Long-term incentive are, in principle, defined as incentives maximizing long-term profits. In contrast to the standard contracting literature, the inefficiencies in my model do not arise due to frictions in the investment behavior of the manager but because of a disclosure strategy eliciting a potentially inefficient amount of feedback. While in other models it is usually sufficient to eliminate investment frictions by writing contracts on the long-term profits, this is not the case in my model. Thus, while the term *long-term* incentives usually implies both contracting on the long-term profit as well as *long-term* efficient investment, this dual connotation does not hold in my case. Here, the term *long-term* just means incentives based on the *long-term* growth option's payoff without an implication of efficiency.

or conceals her signal to elicit as much feedback as possible and invests optimally given the combined information from the internal signal and market feedback.

Now, what disclosure equilibrium occurs if the manager does not care about the investment in the growth opportunity and just tries to maximize valuation in the stock market in $t = 2$? Lemma 2 characterizes the disclosure equilibrium with short-term incentives.

Lemma 2 (Disclosure Equilibrium with Short-Term Incentives) *In the disclosure game where the manager maximizes her expected stock price, the unique disclosure equilibrium is characterized by $\Omega^*_{ST} \equiv \Omega = [0, s^*_{ST}]$. The manager conceals all signals $s \leq s^*_{ST}$ and discloses them otherwise. s^*_{ST} is the unique minimum nondisclosure belief which can be induced by any disclosure policy Ω.*

Lemma 2 is an extension of Frenkel et al.'s (2020) Proposition 3 with endogenous information acquisition by the informed trader, which itself is an extension of Dye [1985], Jung and Kwon [1988], and Acharya et al. [2011].

The nondisclosure belief is characterized by Equation 3 with $\Omega = [0, s^*_{ST}]$. As is standard in equilibria with threshold strategies, the manager with internal information $s = s^*_{ST}$ is indifferent between disclosing or not, as the nondisclosure belief is $\mu_\varnothing = s^*_{ST}$. Thus, all managers with signals $s \leq s^*_{ST}$ withhold while $s > s^*_{ST}$ disclose their signals.

The disclosure strategy maximizes the expected stock price realizing in $t = 2$. However, even though not taken into account by the myopic manager, her disclosure choice has an impact on price informativeness. In particular, after observing the stock price, the manager updates her belief and faces the opportunity to invest in the growth option.

Note the difference between short-term and long-term incentives in terms of the manager's decisions. In the absence of any standard agency frictions, the manager with short-term incentives is indifferent between all *investment decisions* I. Therefore, I assume the manager always invests in a profit-maximizing way. Thus, the only difference between the two incentive schemes arises in terms of the disclosure strategy. Whereas short-term incentives induces

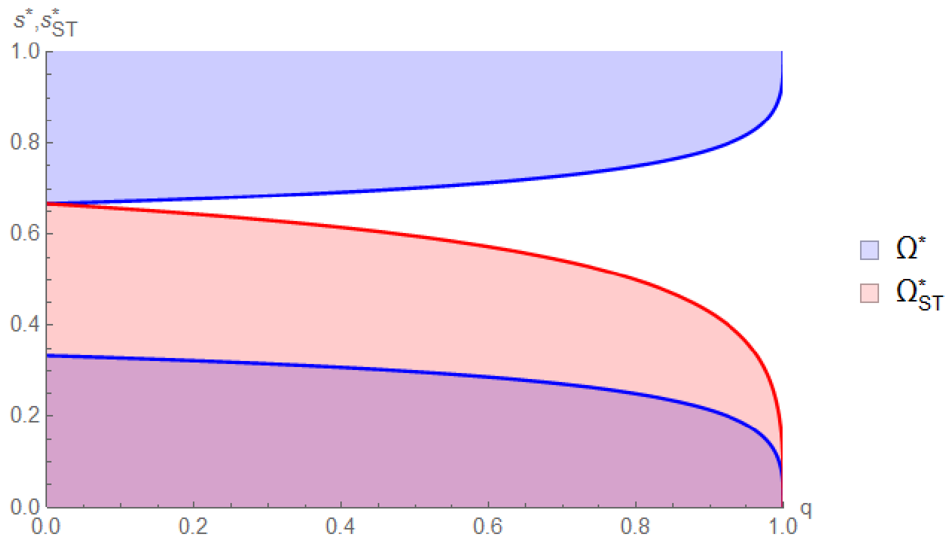


Figure 4: Disclosure equilibria given short-term incentives Ω^*_{ST} and long-term incentives Ω^*

the manager to maximize the firm's valuation given her private information, for long-term incentives the manager maximizes the information she can extract from the market with her disclosure decision. Therefore, any efficiency comparison between short-term and long-term incentives discussed here abstracts away from standard *investment inefficiencies* induced by short-term incentives.[30]

Figure 4 illustrates the different disclosure equilibria Ω^*_{ST} and Ω^* given short-term and long-term incentives, respectively.

While long-term incentives maximize stock price informativeness and the feedback generation by market prices, they do so only ex-post. As already mentioned, this results in a real inefficiency from an ex-ante perspective.

Despite aiming at maximizing short-term valuation in the market, the disclosure policy that follows from short-term incentives Ω^*_{ST} also shapes price informativeness and thus matters for RE. In fact, as Proposition 5 in combination with Corollary 1 shows, there exist situations where a short-term contract is preferable in terms of real efficiency.

Proposition 5 (Higher RE with Short-term Incentives than Full Nondisclosure) *The disclosure policy induced by short-term incentives results in higher real efficiency than*

[30] See, e.g., Narayanan [1985], Stein [1989], Bebchuk and Stole [1993], or Ben-Porath et al. [2018].

full nondisclosure, that is $\zeta(\Omega^*_{ST}) > \zeta(\Omega^*)$*, iff* $q \in (0, q^{ST})$*.*

The intuition behind the result in Proposition 5 is similar to the one associated with Proposition 3. As Figure 4 illustrates, for not too high q, the short-term policy induces a higher degree of feedback conditional on nondisclosure compared to a policy of full nondisclosure. By that, all $s \in (0, \frac{2}{3})$ receive a higher degree of feedback under Ω^*_{ST} than under Ω_{ND}. Their joint probability-weighted marginal benefit of feedback outweighs the one of types $s \in (\frac{2}{3}, 1)$ who benefit under a full nondisclosure policy. Therefore, for $q < q^{ST}$, the short-term policy dominates a policy of full nondisclosure in terms of real efficiency.

Corollary 1 *For* $q \in (0, q^{ST})$*, the disclosure policy induced by short-term incentives results in higher real efficiency than the policy induced by long-term incentives.*

The same reasoning also applies when comparing the long-term with the short-term disclosure policy. As Figure 4 illustrates, s^*_{ST} is almost everywhere closer to $1/2$ than s^* which implies that in these situations the nondisclosing types receive higher feedback under the short-term compared to the long-term disclosure policy. The voluntary disclosing behavior of some manager types given long-term incentives results in an information spillover effect which reduces $x^*(\mu^*_\varnothing)$. In contrast, under short-term incentives, the negative consequences of the information spillover effect is less severe or even becomes positive. Take for instance the region where $s^*_{ST} > 1/2$. In this situation, nondisclosing types would benefit from more disclosure from high manager types as this would push the nondisclosure belief ever closer to $1/2$ and thus increase stock market feedback. Thus, voluntary disclosure given short-term incentives may even result in an information spillover effect which increases feedback after nondisclosure.

For a large enough q, however, the consequence of the spillover effect turns negative as the short-term equilibrium approaches unraveling and the nondisclosure belief moves further away from $1/2$. Thus, for $q \in (q^{ST}, 1)$, the advantage of a long-term policy dominates. In particular, for large enough q, the probability that types in $s \in [s^*, 1]$ realize is quite high and therefore their marginal benefit of feedback matter to a large extent for overall efficiency. In these situations the disclosure policy given long-term incentives ensures more efficient feedback compared to the short-term policy.

As the results in this section show, the implications of different disclosure policies on real efficiency are rather nuanced and generate potentially counter-intuitive results. In the next section I turn to another commonly used efficiency measure, market efficiency, and study the implications of the described disclosure policies.

6.2 Market Efficiency

Proposition 6 (Market Efficiency) *The disclosure policies can be ranked in terms of market efficiency as follows:*

$$ME(\Omega_{ND}) \leq ME(\Omega^*) \leq ME(\Omega^*_{ST}) \leq ME(\Omega_{FD}).$$

Proposition 6 captures the widely acknowledged market efficiency aspect of better disclosure. Among all disclosure policies, full disclosure maximizes and full nondisclosure minimizes market efficiency as the former (latter) results in the lowest (highest) expected payoff variance V conditional on the disclosure outcome d and resulting stock price.

The expected conditional variance of the long-term disclosure policies is higher than of the short-term policy. Due to the pooling of "corner types" by nondisclosure and the disclosure of "middle" types $s \in (1-s^*, s^*)$, the expected conditional variance induced by the long-term disclosure policy is higher than under the short-term policy. Under the short-term disclosure policy, the pooling of nondisclosing types features only one region and disclosure occurs at relatively certain types, i.e. $s \in (s^*_{ST}, 1]$ as opposed to types in the middle region as in the long-term disclosure policy. Combined, the overall average expected variance is lower for the short-term disclosure policy which results in higher market efficiency.

Again, market efficiency is directly related to the expected conditional payoff variance a disclosure policy induces. As the intensity of informed trading x^* is linearly increasing in the pay-of variance (see Lemma 1), the disclosure policy that induces the highest expected conditional variance also induces the highest degree of informed trading and most informative stock prices in expectations. While important for real efficiency, it also matters how the degree of information acquisition of traders is distributed among the manager's private information states. Therefore, while the full nondisclosure policy induces the highest degree of *expected* information acquisition it does not necessarily imply that the nondisclosure policy dominates in terms of real efficiency. Therefore, the model stresses a general disconnect between market and efficiency measures. In particular, even if disclosure policies can be ranked in terms of market efficiency, implications for real efficiency do not need to follow.

The next section summarizes the theoretical insights of the model and provides corresponding empirical implications.

7 Empirical Implications

The implications of the disclosure equilibrium may be interpreted literally and figuratively. The former view compares voluntarily disclosing firms with nondisclosing ones. In contrast, taking the model's implications figuratively means that firms with precise internal information disclose their private information with some added "noise," which increases uncertainty of market participants relative to disclosing the internal information without noise. Remember, in equilibrium, firms with precise information (i.e., close to the conclusive signal of $s = 0$ or $s = 1$) pool by choosing "nondisclosure" and thus add endogenous noise to their private information. Here, I discuss the empirical implication under a literal interpretation; however, the same predictions follow under the figurative view.

The model speaks to several different empirical findings in the literature and provides associated predictions.

Post-disclosure price effects:

While the bulk of the theoretical literature[31] predicts that firms voluntarily disclose their private information to improve their market valuation, the empirical evidence of market reactions upon disclosure is rather mixed (see, e.g., Frankel et al. [1995], Lang and Lundholm [2000], and Kothari et al. [2006] for a positive valuation effect of voluntary disclosure and Kross et al. [2011] and Anilowski et al. [2007] for studies finding a negative market reaction). As Proposition 1 shows, the disclosure threshold s^* in equilibrium is always higher than the prior belief if the manager tries to maximize the feedback from financial markets. Thus, for manager types $s \in (1 - s^*, 2/3)$, the voluntary disclosure of the internal information leads to a decrease in the public belief and ultimately an expected decrease of the stock price. Similarly, all types $s \in (2/3, s^*)$ who disclose in equilibrium induce a higher stock price on average. Thus, if the manager uses voluntary disclosure to induce stock market feedback, the enduring empirical regularity of mixed market reactions upon voluntary disclosure can be explained.

Post-disclosure measures of uncertainty:

The second empirical implication refers to the posterior uncertainty upon disclosure. In the model, the manager discloses only if the resulting uncertainty in the market is higher relative to nondisclosure. Neururer et al. [2016] and Hann et al. [2019] find that the disclosure of earnings innovations may increase or decrease the uncertainty in the market depending on the signal that is being published. This also holds in the equilibrium Ω^*, as post-disclosure uncertainty may increase (for disclosing types $s \in (1/3, 2/3)$) or decrease (for disclosing types $s \in (1 - s^*, 1/3) \cup (2/3, s^*)$) relative to the prior uncertainty. Admittedly, as opposed to my model, Neururer et al. [2016] and Hann et al. [2019] consider a *mandatory* disclosure setting. Nevertheless, the findings by those two papers confirm my modeling choices of a binary asset payoff and a continuous distribution of the manager's internal information, which implies that uncertainty may increase or decrease post-disclosure, depending on the specific signal being disclosed.

[31] See, e.g., Dye [1985], Verrecchia [1983], and the literature that followed.

In addition, my model also speaks to uncertainty measures after *voluntary nondisclosure*. Given the information spillover effect discussed in Proposition 2, uncertainty after nondisclosure is expected to be lower than the prior uncertainty ($\mu_0(1-\mu_0) > \mu^*_\varnothing(1-\mu^*_\varnothing)$) and lower than the average uncertainty after disclosure.

Post-disclosure information acquisition efforts of traders:

Third, the model implies that the manager's voluntary disclosure has a direct impact on the information acquisition efforts of market participants. Importantly, the model implies that the degree of information acquisition is increasing in the post-disclosure level of uncertainty. Despite considering mandatory disclosure, the findings by Wang [2020] are consistent with this association. In particular, he documents higher downloading activity by traders of company filings through the EDGAR system if the firm's filing is "more surprising" and thus can be expected to be associated with higher levels of post-disclosure uncertainty.

Post-disclosure measures of informed trading:

The fourth empirical implication is an average increase of informed trading measured after voluntary disclosure. Most related to the mechanism in my paper is the setting studied by Jayaraman and Wu [2019b]. They analyze the role of voluntary CAPEX forecasts disclosure on the feedback-providing role of a firm's stock price. Because they do not take into account the voluntary nature of the disclosure decision, the sample does not contain nondisclosing firms and their respective CAPEX. My model predicts that the average uncertainty in the market is higher after disclosure than after nondisclosure; driven by the information spillover effect of Proposition 2. This ultimately leads to a higher degree of informed trading, higher investment sensitivity to stock market price changes, and gains in investment efficiency for disclosing compared to withholding firms.

Unfortunately, Jayaraman and Wu [2019b] do not study the effects of voluntary disclosure on market uncertainty, but rather focus directly on measures of informed trading. They show that measures of information asymmetry around a [-2,2] day window around the disclosure increase, which they interpret as an indication of informed trading. Admittedly, it is an empirical challenge to cleanly disentangle the predicted effect of an uncertainty increasing effect of disclosure with the shown effect of increases in measures of informed trading. However, doing so would corroborate the findings by Jayaraman and Wu [2019b] and help us to better understand the economic link between voluntary disclosure and the feedback effect.

Relatedly, Badia et al. [2020] study a mandatory risk-disclosure setting, where oil and gas exploration firms are mandated to disclose information regarding fluctuations of their oil and gas reserves. They show that the disclosure of more uncertain reserve values leads to increases in bid-asks spreads, indicative of higher informed trading activities.

Association between market and real efficiency:

Finally, the model implies that using market efficiency measures as a proxy for real efficiency is generally inappropriate when taking into account the endogenous nature of disclosure aimed at enhancing the manager's information for investment purposes. Because the manager wants to incentivize information acquisition by the strategic trader, the disclosure decision actively increases uncertainty and by that reduces market efficiency. Ultimately, the strategic trader acquires more information, and the manager learns more from the stock price. Therefore, whenever the manager uses her disclosure decision to improve investment-making, market efficiency and real efficiency tend to move in opposite directions. One may expect that the relationship that follows from this line of reasoning is that real efficiency is maximized when market efficiency is minimized. Indeed, a full nondisclosure policy maximizes average uncertainty in the market prior to the trading stage and thus induces the highest degree of *average* information acquisition by the strategic trader. The high average degree of informed trading, however, is not sufficient to compensate for the lack of information provided by the firm, and thus a full nondisclosure policy minimizes market efficiency.

