

Marking to Market and Inefficient Investment Decisions*

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Abstract

We examine how mark-to-market accounting affects investment decisions of managers with reputation concerns. Reporting the current market value of a firm's assets can serve as a disciplining device because the information contained in the market prices provides a benchmark against which the management's actions can be evaluated. However, the fact that market prices are informative can have a perverse effect on investment decisions. The firm's management may prefer to ignore relevant but contradictory private information whose revelation would damage its reputation. Surprisingly, this effect can render marking to market *less* desirable when market prices become *more* informative.

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1. Introduction

Since the recent banking crisis, mark-to-market accounting is again at the forefront of the policy debate. Its critics emphasize that markets are inefficient and market prices often diverge from fundamentals. Therefore, mark-to-market accounting can lead to excessive fluctuations in asset valuations, contagion, and downward spirals.¹ Its supporters argue that marking to market provides more timely information and increases transparency. It can thus improve decision making, allow for prompt corrective actions, and help monitor a firm's management.²

Two important preconditions must be met so that marking to market can generate the aforementioned benefits. First, mark-to-market accounting must provide information about the current market value of the firm's assets that is *new* to the recipients of the financial statements. Second, the current market value of the assets must contain *relevant* information about the actions that the firm's management should optimally take.

In this paper, we show that the combination of these two features can have a perverse effect: If managers care about their reputation, they may choose to ignore relevant but contradictory private information when market valuations are reported in the financial statements. This makes marking to market less appealing when optimal managerial decisions depend both on the information contained in the market prices of the firm's existing assets and on private information. Surprisingly, the effect is particularly strong if market

¹A movement against marking to market has gathered strength both in the US (where the FASB dropped the proposal for mark-to-market accounting of the loan portfolio of banks in January 2011) and in Europe (where the IASB's move towards marking to market was opposed by institutional investors, arguing it may lead to a reduction in prudence when market prices are high).

²See Laux and Leuz [2009] for a detailed discussion.

prices are highly informative. This challenges the commonly held view that marking to market naturally becomes more desirable as market prices become more informative.

To give a concrete example of the setting we have in mind, consider a bank that owns a portfolio of marketable securities. On its balance sheet, the bank reports this position as “financial instruments owned.” Even though the bank may provide a break-down into several sub-categories (e.g., government obligations, corporate debt, or equities) in the notes to the financial statements, investors typically do not know exactly which securities the bank owns. Hence, even if all securities have readily available market prices, the investors cannot produce an accurate valuation of the investment portfolio on their own. Instead, they must rely on the bank to report this information. Financial statements based on mark-to-market accounting can thus provide new information to these investors. Further, knowing the current market value of the bank’s existing investment portfolio may be relevant when assessing which new projects the bank should fund. For example, in the presence of financing frictions, it may be optimal to take on more risk if the bank’s existing investments can provide a cushion against future losses. Hence, mark-to-market accounting can provide information that helps monitor the bank’s management.

Suppose that the current market value of the bank’s existing investment portfolio is high, allowing the bank to make large investments in new, risky projects. At the same time, the bank managers’ private information suggests that more cautious investments are optimal. Investing cautiously, however, reveals that the managers disagree with the market. This, in turn, jeopardizes the management’s reputation if the private information of skilled managers is more likely to coincide with (rather than diverge from) the information conveyed by the market prices. Hence, the bank’s management may prefer to ignore their private information and fall in line with the market (i.e., to make an

inefficient investment decision – taking on, in this case, excessive risk).

The above example corresponds closely to the framework we use for our analysis. Specifically, we consider an agency model with the following features. A firm run by a manager (or insider) must make an investment decision on behalf of its shareholders (or outside investors). Which decision maximizes expected profits depends on the manager's private information as well as on information that is conveyed by the market value of the firm's existing assets. This could be the case, for example, because the firm's cost of capital depends on the existing assets' value or because the existing assets and the new investment are complements. However, there is an agency problem: While the shareholders' objective is to maximize profits, the manager's goal is to maximize his reputation (e.g., because of career concerns). Thus, whenever the reputation maximizing investment differs from the profit maximizing choice, a conflict of interest arises.

Using this framework, we examine two accounting rules: marking to market and historical cost accounting. The only difference between the two rules in our setup is that under mark-to-market accounting, the market value of the firm's assets is reported in its financial statements. Under historical cost accounting, assets on the firm's balance sheet are valued at historical cost, and their current market value remains hidden from the outside investors. The idea is that even though market prices for all types of assets in the economy are available and public information, the outside investors do not know precisely which assets the firm owns. As a consequence, they do not know which of the available prices are relevant. Mark-to-market accounting can thus provide new information to these investors.

Our analysis yields the following central result: Marking to market can cause distortions in the manager's investment decisions precisely because market prices contain

relevant information. As a consequence, more informative market prices can render mark-to-market accounting less attractive.

The intuition behind this finding is as follows. If the current market value of the firm's assets contains information regarding which investment maximizes expected net profits, then publicly revealing this information creates a benchmark against which the manager's decisions can be evaluated. This has two effects. On the one hand, it forces the manager to consider the revealed information when making the investment decision. On the other hand, it creates incentives to ignore relevant but contradictory private information whose revelation would damage the manager's reputation. The first effect ameliorates the agency problem between the manager and the firm's shareholders. The second effect, however, aggravates the problem.

Whether the shareholders are better off when an informative market valuation is revealed thus depends on which effect dominates. If the market prices are relatively uninformative (compared to the manager's private information), revealing a divergence between the private and the market information causes little reputational damage. In this case, the expected boost in reputation that the manager obtains if, ex post, his private information turns out to be correct induces him to choose the first-best investment (which depends both on the private and the market information). If, instead, the market prices are relatively informative, mark-to-market accounting can be less desirable. In that case, revealing that his private information differs from the market information has a more negative effect on the manager's reputation. At the same time, there is a smaller probability that his private information will later prove to be correct. Marking to market thus magnifies the manager's incentives to disregard his private information. If this effect

is sufficiently large, the first-best investment can no longer be implemented.³

After deriving this central result, we examine how the accounting rules affect the types of assets that firms choose to hold on their balance sheets. Specifically, we consider the choice of asset-opaqueness, assuming that more opaque assets have less informative prices. We then show that marking to market creates a preference for more opaque assets.

Further, we show that our findings are robust to several model variations. In particular, we consider voluntary disclosure as well as fraudulent reporting and show that our results are not affected. Moreover, we show that our findings remain qualitatively unchanged in the presence of incentive compensation. Finally, we consider the case of asymmetric information between the shareholders and the manager regarding the quality of the manager's private information. In that case, we show that the first-best investment cannot be implemented and that marking to market leaves the shareholders worse off.

Our paper contributes to the growing literature on the costs and benefits of marking to market.⁴ The common view is that mark-to-market accounting is costly in periods of crisis. Allen and Carletti [2008], for example, argue that marking to market can lead to contagion across firms during a liquidity crisis. Plantin, Sapra, and Shin [2008] show how mark-to-market accounting can add endogenous volatility to prices. This, in turn, can lead to financial cycles when financial institutions actively readjust their balance sheets (see, for example, Adrian and Shin [2009]).⁵

³The detrimental effect of more informative market prices is thus distinct from the “Hirshleifer effect” (after Hirshleifer [1971]), i.e., an adverse effect of additional information on risk-sharing.

⁴See Leuz and Wysocki [2008] and Sapra [2010] for detailed surveys.

⁵Heaton, Lucas, and McDonald [2010] also focus on financial institutions and argue that marking to market needs to be combined with procyclical capital requirements. O'Hara [1993] shows how mark-to-market accounting can cause a shift towards short-term lending, and Ellul, Jotikasthira, Lundblad, and

Unlike these papers, we show that mark-to-market accounting can be associated with costs even in normal times (i.e., outside periods of crisis). Moreover, instead of focusing on the distortions that may be caused by deviations between prices and fundamentals, we examine how the different accounting rules can affect an agency problem inside the firm. Because it changes the firm’s information environment, marking to market can be detrimental even if there are no exogenous capital requirements and if prices reflect all available public information. Indeed, we show that marking to market can even become *less* desirable when market prices become *more* informative.

Our paper is further related to the literature on the effect of reputation concerns on managerial decisions. Holmström and Ricart i Costa [1986] suggest that an important reason for the misalignment of incentives between managers and shareholders is that the reputation value of an investment may differ from its financial value. They further point out that managers’ freedom to quit their current job and obtain a better-paid position elsewhere provides them with strong incentives to care about their reputation. Hirshleifer [1993] reviews the research on distortions of investment decisions due to reputation concerns and concludes that “managers have an incentive to use investment choices as a tool for building their personal reputations or the reputation of their firms“ (Hirshleifer [1993] p. 146).

Regarding the modeling of reputation concerns in our analysis, we borrow from the literature on rational herding. In particular, the mechanism at the core of our model builds on Scharfstein and Stein [1990], who show how reputation concerns may induce managers to ignore valuable private information and mimic the investment decisions of others.⁶ However, unlike Scharfstein and Stein [1990], we consider two signals of

Wang [2013] find that marking to market can lead to more conservative investments ex ante.