However, a full nondisclosure policy is not maximizing real efficiency. What matters for real efficiency is not the average amount of feedback provided by the stock market, but the probability-weighted marginal value of feedback; taking into account the manager's internal information and the probability that the manager ends up in this specific information sate. Therefore, even if disclosure policies can be ranked in terms of their market efficiency implications, there is not a direct mapping to real efficiency. While the insight that the notions of market and real efficiency do not have to coincide is not new, this paper adds the perspective that the divergence of the two efficiency notions is partly driven by the distortions caused by voluntary disclosure.

Jayaraman and Wu highlight this nuanced perspective on real efficiency in two related papers where they study the feedback effect implications of voluntary (Jayaraman and Wu [2019b]) and mandatory (Jayaraman and Wu [2019a]) disclosure. Overall, they highlight a decrease in investment efficiency of mandatory disclosure and an increase in investment efficiency, given voluntary disclosure. These results are in line with my model (see Proposition 3), which predicts that the equilibrium voluntary policy dominates a policy of mandated full disclosure.

Thus, while the literature highlights several costs and benefits of disclosure (see Leuz and Wysocki [2016]), this paper highlights that it may come at the cost of reducing real efficiency in a nuanced way.

8 Conclusion

The model I present analyzes the role of a firm's voluntary disclosure to shape the information environment of market participants and thus the feedback-providing role of its own stock price. In particular, the model is relevant for voluntary firm communication of future investment plans, growth strategies, and discussions of drivers of future profitability, in order to gauge the market's view on those items.

The disclosure equilibrium features partial disclosure, where the manager discloses or conceals her private information, depending on how her signal's communication influences price informativeness. While voluntary disclosure results in relatively informative prices, it creates an information spillover effect encroaching on the learning ability of manager types who choose to withhold their signals. In particular, Proposition 2 shows that the information spillover has negative consequences for the feedback-providing role of the market conditional on nondisclosure. Therefore, while voluntary disclosure causes price informativeness to be high after disclosure, it reduces price informativeness upon nondisclosure. Notably, the manager's voluntary disclosing behavior in equilibrium results in an *average* decline of price informativeness and therefore harms the market's feedback-providing role. This inefficiency caused by voluntary disclosure is at the heart at the paper and generates three main insights.

First, despite having a direct positive effect on investment-making, improving the manager's ability to learn from internal sources may backfire and reduce overall investment efficiency. By equipping the manager with better internal information, the negative information spillover effect is strengthened and, if strong enough, may reduce overall real efficiency.

Second, the investment inefficiency in the model arises because neither the manager nor the firm owners can commit to a particular disclosure policy. Therefore, long-term incentives do not help to restore efficient investment. Quite to the contrary. Because the manager cares about the profit of the growth option, she engages in ex-post optimal, but ex-ante inefficient voluntary disclosure. Thus, the paper highlights a novel efficiency cost of long-term incentives. In addition, the model highlight the role of incentives beyond standard implications for agency conflicts. Because incentives matter for the manager's equilibrium-disclosing behavior, they influence the extent to which decision-relevant information is reflected in the stock price. Thus, incentives end up having a real effect because they influence the manager's ability to extract information from the market.

Third, the model highlights a nuanced disconnect between market and real efficiency measures if voluntary disclosure is taken into account. Therefore, I caution researchers and policymakers to extrapolate implications from market efficiency on real efficiency.

A Proofs

Proof of Lemma 1. Start with a positively informed trader. His profits are $1-1/2(P(2)+P(0)) = 1/2(1-\mu) > 0$ if he buys, $1/2(P(0)+P(-2)) - 1 = 1/2\mu - 1 < 0$ if he sells, and zero if he does not trade. Therefore, the strategic trader who knows $V = 1$ always buys for interior μ. Equivalently, a trader who knows $V = 0$ always sells as the expected profits from selling are $1/2\mu > 0$, whereas from buying are $-1/2(1+\mu) < 0$ and not trading are 0. In addition, the uninformed strategic trader always makes an expected loss when trading and therefore abstains from trading.

Given the outlined trading strategy, the strategic trader's objective function for the information acquisition decision is[32] $x\left[\mu\left(1-1/2(1+\mu)\right)+(1-\mu)\left(1/2(\mu+0)\right)\right]-\frac{x^2}{2k}$ with the solution being $x^* = \min\left(\frac{\mu(1-\mu)}{k}, 1\right)$. For $k \leq 1/4$ given Assumption 1, $x^* \in (0,1]$ for all $s \in [0,1]$.

Given the speculator's trading and information acquisition strategy, it is trivial to show that the market maker's conjectures are consistent with Bayes rule. ■

The following lemma will provide useful in characterizing management's incentives to collect information from market prices.

Lemma 3 (Benefit of Feedback) *Given a fixed public belief μ, the expected return on the growth option, $\Psi(s,\mu)$, has the following properties:*

1. *It is strictly increasing in the manager's private belief s;*
2. *it is strictly increasing in the information x of the strategic trader for $s \in (0,1)$; and*
3. *the marginal value of an increase in x is inverse U-shaped in s and symmetric around $s = 1/2$.*

Proof of Lemma 3.

1.

$$\frac{\partial\Psi(s,\mu)}{\partial s} = 1/2x^*(\mu) + 2s(1-1/2x^*(\mu)) > 0$$

2. and 3.

$$\frac{\partial\Psi(s,\mu)}{\partial x} = 1/2(s-s^2) > 0$$

[32]The market maker conjectures that the strategic trader chose the outlined trading strategy. Naturally, this conjecture is true in equilibrium.

Indeed, the marginal value of an increase in x is inverse U-shaped and symmetric around $s = 1/2$ as $\frac{\partial \Psi(s,\mu)}{\partial x} = \frac{\partial \Psi(1-s,\mu)}{\partial x}$. ■

Proof of Proposition 1.

Step 1: Types $s = \{0, 1\}$ are indifferent:

Note that $\Psi(1, \mu) = 1/2$ and $\Psi(0, \mu) = 0$ and therefore are independent of the belief that d induces. By the tie-breaking assumption, both types $s = \{0, 1\}$ do not disclose.

Step 2: Return on growth option increasing in x:

As already mentioned in the text, the only impact the public belief has on the expected return of the growth option is through the endogenous intensity of informed trading x. The proof, that the expected return on the growth option is increasing in x can be found in the proof of Lemma 3.

Step 3: Type $s = 1/2$ discloses.

By step 2, the expected return of the growth option is increasing in x. As $x(\mu)^*$ is maximized at $\mu = 1/2$ (see Lemma 1), the manager wants to induce a belief as close to 1/2 as possible. Hence, the manager type $s = 1/2$ always discloses if the nondisclosure belief is $\mu_\varnothing \neq 1/2$. For $\mu_\varnothing = 1/2$, type $s = 1/2$ is indifferent and by assumption does not disclose.

Step 4: Thresholds symmetric around $s = 1/2$.

Lemma 1 tells us that $x^*(\mu)$ is symmetric around $\mu = 1/2$ which means that $x^*(\mu) = x^*(1-\mu)$. Type s_1 and $s_2 = 1-s_1$ have the same incentive to disclose or withhold as both choices induces the same amount of informed trading $x(s_1) = x(s_2)$ after disclosure and after nondisclosure $x(\mu_\varnothing)$. In addition, by Lemma 3, the marginal benefit of an increase in x is the same for s_1 and s_2. Therefore, if manager type s_1 prefers to disclose, manager type $s_2 = 1 - s_1$ does so too.

Step 5: Even number of interior thresholds.

Suppose to the contrary, that there exist an uneven number of interior thresholds. Step 4 tells us that, for every type s, there exists another type s', characterized by $s = 1 - s'$ that has the exact same preferences to disclose or withhold. Thus, the number of interior thresholds has to be even.

Step 6: At most two interior thresholds.

Suppose that there are more than two interior thresholds. Given that the thresholds types are indifferent between disclosing or not all of the indifferent types have to induce the same belief with disclosure and nondisclosure. However, as $\mathbb{E}[V|s] = s$, the posterior belief is strictly increasing in s. Thus the only way that s_2 induces the same belief as s_1 is if $s_2 = s_1$ which proves that there can only exists two interior thresholds.

Step 7: Types $s = \{0 + \epsilon, 1 - \epsilon\}$ (with $\epsilon > 0$ arbitrarily small), never disclose.

Suppose that $s_1 = \epsilon$ and $s_2 = 1-\epsilon$ with $\epsilon > 0$ being arbitrarily small. After nondisclosure, types s_1 and s_2 would receive the belief $\mu_\varnothing = \frac{(1-q)\mu_0 + q\int_\Omega sf(s)ds}{(1-q)+q\int_\Omega f(s)ds}$. It is easy to see that $0 < \mu_\varnothing < 1$ for any Ω. Therefore, there exists an $\epsilon > 0$ for which types $s_1 = \epsilon$ and $s_2 = 1-\epsilon$ are better off not disclosing for all potential strategies of other types. Thus, there has to exist a nondisclosure region for induced beliefs close to zero and one.

Step 8: Intermediate value theorem

Suppose, without loss of generality, that $\mu_0 < 1/2$. For some type $0 < s_1 < 1/2$, the following has to hold

$$s_1 = \mu_\varnothing = \frac{\mu_0(1-q) + q\left[\int_0^{s_1} sf(s)ds + \int_{1-s_1}^1 sf(s)ds\right]}{(1-q) + q\left[\int_0^{s_1} f(s)ds + \int_{1-s_1}^1 f(s)ds\right]}$$

Now in the limit of $s_1 \to 0$, the LHS is 0 while the RHS is $\mu_0 \in (0, 1/2)$. At the limit of $s_1 \to 1/2$, the LHS is $1/2$ while the RHS is $\mu_0 \in (0, 1/2)$. By continuity of $f(s)$, there exists an Equilibrium for $\mu_0 < 1/2$ which boils down s_1^*. By step 4, the thresholds s_1^* and $1 - s_1^*$ yield the equilibrium pair of thresholds. Given step 6, this pair of interior thresholds defines the unique equilibrium.

Note, $s_1^* < \mu_0$ for $\mu_0 < \frac{1}{2}$. To see this, consider the first few iteration steps of determining the equilibrium. Let's start with a full nondisclosure policy $\Omega = [0, 1]$ which implies $\mu_\varnothing = \mu_0$. Every type $s \in (\mu_0, 1-\mu_0)$ has an incentive to disclose and induce a more uncertain belief after disclosure compared to the uncertainty nondisclosure induces ($\mu_0(1-\mu_0)$). This implies that the set of nondisclosing types will change to $\Omega' = [0, \mu_0] \cup [1-\mu_0, 1]$. Because all disclosing types are larger than μ_0, the new nondisclosure belief is reduced to $\mu'_\varnothing < \mu_0$. In the next iteration step, all types $s \in (\mu'_\varnothing, \mu_0) \cup (1-\mu_0, 1-\mu'_\varnothing)$ find it beneficial to deviate from nondisclosure to disclosure. Thus, the new nondisclosure set changes to $\Omega = [0, \mu'_\varnothing] \cup [1-\mu'_\varnothing, 1]$. Again, as all newly disclosing types are larger than the current nondisclosure belief $\mu'_\varnothing$, the updated nondisclosure belief $\mu''_\varnothing$ diminishes even further. This iteration process continues until the fixed-point highlighted in the proposition is found. It is easy to see, that every iteration process reduces the nondisclosure belief even further. By that $\mu^*_\varnothing = s_1^* < \mu_0$ for $\mu_0 < \frac{1}{2}$.

For $\mu_0 > 1/2$, the unique pair of equilibrium thresholds s_2^* and $1 - s_2^*$ is defined by

$$s_2^* = \frac{(1-q)\mu_0 + q(\int_0^{1-s_2^*} sf(s)ds + \int_{s_2^*}^1 sf(s)ds)}{(1-q) + q(\int_0^{1-s_2^*} f(s)ds + \int_{s_2^*}^1 f(s)ds)}.$$

It is easy to apply the arguments from above to show that $\mu^*_\varnothing = s_2^* > \frac{1}{2}$ for $\mu_0 > \frac{1}{2}$.

For $\mu_0 = 1/2$, the unique disclosure equilibrium is $\Omega^* = [0,1]$. As the nondisclosure belief is at $1/2$, no type benefits from deviating from nondisclosure. As for $s_1^* < \mu_0$ for $\mu_0 < \frac{1}{2}$, one can easily show that $s_2^* > \mu_0$ for $\mu_0 > \frac{1}{2}$.

Given that the equilibrium definition does not specify off-equilibrium beliefs, there always exists an unraveling equilibrium for $q = 1$. However, there also exists an equilibrium of the form shown in the proposition for $q = 1$ given that $f(1) > 0$ for $\mu_0 < 1/2$ or $f(0) > 0$ for $\mu_0 > 1/2$. To see this rewrite the equilibrium condition for $\mu_0 < 1/2$ for $q = 1$:

$$s_1^* = \frac{\int_0^{s_1^*} sf ds + \int_{1-s_1^*}^1 sf ds}{\int_0^{s_1^*} f ds + \int_{1-s_1^*}^1 f ds}.$$

For $s_1^* \to 0$, the LHS is 0 while the RHS is $\frac{f(1)}{f(0)+f(1)} \geq 0$ after applying L'Hôspital's rule. Thus, whenever $f(1) > 0$, the LHS is 0 while the RHS is positive. For $s_1^* \to 1/2$ the LHS is $1/2$ while the RHS is $\mu_0 < 1/2$. Thus there has to exist a $s_1^* \in (0, \mu_0)$ whenever $f(1) > 0$. For $f(1) = 0$, the equilibrium is characterized by $s_1^* = 0$ and thus features full disclosure. Similarly, for $\mu_0 > 1/2$ there is full disclosure whenever $f(0) = 0$. For $f(0) > 0$, the disclosure equilibrium is characterized by $s_2^* \in (\mu_0, 1)$. ■

Proof of Proposition 2 . Part i): The statement follows from the equilibrium property that $s_1^* < \mu_0 < \frac{1}{2}$ and $s_2^* > \mu_0 > \frac{1}{2}$ combined with Lemma 1.

Part ii): Consider the equilibrium condition for $\mu_0 < 1/2$:

$$s_1^* = \mu_\varnothing = \frac{\mu_0(1-q) + q\left[\int_0^{s_1^*} sf(s)ds + \int_{1-s_1^*}^1 sf(s)ds\right]}{(1-q) + q\left[\int_0^{s_1^*} f(s)ds + \int_{s_1^*}^1 f(s)ds\right]}.$$

A change in q results in:

$$\begin{aligned}
\frac{\partial \mu_\varnothing}{\partial q} \propto & \left(-\mu_0 + \int_0^{s_1^*} sfds + \int_{1-s_1^*}^1 sfds\right)(1-q+q(F(s_1^*)+1-F(1-s_1^*))) \\
& - \left((1-q)\mu_0 + q\left(\int_0^{s_1^*} sfds + \int_{1-s_1^*}^1 sfds\right)\right)(F(s_1^*)-F(1-s_1^*)) \\
= & \int_0^{s_1^*} sfds + \int_{1-s_1^*}^1 sfds - \mu_0(F(s_1^*)-F(1-s_1^*)+1) \\
= & \int_{s_1^*}^{1-s_1^*} fds \left(\int_0^{s_1^*} sfds + \int_{1-s_1^*}^1 sfds\right) - \int_{s_1^*}^{1-s_1^*} sfds \left(\int_0^{s_1^*} fds + \int_{1-s_1^*}^1 fds\right) \\
= & (F(1-s_1^*)-F(s_1^*))\left(s_1^*F(s_1^*) - \int_0^{s_1^*} fds + 1 - (1-s_1^*)F(1-s_1^*) - \int_{1-s_1^*}^1 fds\right) \\
& - (1-F(1-s_1^*)+F(s_1^*))\left((1-s_1^*)F(1-s_1^*) - s_1^*F(s_1^*) - \int_{s_1^*}^{1-s_1^*} fds\right) \\
= & s_1^*F(s_1^*) - (1-s_1^*)F(1-s_1^*) + (F(1-s_1^*)-F(s_1^*))\left(1 - \int_0^{s_1^*} fds - \int_{1-s_1^*}^1 fds\right) \\
& + (1-F(1-s_1^*)+F(s_1^*))\int_{s_1^*}^{1-s_1^*} fds \\
= & s_1^*F(s_1^*) - (1-s_1^*)F(1-s_1^*) + \int_{s_1^*}^{1-s_1^*} fds - (F(1-s_1^*)-F(s_1^*))\left(\int_0^1 fds - 1\right) \\
= & -\int_{s_1^*}^{1-s_1^*} sfds - (F(1-s_1^*)-F(s_1^*))\underbrace{\left(\int_0^1 fds - 1\right)}_{=-\mu_0}
\end{aligned}$$

Note that $\mathbb{E}[S|s \in (s_1^*, 1-s_1^*)] = (F(1-s_1^*)-F(s_1^*))^{-1}\int_{s_1^*}^{1-s_1^*} sfds$. Thus the last line can be rewritten as:

$$\frac{\partial \mu_\varnothing^*}{\partial q} \propto \underbrace{(F(1-s_1^*)-F(s_1^*))}_{>0 \text{ as } s_1^*<1/2}(\mu_0 - \mathbb{E}[S|s \in (s_1^*, 1-s_1^*)]).$$

I am therefore left to show the sign of $\mu_0 - \mathbb{E}[S|s \in [s_1^*, 1-s_1^*]]$.

By the law of iterated expectations, the following has to hold:

$$\begin{aligned}
\mu_0 &= Pr(d=s)\mathbb{E}[S|s \in (s_1^*, 1-s_1^*)] + Pr(d=\varnothing)s_1^* \\
\mu_0 - \mathbb{E}[S|s \in (s_1^*, 1-s_1^*)] &= Pr(d=\varnothing)\left(s_1^* - \mathbb{E}[S|s \in (s_1^*, 1-s_1^*)]\right)
\end{aligned}$$

Clearly, the RHS of this equation is negative as all $s \in (s_1^*, 1 - s_1^*)$ are larger than s_1^*. Therefore, the LHS is also negative which implies that $\frac{\partial \mu_\varnothing^*}{\partial q} < 0$. Therefore, for $\mu_0 < \frac{1}{2}$, the nondisclosure belief s_1^* is decreasing in q which given Lemma 1 implies $\frac{dx^*(\mu_\varnothing^*)}{dq} < 0$.

A similar calculation for $\mu_0 > \frac{1}{2}$ shows that $\frac{\partial s_2^*}{\partial q} > 0$ and thus $\frac{dx^*(\mu_\varnothing^*)}{dq} < 0$.

Part iii): Any disclosure policy Ω induces a distribution of posterior beliefs μ (i.e. either s or $\mu_\varnothing$) and thus equivalently induces a distribution of $x^*(\mu)$. Given Lemma 1, $x^*(\mu)$ is concave in the belief μ.

By Jensen's inequality, $\mathbb{E}_{\Omega=[0,1]}[x^*] = x^*(\mu_0) > \mathbb{E}_{\Omega^*}[x^*]$. The left part of the inequality represents the ex-ante expected degree of feedback given a policy of full nondisclosure $\Omega = [0, 1]$. The right part of the inequality denotes the ex-ante expected degree of feedback given the equilibrium disclosure policy Ω^*.

■

Proof of Proposition 3.

Step 1, $\zeta(\Omega_{FD}) > \zeta(\Omega_{ND})$:

Let's start with comparing Ω_{FD} with Ω_{ND}.

Suppose, contrary to the proposition's statement, that $\zeta(\Omega_{FD}) \geq \zeta(\Omega_{ND})$. This implies,

$$\begin{aligned}
&\zeta(\Omega_{FD}) - \zeta(\Omega_{ND}) \geq 0 \\
&\Leftrightarrow \int_0^1 \Psi(s,s)f(s)ds - \int_0^1 \Psi(s,\mu_0)f(s)ds \geq 0 \\
&\Leftrightarrow \int_0^1 2(1-s)^2 s^3 ds - \frac{2}{9}\int_0^1 2(1-s)s^2 ds \geq 0 \\
&\Leftrightarrow \frac{1}{30} - \frac{1}{6}\frac{2}{9} = \frac{1}{30} - \frac{1}{27} \geq 0
\end{aligned}$$

which is a contradiction.

Step 2: $\zeta(\Omega_{ND}) \geq \zeta(\Omega^*)$:

Given Assumption 3, the equilibrium nondisclosure belief is

$$\begin{aligned}
g(a,q) \equiv a &= \frac{(1-q)2/3 + q\left(\int_0^{1-a} sf(s)ds + \int_a^1 sf(s)ds\right)}{(1-q) + q\left(\int_0^{1-a} f(s)ds + \int_a^1 f(s)ds\right)} \\
\Leftrightarrow 0 &= \frac{2}{3}\frac{(1-q) + q\left((1-a)^3 + (1-a^3)\right)}{(1-q) + q\left((1-a)^2 + (1-a^2)\right)} - a \\
0 &= \frac{3a - 2 - (2-a)(1-2a)^2 q}{3(2a-1)q - 3} \qquad (6)
\end{aligned}$$

where $h(a = s^*, q) = 0$ boils down the equilibrium.

Next, let's compare Ω_{ND} with Ω^*.

$$
\begin{aligned}
h(q) \equiv& \zeta(\Omega_{ND}) - \zeta(\Omega^*) \\
=& (1-q)\Psi(2/3,2/3) + q\int_0^1 \Psi(s,2/3)f(s)ds - (1-q)\Psi(2/3,\mu_\varnothing) \\
&- q\left(\int_0^{1-s^*}\Psi(s,\mu_\varnothing)f(s)ds + \int_{1-s^*}^{s^*}\Psi(s,s)f(s)ds + \int_{s^*}^{1}\Psi(s,\mu_\varnothing)f(s)ds\right) \\
h(q)4k =& (1-q)2/9(2/9-\mu_\varnothing(1-\mu_\varnothing)) + q\left(2/9\int_0^1 s(1-s)f(s)ds\right. \\
&\left.- \mu_\varnothing(1-\mu_\varnothing)\left(\int_0^{1-s^*} s(1-s)f(s)ds + \int_{s^*}^1 s(1-s)f(s)ds\right) - \int_{1-s^*}^{s^*} s^2(1-s)^2 f(s)ds\right) \\
=& \left((1-q)2/9 + \frac{q}{6}\right)(2/9-\mu_\varnothing(1-\mu_\varnothing)) \\
&+ q\left(\int_{1-s^*}^{s^*} s(1-s)(\mu_\varnothing(1-\mu_\varnothing) - s(1-s))f(s)ds\right) \\
=& \frac{1}{6}q\left(2/9-(1-s^*)s^*\right) + 2/9(1-q)\left(2/9-(1-s^*)s^*\right) \\
&+ \frac{1}{30}q\left((s^*)^2 - s^* - 1\right)(2s^*-1)^3,
\end{aligned}
$$

where in the last line I explicitly solve for the integrals and insert the equilibrium nondisclosure belief $\mu_\varnothing = s^*$.

From Proposition 1 we know that $s^* > 2/3$. Thus, for $\zeta(\Omega_{ND}) < \zeta(\Omega^*)$,

$$
\begin{aligned}
&h(q) < 0 \\
\Leftrightarrow& \frac{2}{3} < s^* < \tilde{s}
\end{aligned}
$$

with $\tilde{s}(a)$ being the solution to $40+17q-2(90-q)a+40(2+q)a^2+270q1^3-540qs^4+216qs^5=0$.

Comparing this condition with the equilibrium condition for s^* in Equation 6, that is, $s^*(x) \equiv 0 = -2(1+q)+(3+9q)x-12qx^2+4qx^3$, it is easy to show that $s^*(x) < \tilde{s}$ is not feasible.

Step 3: $\zeta(\Omega_{FD}) \leq \zeta(\Omega^*)$**:**

As in step 2, consider:

$$
\begin{aligned}
h_2(q) \equiv & \zeta(\Omega_{FD}) - \zeta(\Omega^*) \\
= & (1-q)\Psi(/3,/3) + q\int_0^1 \Psi(s,s)f(s)ds - (1-q)\Psi(/3,\mu_\varnothing) \\
& - q\left(\int_0^{1-s_2^*} \Psi(s,\mu_\varnothing)f(s)ds + \int_{1-s_2^*}^{s_2^*} \Psi(s,s)f(s)ds + \int_{s_2^*}^{1} \Psi(s,\mu_\varnothing)f(s)ds\right) \\
4kh_2(q) = & (1-q)2/9(2/9-\mu_\varnothing(1-\mu_\varnothing)) + q\left(\int_0^1 s^2(1-s)^2 f(s)ds\right. \\
& \left. - \mu_\varnothing(1-\mu_\varnothing)\left(\int_0^{1-s_2^*} s(1-s)f(s)ds + \int_{s_2^*}^1 s(1-s)f(s)ds\right) - \int_{1-s_2^*}^{s_2^*} s^2(1-s)^2 f(s)ds\right) \\
= & \left((1-q)2/9\right)\left(2/9-\mu_\varnothing(1-\mu_\varnothing)\right) \\
& + q\left(\frac{1}{30} - \frac{\mu_\varnothing(1-\mu_\varnothing)}{6} + \int_{1-s_2^*}^{s_2^*} s(1-s)(\mu_\varnothing(1-\mu_\varnothing) - s(1-s))f(s)ds\right) \\
= & 2/9(1-q)\left(2/9-(1-s^*)\,s^*\right) \\
& + \frac{1}{30}q\left((s^*)^2 - s^* - 1\right)(2s^*-1)^3 + q\left(\frac{1}{30} - \frac{1}{6}(1-s^*)\,s^*\right)
\end{aligned}
$$

In order for $h_2(q) > 0$, $s^* \in (\hat{s}, 1]$ with $\hat{s}(x)$ being the solution to $20 + 7q - 45(2+q)x + 35(2+q)x^2 + 135qx^3 - 270qx^4 + 108qx^5$. It is easy to show that $s^* < \hat{s}(x)$ for all q which contradicts $h_2(q) > 0$.

■

Proof of Proposition 4.

The real efficiency of the disclosure equilibrium is:

$$
\begin{aligned}
\zeta(q;\mu_\varnothing^*) = & (1-q)\Psi(2/3,\mu_\varnothing) + q\left(\int_0^{1-s^*} \Psi(s,\mu_\varnothing)f(s)ds + \int_{1-s^*}^{s^*} \Psi(s,s)f(s)ds + \int_{s^*}^1 \Psi(s,\mu_\varnothing)f(s)ds\right) \\
= & (1-q)\left(\frac{1}{18} + \frac{1}{4k}\frac{2}{9}\mu_\varnothing(1-\mu_\varnothing)\right) + q\left(\frac{1}{2}\int_0^1 s^2 f(s)ds\right. \\
& \left. + \frac{1}{4k}\left[\int_0^{1-s^*} s(1-s)\mu_\varnothing(1-\mu_\varnothing)f(s)ds + \int_{1-s^*}^{s^*} s^2(1-s)^2 f(s)ds + \int_{s^*}^1 s^2(1-s)^2 f(s)ds\right]\right) \\
= & (1-q)\left(\frac{1}{18} + \frac{1}{18k}\mu_\varnothing(1-\mu_\varnothing)\right) + q\left(\frac{1}{2}\int_0^1 s^2 f(s)ds\right. \\
& \left. + \frac{1}{4k}\left[\mu_\varnothing(1-\mu_\varnothing)\int_0^1 s(1-s)f(s)ds + \int_{1-s^*}^{s^*} s(1-s)(s(1-s) - \mu_\varnothing(1-\mu_\varnothing))f(s)ds\right]\right),
\end{aligned}
$$

where the second equations plugs in the equilibrium degree of information acquisition of the strategic trader $x^*(\mu) = \frac{\mu(1-\mu)}{4k}$. Now, the direct effect can be shown to be:

$$\begin{aligned}
\frac{\partial \zeta}{\partial q} =& \frac{1}{4k}\left[\mu_\varnothing(1-\mu_\varnothing)\int_0^1 s(1-s)f(s)ds + \int_{1-s_2^*}^{s_2^*} s(1-s)(s(1-s)-\mu_\varnothing(1-\mu_\varnothing))f(s)ds\right. \\
&\left. -\mu_\varnothing(1-\mu_\varnothing)\mu_0(1-\mu_0)\right] + \frac{1}{2}\int_0^1 s^2 f(s)ds - \frac{1}{2}\mu_0^2 \\
=& \frac{1}{4k}\left[\frac{1}{6}\mu_\varnothing(1-\mu_\varnothing) + \int_{1-s_2^*}^{s_2^*} s(1-s)(s(1-s)-\mu_\varnothing(1-\mu_\varnothing))f(s)ds\right] + \frac{1}{36} \\
=& \frac{1}{4k}\left[\frac{1}{6}s^*(1-s^*) + \frac{1}{30}\left(1+s^*(1-s^*)\right)(2s^*-1)^3\right] + \frac{1}{36},
\end{aligned}$$

where I explicitly calculated the integrals and used the fact that in equilibrium $s^* = \mu_\varnothing$. Given Proposition 1 which implies $s^* > 2/3$ for and the assumption on $k \geq \frac{1}{4}$, it is easy to verify that $\frac{\partial \zeta}{\partial q} > 0$.

Next, consider the indirect benefit:

$$\begin{aligned}
\frac{\partial \zeta}{\partial \mu_\varnothing}\frac{\partial \mu_\varnothing}{\partial q} =& \frac{\partial \mu_\varnothing}{\partial q}\left[\frac{(1-q)}{4k}\frac{2}{9}(1-2\mu_\varnothing)\right. \\
&\left. + \frac{q}{4k}\left((1-2\mu_\varnothing)\int_0^1 s(1-s)f(s) + (1-2\mu_\varnothing)\int_{1-s_2^*}^{s_2^*} s(1-s)f(s)\right)\right] \\
=& \frac{\partial \mu_\varnothing}{\partial q}\frac{(1-2\mu_\varnothing)}{4k}\underbrace{\left((1-q)\frac{2}{9} + q\left(\int_0^{1-s_2^*} s(1-s)f(s)ds + \int_{s_2^*}^1 s(1-s)f(s)ds\right)\right)}_{>0}.
\end{aligned}$$

According to Proposition 2, $\frac{\partial \mu_\varnothing}{\partial q} > 0$. Then, $\frac{d\zeta}{dq} < 0$ follows as Proposition 1 implies $s^* = \mu_\varnothing > \frac{2}{3}$.