⁶Also related are Brandenburger and Polak [1996], Gentzkow and Shapiro [2006], Graham [1999],

potentially different quality: a market signal and a private signal. We then examine the effect of increasing the informativeness of the market signal while holding the quality of the private signal fixed. Further, we study under which conditions publicly revealing the market signal is optimal. Moreover, we show that firms may react to mandatory market-to-market accounting by holding assets on their balance sheets that have less informative market prices.

Finally, our paper is related to the literature on information disclosure. Prat [2005], for example, also shows how increasing transparency can have detrimental effects. Unlike Prat [2005], however, we not only examine whether a certain signal should be made public, but also study the effects of increasing the informativeness of the signal (conditional on being public). Interestingly, we find that more informative market valuations can be a double-edged sword.⁷ On the one hand, increasing the informativeness of public valuations implies that more information can be used to make investment decisions. On the other hand, increasing the valuations' informativeness magnifies the incentives to ignore relevant private information. As a consequence, more informative market valuations can actually lead to less informed investment decisions.

The remainder of the paper is organized as follows. In Section 2, we describe the setup of our model and discuss the assumptions. Section 3 examines the optimal investment rules and whether such strategies can be implemented. Section 4 presents four extensions of our model. Section 5 discusses testable implications. Section 6 concludes. All proofs are in the Appendix.

Ottaviani and Sørensen [2006], Prendergast [1993], Prendergast and Stole [1996], and Trueman [1994].

⁷The result that more informative disclosure can be detrimental is also related to Crémer [1995], Goldstein and Sapra [2013], Hermalin and Weisbach [2012], Kanodia, Singh, and Spero [2005], Morris and Shin [2002], and Vives [2014].

2. Model

2.1. Setup

Consider a firm that is run by a manager (or insider) on behalf of its shareholders (or outside investors). Everyone is risk-neutral. There are three dates – $t = 0, 1, 2$ – corresponding to the end of a first fiscal period, an intermediate date during a second fiscal period, and the end date of the second fiscal period.

At $t = 0$, the firm starts out with a set of assets in place. The manager knows the exact nature of these assets. The shareholders, however, do not. The idea is that there are many different types of assets in the economy, and the shareholders cannot observe precisely which assets were acquired with the capital they originally provided to the firm. Instead, to learn about these assets, the shareholders must rely on the firm's accounting reports, which are released at the end of each fiscal period.

The firm's existing assets will generate a future cash-flow π , which we normalize to $\pi \in \{0, 1\}$. This cash-flow depends on the asset specific state of the world $\omega \in \{H, L\}$ in the following way:

$$\Pr(\pi = 1 | \omega = H) = p \tag{1}$$

and

$$\Pr(\pi = 1 | \omega = L) = 1 - p \tag{2}$$

for some $p \in (1/2, 1)$. In the absence of additional information, the two possible states are equally likely: $\Pr(\omega = L) = \Pr(\omega = H) = 1/2$.

In the firm's financial statements, the value of the assets in place is reported according to the prevailing accounting rules: either based on the assets' historical cost (historical

cost accounting) or based on the assets' current market value (mark-to-market accounting). Under historical cost accounting, the current market value of the firm's existing assets remains unknown to the shareholders.⁸ Under marking to market, the shareholders learn the assets' market valuation from the financial statements.⁹ This is the only difference between mark-to-market accounting and historical cost accounting in our setup. Under mark-to-market accounting, the financial statements reveal information that the firm's shareholders would not be able to obtain otherwise: Even though market prices for all types of assets in the economy are available and public information, the shareholders do not know exactly which assets the firm owns. Hence, the shareholders do not know which of the available prices are relevant.¹⁰

The market price of the firm's existing assets is equal to their expected cash-flow, conditional on some asset specific signal $\sigma \in \{H, L\}$ that is available to the market.¹¹ It is common knowledge that the signal is either informative (i.e., the signal's type is $\theta_M = i$) or uninformative ($\theta_M = u$) with probability $\Pr(\theta_M = i) \equiv \phi \in [0, 1]$. If the signal is informative, it perfectly reveals the state of the world:

$$\Pr(\sigma = H|\omega = H, \theta_M = i) = \Pr(\sigma = L|\omega = L, \theta_M = i) = 1. \quad (3)$$

If the signal is uninformative, it is pure noise:

$$\Pr(\sigma = H|\omega = H, \theta_M = u) = \Pr(\sigma = L|\omega = L, \theta_M = u) = \frac{1}{2}. \quad (4)$$

⁸The reported book value, in that case, is the assets' historical cost (less any accumulated depreciation), which we assume to be uninformative about the future state of the world.

⁹In Section 4, we show that truthful reporting is the equilibrium outcome in our setting.

¹⁰Alternatively, we could assume that learning about the market value of the assets is very costly to the shareholders if they do so on their own, i.e., without relying on the financial statements.

¹¹For simplicity, we assume risk-neutrality and no discounting.

The market price of the assets is therefore equal to either

$$\begin{aligned} E[\pi|\sigma = H] &= \Pr(\omega = H|\sigma = H) \cdot p + \Pr(\omega = L|\sigma = H) \cdot (1 - p) \\ &= \frac{1}{2} + \phi \left(p - \frac{1}{2} \right) \end{aligned} \quad (5)$$

or

$$\begin{aligned} E[\pi|\sigma = L] &= \Pr(\omega = H|\sigma = L) \cdot p + \Pr(\omega = L|\sigma = L) \cdot (1 - p) \\ &= \frac{1}{2} - \phi \left(p - \frac{1}{2} \right). \end{aligned} \quad (6)$$

Thus, the assets' price reveals the information that is available to the market.¹² Mark-to-market accounting makes this information available to the firm's shareholders: They can infer the market signal (σ) from the assets' current market value that is reported in the financial statements. Henceforth, we will therefore treat marking to market as revealing the market signal to the shareholders.

Unlike the shareholders, the manager knows the exact nature of the firm's existing assets. Hence, the manager can directly observe the relevant market price. As a consequence, he can infer the market signal irrespective of the accounting rules. In addition, he also receives an asset specific private signal $s \in \{H, L\}$. Similar to the market signal, the manager's private signal may or may not be informative, depending on the manager's type. A good manager (type $\theta_A = g$) receives informative signals, and a bad manager (type $\theta_A = b$) does not:

$$\Pr(s = H|\omega = H, \theta_A = g) = \Pr(s = L|\omega = L, \theta_A = g) = 1 \quad (7)$$

and

$$\Pr(s = H|\omega = H, \theta_A = b) = \Pr(s = L|\omega = L, \theta_A = b) = \frac{1}{2}. \quad (8)$$

¹²The price is uninformative in the special case of $\phi = 0$, i.e., if the market signal is pure noise.

Neither the manager nor the shareholders know with certainty whether or not the manager's private signal is informative.¹³ However, it is common knowledge that the probability that the manager's type is good is $\Pr(\theta_A = g) \equiv \delta \in [0, 1)$.

At $t = 1$, the manager's task is to choose an amount $a \in \mathbb{R}_+$ to invest in a new project. This amount will be reported (e.g., as a capital expenditure) in the firm's financial statements at the end of the fiscal period.

At $t = 2$, the firm's final profit $\Pi(\pi, a)$ – net of any costs – is generated by the existing assets and the new project. We assume that $\Pi(\pi, a)$ satisfies

$$\Pi(1, a) > \Pi(0, a) \tag{9}$$

$$\frac{\partial \Pi}{\partial a}(1, a) > \frac{\partial \Pi}{\partial a}(0, a) \tag{10}$$

$$\frac{\partial^2 \Pi}{\partial a^2}(\pi, a) < 0 \tag{11}$$

for all $a \in \mathbb{R}_+$ and $\pi \in \{0, 1\}$. That is, we assume that, for any given level of investment in the new project, the firm's final net profit is increasing in the payoff of the existing assets. Further, the marginal benefit of investing in the new project is increasing in the payoff of the existing assets, and the final net profit is concave in the level of investment. Finally, we assume that $\frac{\partial \Pi}{\partial a}(\pi, a)$ is continuous in a for all π , and that there exist an $\underline{a} \geq 0$ and an $\bar{a} > \underline{a}$ such that $\frac{\partial \Pi}{\partial a}(0, a) \geq 0$ for all $a \leq \underline{a}$ and $\frac{\partial \Pi}{\partial a}(1, a) \leq 0$ for all $a \geq \bar{a}$. These assumptions ensure the existence of a unique a^* that maximizes the firm's expected net profit.

Also at $t = 2$, the amount of investment in the new project (a), the payoff of the existing assets (π), and the final net profit (Π) are reported in the firm's financial statements. We assume that the reported information is observable but not verifiable.¹⁴ Using this

¹³We relax this assumption in an extension in Section 4.

¹⁴We relax the assumption of non-verifiability in an extension in Section 4.

information, the shareholders can update their beliefs regarding the probability that the manager receives informative private signals, i.e., the probability that the manager’s type is good.