Next, combine the direct effect with the indirect effect to analyze the combined effect of a change in q on real efficiency.

$$
\begin{aligned}
\frac{d\zeta}{dq} =& \frac{\partial \zeta}{\partial q} + \frac{\partial \zeta}{\partial \mu_\varnothing}\frac{\partial \mu_\varnothing}{\partial q} \\
=& \frac{1}{4k}\left[\frac{1}{6}\mu_\varnothing(1-\mu_\varnothing) + \frac{1}{30}\left(1+\mu_\varnothing(1-\mu_\varnothing)\right)(2\mu_\varnothing - 1)^3\right] + \frac{1}{36} \\
&+ \frac{\partial \mu_\varnothing}{\partial q}\frac{(1-2\mu_\varnothing)}{4k}\left((1-q)2/9 + q\left(\int_0^{1-s^*} s(1-s)f(s)ds + \int_{s^*}^1 s(1-s)f(s)ds\right)\right) \\
=& \frac{1}{36} + \frac{1}{4k}\left[\frac{1}{6}\mu_\varnothing(1-\mu_\varnothing) + \frac{1}{30}\left(1+\mu_\varnothing(1-\mu_\varnothing)\right)(2\mu_\varnothing - 1)^3\right. \\
&\left.+ \frac{\partial \mu_\varnothing}{\partial q}(1-2\mu_\varnothing)\left(\frac{1}{3}(1+2\mu_\varnothing)(1-\mu_\varnothing)^2 q + 2/9(1-q)\right)\right]. \qquad (7)
\end{aligned}
$$

Note that the partial derivative of q with respect to $\mu_\varnothing$ can be written as:

$$
\frac{\partial \mu_\varnothing}{\partial q} = \frac{2s^*(s^*(3-2s^*)-1)}{3(1-(2a-1)q)^2}
$$

Plugging this term into Equation 7 results in in $\frac{d\zeta}{dq}$ being a seventh-order polynomial in $\mu_\varnothing$. From the proof of Proposition 1, we know that $\mu_\varnothing$ is itself the root of a third-order polynomial. Therefore, showing that $\frac{\partial \mu_\varnothing}{\partial q} < 0$ given the equilibrium $\mu_\varnothing$ is tedious, but results in the claimed parameter restriction of $q \in (\bar{q}, 1)$ and $k \in [\frac{1}{4}, \bar{k})$. In fact, $\bar{k} = \frac{9}{20}$ while $\bar{q}(x)$ is the solution to

$$
\begin{aligned}
0 =& -693279 + 5314410k + (21490 - 413100k)x + (655625 - 5246550k)x^2 \\
&+ (50400 - 1699200k + 10368000k^2)x^3 + (-191700 + 3094200k - 12700800k^2 + 1728000k^3)x^5
\end{aligned}
$$

■

Proof of Lemma 2. The incentives of the manager are such that she wants to maximize the expected stock price in $t = 2$. For now, let's ignore the trading stage in $t = 2$ and suppose the stock price is set to the expected value of the asset conditional on the public belief induced after the disclosure stage. The next lemma characterizes the disclosure equilibrium in such a situation.

Lemma 4 (Disclosure to maximize market beliefs) *In the disclosure game where the manager maximizes the market belief, the unique disclosure equilibrium is characterized by*

$\Omega = [0, s^*]$. *The disclosure threshold s^* is given by the condition:*

$$s^* = \frac{(1-q)\mu_0 + qPr(s \le s^*)\mathbb{E}[V|s \le s^*]}{(1-q) + qPr(s \le s^*)} = \frac{(1-q)\mu_0 + q\int_0^{s^*} sf(s)ds}{(1-q) + q\int_0^{s^*} f(s)ds} \tag{8}$$

Given $f(s) = 2s$ and $\mu_0 = \frac{2}{3}$, define

$$\begin{aligned} g(a) &= \frac{2 - 2(1-a^3)q}{3 - 3(1-a^2)q} - a \\ &= \frac{2 - 3a - (1-a)^2(2+a)q}{3 - 3(1-a^2)q}. \end{aligned} \tag{9}$$

The equilibrium is boiled down by $g(a = s^*_{ST}) = 0$.

Proof of Lemma 4. The proof of the lemma is analogous to Dye [1985], Jung and Kwon [1988], and Acharya et al. [2011]. ■

Now let's go back to the full model and consider the incentives of the manager to maximize the expected stock price in $t = 2$.

The manager attaches the following probabilities to potential asset demands z and the associated stock prices $P(z)$ given a public belief of μ:

$$Pr(z|s) = \begin{cases} 1/2x^*(\mu)s, & \text{for } z = \{1, 1\} \\ 1/2x^*(\mu)(1-s), & \text{for } z = \{-1, -1\} \\ 1/2(1 - x^*(\mu)), & \text{for } z = \{0, \cdot\} \\ 1/2x^*(\mu), & \text{for } z = \{-1, 1\}. \end{cases} \tag{10}$$

Given the equilibrium prices outlined in Lemma 1, it is easy to see that the law of iterated expectations applies when the manager disclosed her signal. Thus, the manager expects the price to be s. That is, $\mathbb{E}[P(z, s)|s] = \mathbb{E}[\mathbb{E}[V|s, z]|s] = \mathbb{E}[V|s] = s$.

Suppose the market belief after nondisclosure is $\mu_\varnothing$. The equilibrium is boiled down by the type s for whom $s = \mu_\varnothing$. As the law of iterated expectations applies after disclosure and nondisclosure for type $s = \mu_\varnothing$, the expected stock price is s either way.

For $s \neq \mu_\varnothing$, the manager's expected stock price conditional on nondisclosure is characterized by

$$\mathbb{E}[P(z, \mu_\varnothing)|s] = \mathbb{E}[\mathbb{E}[V|z, \mu_\varnothing]|s] = \sum_z Pr(z|s)P(z),$$

which is a function of the manager's not disclosed private type s and the market belief conditional on nondisclosure $\mu_\varnothing$. The law of iterated expectations does not apply here, as the manager conditions on belief s while both the market maker and strategic trader use $\mu_\varnothing$ for their price setting and information acquisition decision, respectively. Using the manager's assessed probabilities in Equation 10 and the equilibrium prices in Lemma 1, it is easy to show that the derivative with respect to s of the expected stock price is $\frac{\partial \mathbb{E}[P(z,\mu_\varnothing)|s]}{\partial s} = 1/2x^*(\mu) < 1$. Therefore, all types $s > \mu_\varnothing$ ($s < \mu_\varnothing$) prefer to disclose (conceal) their types.

Finally, given the equilibrium disclosure strategy is a threshold one, the belief conditional on nondisclosure is defined by Equation 8, which is the same threshold as in the model where the disclosure game is defined as maximizing market beliefs. ■

Proof of Proposition 5. Remember, Lemma 2 implies that short-term incentives lead to a disclosure policy of the form $\Omega^*_{ST} = [0, s^*_{ST}]$.

Let's compare this policy with a full nondisclosure policy in terms of real efficiency:

$$\begin{aligned}
\zeta(\Omega^*_{ST}) - \zeta(\Omega_{ND}) =& (1-q)\left(\Psi(2/3, s^*_{ST}) - \Psi(2/3, 2/3)\right) \\
&+ q\left(\int_0^{s^*_{ST}} \Psi(s, s^*_{ST}) f(s)ds + \int_{s^*_{ST}}^1 \Psi(s,s)f(s)ds - \int_0^1 \Psi(s,s)f(s)ds\right) \\
4k\left(\zeta(\Omega^*_{ST}) - \zeta(\Omega_{ND})\right) =& (1-q)\left(2/9(s^*_{ST}(1-s^*_{ST}) - 2/9)\right) \\
&+ q\left(\int_0^s {}^*_{ST} s(1-s)(s^*_{ST}(1-s^*_{ST}) - 2/9)f(s)ds \right.\\
&\left. + \int_{s^*_{ST}}^1 s(1-s)(s(1-s) - 2/9)f(s)ds\right) \\
=& \left(s^*_{ST}(1-s^*_{ST}) - 2/9)\right)\left((1-q)2/9 + q/6\right) \\
&+ q\left(\int_{s^*_{ST}}^1 s(1-s)(s(1-s) - s^*_{ST}(1-s^*_{ST}))f(s)ds\right)
\end{aligned} \tag{11}$$

Now consider the threshold belief s^*_{ST} of the short-term policy defined by Equation 9. In order for short-term incentives to result in higher real efficiency than a full nondisclosure policy, Equation 15 has to be positive given s^*_{ST} being the solution to Equation 9. It can be shown that both conditions hold for $q \in (0, q^{ST})$, where $q^{ST}(a) \approx 0.73$ is the solutions to:

$$0 = 31000725 - 146458287a + 269722575a^2 - 242454340a^3 + 108711525a^4 - 22664325a^5 + 2142100a^6.$$

■

Proof of Corollary 1. The corollary follows from Proposition 3 and Proposition 5. ■

Proof of Proposition 6. For any public belief μ after the disclosure outcome, the variance of V conditional on the price is $Var(V|P) = 0$ for prices of $P \in \{0, 1\}$ and $Var(V|P) = \mu(1-\mu)$ for a price of $P = \mu$.

Taking the expectation over the price realizations, in particular as a function of the strategic trader's information acquisition decision, gives:

$$\begin{aligned}\mathbb{E}[Var(V|P)|d] &= Pr(P=\mu)\mu(1-\mu) = \left(1 - \frac{1}{2}x^*(\mu)\right)\mu(1-\mu) \\ &= \left(1 - \frac{1}{2}\frac{\mu(1-\mu)}{k}\right)\mu(1-\mu).\end{aligned}$$

where the last equality inserts the equilibrium degree of information acquisition of the strategic trader $x^*(\mu)$ given in Lemma 1.

It is easy to see that $\mathbb{E}[Var(V|P)|d]$ is (strictly) concave for $k \geq 1/4$ ($k > 1/4$) for any $\mu \in (0, 1)$. Thus, by Jensen's inequality, the full disclosure policy Ω_{FD} minimizes $\mathbb{E}_\Omega[Var(V|P, d)]$, whereas the full nondisclosure policy Ω_{ND} maximizes the expected conditional variance. By the definition of $ME = -\mathbb{E}_\Omega\left[\frac{Var(V|P,d)}{Var(V)}\right]$, it follows that $ME(\Omega_{FD}) > ME(\Omega_{ND})$

Next, let's compare market efficiency for short-term incentives with the full disclosure policy.

$$\begin{aligned}ME(\Omega_{FD}) - ME(\Omega^*_{ST}) = &-\frac{9}{2}\left[(1-q)\left(1-\frac{1}{9k}\right)\frac{2}{9} + q\int_0^1\left(1-\frac{1}{2k}s(1-s)\right)s(1-s)f(s)ds\right. \\ &-(1-q+qF(s^*_{ST}))\left(1-\frac{1}{2k}s^*_{ST}(1-s^*_{ST})\right)s^*_{ST}(1-s^*_{ST}) \\ &\left.+q\left(\int_{s_{ST}}^1\left(1-\frac{1}{2k}s(1-s)\right)s(1-s)f(s)ds\right)\right] \\ =&\frac{9(1-q)}{2}s^*_{ST} - \frac{9}{2}\left(1+\frac{1}{2k}\right)(1-q)(s^*_{ST})^2 + \frac{1}{2}\left(\frac{9(1-q)}{2k}+3q\right)(s^*_{ST})^3 \\ &-\frac{9}{4}\left(\frac{1}{k}+q\left(1-\frac{1}{2k}\right)\right)(s^*_{ST})^4 + \frac{27q}{10k}(s^*_{ST})^5 - \frac{3q}{2k}(s^*_{ST})^6 - 1 + \frac{9}{k}.\end{aligned} \tag{12}$$

It can be shown that $ME(\Omega_{FD}) - ME(\Omega^*_{ST}) < 0$ only if $s^*_{ST} \in [0, \tilde{s})$ where $\tilde{s} = s^*_{ST}$ sets Equation 12 to zero. Given the condition for s^*_{ST} in Equation 8, $s^*_{ST} > \tilde{s}$ which shows that $ME(\Omega_{FD}) \geq ME(\Omega^*_{ST})$.

Next, let's compare $ME(\Omega^*)$ with $ME(\Omega_{ND})$:

$$\begin{aligned}
ME(\Omega_{ND}) - ME(\Omega^*) = & -\frac{9}{2}\left[\frac{2}{9}\left(1-\frac{1}{9k}\right)\right. \\
& -\left(1-q+q\left(1-f(s^*)+f(1-s^*)\right)\right)\left(1-\frac{s^*(1-s^*)}{2k}\right)s^*(1-s^*) \\
& \left.-q\int_{1-s^*}^{s^*}\left(1-\frac{s(1-s)}{2k}\right)s(1-s)f(s)ds\right] \\
= & \frac{1}{k}\left(\frac{1}{9}+\frac{3q}{40}\right)-\left(1+\frac{3q}{4}\right)+\frac{9}{2}(1+q)s^*-\frac{9}{2}\left(1+2q+\frac{1+q}{2k}\right)(s^*)^2 \\
& +\left(6q+\frac{9+15q}{2k}\right)(s^*)^3-\frac{9}{k}\left(\frac{1}{4}+q\right)(s^*)^4+\frac{18q}{5k}(s^*)^5. \qquad (13)
\end{aligned}$$

It can be shown that $ME(\Omega_{ND}) - ME(\Omega^*) > 0$ only if $s^* \in [2/3, \hat{s})$ where $\hat{s} = s^*$ sets Equation 13 to zero. Given the equilbrium condition for s^* in Equation 6, $s^* > \tilde{s}$ which shows that $ME(\Omega_{ND}) \leq ME(\Omega^*_{ST})$.

The same approach can be utilized to show that $ME(\Omega^*_{ST}) \geq ME(\Omega^*)$ ■

B Alternative internal signal distributions

In this appendix, I drop assumption 2 and consider two alternative distributional assumptions on the internal learning technology:

Assumption 3 (Linear pdf) *The manager's private signal s is distributed according to $f(s) = 4 - 6(s + \mu_0(1 - 2s))$ for $\mu_0 \in [\frac{1}{3}, \frac{2}{3}]$.*

Assumption 4 (Monotone pdf) *The manager's private signal s is distributed according to $f(s) = \frac{2(1-\mu_0)^2\mu_0^2}{(\mu_0 - s(2\mu_0-1))^3}$ for $\mu_0 \in (0, 1)$.*

In what follows, I repeat the analysis under Assumption 3 (4) and show analytically (numerically) that the main results are robust to these alternative internal signal distributions.

B.1 Analytical solutions with Assumption 3

Lemma 1 and 3 are independent of the internal signal distribution. Proposition 1 holds for any distributional assumption.

The next corollary shows the comparative statics of the equilibrium with respect to q and μ_0.

Corollary 2 (Comparative statics of Disclosure Equilibrium with respect to q and μ_0) *The equilibrium nondisclosure region Ω^* is:*

- *decreasing (constant) in q for $\mu_0 \neq 1/2$ ($\mu_0 = 1/2$)*
- *and increasing (decreasing) in μ_0 for $\mu_0 < 1/2$ ($\mu_0 > 1/2$)*

Proof of Corollary 2.
1. Comparative static with respect to q: Note, the statement that the equilibrium nondisclosure region Ω^* is decreasing in q is equivalent to the statement ii) of Proposition 2 ($\frac{dx^*(\mu_\varnothing^*)}{dq} < 0$). Therefore, the proof here follows from the proof of Proposition 2.

2. Comparative static with respect to μ_0:
Given Assumption 3, we can rewrite the nondisclosure belief for $\mu_0 < 1/2$ as:

$$\begin{aligned}\mu_\varnothing =& \frac{(1-q)\mu_0 + q\left(\int_0^{s_1^*} sf(s)ds + \int_{1-s_1^*}^1 sf(s)ds\right)}{1-q+q\left(\int_0^{s_1^*} f(s)ds + \int_{1-s_1^*}^1 f(s)ds\right)}\\ =& \frac{\mu_0\left((2s_1^*-1)^3q+1\right) - 2s_1^*\left(2(s_1^*)^2 - 3s_1^* + 1\right)q}{2s_1^* - q + 1}.\end{aligned}$$

It follows that the partial derivative with respect to μ_0 is:

$$\frac{\partial\mu_\varnothing}{\partial\mu_0} = \frac{((2s_1^*-1)^3q+1)}{2s_1^*-q+1} > 0$$

. Thus, $\mu_\varnothing$ is increasing in μ_0 for $\mu_0 < 1/2$ which results in $\Omega^* = [0, s_1^*] \cup [1-s_1^*, 1]$ increasing in μ_0.

Similarly for $\mu \geq 1/2$:

$$\frac{\partial\mu_\varnothing}{\partial\mu_0} = \frac{(2s_2^*-1)^3q-1}{2s_2^*+q-3} > 0$$

Thus, $\mu_\varnothing$ is increasing in μ_0 for $\mu_0 \geq 1/2$ which results in $\Omega^* = [0, 1-s_2^*] \cup [s_2^*, 1]$ decreasing in μ_0. ■

Proposition 3 also holds for Assumption 3.

Proof of Proposition 3 given Assumption 3.
Step 1, $\zeta(\Omega^{FD}) > \zeta(\Omega^{ND})$:
Let's start with comparing Ω^{FD} with Ω^{ND}.

Suppose, contrary to the proposition's statement, that $\zeta(\Omega^{FD}) \geq \zeta(\Omega^{ND})$. This implies,

$$\begin{aligned}
&\zeta(\Omega^{FD}) - \zeta(\Omega^{ND}) \geq 0 \\
\Leftrightarrow &\int_0^1 \Psi(s,s)f(s)ds - \int_0^1 \Psi(s,\mu_0)f(s)ds \geq 0 \\
\Leftrightarrow &\int_0^1 (1-s)^2 s^2 f(s)ds - (1-\mu_0)\mu_0 \int_0^1 (1-s)sf(s)ds \geq 0 \\
\Leftrightarrow &\frac{1}{30} - \frac{1}{6}(1-\mu_0)\mu_0 > 0
\end{aligned}$$

which is a contradiction for all $\mu_0 \in [\frac{1}{3}, \frac{2}{3}]$.

Step 2: $\zeta(\Omega^{ND}) \geq \zeta(\Omega^*)$:

Next, let's compare Ω^{ND} with Ω^*. Given Proposition 1, $\Omega^* = \Omega^{ND}$ for $\mu_0 = \frac{1}{2}$ which implies $\zeta(\Omega^*) = \zeta(\Omega^{ND})$.

Suppose $\mu_0 > \frac{1}{2}$, then:

$$\begin{aligned}
h(\mu_0, q) \equiv &\zeta(\Omega^{ND}) - \zeta(\Omega^*) \\
= &(1-q)\Psi(\mu_0,\mu_0) + q\int_0^1 \Psi(s,\mu_0)f(s)ds - (1-q)\Psi(\mu_0,\mu_\varnothing) \\
&- q\left(\int_0^{1-s_2^*} \Psi(s,\mu_\varnothing)f(s)ds + \int_{1-s_2^*}^{s_2^*} \Psi(s,s)f(s)ds + \int_{s_2^*}^1 \Psi(s,\mu_\varnothing)f(s)ds\right) \\
= &(1-q)\mu_0(1-\mu_0)(\mu_0(1-\mu_0) - \mu_\varnothing(1-\mu_\varnothing)) + q\left(\mu_0(1-\mu_0)\int_0^1 s(1-s)f(s)ds\right. \\
&\left.- \mu_\varnothing(1-\mu_\varnothing)\left(\int_0^{1-s_2^*} s(1-s)f(s)ds + \int_{s_2^*}^1 s(1-s)f(s)ds\right) - \int_{1-s_2^*}^{s_2^*} s^2(1-s)^2 f(s)ds\right) \\
= &\left((1-q)\mu_0(1-\mu_0) + \frac{q}{6}\right)(\mu_0(1-\mu_0) - \mu_\varnothing(1-\mu_\varnothing)) \\
&+ q\left(\int_{1-s_2^*}^{s_2^*} s(1-s)(\mu_\varnothing(1-\mu_\varnothing) - s(1-s))f(s)ds\right) \\
= &\frac{1}{6}q\left((1-\mu_0)\mu_0 - (1-s_2^*)s_2^*\right) + (1-\mu_0)\mu_0(1-q)\left((1-\mu_0)\mu_0 - (1-s_2^*)s_2^*\right) \\
&+ \frac{1}{30}q\left((s_2^*)^2 - s_2^* - 1\right)(2s_2^* - 1)^3,
\end{aligned}$$

where in the last line I solve the integral and insert the equilibrium nondisclosure belief $\mu_\varnothing = s_2^*$.

From Proposition 1 we know that $s_2^* > \mu_0$. Together with the restriction in the supposition that $\mu \in (\frac{1}{2}, \frac{2}{3}]$, one can show that $h(\mu_0, q) < 0 \Leftrightarrow s_2^* \in (\mu_0, \tilde{s})$ with $\tilde{s}$ being the solution to

$$
\begin{aligned}
0 =& 30\mu_0^4(1-q) - 60\mu_0^3(1-q) - 5\mu_0^2(7q-6) + 5\mu_0 q + q + \\
&+ \left(30\mu_0^2 - 30\mu_0 - 30\mu_0^2 q + 30\mu_0 q - 10q\right)(s - s^2) + 10qs^3 - 20qs^4 + 8qs^5.
\end{aligned}
$$

From Proposition 1, we know that s_2^* is the solution to

$$
s_2^* = q\left(1 - 2s_2^*\right)\left(\mu_0 + 2\left(2\mu_0 - 1\right)\left(s_2^* - 1\right)s_2^*\right) - qs_2^* + \mu_0 - 2q(s_2^*)^2.
$$

Given the parameter restrictions of the supposition $\mu_0 \in (\frac{1}{2}, \frac{2}{3}]$, one can show that $s_2^* > \tilde{s}$. Therefore, $\zeta(\Omega^{ND}) - \zeta(\Omega^*) < 0$ is not feasible which proves $\zeta(\Omega^{ND}) \geq \zeta(\Omega^*)$ for $\mu_0 \in (\frac{1}{2}, \frac{2}{3}]$.

It is easy to repeat the calculations for $\mu_0 \in [\frac{1}{3}, \frac{1}{2})$, where again the parameters restrictions are not feasible given the equilibrium s_1^*. It thus follows that $\zeta(\Omega^{ND}) \geq \zeta(\Omega^*)$ for $\mu_0 \in [\frac{1}{3}, \frac{2}{3}]$.
Step 3: $\zeta(\Omega^{FD}) \leq \zeta(\Omega^*)$**:**
First, note that at $\mu_0 = \frac{1}{2}$, $\zeta(\Omega^*) = \zeta(\Omega^{ND}) > \zeta(\Omega^{FD})$.

Suppose $\mu_0 > \frac{1}{2}$. Then, as in step 2, consider:

$$
\begin{aligned}
h_2(\mu_0, q) \equiv& \zeta(\Omega^{FD}) - \zeta(\Omega^*) \\
=& (1-q)\Psi(\mu_0, \mu_0) + q\int_0^1 \Psi(s,s)f(s)ds - (1-q)\Psi(\mu_0, \mu_\varnothing) \\
&- q\left(\int_0^{1-s_2^*} \Psi(s, \mu_\varnothing)f(s)ds + \int_{1-s_2^*}^{s_2^*} \Psi(s,s)f(s)ds + \int_{s_2^*}^1 \Psi(s, \mu_\varnothing)f(s)ds\right) \\
\frac{h_2(\mu_0, q)}{4k} =& (1-q)\mu_0(1-\mu_0)(\mu_0(1-\mu_0) - \mu_\varnothing(1-\mu_\varnothing)) + q\left(\int_0^1 s^2(1-s)^2 f(s)ds\right. \\
&\left. - \mu_\varnothing(1-\mu_\varnothing)\left(\int_0^{1-s_2^*} s(1-s)f(s)ds + \int_{s_2^*}^1 s(1-s)f(s)ds\right) - \int_{1-s_2^*}^{s_2^*} s^2(1-s)^2 f(s)ds\right) \\
=& \left((1-q)\mu_0(1-\mu_0)\right)\left(\mu_0(1-\mu_0) - \mu_\varnothing(1-\mu_\varnothing)\right) \\
&+ q\left(\frac{1}{30} - \frac{\mu_\varnothing(1-\mu_\varnothing)}{6} + \int_{1-s_2^*}^{s_2^*} s(1-s)(\mu_\varnothing(1-\mu_\varnothing) - s(1-s))f(s)ds\right) \\
=& \left(1-\mu_0\right)\mu_0(1-q)\left(\left(1-\mu_0\right)\mu_0 - \left(1-s_2^*\right)s_2^*\right) \\
&+ \frac{1}{30}q\left((s_2^*)^2 - s_2^* - 1\right)\left(2s_2^* - 1\right)^3 + q\left(\frac{1}{30} - \frac{1}{6}\left(1-s_2^*\right)s_2^*\right)
\end{aligned}
$$

The parameter restriction of the supposition implies that in order for $h_2(\mu_0, q) > 0$, $s_2^* \in (\hat{s}, 1]$

with $\hat{s}$ being the solution to:

$$
\begin{aligned}
0 =& 4s^5 q - 10s^4 q + 5s^3 q - s^2\left(15\mu_0^2(1-q) - 15\mu_0(1-q) - 5q\right) \\
&+ s\left(15\mu_0^2(1-q) - 15\mu_0(1-q) - 5q\right) + 15\mu_0^4(1-q) - 30\mu_0^3(1-q) + 15\mu_0^2(1-q) + q.
\end{aligned}
$$

This condition, however, is incompatible with the equilibrium characterization of Proposition 1. Thus $h_2(\mu_0, q) \leq 0$ which implies that $\zeta(\Omega^{FD}) \leq \zeta(\Omega^*)$ for $\mu_0 \in [\frac{1}{2}, \frac{2}{3}]$.

Approaching similarly for $\mu_0 < \frac{1}{2}$, one can show that $\zeta(\Omega^{FD}) \leq \zeta(\Omega^*)$ also holds for $\mu_0 < \frac{1}{2}$. ■

Proposition 4 also holds with Assumption 3.

Proof of Proposition 4 with Assumption 3.

Suppose $\mu_0 > \frac{1}{2}$, then real efficiency of the disclosure equilibrium is:

$$
\begin{aligned}
\zeta(q;\mu_\varnothing^*) =& (1-q)\Psi(\mu_0,\mu_\varnothing) + q\left(\int_0^{1-s_2^*}\Psi(s,\mu_\varnothing)f(s)ds + \int_{1-s_2^*}^{s_2^*}\Psi(s,s)f(s)ds + \int_{s_2^*}^{1}\Psi(s,\mu_\varnothing)f(s)ds\right) \\
=& (1-q)\left(\frac{1}{2}\mu_0^2 + \frac{1}{4k}\mu_\varnothing(1-\mu_\varnothing)\mu_0(1-\mu_0)\right) + q\left(\frac{1}{2}\int_0^1 s^2 f(s)ds \right.\\
&\left. + \frac{1}{4k}\left[\int_0^{1-s_2^*} s(1-s)\mu_\varnothing(1-\mu_\varnothing)f(s)ds + \int_{1-s_2^*}^{s_2^*} s^2(1-s)^2 f(s)ds + \int_{s_2^*}^{1} s^2(1-s)^2 f(s)ds\right]\right) \\
=& (1-q)\left(\frac{1}{2}\mu_0^2 + \frac{1}{4k}\mu_\varnothing(1-\mu_\varnothing)\mu_0(1-\mu_0)\right) + q\left(\frac{1}{2}\int_0^1 s^2 f(s)ds \right.\\
&\left. + \frac{1}{4k}\left[\mu_\varnothing(1-\mu_\varnothing)\int_0^1 s(1-s)f(s)ds + \int_{1-s_2^*}^{s_2^*} s(1-s)(s(1-s)-\mu_\varnothing(1-\mu_\varnothing))f(s)ds\right]\right),
\end{aligned}
$$

where the second equations plugs in the equilibrium degree of information acquisition of the strategic trader $x^*(\mu) = \frac{\mu(1-\mu)}{k}$. Now, the direct effect can be shown to be:

$$
\begin{aligned}
\frac{\partial\zeta}{\partial q} =& \frac{1}{4k}\left[\mu_\varnothing(1-\mu_\varnothing)\int_0^1 s(1-s)f(s)ds + \int_{1-s_2^*}^{s_2^*} s(1-s)(s(1-s)-\mu_\varnothing(1-\mu_\varnothing))f(s)ds \right.\\
&\left. - \mu_\varnothing(1-\mu_\varnothing)\mu_0(1-\mu_0)\right] + \frac{1}{2}\int_0^1 s^2 f(s)ds - \frac{1}{2}\mu_0^2 \\
=& \frac{1}{4k}\left[\frac{1}{6}\mu_\varnothing(1-\mu_\varnothing) + \int_{1-s_2^*}^{s_2^*} s(1-s)(s(1-s)-\mu_\varnothing(1-\mu_\varnothing))f(s)ds\right] + \frac{\mu_0(1-\mu_0)-\frac{1}{6}}{2} \\
=& \frac{1}{4k}\left[\frac{1}{6}\mu_\varnothing(1-\mu_\varnothing) + \frac{1}{30}\left(1+\mu_\varnothing(1-\mu_\varnothing)\right)(2\mu_\varnothing-1)^3\right] + \frac{\mu_0(1-\mu_0)-\frac{1}{6}}{2},
\end{aligned}
$$

where I explicitly calculated the integrals and used the fact that in equilibrium $s_2^* = \mu_\varnothing$.

Given Proposition 1 which implies $\mu^*_\varnothing > \mu_0$ for $\mu_0 > \frac{1}{2}$ and the assumption on $k \geq \frac{1}{4}$, it is easy to verify that $\frac{\partial \zeta}{\partial q} > 0$.

Next, consider the indirect benefit:

$$\begin{aligned}\frac{\partial \zeta}{\partial \mu_\varnothing}\frac{\partial \mu_\varnothing}{\partial q} =& \frac{\partial \mu_\varnothing}{\partial q}\Bigg[\frac{(1-q)}{4k}\mu_0(1-\mu_0)(1-2\mu_\varnothing)\\ &+\frac{q}{4k}\left((1-2\mu_\varnothing)\int_0^1 s(1-s)f(s) + (1-2\mu_\varnothing)\int_{1-s_2^*}^{s_2^*} s(1-s)f(s)\right)\Bigg]\\ =&\frac{\partial \mu_\varnothing}{\partial q}\frac{(1-2\mu_\varnothing)}{4k}\underbrace{\left((1-q)\mu_0(1-\mu_0) + q\left(\int_0^{1-s_2^*} s(1-s)f(s)ds + \int_{s_2^*}^1 s(1-s)f(s)ds\right)\right)}_{>0}.\end{aligned}$$

According to Corollary 2, $\frac{\partial \mu_\varnothing}{\partial q} > 0$ whenever $\mu_0 > \frac{1}{2}$. Then, it follows that $\frac{d\zeta}{dq} < 0$ as $\mu_0 > \frac{1}{2}$ implies that $\mu_\varnothing > \mu_0$.