Finally, the manager obtains a benefit $\Omega \cdot \Pr(\theta_A = g|I_2)$, where I_2 is the relevant information that is available to the shareholders at $t = 2$, and $\Omega > 0$. That is, we assume that the manager derives utility from being considered a good type. This utility captures the manager’s career concerns in a reduced form. Such career concerns could be modeled explicitly by adding a further period to the setup, during which competition for skilled managers links compensation to perceived ability. In that case, assuming that legal constraints prevent involuntary servitude (including bonding), the manager’s freedom to leave for a better-paid job creates incentives to improve his reputation (e.g., Holmström and Ricart i Costa [1986]). Figure 1 shows the timing of events and decisions:

Figure 1: Timing of Events and Decisions

$t = 0$	$t = 1$	$t = 2$
- Firm starts out with assets in place	- Manager receives private signal	- Final net profit is realized
- Manager observes market prices	- Manager chooses investment	- Financial statements are released
- Financial statements are released		- Shareholders update beliefs

2.2. Discussion of assumptions

Observability of prices, payoffs, and the firm’s asset portfolio. We assume that the market prices and realized payoffs of the different assets in the economy are observable by everyone: outside investors, unskilled managers, and skilled managers. Thus, our model is most applicable to assets that have readily observable market prices and ex post observable payoffs – a condition met by many financial securities for which mark-to-market accounting is relevant. Managers, both skilled and unskilled, know which assets

a firm owns and can thus compute the current market value of the firm's existing asset portfolio.¹⁵ Outsiders, however, do not know precisely which assets the firm owns. This assumption corresponds to the fact that even though a firm may list a position such as "financial instruments owned" on its balance sheet, the reported information (including any break-down in the footnotes) does typically not reveal exactly which securities the firm owns. Hence, outside investors cannot compute the current market value of the firm's existing asset portfolio on their own, and mark-to-market accounting can indeed provide them with new information.

Timing of the arrival of private information. We assume that the manager receives his private signal after the financial statements are published, but before he decides how much to invest in the new project. This assumption is motivated by the observation that financial statements are produced only periodically, so that it is likely that (additional) private information arrives after the publication of the financial statements (i.e., during the fiscal year). In that case, the manager must take any information that has already been revealed in the financial statements as given and only decides how to respond to his new, private information. However, none of our results change if we assume instead that the private signal is received before the financial statements are released, as long as the current market value of the firm's existing assets cannot be misrepresented (conditional on being reported at all).¹⁶

¹⁵The only difference between skilled and unskilled managers is that skilled managers receive additional, useful, private information about the expected future payoff of the firm's assets that is not contained in the assets' market price.

¹⁶In that case, the current market value of the firm's existing assets is truthfully reported in the financial statements, and, thereafter, the manager makes his investment decision – exactly as in the case in which the private signal is received after the financial statements are published.

Relevance of the existing assets' value for the investment decision. We assume that the marginal benefit of investing in the new project is increasing in the payoff of the firm's existing assets. This assumption captures the notion that information about the firm's existing assets is relevant for the investment decision. This could be the case, for example, because the existing assets and the new project are complements. Alternatively, the cost of undertaking the new project could depend on the payoff of the existing assets because of financing constraints: Investing a lot in the new project may cause distress or refinancing costs if the firm's existing assets do not generate a sufficiently high cash flow.

Feedback effects between prices and investment decisions. Several papers, starting with Dow and Gorton [1997], focus on the feedback effects between market prices and investment decisions. The typical model in this area of research considers the interaction between two effects. On the one hand, the information contained in a firm's stock price guides the investment decisions made by the firm's managers. On the other hand, the stock price reflects the expectations that market participants have regarding the managers' investment decisions. The interaction between these two effects can cause multiple equilibria and inefficient investments. In our model, there is no such feedback effect. The current market price of the firm's existing assets contains information that the manager can use to choose the level of investment in the new project. This price does not, however, reflect any expectations about the manager's future investment decisions.¹⁷ We believe that this is the appropriate assumption when one wants to examine the effect of mark-to-market accounting, i.e., requiring a firm to report the current market value of (some of) its assets. Consider, for example, the case of a financial institution that

¹⁷Note that this is the price at which assets that the firm owns are traded in the marketplace – not the firm's stock price.

owns a portfolio of publicly traded shares. The price at which these securities are traded on the stock exchange – and hence the value that the financial institution would report under mark-to-market accounting – is unlikely to reflect expectations about any future investments that the financial institution owning the shares may undertake.

The role of mark-to-market accounting. The proponents of mark-to-market accounting often argue that it provides more timely information than historical cost accounting and that this information can increase transparency and help to monitor a firm’s management. This is precisely the role that marking to market plays in our setup. Mark-to-market accounting provides new information to outside investors about the expected future cash flows of the firm’s existing assets. The information is useful because it allows the outsiders to update their belief about which investment decision maximizes the firm’s expected net profit. This, in turn, can help address agency problems between the investors and the firm’s management: Knowing which investment is efficient can help induce the management to invest optimally. Sometimes, however, ignorance is bliss. As we will show in the next section, if the outsiders’ belief about which investment is optimal is sufficiently strong, managers may not want to disagree – even if doing so would improve the investment decision. In that case, marking to market may lead to inefficient investment decisions.

Asset payoffs and signal structures. We assume that the existing assets’ future payoff as well as the market signal and the private signal can take only two possible values: high or low. This assumption greatly simplifies our analysis, but it is not crucial. In an extension of our model – available from the authors upon request – we show that allowing the existing assets’ payoff, the market signal, and the private signal to take on

$N > 2$ distinct values does not change our main results.

3. Investment strategies

We now examine the equilibrium effects of historical cost and mark-to-market accounting on the manager's investment decision. First, we derive the first-best investment strategy. Then, we discuss the agency problem that arises in our setup. Thereafter, we explore whether the first-best strategy can be implemented in equilibrium. Finally, we examine which strategies can be implemented when the first-best strategy is not implementable.

3.1. First-best strategy

At $t = 1$, the optimal amount of investment conditional on σ and s is given by

$$a_{\sigma s}^* \in \arg \max_{a \geq 0} E[\Pi(\pi, a) | \sigma, s] \quad (12)$$

with

$$E[\Pi(\pi, a) | \sigma, s] = \Pr(\pi = 1 | \sigma, s) \cdot \Pi(1, a) + \Pr(\pi = 0 | \sigma, s) \cdot \Pi(0, a). \quad (13)$$

The solution to this problem is given by the first order condition¹⁸

$$\frac{\partial \Pi}{\partial a}(0, a_{\sigma s}^*) + \Pr(\pi = 1 | \sigma, s) \cdot \left[\frac{\partial \Pi}{\partial a}(1, a_{\sigma s}^*) - \frac{\partial \Pi}{\partial a}(0, a_{\sigma s}^*) \right] = 0 \quad (14)$$

with

$$\frac{da_{\sigma s}^*}{d\Pr(\pi = 1 | \sigma, s)} = - \frac{\frac{\partial \Pi}{\partial a}(1, a_{\sigma s}^*) - \frac{\partial \Pi}{\partial a}(0, a_{\sigma s}^*)}{\Pr(\pi = 1 | \sigma, s) \cdot \frac{\partial^2 \Pi}{\partial a^2}(1, a_{\sigma s}^*) + \Pr(\pi = 0 | \sigma, s) \cdot \frac{\partial^2 \Pi}{\partial a^2}(0, a_{\sigma s}^*)} > 0. \quad (15)$$

Hence, the optimal amount of investment in the new project is increasing in the probability that the existing assets generate a positive payoff. Given that there are four possible

¹⁸The second order condition for a maximum is satisfied because $\Pi(\pi, a)$ is concave in a by assumption.

combinations of the market signal and the private signal, there are four possible first-best levels of investment:

$$a_{\sigma s}^* \in \{a_{HH}, a_{LH}, a_{HL}, a_{LL}\} \quad (16)$$

with $a_{HH} > a_{LH} > a_{HL} > a_{LL}$ if $\delta > \phi > 0$ and $a_{HH} > a_{HL} > a_{LH} > a_{LL}$ if $\phi > \delta > 0$.

3.2. Agency problem

By assumption, the firm's shareholders cannot choose the amount of investment directly. The question thus becomes whether the manager chooses the investment strategy $a_{\sigma s}^*$ which is desired by the shareholders, or, in other words, whether the first-best strategy can be implemented.

It is important to note that the manager only cares about the benefit he derives from the shareholders' posterior belief regarding his type.¹⁹ That is, the manager is motivated only by his reputation concerns and thus chooses the investment that maximizes the expected posterior belief about his type, conditional on the relevant information I_2 that will be available to the shareholders at $t = 2$. Hence, the manager chooses a to maximize $E[\widehat{\delta}(I_2)] \equiv E[\Pr(\theta_A = g|I_2)]$.

Depending on the accounting rules and the investment decision, the relevant information that is available to the shareholders is $I_2 \in \{(\pi), (\pi, \sigma), (\pi, s), (\pi, \sigma, s)\}$.²⁰ The

¹⁹The final cash-flows of the firm are not verifiable, so that incentive contracts are not feasible. We relax this assumption in an extension in Section 4.