Next, combine the direct effect with the indirect effect to analyze the combined effect of a change in q on real efficiency.

$$\begin{aligned}\frac{d\zeta}{dq} =& \frac{\partial \zeta}{\partial q} + \frac{\partial \zeta}{\partial \mu_\varnothing}\frac{\partial \mu_\varnothing}{\partial q}\\ =&\frac{1}{4k}\left[\frac{1}{6}\mu_\varnothing(1-\mu_\varnothing) + \frac{1}{30}\left(1+\mu_\varnothing(1-\mu_\varnothing)\right)(2\mu_\varnothing - 1)^3\right] + \frac{\mu_0(1-\mu_0)-\frac{1}{6}}{2}\\ &+\frac{\partial \mu_\varnothing}{\partial q}\frac{(1-2\mu_\varnothing)}{4k}\left((1-q)\mu_0(1-\mu_0) + q\left(\int_0^{1-s_2^*} s(1-s)f(s)ds + \int_{s_2^*}^1 s(1-s)f(s)ds\right)\right)\\ =&\frac{\mu_0(1-\mu_0)-\frac{1}{6}}{2} + \frac{1}{4k}\Bigg[\frac{1}{6}\mu_\varnothing(1-\mu_\varnothing) + \frac{1}{30}\left(1+\mu_\varnothing(1-\mu_\varnothing)\right)(2\mu_\varnothing-1)^3\\ &+\frac{\partial \mu_\varnothing}{\partial q}(1-2\mu_\varnothing)\left(\frac{1}{3}(1+2\mu_\varnothing)(1-\mu_\varnothing)^2 q + (1-\mu_0)\mu_0(1-q)\right)\Bigg]. \qquad (14)\end{aligned}$$

Note that the partial derivative of q with respect to $\mu_\varnothing$ can be written as:

$$\frac{\partial \mu_\varnothing}{\partial q} = \frac{1-2(\mu_\varnothing)\mu_\varnothing(1-2\mu_\varnothing)(2\mu_0-1)}{(1-2\mu_\varnothing)^2 q^2(\mu_\varnothing(8\mu_0-4)-4\mu_0+1) - 4q(\mu_\varnothing(2-6(1-\mu_\varnothing)\mu_0-3\mu_\varnothing)+\mu_0)-1}.$$

Plugging this term into Equation 14 results in in $\frac{d\zeta}{dq}$ being a seventh-order polynomial in $\mu_\varnothing$. From the proof of Proposition 1, we know that $\mu_\varnothing$ is itself the root of a third-order polynomial. Therefore, showing that $\frac{\partial \mu_\varnothing}{\partial q} < 0$ given the equilibrium $\mu_\varnothing$ is tedious, but results in the claimed parameter restriction of $q \in (\bar{q}, 1)$ and $\mu_0 \in (\bar{\mu}, \frac{2}{3}]$. In order to represent the parameter bounds in a digestible manner, suppose $k = 1/4$ which maximizes the degree of feedback and thus the importance of the indirect effect of an increase in q. Then, $\bar{\mu_0}$ is the solution to:

$$
\begin{aligned}
\bar{\mu_0}(\mu_0) \equiv 0 = &-63 + 576\mu_0 - 810\mu_0^2 - 7920\mu_0^3 + 42300\mu_0^4 - 94824\mu_0^5 + 112608\mu_0^6 - 69120\mu_0^7 \\
&+ 17280\mu_0^8
\end{aligned}
$$

with $\bar{\mu_0} \approx 0.6575$. In addition, $\bar{q}$ is the solution to:

$$
\begin{aligned}
\bar{q}(q, \mu_0) \equiv 0 = &17280\mu_0^8 - 69120\mu_0^7 + 112608\mu_0^6 - 94824\mu_0^5 + 42300\mu_0^4 - 7920\mu_0^3 \\
&- 810\mu_0^2 + 576\mu_0 - 63 + \alpha_1 q + \alpha_2 q^2 + \alpha_3 q^3 + \alpha_4 q^4 + \alpha_5 q^5 + \alpha_6 q^6 + \alpha_7 q^7
\end{aligned}
$$

with

$$
\begin{aligned}
\alpha_1 =& 55296000\mu_0^{15} - 414720000\mu_0^{14} + 1390694400\mu_0^{13} - 2746137600\mu_0^{12} \\
& + 3536363520\mu_0^{11} - 3100872960\mu_0^{10} + 1867919872\mu_0^{9} - 752120064\mu_0^{8} + 181906496\mu_0^{7} \\
& - 14492544\mu_0^{6} - 5642272\mu_0^{5} + 2119744\mu_0^{4} - 353968\mu_0^{3} + 44392\mu_0^{2} - 5208\mu_0 + 336 \\
\alpha_2 =& 82944000\mu_0^{15} - 622080000\mu_0^{14} + 2164838400\mu_0^{13} - 4643481600\mu_0^{12} + 6849653760\mu_0^{11} \\
& - 7308506880\mu_0^{10} + 5759157120\mu_0^{9} - 3360925440\mu_0^{8} + 1438532640\mu_0^{7} - 442788752\mu_0^{6} \\
& + 95282976\mu_0^{5} - 13919520\mu_0^{4} + 1404600\mu_0^{3} - 121740\mu_0^{2} + 11376\mu_0 - 658 \\
\alpha_3 =& 41472000\mu_0^{15} - 352512000\mu_0^{14} + 1349913600\mu_0^{13} - 3063744000\mu_0^{12} + 4563993600\mu_0^{11} \\
& - 4670265600\mu_0^{10} + 3336499200\mu_0^{9} - 1652252160\mu_0^{8} + 544400640\mu_0^{7} \\
& - 103749600\mu_0^{6} + 3179840\mu_0^{5} + 4155280\mu_0^{4} - 1266080\mu_0^{3} + 190600\mu_0^{2} \\
& - 15640\mu_0 + 560 \\
\alpha_4 =& 6912000\mu_0^{15} - 342144000\mu_0^{14} + 2210112000\mu_0^{13} - 6796051200\mu_0^{12} + 12665779200\mu_0^{11} \\
& - 15821539200\mu_0^{10} + 13941017600\mu_0^{9} - 8898556800\mu_0^{8} + 4160725600\mu_0^{7} \\
& - 1423375600\mu_0^{6} + 351341800\mu_0^{5} - 60706700\mu_0^{4} + 6945000\mu_0^{3} - 475450\mu_0^{2} + 16000\mu_0 - 175 \\
\alpha_5 =& - 41472000\mu_0^{14} + 290304000\mu_0^{13} - 915840000\mu_0^{12} + 1721088000\mu_0^{11} \\
& - 2143584000\mu_0^{10} + 1860019200\mu_0^{9} - 1147742400\mu_0^{8} + 502363200\mu_0^{7} - 150916000\mu_0^{6} \\
& + 27972000\mu_0^{5} - 1833600\mu_0^{4} - 488400\mu_0^{3} + 145800\mu_0^{2} - 16200\mu_0 + 700 \\
\alpha_6 =& 186624000\mu_0^{15} - 1399680000\mu_0^{14} + 4867776000\mu_0^{13} - 10412064000\mu_0^{12} + 15306624000\mu_0^{11} \\
& - 16360272000\mu_0^{10} + 13113360000\mu_0^{9} - 8013945600\mu_0^{8} + 3759494400\mu_0^{7} - 1351764000\mu_0^{6} \\
& + 368641600\mu_0^{5} - 74573200\mu_0^{4} + 10755200\mu_0^{3} - 1032400\mu_0^{2} + 58000\mu_0 - 1400 \\
\alpha_7 =& 3456000\mu_0^{12} - 20736000\mu_0^{11} + 57024000\mu_0^{10} - 95040000\mu_0^{9} + 106776000\mu_0^{8} - 85032000\mu_0^{7} \\
& + 49156000\mu_0^{6} - 20786400\mu_0^{5} + 6388000\mu_0^{4} - 1391600\mu_0^{3} + 203400\mu_0^{2} - 17800\mu_0 + 700
\end{aligned}
$$

For instance, this tedious expression is $\bar{q}(q, \mu_0 = \frac{2}{3}) \approx .99$.

All the findings from above can be repeated with $\mu_0 < \frac{1}{2}$ with the same results. ■.
The characterization of the short-term disclosure equilibrium in Lemma 2 does not change.

Proof of Proposition 5 with Assumption 3. Remember, Lemma 2 implies that short-term incentives lead to a disclosure policy of the form $\Omega^{ST} = [0, s^*_{ST}]$.

Let's compare this policy with a full nondisclosure policy in terms of real efficiency:

$$
\begin{aligned}
\zeta(\Omega^{ST}) - \zeta(\Omega^{ND}) =&(1-q)\left(\Psi(\mu_0, s^*_{ST}) - \Psi(\mu_0, s^{\mu_0})\right) \\
&+ q\left(\int_0^{s^*_{ST}} \Psi(s, s^*_{ST}) f(s) ds + \int_{s^*_{ST}}^1 \Psi(s,s) f(s) ds - \int_0^1 \Psi(s,s) f(s) ds\right) \\
=&(1-q)\left(\mu_0(1-\mu_0)(s^*_{ST}(1-s^*_{ST}) - \mu_0(1-\mu_0))\right) \\
&+ q\left(\int_0^s {}^*_{ST} s(1-s)(s^*_{ST}(1-s^*_{ST}) - \mu_0(1-\mu_0)) f(s) ds\right. \\
&\left. + \int_{s^*_{ST}}^1 s(1-s)(s(1-s) - \mu_0(1-\mu_0)) f(s) ds\right) \\
=&\left(s^*_{ST}(1-s^*_{ST}) - \mu_0(1-\mu_0)\right)\left((1-q)\mu_0(1-\mu_0) + \frac{q}{6}\right) \\
&+ q\left(\int_{s^*_{ST}}^1 s(1-s)(s(1-s) - s^*_{ST}(1-s^*_{ST})) f(s) ds\right) \qquad (15)
\end{aligned}
$$

Now consider the threshold belief s^*_{ST} of the short-term policy. Taking equation 8 and using the distributional Assumption 2, $s^*_{ST}(a)$ is the solution to:

$$
\begin{aligned}
a &= \frac{(1-q)\mu_0 + q\left(\int_0^a s f(s) ds\right)}{(1-q) + q\left(\int_0^a f(s) ds\right)} \\
&= \frac{(1-q)\mu_0 + q(a)^2\left(2a\left(2a-1\right) - 3a + 2\right)}{(1-q) + q\left(a\left(3a\left(2\mu_0 - 1\right) - 6\mu_0 + 4\right)\right)} \\
0 &= \frac{\mu_0 - a - (1-a)^2 q(\mu_0 - a(1-2\mu_0))}{1 - (1-a)(1-3a(1-2a))q} \\
0 &= (1-q)(a-\mu_0) + (2-3\mu_0)qa^2 + (2\mu_0 - 1)qa^3 \qquad (16)
\end{aligned}
$$

In order for short-term incentives to result in higher real efficiency than a full nondisclosure policy, Equation 15 has to be positive given s^*_{ST} being the solution to Equation 16. It can be shown, that both conditions hold for $q \in (0, q^{ST})$ and $\mu_0 \left(\mu^{ST}, \frac{2}{3}\right]$, where q^{ST} and μ^{ST} are the solutions to:

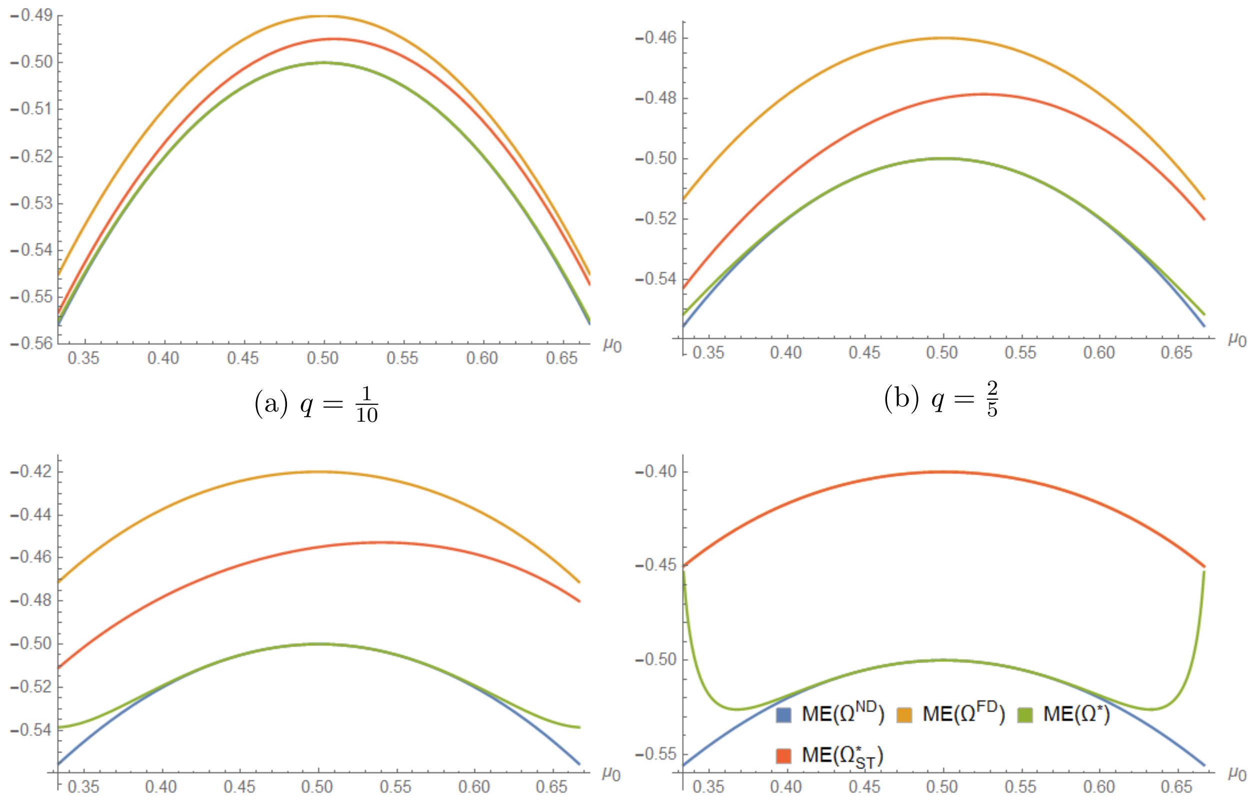
$$
\begin{aligned}
\mu^{ST} \equiv& 0 = 1 - 2x - 4x^2 - 45x^3 + 90x^4 \\
\mu^{ST} \approx& 0.5853 \\
q^{ST}(\mu_0) \equiv& 0 = -225 + 1125\mu_0 - 900\mu_0^2 + 8325\mu_0^3 - 48825\mu_0^4 + 81000\mu_0^5 - 40500\mu_0^6 \\
&+ \beta_1 x + \beta_2 x^2 + +\beta_3 x^3 + \beta_4 x^4 + \beta_5 x^5 + \beta_6 x^6
\end{aligned}
$$

with

$$
\begin{aligned}
\beta_1 =& -594000\mu_0^9 + 2079000\mu_0^8 - 2752200\mu_0^7 + 1831500\mu_0^6 - 748920\mu_0^5 + 241605\mu_0^4 - 70301\mu_0^3 + 20308\mu_0^2 \\
& - 5373\mu_0 + 631 \\
\beta_2 =& -216000\mu_0^{12} + 1080000\mu_0^{11} - 792000\mu_0^{10} - 1314000\mu_0^9 + 962100\mu_0^8 + 1716300\mu_0^7 - 2387100\mu_0^6 \\
& + 1270560\mu_0^5 - 421815\mu_0^4 + 121795\mu_0^3 - 32850\mu_0^2 + 6375\mu_0 - 555 \\
\beta_3 =& -864000\mu_0^{15} + 5616000\mu_0^{14} - 15336000\mu_0^{13} + 23652000\mu_0^{12} - 25434000\mu_0^{11} + 20583000\mu_0^{10} \\
& - 9709200\mu_0^9 + 22800\mu_0^8 + 2286000\mu_0^7 - 908400\mu_0^6 + 78360\mu_0^5 + 33740\mu_0^4 - 21010\mu_0^3 + 8730\mu_0^2 \\
& - 1930\mu_0 + 160 \\
\beta_4 =& 2592000\mu_0^{15} - 16848000\mu_0^{14} + 46440000\mu_0^{13} - 71671500\mu_0^{12} + 72659700\mu_0^{11} - 55724400\mu_0^{10} \\
& + 34379100\mu_0^9 - 15874200\mu_0^8 + 4796700\mu_0^7 - 755050\mu_0^6 - 44500\mu_0^5 + 80825\mu_0^4 - 36325\mu_0^3 \\
& + 9500\mu_0^2 - 1325\mu_0 + 75 \\
\beta_5 =& -2592000\mu_0^{15} + 16848000\mu_0^{14} - 46872000\mu_0^{13} + 73251000\mu_0^{12} - 73409400\mu_0^{11} + 53070300\mu_0^{10} \\
& - 31266000\mu_0^9 + 16109700\mu_0^8 - 7140300\mu_0^7 + 2636250\mu_0^6 - 818600\mu_0^5 + 216125\mu_0^4 - 45825\mu_0^3 \\
& + 6900\mu_0^2 - 625\mu_0 + 25 \\
\beta_6 =& 864000\mu_0^{15} - 5616000\mu_0^{14} + 15768000\mu_0^{13} - 25015500\mu_0^{12} + 25103700\mu_0^{11} - 17136900\mu_0^{10} \\
& + 8508100\mu_0^9 - 3303275\mu_0^8 + 1062575\mu_0^7 - 282275\mu_0^6 + 57550\mu_0^5 - 8075\mu_0^4 + 675\mu_0^3 - 25\mu_0^2.
\end{aligned}
$$