²⁰The shareholders directly observe (a, π, Π) under historical cost accounting and $(E_1[\pi|\sigma], a, \pi, \Pi)$ under marking to market. Under marking to market, σ can be inferred from $E_1[\pi|\sigma]$, the existing assets' price at $t = 1$. Further, depending on the investment rule followed in equilibrium, σ and s may be inferred from a . Given that only π , σ , and s are relevant for updating the shareholders' belief regarding the manager's type, we refer to the relevant information set directly as $I_2 \in \{(\pi), (\pi, \sigma), (\pi, s), (\pi, \sigma, s)\}$.

shareholders always learn the cash-flow (π) that is generated by the existing assets. They may also learn the market signal (σ) if there is mark-to-market accounting or if the manager's investment decision reveals the market signal. If the investment decision reveals the manager's private signal, the shareholders can also learn the private signal (s). Finally, if the manager's investment decision reveals both his private signal and the market signal, the shareholders learn everything: π , σ , and s . This happens, for example, if the first-best investment is chosen in equilibrium.²¹

However, the manager's objective function – maximizing the expected posterior belief that his type is good – differs from the shareholders' objective function – maximizing expected net profits. Thus, it is not clear that the first-best decision rule can always be implemented. Furthermore, because the shareholders' information set depends on whether the current market price of the assets in place is reported in the firm's financial statements, moving from historical cost accounting to mark-to-market accounting or vice versa can ameliorate or aggravate the agency problem.²²

3.3. Implementing the first-best strategy

Under historical cost accounting, the market price of the assets in place at $t = 0$ is not revealed to the shareholders. This implies that the shareholders do not directly learn the market signal (σ). Of course, they do not directly observe the manager's private signal

²¹ $\Pr(\pi = 1|\sigma, s)$ is a one-to-one function of σ and s (with the exception of the special case $\delta = \phi$). Hence, if chosen in equilibrium, the first-best investment reveals both signals σ and s .

²²Allowing for the existence of sophisticated investors that know the market value of the firm's assets does not change our main results. All that is needed is that there are at least some investors who can learn this information only from the financial statements and that the manager cares about his reputation as perceived by these investors.

(s) either. If, however, the manager were to follow the first-best investment strategy, his actions would reveal both the market and his private signal ex post. This is in the manager's interest only if doing so maximizes the expected posterior belief about his type. As shown in the following proposition, this is not always the case. Intuitively, following the first-best strategy reveals, in some cases, a divergence between the market signal and the private signal. However, because informative signals coincide, revealing divergent signals leads to a lower expected posterior belief about the manager's type.

Proposition 1 *With historical cost accounting, the first-best investment rule cannot be implemented.*

The intuition behind this result is as follows. In an equilibrium in which the manager invests according to the first-best strategy, the shareholders learn the manager's private signal (s), the market signal (σ), and the existing assets' payoff (π). Based on this information, the shareholders then update their beliefs regarding the manager's type. For any given private signal, however, the posterior probability that the manager's type is good is larger if the market signal coincides with the private signal than if the signals diverge. Thus, the manager always prefers to pretend that the market signal coincides with his private signal: He either chooses an investment that indicates $\sigma = s = H$ or an investment that indicates $\sigma = s = L$, but never an investment that indicates $\sigma \neq s$. This implies that the first-best investment strategy does not satisfy the manager's incentive compatibility constraints in case the market signal and the private signal do not coincide. It follows that the first-best investment rule cannot be implemented.

With mark-to-market accounting, the market price of the assets in place at $t = 0$ is reported in the firm's financial statements. Hence, the shareholders directly learn the market signal, whereas they do not directly observe the manager's private signal. If the

manager were to follow the first-best strategy, his actions would reveal his private signal to the shareholders ex post. However, as before, this is in the manager's interest only if doing so maximizes the expected posterior belief about his type.

As shown in the following proposition, the first-best investment rule can only be implemented if the quality of the market signal is sufficiently low. This is the case because following the first-best strategy reveals, in some cases, a divergence between the market signal and the private signal. A divergence between the two signals, however, conveys negative news regarding the quality of the manager – and the more so, the more informative the market signal.

Proposition 2 *With mark-to-market accounting, there exists a unique $\phi^* \in (0, \delta)$ such that the first-best strategy can be implemented if $\phi \leq \phi^*$ and cannot be implemented if $\phi > \phi^*$.*

The proof of this result is based on a similar intuition as the proof of Proposition 1. In an equilibrium in which the manager follows the first-best strategy, the shareholders form posterior beliefs about the manager's type based on σ , s , and π . However, as before, the manager may want to deviate from an investment decision that reveals a divergence between the market signal and his private information. The difference compared to the case of historical cost accounting is that the manager can only lie about his private signal but not about the market signal (which is revealed directly to the shareholders in the financial statements).²³ Thus, unlike before, the manager cannot choose between investments that indicate $\sigma = s = H$ or $\sigma = s = L$. Instead, he must take the market signal as given and choose between investments that indicate $s = \sigma$ or $s \neq \sigma$.

²³In Section 4, we show that even if the manager were able to misreport the current market value of the firm's assets at $t = 0$, he would prefer not to do so in equilibrium.

In that situation, choosing an investment that indicates $s \neq \sigma$ may be preferable if the manager is sufficiently confident that his private signal is correct while the market signal is incorrect. Hence, whether the manager's incentive compatibility constraint is satisfied depends on the quality of the market signal relative to the private information. Revealing a divergence between the private signal and the market signal is less costly when the market signal is less informative. Indeed, it can be shown that there exists a unique threshold $\phi^* < \delta$ such that the manager's incentive compatibility constraint is satisfied for $\phi \leq \phi^*$ and violated for $\phi > \phi^*$.

Surprisingly, switching from historical cost accounting to mark-to-market accounting helps implement the first-best investment if the quality of the market signal is low, but not when the quality of the market signal is high. In that case, the information content of the market signal distorts the manager's decision: Choosing an investment that reveals that his private information differs from the (highly informative) market signal would damage the manager's reputation.

3.4. Implementable (second-best) strategies

In the previous section, we showed that the shareholders can never implement the first-best strategy under historical cost accounting. Under mark-to-market accounting, the shareholders can implement the first-best strategy only if the market signal is not too informative (i.e., if $\phi \leq \phi^*$). The reason for this result is that the first-best strategy is based on both the market signal (σ) and the private signal (s), and prescribes a different level of investment for each of the four possible signal combinations. This implies that if the manager were to choose the first-best level of investment, the shareholders would learn both the market signal as well as the manager's private signal. This, however, is

not in the manager's interest in case the two signals do not coincide. Thus, the manager prefers to deviate from the first-best strategy. An important corollary to this finding is the following:

Corollary 1 *If the first-best strategy cannot be implemented, any other strategy that perfectly reveals both the market signal and the private signal cannot be implemented either.*

Given this result, we now examine if the shareholders can instead implement strategies that perfectly reveal only the market signal or only the manager's private signal. We refer to these strategies as "second-best strategies." We show in the Appendix that if the first-best investment cannot be implemented under mark-to-market accounting, (mixed) strategies in which the manager's investment decision reveals partial information about his private signal cannot be implemented either. It follows that allowing for such strategies cannot increase the desirability of marking to market relative to historical cost accounting. For this reason, we now focus on strategies that perfectly reveal either the market or the private signal.

Whether the shareholders' preferred strategy is a function of the market signal or the private signal depends on the relative informativeness of the two signals. If the market signal is more informative ($\phi > \delta$), the shareholders prefer the manager to rely on the market signal. Conversely, if the private signal is more informative ($\delta > \phi$), the shareholders prefer the manager to rely on his private signal.

Hence, if $\phi > \delta$, the second-best level of investment is the solution to

$$a_{\sigma}^{SB} \in \arg \max_{a \geq 0} E [\Pi (\pi, a) | \sigma] \quad (17)$$

with first order condition

$$\frac{\partial \Pi}{\partial a}(0, a_{\sigma}^{SB}) + \Pr(\pi = 1|\sigma) \cdot \left[\frac{\partial \Pi}{\partial a}(1, a_{\sigma}^{SB}) - \frac{\partial \Pi}{\partial a}(0, a_{\sigma}^{SB}) \right] = 0. \quad (18)$$

This implies two possible second-best levels of investment: a_H and a_L with $a_H > a_L$.

If, instead, $\delta > \phi$, the second-best investment is the solution to

$$a_{.s}^{SB} \in \arg \max_{a \geq 0} E[\Pi(\pi, a) | s] \quad (19)$$

with first order condition

$$\frac{\partial \Pi}{\partial a}(0, a_{.s}^{SB}) + \Pr(\pi = 1|s) \cdot \left[\frac{\partial \Pi}{\partial a}(1, a_{.s}^{SB}) - \frac{\partial \Pi}{\partial a}(0, a_{.s}^{SB}) \right] = 0. \quad (20)$$

As before, this implies two possible second-best levels of investment: a_H and a_L with $a_H > a_L$.

In what follows, we show that the second-best strategy is always implementable with historical cost accounting but not always with mark-to-market accounting.

Proposition 3 *With historical cost accounting, the second-best strategy is implementable.*

The intuition behind this result is as follows. If the market signal is more informative than the private signal (i.e., $\phi > \delta$), by following the second-best strategy, the manager reveals the market signal but not the private signal. Thus, there is no updating regarding the manager's type because no information about the manager's private signal is revealed. This, in turn, leaves the manager indifferent between the different investment levels that are prescribed by the second-best strategy. It follows that the manager has no reason to deviate from the proposed equilibrium. Hence, the second-best strategy can be implemented under the tie-breaking assumption that the manager behaves in the interest of the shareholders when indifferent. If, instead, the manager's private information is more informative than the market signal (i.e., $\delta > \phi$), by following the second-best strategy, the

manager reveals his private information to the shareholders but not the market signal. Again, the manager has no reason to deviate from the proposed equilibrium. Thus, the second-best strategy can be implemented.

In the case of mark-to-market accounting, we obtain the following result.

Proposition 4 *With mark-to-market accounting, the second-best strategy cannot be implemented if $\phi \in (\phi^*, \delta)$ and can be implemented otherwise.*

Intuitively, when $\phi > \delta$, the analysis is identical to the case of historical cost accounting. In that case, if the manager follows the second-best strategy, his action reveals the market signal but not the private signal. As before, there is no updating regarding the manager's type because no information about the manager's private signal is revealed. Hence, the second-best strategy can be implemented.

The situation is different when $\delta > \phi$. In that case, if the manager follows the second-best strategy, the shareholders learn the market signal from the asset values reported in the financial statements. In addition, the shareholders learn the private signal from the manager's action. Thus, the posterior beliefs regarding the manager's type as well as the manager's incentive compatibility constraints are exactly as in the proof of Proposition 2. It follows that the second-best strategy can be implemented for $\phi \leq \phi^*$ and cannot be implemented for $\phi > \phi^*$.

Combining Propositions 2 and 4, we have shown that neither the first-best nor the second-best strategy can be implemented with mark-to-market accounting if $\phi \in (\phi^*, \delta)$. What happens then? The third-best level of investment in case of $\phi \in (\phi^*, \delta)$ is the solution to

$$a_{\sigma}^{TB} \in \arg \max_{a \geq 0} E [\Pi (\pi, a) | \sigma] \tag{21}$$

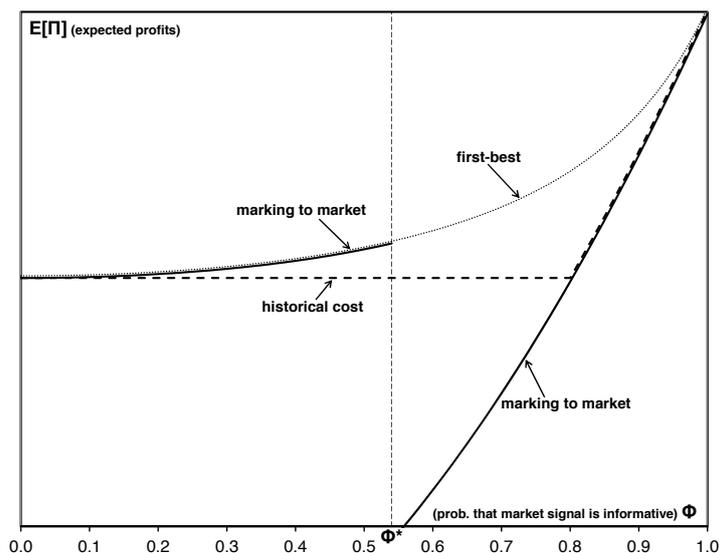
which can be implemented in equilibrium.²⁴ Hence, we can conclude the following:

Corollary 2 *With mark-to-market accounting, if $\phi \in (\phi^*, \delta)$, the third-best strategy can be implemented.*

3.5. Mark-to-market versus historical cost accounting

Figure 2 shows a comparison of the expected profits under mark-to-market accounting, historical cost accounting, and in the first-best case. It plots the expected profits as a function of ϕ under the specific assumptions that $\Pi(\pi, a) = \pi a - a^2$, $p = 0.95$, and $\delta = 0.8$.²⁵

Figure 2: Expected Profits



As shown in the figure, when the market signal is not too informative ($\phi < \phi^*$), the expected profits under mark-to-market accounting are identical to the profits in the first-

²⁴The proof of Proposition 4 shows that this strategy can be implemented in equilibrium.

²⁵These assumptions are made to facilitate the graphical representation of the expected profits. Similar results obtain for generic combinations of the parameters.

best case. The expected profits increase with ϕ as a more informative market signal improves the manager's investment decisions. Under historical cost accounting, the expected profits are both lower and unaffected by the informativeness of the market signal because only the manager's private information is used to choose the level of investment.

As the informativeness of the market signal increases above ϕ^* (but still remains below the informativeness of the private signal (δ)), the expected profits under marking to market fall below the expected profits under historical cost accounting. Decisions under mark-to-market accounting are now only based on the market signal, which is less informative than the private signal. This entails a discrete drop in the expected profits under marking to market – despite the fact that the expected profits are increasing in the informativeness of the market signal (ϕ) for both $\phi < \phi^*$ and for $\phi > \phi^*$.

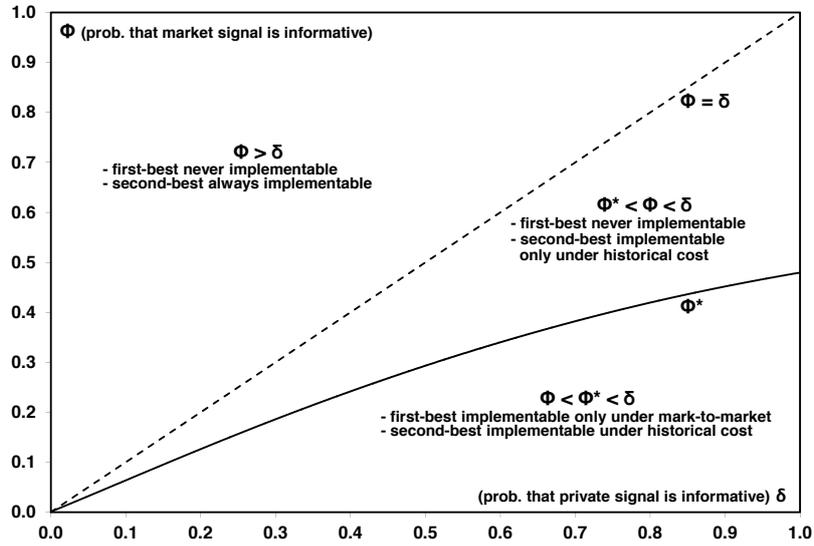
The intuition for this result is as follows. Moving from $\phi < \phi^*$ to $\phi' > \phi^*$ increases the informativeness of the market signal by $\Delta\phi = \phi' - \phi$. This increase, however, causes a change in the manager's equilibrium behavior: He no longer relies on both the market signal and his private signal. Instead, the manager stops using his private signal and relies exclusively on the information conveyed by the market. The total amount of information that is used to make the investment decision therefore drops by $\delta - \Delta\phi > 0$. As a result, the firm's expected profits are now lower than before.

When the informativeness of the market signal (ϕ) increases beyond the informativeness of the private signal (δ), the investment decisions under historical cost accounting and mark-to-market accounting coincide: Both are based only on the market signal. Thus, there is no difference between marking to market and historical cost accounting when $\phi > \delta$. As ϕ reaches one, the expected profits under both marking to market and historical cost accounting converge to the first-best profits because the market signal

becomes perfectly informative.

Figure 3 presents an alternative view on our findings. It summarizes the results in the parameter space (δ, ϕ) . When the market signal is more informative than the private signal ($\phi > \delta$), there is no difference between mark-to-market and historical cost accounting. In both cases, the first-best strategy cannot be implemented. The second-best strategy of relying solely on the market signal, however, can be implemented under both accounting rules.

Figure 3: Implementable Strategies



When $\phi < \delta$ instead, the two accounting rules lead to different equilibria. If $\phi \leq \phi^*$, mark-to-market accounting leads to the first-best while historical cost accounting allows only the implementation of the second-best strategy. If instead $\phi \in (\phi^*, \delta)$, neither accounting rule leads to the first-best. However, historical cost accounting dominates mark-to-market accounting: Under historical cost accounting, the manager relies on the (more informative) private signal. Under mark-to-market accounting, the manager relies on the (less informative) market signal.

Using the results obtained so far, we can examine which accounting regime maximizes the firm's value. Under historical cost accounting, the first-best decision rule can never be implemented, and the second-best decision rule can always be implemented. Under mark-to-market accounting, the first-best decision rule can be implemented if $\phi \leq \phi^*$. In that case, mark-to-market accounting increases the value of the firm compared to historical cost accounting. For $\phi \in (\phi^*, \delta)$, however, only the third-best strategy can be implemented. In that case, mark-to-market accounting decreases the value of the firm compared to historical cost accounting. Finally, for $\phi \geq \delta$, the second-best strategy can be implemented under both accounting regimes. Thus, in that case, the firm's value does not depend on the choice between historical cost and mark-to-market accounting. Corollary 3 summarizes these results:

Corollary 3 *Mark-to-market accounting maximizes the firm's value for $\phi \in [0, \phi^*]$. Historical cost accounting maximizes the firm's value for $\phi \in (\phi^*, \delta)$. For $\phi \in [\delta, 1)$, the firm's value does not depend on the accounting rules.*

4. Extensions

In this section, we consider four extensions of our model. First, we examine how the accounting rules affect the types of assets that a firm chooses to hold on its balance sheet. Second, we consider voluntary disclosure of the assets' current market value as well as fraudulent reporting. Third, we examine the effect that incentive compensation may have on our findings. Fourth, we study the effect of asymmetric information between the shareholders and the manager regarding the quality of the manager's private information.

4.1. Responding to marking to market: holding opaque assets

One caveat of our previous analysis is that we have treated the informativeness of the market signal as given. A firm, however, may respond to accounting regulation by changing the assets that it holds on its balance sheet. In this extension, we will consider such changes in a firm's asset composition.