■ Given the proof of Proposition 5 under Assumption 3, Corollary 1 also holds under Assumption 3.

Let's consider Proposition 6 under Assumption 4. From the proof of Proposition 6 it follows that Ω^{ND} minimizes and Ω^{FD} maximizes market efficiency for any internal signal distribution and thus also under Assumption 3. The relationship of $ME(\Omega^*_{ST})$ and $ME(\Omega^*_{ST})$, however, is more tedious to proof and left out for brevity. Nevertheless, the following Figure 5 depicts the ordering of the four disclosure policies in terms of market efficiency. In line with Proposition 6, the results also follow under Assumption 3.



(a) $q = \frac{1}{10}$

(b) $q = \frac{2}{5}$

(c) $q = \frac{4}{5}$

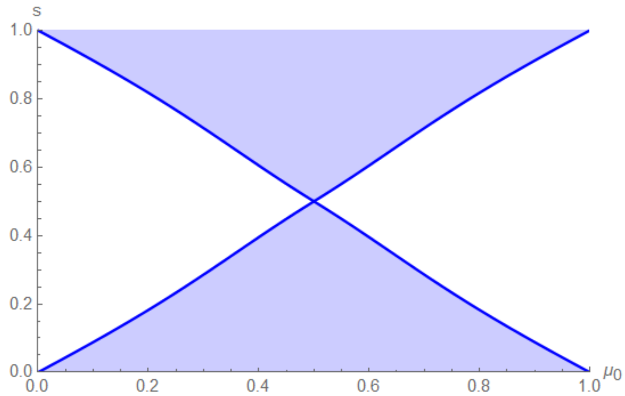
(d) $q = 1$

Figure 5: ME comparison of Ω^{ND}, Ω^{FD}, Ω^{*}_{ST}, and Ω^{*} given Assumption 3
All figures above use $k = \frac{1}{4}$

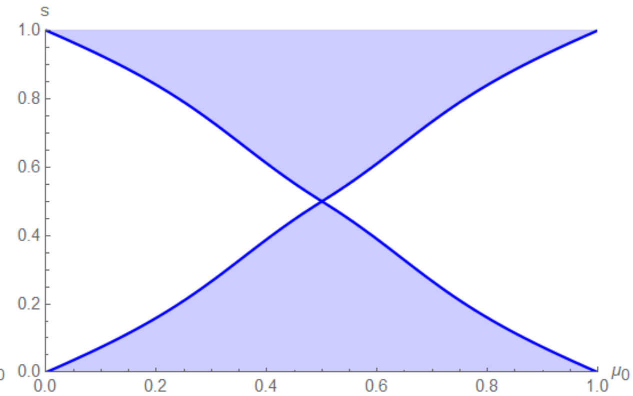
B.2 Numerical solutions with Assumption 4

Figure 6 and 7 visualize disclosure equilibria given Assumption 4 under different parameter values of q and μ_0. In line with Proposition 2 and Corollary 2, the nondisclosure region Ω^* is decreasing in q, however, does not feature unraveling for $q = 1$. Given Assumption 4, $f(0), f(1) > 1$ and therefore the condition for unraveling outlined in Proposition 1 is not met.

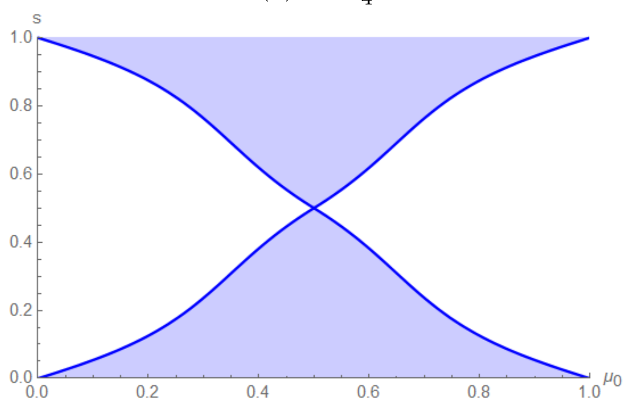
In addition, the nondisclosure region Ω^* is increasing in μ_0 for $\mu_0 < \frac{1}{2}$ and decreasing for $\mu_0 \geq \frac{1}{2}$.



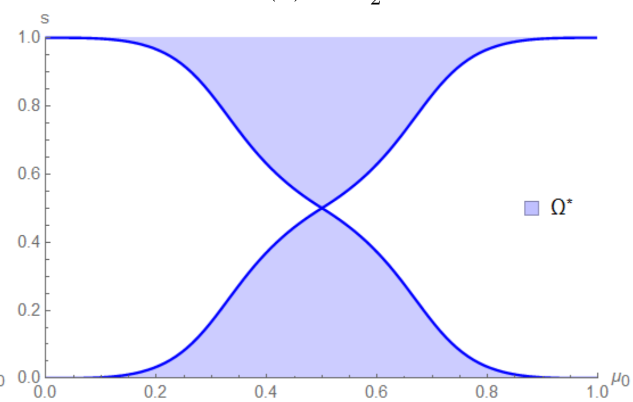
(a) $q = \frac{1}{4}$



(b) $q = \frac{1}{2}$

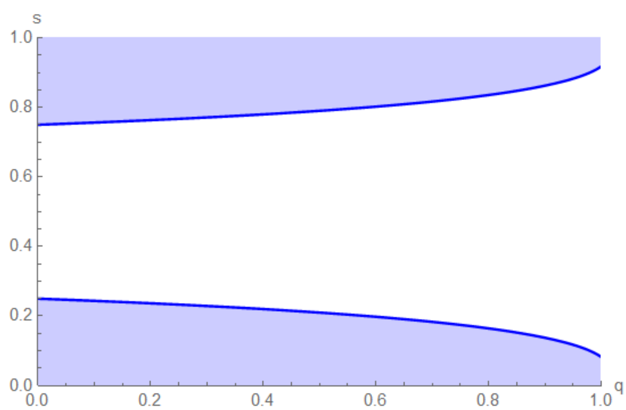


(c) $q = \frac{3}{4}$

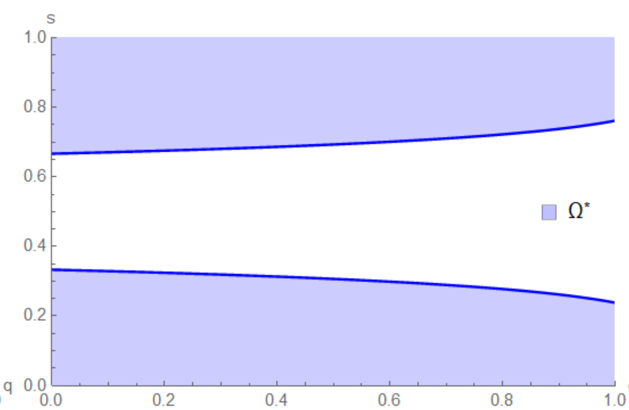


(d) $q = 1$

Figure 6: Disclosure equilibria given Assumption 4 (I/II)



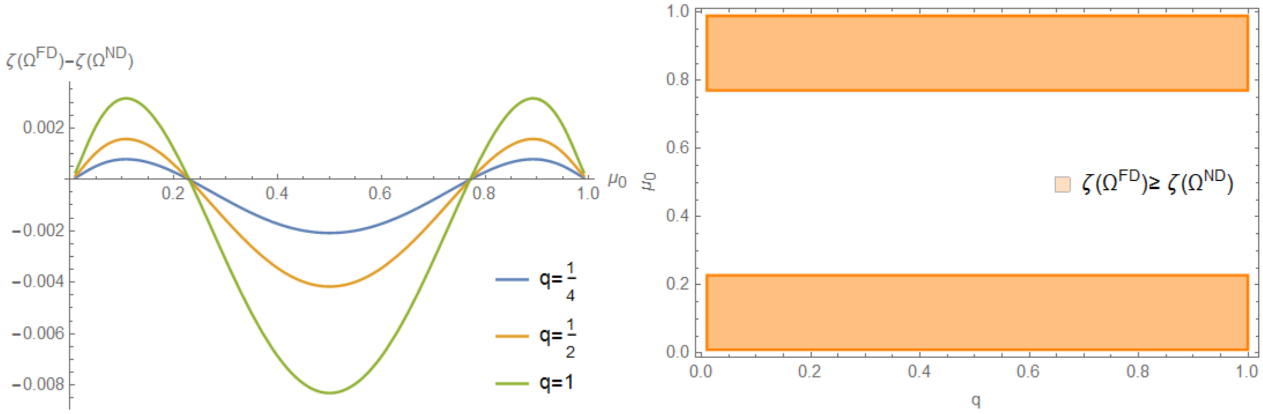
(a) $\mu_0 = \frac{1}{4}$



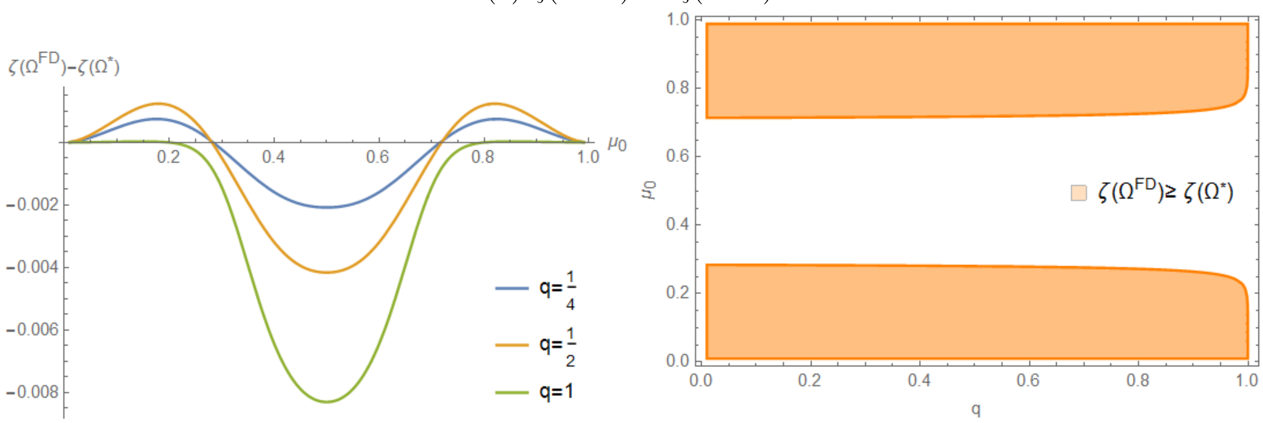
(b) $\mu_0 = \frac{2}{3}$

Figure 7: Disclosure equilibria given Assumption 4 (II/II)

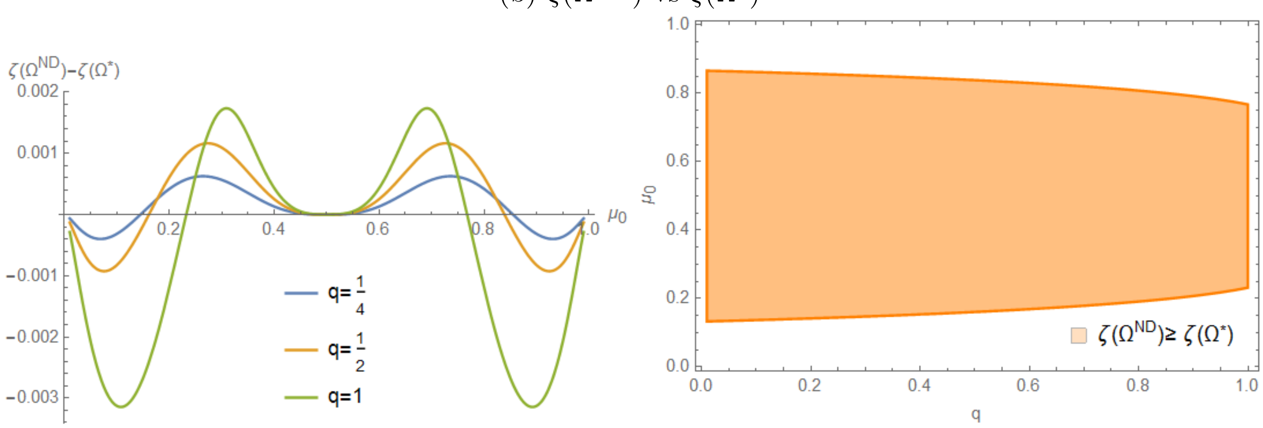
Next, let's consider the insights from Proposition 3 and how they change given Assumption 4. The strict ordering of the disclosure policies in terms of real efficiency continues to hold, however, only for a subset of the parameter space. Figure 8 compares the policies of full disclosure and full nondisclosure with the equilibrium disclosure policy Ω^*. As outlined in Footnote 25, for sufficiently extreme prior beliefs of μ_0, a full disclosure policy dominates a policy of full nondisclosure.