Specifically, we will assume that before $t = 0$, the firm's shareholders can give a mandate to the manager to only hold assets that belong to a specific class of assets. Further, we assume that different asset classes are distinguished by the informativeness of their market prices. The manager may thus be mandated to hold transparent assets on the firm's balance sheet, whose market prices are relatively informative. Or he may be mandated to hold opaque assets with less informative market prices.²⁶ Using this framework, we obtain the following result:

Proposition 5 *Suppose that before $t = 0$ the firm's shareholders can give a mandate to the manager to only hold assets that belong to a specific class of assets with price informativeness $\phi \in [0, \bar{\phi}]$ for some $\bar{\phi} < 1$. Under historical cost accounting, the shareholders choose to mandate $\phi = \bar{\phi}$ for $\bar{\phi} \geq \delta$ and are indifferent between any $\phi \in [0, \bar{\phi}]$ for $\bar{\phi} < \delta$. Under mark-to-market accounting, there exists a $\bar{\delta} \in (0, \bar{\phi})$, such that for $\delta < \bar{\delta}$ the shareholders mandate $\phi = \bar{\phi}$, and for $\delta > \bar{\delta}$ the shareholders mandate $\phi = \min \{ \phi^*(\delta), \bar{\phi} \}$.*

Intuitively, under historical cost accounting, for $\phi \geq \delta$, the best implementable investment strategy depends only on the market signal, and the firm's expected profit is strictly increasing the market signal's informativeness (ϕ). Thus, the shareholders choose

²⁶We maintain the assumption, however, that the shareholders do not know exactly which assets the manager has chosen from the class of assets he is mandated to hold on the firm's balance sheet.

the highest feasible informativeness ($\phi = \bar{\phi}$), provided that $\bar{\phi} > \delta$. For $\phi < \delta$, the best implementable strategy under historical cost accounting depends only on the manager's private signal, so that the firm's expected profit does not depend on the informativeness of the market signal. Hence, for $\bar{\phi} < \delta$, the shareholders are indifferent between any $\phi \in [0, \bar{\phi}]$.

Under mark-to-market accounting, the firm's expected profit is strictly increasing in the informativeness of the market signal (ϕ) for $\phi \in [0, \phi^*]$ and for $\phi \in (\phi^*, 1)$. However, there is a discrete drop at $\phi = \phi^*$. At this point, the best implementable strategy switches from the first-best strategy based on both the market signal (σ) and the private signal (s) to the third-best strategy based only on the market signal. Using these results, it can be shown that there exists a $\bar{\delta} \in (0, \bar{\phi})$ such that for $\delta < \bar{\delta}$ the firm's shareholders mandate $\phi = \bar{\phi}$, and for $\delta > \bar{\delta}$ the shareholders choose $\phi = \min \{\phi^*(\delta), \bar{\phi}\}$. The intuition is that if the manager's private signal is sufficiently uninformative ($\delta < \bar{\delta}$), the shareholders are better off implementing a strategy based only on the market signal. In that case, the most informative market signal ($\phi = \bar{\phi}$) is optimal. If, however, the manager's private signal is sufficiently informative ($\delta > \bar{\delta}$), the shareholders are better off implementing a strategy that utilizes the manager's private information. In that case, the best the shareholders can do is to choose the most informative market signal that still allows them to implement the first-best investment rule ($\phi = \min \{\phi^*(\delta), \bar{\phi}\}$).

Which types of assets the firm optimally holds on its balance sheet thus depends both on the accounting rules and on the quality of the manager to whom any subsequent investments are delegated. Under historical cost accounting, the firm's shareholders prefer the most transparent asset class if its price informativeness exceeds the informativeness of the manager's private information. If not, the shareholders are indifferent among the

various asset classes. Under mark-to-market accounting, however, the shareholders either choose the asset class with the highest transparency or a more opaque asset class. If the manager's quality is lower than a given threshold, the most transparent asset class is chosen. If the manager's quality is higher than the threshold, the shareholders prefer more opaque assets. Our analysis thus suggests that if mark-to-market accounting is mandatory, firms – in particular, those with skilled managers – may optimally respond by holding more opaque assets with less informative market prices on their balance sheets.²⁷

4.2. *Voluntary disclosure and fraudulent reporting*

So far, we did not explicitly consider any type of voluntary disclosure or fraudulent reporting in our analysis. One may be concerned, for example, that the manager voluntarily reports the market signal at $t = 0$, or that he misreports the assets' market value. However, we can show that even if the manager were able to misreport the current market value of the firm's assets at $t = 0$, he would not do so in equilibrium:²⁸

Proposition 6 *Suppose, in case of mark-to-market accounting, the manager can misreport the current market value of the firm's assets at $t = 0$. Then, for $\phi \leq \phi^*$, the manager prefers truthful reporting to misreporting. For $\phi > \phi^*$ the manager is indifferent.*

Further, note that at $t = 0$, the manager's expected reputation is a martingale, $E[\widehat{\delta}] = \delta$, both in case of historical cost accounting and in case of marking to market.

²⁷Note that the manager is indifferent between the various asset classes: From an ex ante point of view, his expected reputation is equal to δ and does not depend on ϕ . It follows that the manager will follow the shareholders' mandate to choose assets from a specific asset class.

²⁸In case of $\phi > \phi^*$, we make the tie-breaking assumption that the manager acts in the shareholders' interest when indifferent.

Irrespective of the accounting rules, the manager's expected reputation is equal to the ex ante prior about his type. Hence, the manager is indifferent between both accounting regimes. This implies that the manager has no incentives to voluntarily disclose the assets' market value in the firm's financial statements in case the accounting rules do not require him to do so. As a consequence, if a firm is allowed to choose whether to disclose the current market value of its assets, the choice can be made by the firms' shareholders. The manager will then follow the shareholders' mandate under the tie-breaking assumption that he acts in their interest when indifferent. Corollary 4 summarizes this result:

Corollary 4 *At $t = 0$, the manager is indifferent between historical cost accounting and marking to market. Hence, if a firm is allowed to choose which accounting rule to follow, the choice can be made by its shareholders, and the manager will follow their mandate.*

4.3. Incentive compensation

Up to this point, we have assumed that the firm's cash-flows at $t = 2$ are observable but not verifiable. As a consequence, we have not considered any incentive contracts when assessing the conditions under which the first-best investment can be implemented. In what follows, we will instead assume that both actions and outcomes are verifiable and consider potential incentive contracts. We are able to derive the following result:

Proposition 7 *Suppose the first-best investment rule cannot be implemented without incentive pay. Assume further that (i) the manager has limited liability, (ii) the firm's shareholders have limited liability, and (iii) the manager's compensation must not be decreasing in the firm's final profit. Then, under historical cost accounting, there exists an Ω^* such that for $\Omega > \Omega^*$ an incentive contract that induces the manager to follow the first-best investment rule does not exist. Furthermore, under mark-to-market accounting,*

*there exists an Ω^{**} such that for $\Omega > \Omega^{**}$ an incentive contract that induces the manager to follow the first-best investment rule does not exist. In particular, if $\Pi(0, a) \leq 0$, then the first-best rule cannot be implemented for any $\Omega > 0$ under either accounting rule.*

The intuition for this finding is as follows. If the first-best investment cannot be implemented without incentive pay, it is because the manager does not want to reveal a divergence between the market signal and his private information as this would hurt his reputation. Hence, to implement the first-best investment, the manager needs to be compensated for choosing an investment that reveals a divergence between the two signals. The payments that can be promised to the manager, however, are limited by the firm's final profit. It may therefore not be feasible to compensate the manager for his loss of reputation if the value of a good reputation is very high, i.e., if Ω is sufficiently large.

Thus, if compensation contracts must satisfy (i) limited liability for the manager, (ii) limited liability for the firm's shareholders, and (iii) compensation that is not decreasing in the firm's final profit, then verifiable actions and outcomes will not, in all cases, allow the shareholders to implement the first-best investment. Furthermore, if $\phi \in (\phi^*, \delta)$ in those cases, historical cost accounting continues to dominate mark-to-market accounting.

4.4. Managers who know their type

Throughout our analysis, we have assumed that neither the manager nor the firm's shareholders know the manager's type with certainty: Both believe that the manager is good with probability $\delta \in (0, 1)$. In this extension, we examine whether and how our findings change if we assume instead that the manager knows his type. In that case, we can derive the following result:

Proposition 8 *Suppose the manager knows his type while the firm's shareholders do not. Then, the first-best investment rule can never be implemented. Under historical cost accounting, the best implementable strategy specifies two levels of investment, a_H^{SB} and a_L^{SB} . The good type chooses a_H^{SB} if $s = H$ and a_L^{SB} if $s = L$. The bad type chooses a_H^{SB} if $\sigma = H$ and a_L^{SB} if $\sigma = L$. Under mark-to-market accounting, the best implementable strategy specifies two levels of investment, a_H^{TB} and a_L^{TB} , and both types of managers choose a_H^{TB} if $\sigma = H$ and a_L^{TB} if $\sigma = L$.*

If the manager knows his type, the first-best strategy specifies different investment levels for the two types of managers. If the manager's type is good, he should choose the investment based only on his private signal. In that case, the first-best investment, a_{Gs}^{FB} , is given by

$$\frac{\partial \Pi}{\partial a}(0, a_{Gs}^{FB}) + \Pr(\pi = 1|s) \cdot \left[\frac{\partial \Pi}{\partial a}(1, a_{Gs}^{FB}) - \frac{\partial \Pi}{\partial a}(0, a_{Gs}^{FB}) \right] = 0 \quad \text{for } s \in \{H, L\} \quad (22)$$

and the manager chooses a_{GH}^{FB} if $s = H$ and a_{GL}^{FB} if $s = L$.

If the manager is bad, he should always choose based only on the market signal. In that case, the first-best investment, $a_{B\sigma}^{FB}$, is given by

$$\frac{\partial \Pi}{\partial a}(0, a_{B\sigma}^{FB}) + \Pr(\pi = 1|\sigma) \cdot \left[\frac{\partial \Pi}{\partial a}(1, a_{B\sigma}^{FB}) - \frac{\partial \Pi}{\partial a}(0, a_{B\sigma}^{FB}) \right] = 0 \quad \text{for } \sigma \in \{H, L\} \quad (23)$$

and the manager chooses a_{BH}^{FB} if $\sigma = H$ and a_{BL}^{FB} if $\sigma = L$.

Such a type-dependent strategy, however, cannot be implemented. The intuition behind this result is as follows. If each type of manager chooses according to the specified strategy, then the manager's action perfectly reveals his type. This, however, is not incentive-compatible for a bad manager. Instead, a bad manager always prefers to mimic a good manager.

The best strategy that can possibly be implemented is one in which both types of managers choose from the same set of actions. While the good type uses his private signal to choose among the actions, the bad type chooses based on the market signal. In case of $(\theta_A = g, s = H)$ or $(\theta_A = b, \sigma = H)$, the second-best investment, a_H^{SB} , is then given by

$$\frac{\partial \Pi}{\partial a}(0, a_H^{SB}) + \left[\delta p + (1 - \delta) \left(\frac{1}{2} + \phi \left(p - \frac{1}{2} \right) \right) \right] \cdot \left[\frac{\partial \Pi}{\partial a}(1, a_H^{SB}) - \frac{\partial \Pi}{\partial a}(0, a_H^{SB}) \right] = 0. \quad (24)$$

In case of $(\theta_A = g, s = L)$ or $(\theta_A = b, \sigma = L)$, the second-best investment, a_L^{SB} , is given by

$$\frac{\partial \Pi}{\partial a}(0, a_L^{SB}) + \left[\delta(1 - p) + (1 - \delta) \left(\frac{1}{2} - \phi \left(p - \frac{1}{2} \right) \right) \right] \cdot \left[\frac{\partial \Pi}{\partial a}(1, a_L^{SB}) - \frac{\partial \Pi}{\partial a}(0, a_L^{SB}) \right] = 0. \quad (25)$$

This strategy is similar to the second-best strategy when the manager does not know his type. There is, however, one important difference. When types are unknown, both types choose based on the same signal: either the private signal (if $\delta > \phi$) or the market signal (if $\delta < \phi$). If the manager knows his type, he can use this knowledge to decide which signal to use. The good type can choose based on his private signal (which he knows is informative), and the bad manager can choose based on the market signal (which he knows is more informative than his private signal). This suggests that if this strategy can be implemented, the firm's shareholders are better off when the manager knows his type than when he does not.

Under historical cost accounting, the above strategy can be implemented. If the manager follows this investment rule, the firm's shareholders do not learn whether the manager uses the private or the market signal. However, the shareholders update their beliefs regarding the manager's type on the basis of the manager's actions and the realized

payoffs. If the existing assets' realized payoff is one, the manager's reputation is higher if he has chosen a_H^{SB} than if he has chosen a_L^{SB} . Conversely, if the realized payoff is zero, his reputation is higher if he has chosen a_L^{SB} than if he has chosen a_H^{SB} . Therefore, with historical cost accounting, the manager has the incentive to base his investment decision on the most informative signal: the private signal if he is good and the market signal if he is bad.

Under mark-to-market accounting, however, the second-best strategy is not implementable. In that case, because the market signal is always revealed to the shareholders, the choice of an action that is not aligned with the market signal (e.g., choosing a_H^{SB} when $\sigma = L$) reveals that the manager is good. This, in turn, creates incentives for the bad type to deviate from the proposed strategy by choosing an action that is in conflict with the market signal. The shareholders are left with the third-best investment rule – i.e., both managers follow the market signal – as the best implementable strategy under marking to market. This implies:

Corollary 5 *Suppose the manager knows his type while the firm's shareholders do not. In that case, the shareholders prefer historical cost accounting to marking to market.*

5. Empirical predictions

The two key variables in our model – the informativeness of the market signal (ϕ) and the informativeness of the private signal (δ) – are typically unobservable to the econometrician and difficult to estimate. As a consequence, several immediate implications of our theory do not lend themselves to simple empirical tests. However, in this section, we highlight two predictions of our model that are based on variables that are more easily observed/estimated and can thus be examined empirically.

The first prediction concerns the correlation of the investment decisions of firms that are likely to have similar assets. Our model implies that if the market price of a firm's existing assets is relatively uninformative ($\phi \leq \phi^*$), mark-to-market accounting allows for investment decisions that are based on the market signal in addition to the manager's private signal. If, however, the existing assets' market price is relatively informative ($\phi > \phi^*$), investment decisions under mark-to-market accounting are based only on the market signal. Under historical cost accounting, instead, investment decisions are either based only on the private signal (if $\phi < \delta$) or only on the market signal (if $\phi > \delta$).

It follows that the average effect (across all values of ϕ) of changing from historical cost to mark-to-market accounting is an increase in the sensitivity of the investment decisions to the market signal. Thus, given that all firms with the same existing assets receive the same market signal (while different managers may receive different private signals), changing from historical cost to mark-to-market accounting increases the correlation of the firms' investment decisions. Hence, our model predicts that mark-to-market accounting increases the correlation of the investment decisions of firms that are likely have the same existing assets:

Prediction 1 *A change from historical cost to mark-to-market accounting increases the correlation of the investment decisions of firms that are likely to hold the same assets.*

The second prediction concerns the efficiency of investment decisions and thus the effect on firms' values. For a firm whose existing assets have a relatively uninformative market price ($\phi \leq \phi^*$), changing from historical cost accounting to marking to market improves the efficiency of the investment decisions. If, however, the informativeness of the market price satisfies $\phi^* < \phi < \delta$, mark-to-market accounting decreases the efficiency of the firm's investment decisions (relative to historical cost accounting).

Further, the increase in the sensitivity of the investment decisions to the market signal due to mark-to-market accounting is smaller in case of $\phi \leq \phi^*$ than in case of $\phi^* < \phi < \delta$. Hence, our model implies that the introduction of marking to market should generate a negative correlation between the change in the efficiency of investment decisions (as measured, for example, by Tobin's Q or return on assets) and the change in their sensitivity to the market signal.²⁹ Given that a higher sensitivity to the market signal leads to a stronger correlation of the investment decisions of different firms that hold the same type of existing assets, our model generates the following prediction:

Prediction 2 *The change in the correlation of different firms' investment decisions (due to a change from historical cost to mark-to-market accounting) is inversely related to the change in their profitability (as measured, for example, by Tobin's Q or return on assets).*

6. Conclusion

In this paper, we examine how mark-to-market accounting affects the investment decisions of a manager with reputation concerns when optimal decisions are based on both information conveyed by market prices and unverifiable private information. As commonly argued by the proponents of marking to market, reporting the current market value of a firm's assets plays a disciplinary role in this setting. The information contained in the market prices provides a benchmark against which the manager's actions can be evaluated. This forces the manager to take the market information into account when making the investment decision. However, the fact that market prices are informative about which decision the manager should take has a negative side effect: The

²⁹Note that for $\phi > \delta$, a change from historical cost to mark-to-market accounting affects neither the sensitivity of the investment decisions to market signal nor their efficiency.

manager may prefer to ignore relevant but contradictory private information whose use (and thus revelation) would damage his reputation. Surprisingly, this effect can render marking to market *less* desirable when market prices become *more* informative.

Our analysis centers on a single aspect of mark-to-market accounting: Reporting the market value of a firm's assets can be useful because it conveys information about what the firm's management should do next. This information facilitates monitoring by investors – but it also incentivizes managers to conform and ignore relevant, private information. The resulting trade-off is the focus of our paper, and we deliberately abstract away from other aspects of marking to market. This is not to say that mark-to-market accounting cannot have other effects or serve additional purposes. However, other benefits (e.g., providing information that is useful to value the firm) and disadvantages (e.g., increasing the volatility of the asset values that are reported on the balance sheet) are unlikely to qualitatively affect our main result: Marking to market can cause distortions in managers' investment decisions precisely because market prices contain relevant information. As a consequence, more informative market prices can render mark-to-market accounting less attractive.

Our findings have several important implications. First, neither accounting rule is always optimal. Depending on the relative informativeness of market prices and private information, marking to market or historical cost accounting may be preferable (or the rules may be irrelevant). Hence, one-size-fits-all accounting rules are not optimal. Instead, our analysis suggests that it may be optimal to let firms choose which accounting rule to follow.³⁰ Second, in contrast to the commonly held view that more informative

³⁰A caveat of our analysis, is that we do not model any externalities that may arise due to each firm's individually optimal accounting choice. For example, a firm that chooses not to report the current market value of its assets deprives other market participants of potentially valuable interim information.

market prices make mark-to-market accounting naturally more appealing, we find that marking to market dominates historical cost accounting only when market prices are not too informative. Third, marking to market can induce firms to rely excessively on public signals. This implies inefficient investment decisions (if there is only one type of investment) and also correlated investment decisions (if firms can choose between different types of investments). Thus, marking to market could lead to less diversification in the economy. Fourth, firms – in particular, those with skilled managers – may optimally respond to mandatory mark-to-market accounting by holding more opaque assets with less informative market prices on their balance sheets.