(a) $\zeta(\Omega^{ND})$ vs $\zeta(\Omega^{FD})$



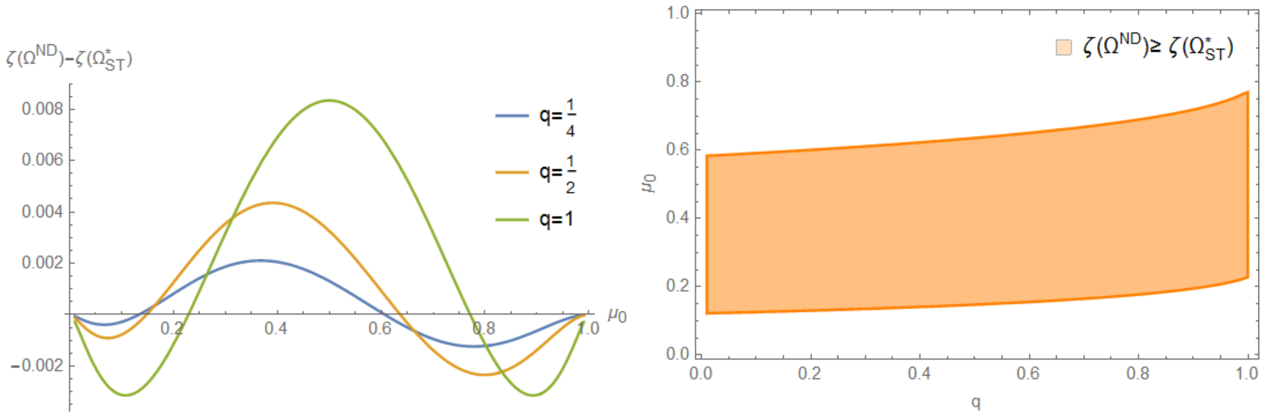
(b) $\zeta(\Omega^{FD})$ vs $\zeta(\Omega^*)$



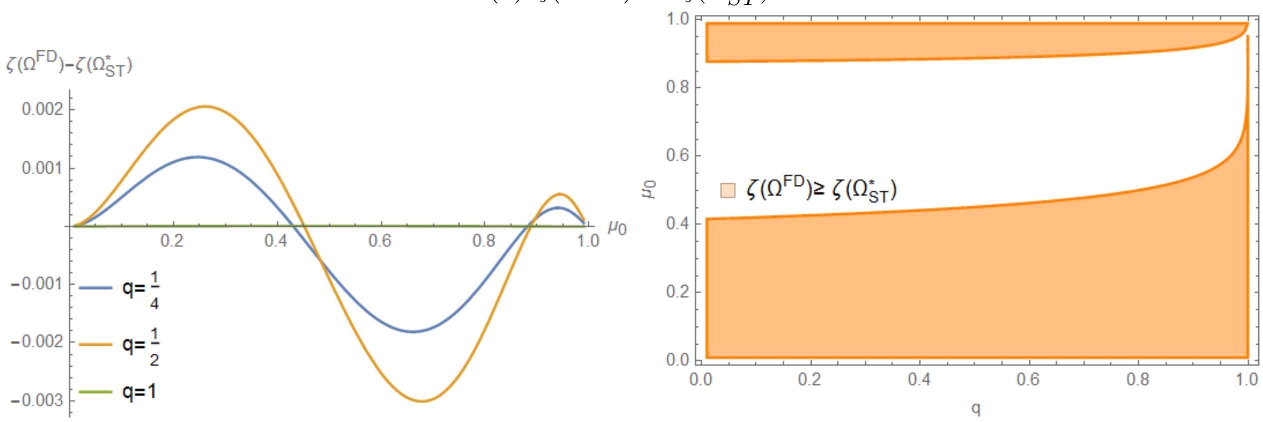
(c) $\zeta(\Omega^{ND})$ vs $\zeta(\Omega^*)$

Figure 8: RE Comparison of Ω^{ND}, Ω^{FD}, and Ω^*
All figures above use $k = \frac{1}{4}$

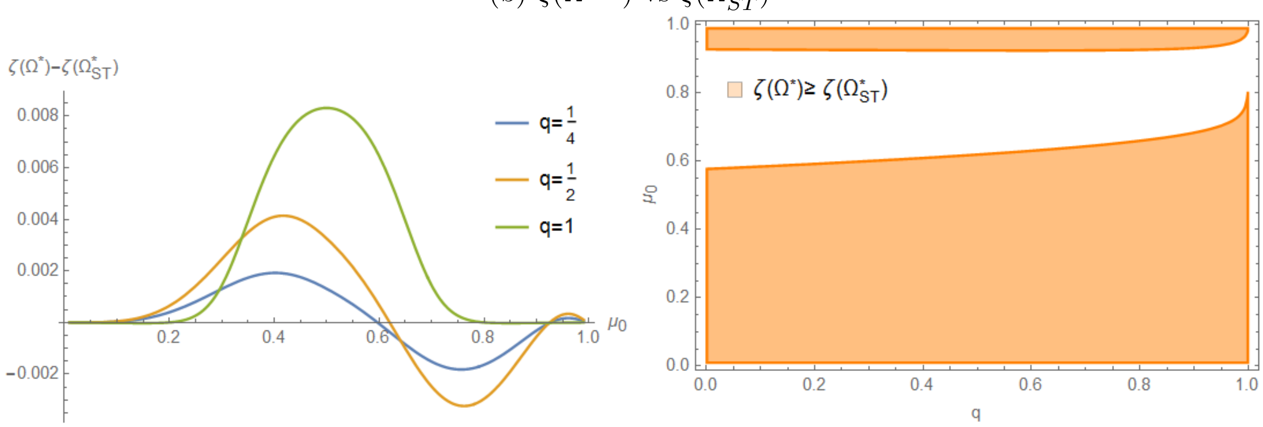
Figure 9 adds the disclosure policy given short-term incentives to the comparison. In line with Proposition 5 and Corollary 1, there exist parameter values for which Ω^*_{ST} dominates Ω^{ND} and Ω^*.



(a) $\zeta(\Omega^{ND})$ vs $\zeta(\Omega^*_{ST})$



(b) $\zeta(\Omega^{FD})$ vs $\zeta(\Omega^*_{ST})$



(c) $\zeta(\Omega^*)$ vs $\zeta(\Omega^*_{ST})$

Figure 9: RE Comparison of Ω^{ND}, Ω^{FD}, Ω^*, and Ω^*_{ST}
All figures above use $k = \frac{1}{4}$

An alternative real efficiency comparison is Figure 10. The regions indicate which of the four policies Ω^*, $\Omega^*_{ST}*$, Ω^{ND}, and Ω^{FD} yields the highest real efficiency for the respective parameter combinations. Interestingly, the region where the disclosure policy given long-term incentives dominates is rather small (see the small shaded blue area at $(q \approx .99, \mu_0 \approx .75)$.

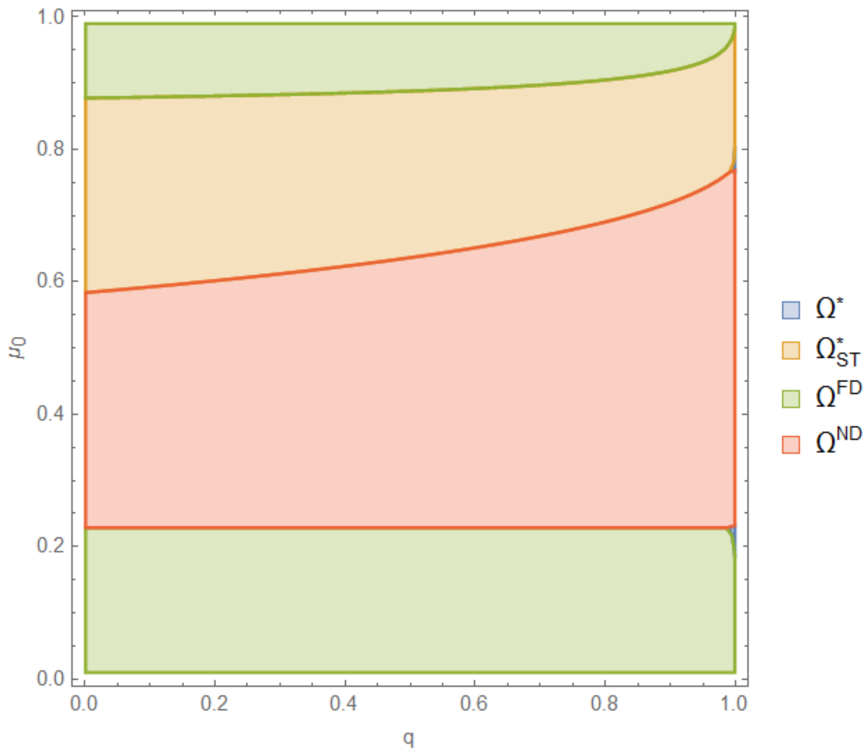
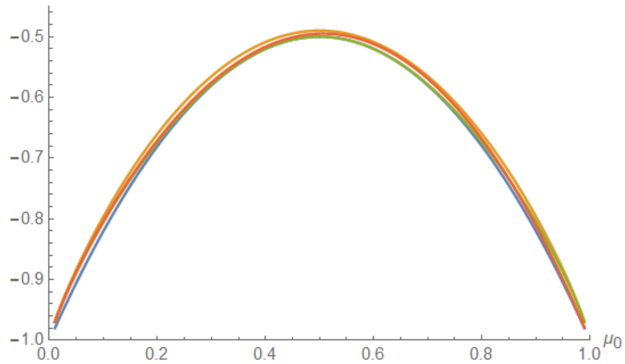


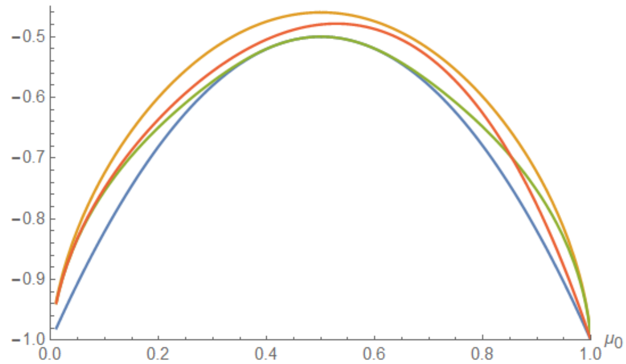
Figure 10: RE dominating policies
The figure above uses $k = \frac{1}{4}$

In terms of Proposition 4, Assumption 4 does not change the implications of a positive direct effect $\frac{\partial \zeta}{\partial q} > 0$ and a negative indirect effect $\frac{\partial \zeta}{\partial s^*} \frac{\partial s^*}{\partial q} < 0$ given a change of q for all permitted parameter values. The proof of this claim is a straight-forward extension of the proof of Proposition 4 with the monotone internal signal Assumption 4. However, the finding that the total effect may be negative does not hold under Assumption 4.

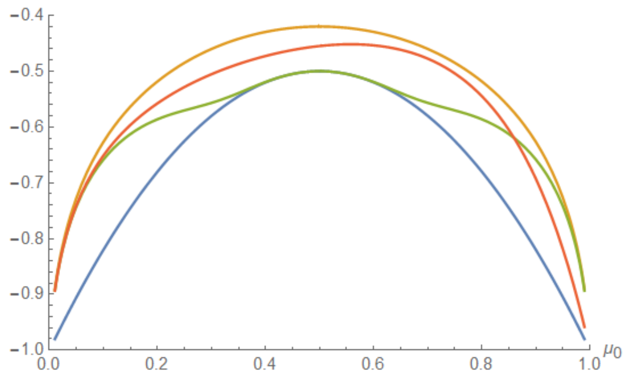
Let's consider Proposition 6 under Assumption 4. Again, Ω^{ND} minimizes and Ω^{FD} maximizes market efficiency. Figure 11 represents market efficiency for the four disclosure policies under different parameter values of q and the distributional Assumption 4. In contrast to the market efficiency results given Assumption 2 and 3, now the policy Ω^*_{ST} does not always dominate Ω^* in terms of market efficiency. It does so, however, for the majority of the parameter space as Figure 12 shows. In fact, the parameter space where the short-term policy dominates in terms of market efficiency coincides with the restrictions of $\mu_0 \in \left[\frac{1}{3}, \frac{2}{3}\right]$ in Assumption 3.



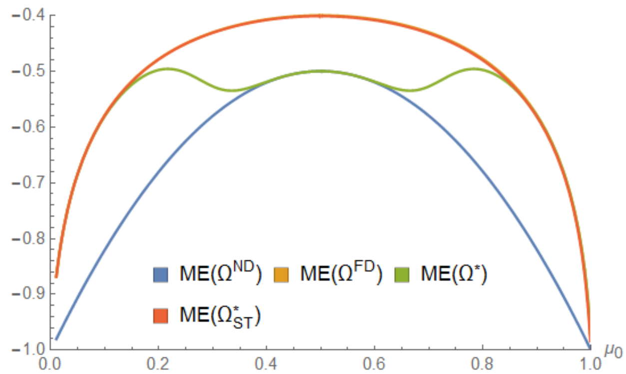
(a) $q = \frac{1}{10}$



(b) $q = \frac{2}{5}$



(c) $q = \frac{4}{5}$



(d) $q = 1$

Figure 11: ME comparison of Ω^{ND}, Ω^{FD}, Ω^{*}_{ST}, and Ω^{*} given Assumption 4
All figures above use $k = \frac{1}{4}$

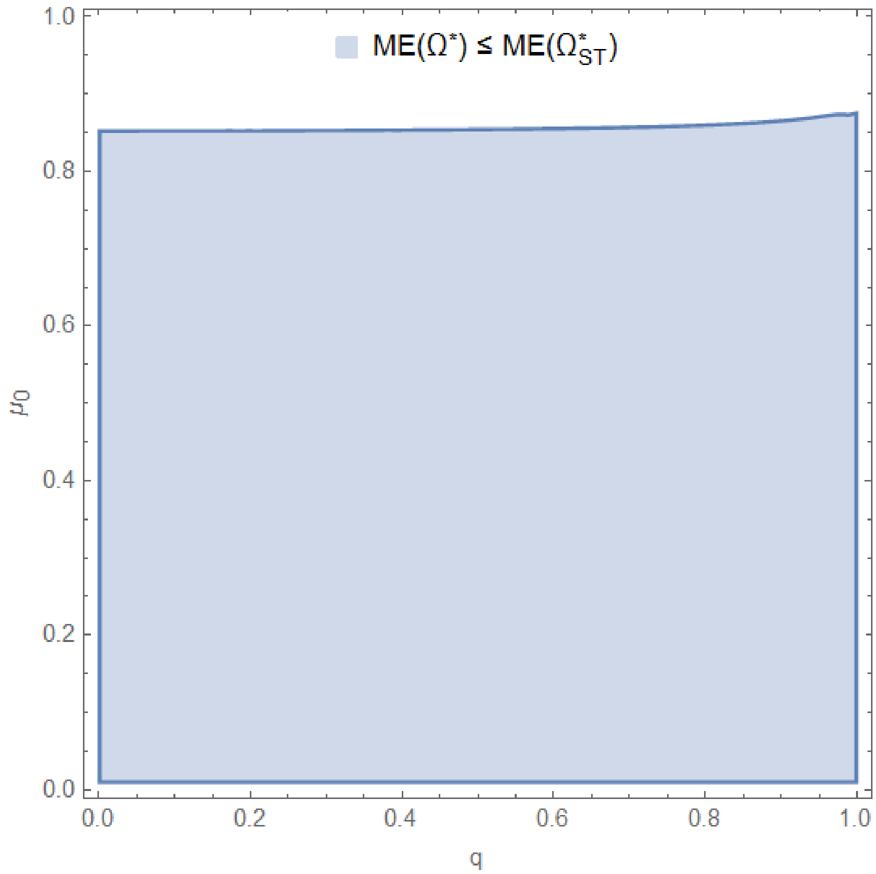


Figure 12: ME comparison between Ω^* and Ω^*_{ST}
The figure above uses $k = \frac{1}{4}$

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