Throughout the paper, we focus on the effects of revealing the market value of its assets on a firm's investment decisions. The framework we use for our analysis, however, is not specific to mark-to-market accounting and investment decisions and could be applied to other settings. For example, our findings suggest that increasing the quality of publicly available credit ratings may adversely affect the quality of financial institutions' internal risk assessment and risk management. If the risk management team is concerned about its reputation, increasing the accuracy of credit ratings provided by rating agencies may increase the team's incentives to confirm the public rating and reduce the incentives for individual research that may uncover additional, contradictory information.

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Appendix

Proof of Proposition 1: Assume an equilibrium in which the manager chooses according to the first-best strategy.³¹ In that case, the firm's shareholders form the following posterior beliefs $\widehat{\delta}(\pi, \sigma, s) \equiv \Pr(\theta_A = g | \pi, \sigma, s)$ regarding the manager's type:

$$\begin{aligned} \widehat{\delta}(\pi = 1, \sigma = H, s = H) &= \widehat{\delta}(\pi = 0, \sigma = L, s = L) \\ &= \frac{2\delta p(1 + \phi)}{2p(\delta + \phi) + (1 - \phi)(1 - \delta)} \end{aligned} \quad (\text{A1})$$

$$\begin{aligned} \widehat{\delta}(\pi = 1, \sigma = L, s = H) &= \widehat{\delta}(\pi = 0, \sigma = H, s = L) \\ &= \frac{2\delta p(1 - \phi)}{2p(\delta - \phi) + (1 - \delta)(1 + \phi)} \end{aligned} \quad (\text{A2})$$

$$\begin{aligned} \widehat{\delta}(\pi = 1, \sigma = H, s = L) &= \widehat{\delta}(\pi = 0, \sigma = L, s = H) \\ &= \frac{2\delta(1 - p)(1 - \phi)}{2(1 - p)(\delta - \phi) + (1 - \delta)(1 + \phi)} \end{aligned} \quad (\text{A3})$$

$$\begin{aligned} \widehat{\delta}(\pi = 1, \sigma = L, s = L) &= \widehat{\delta}(\pi = 0, \sigma = H, s = H) \\ &= \frac{2\delta(1 - p)(1 + \phi)}{2(1 - p)(\delta + \phi) + (1 - \phi)(1 - \delta)}, \end{aligned} \quad (\text{A4})$$

with

$$\widehat{\delta}(\pi = 1, \sigma = H, s = H) > \widehat{\delta}(\pi = 1, \sigma = L, s = H) \quad (\text{A5})$$

$$\widehat{\delta}(\pi = 0, \sigma = H, s = H) > \widehat{\delta}(\pi = 0, \sigma = L, s = H) \quad (\text{A6})$$

and

$$\widehat{\delta}(\pi = 1, \sigma = L, s = L) > \widehat{\delta}(\pi = 1, \sigma = H, s = L) \quad (\text{A7})$$

$$\widehat{\delta}(\pi = 0, \sigma = L, s = L) > \widehat{\delta}(\pi = 0, \sigma = H, s = L). \quad (\text{A8})$$

Thus, irrespective of the expected cash-flow, the manager always prefers to pretend that both signals coincide. It follows that the assumed equilibrium does not satisfy the man-

³¹Throughout our analyses, we restrict attention to perfect Bayesian equilibria.

ager's incentive compatibility constraints in case the private and the market signal do not coincide – the manager never chooses $a = a_{LH}$ or $a = a_{HL}$. ■

Proof of Proposition 2: First, note that under mark-to-market accounting, the shareholders learn the market signal directly from the firm's financial statements. Hence, while the level of investment in the new project can reveal information about the manager's private signal, it cannot reveal any new information about the market signal. The manager's choice is thus whether to make an investment that indicates $s = H$ or to make an investment that indicates $s = L$.

Assume now an equilibrium in which the manager follows the first-best strategy, so that the firm's shareholders form posterior beliefs $\widehat{\delta}(\pi, \sigma, s)$ as in the proof of Proposition 1. Consider the case of $\sigma = L$ and $s = H$. The manager prefers choosing an investment level that indicates $s = H$ to an investment level that indicates $s = L$ if and only if

$$\begin{aligned} & \widehat{\delta}(\pi = 1, \sigma = L, s = H) \cdot \Pr(\pi = 1 | \sigma = L, s = H) \\ & + \widehat{\delta}(\pi = 0, \sigma = L, s = H) \cdot \Pr(\pi = 0 | \sigma = L, s = H) \\ & \geq \end{aligned} \tag{A9}$$

$$\begin{aligned} & \widehat{\delta}(\pi = 1, \sigma = L, s = L) \cdot \Pr(\pi = 1 | \sigma = L, s = H) \\ & + \widehat{\delta}(\pi = 0, \sigma = L, s = L) \cdot \Pr(\pi = 0 | \sigma = L, s = H). \end{aligned}$$

Define

$$\begin{aligned} F(\phi) \equiv & \Pr(\pi = 1 | \sigma = L, s = H) \left[\widehat{\delta}(\pi = 1, \sigma = L, s = L) - \widehat{\delta}(\pi = 1, \sigma = L, s = H) \right] \\ & + \Pr(\pi = 0 | \sigma = L, s = H) \left[\widehat{\delta}(\pi = 0, \sigma = L, s = L) - \widehat{\delta}(\pi = 0, \sigma = L, s = H) \right] \end{aligned} \tag{A10}$$

so that the above constraint is satisfied for $F \leq 0$ and violated for $F > 0$. $F(\phi)$ is

continuous, and we have:

$$F(0) < 0 \tag{A11}$$

$$F(\delta) > 0 \tag{A12}$$

$$\frac{\partial F}{\partial \phi} > 0. \tag{A13}$$

Thus, there exists a unique threshold $\phi^* < \delta$ with $F(\phi^*) = 0$, such that the manager prefers indicating $s = H$ to indicating $s = L$ in case of $\sigma = L$ and $s = H$ if and only if $\phi \leq \phi^*$.

Further, note that the manager is indifferent between all investment levels that indicate $s = H$ and between all investment levels that indicate $s = L$. In particular, the manager is indifferent between the first-best investment $a = a_{LH}$ and any other investment level that indicates $s = H$. It follows that for $\phi \leq \phi^*$ the first-best investment in case of $\sigma = L$ and $s = H$ can be implemented under the tie-breaking assumption that the manager behaves in the interest of the shareholders when indifferent. An analogous argument can be made for the case of $\sigma = H, s = L$. In case of $\sigma = s$, the manager's incentive compatibility constraint is always satisfied. ■

Proof of Proposition 3: Consider first the case $\phi > \delta$. In that case, the second-best strategy does not depend on the manager's private signal. Thus, if this strategy is played in equilibrium, there is no updating regarding the manager's type:

$$\hat{\delta} = \delta \quad \text{for all } a \in \mathbb{R}_+. \tag{A14}$$

Hence, the manager is indifferent between all possible investment levels. It follows that the second-best strategy can be implemented under the tie-breaking assumption that the manager behaves in the interest of the shareholders when indifferent.

If $\delta > \phi$, the second-best strategy does not depend on the market signal. Assuming that this strategy is played in equilibrium, the shareholders form the following posterior beliefs:

$$\widehat{\delta}(\pi = 1, s = H) = \widehat{\delta}(\pi = 0, s = L) = \frac{p\delta}{p\delta + \frac{1}{2}(1-\delta)} > \delta \quad (\text{A15})$$

$$\widehat{\delta}(\pi = 1, s = L) = \widehat{\delta}(\pi = 0, s = H) = \frac{(1-p)\delta}{(1-p)\delta + \frac{1}{2}(1-\delta)} < \delta. \quad (\text{A16})$$

The manager prefers to make an investment indicating $s = H$ rather than $s = L$ if

$$\Pr(\pi = 1|\sigma, s) \widehat{\delta}(\pi = 1, s = H) > \Pr(\pi = 1|\sigma, s) \widehat{\delta}(\pi = 1, s = L) \quad (\text{A17})$$

$$+ \Pr(\pi = 0|\sigma, s) \widehat{\delta}(\pi = 0, s = H) > + \Pr(\pi = 0|\sigma, s) \widehat{\delta}(\pi = 0, s = L) \quad (\text{A18})$$

which is satisfied for $s = H$ and violated for $s = L$ for all $\sigma \in \{L, H\}$ if $\delta > \phi$. Further, the manager is indifferent between all investment levels indicating $s = H$. In particular, the manager is indifferent between the second-best level of investment $a = a_H$ and any other investment that indicates $s = H$. Thus, under the tie-breaking assumption that the manager acts in the interest of the shareholders when indifferent, the assumed rule can be implemented in equilibrium. ■

Proof of Proposition 4: Consider first the case $\phi > \delta$, in which the second-best strategy does not depend on the manager's private signal. As was shown in the proof of Proposition 3, the second-best strategy can be implemented in that case.

If $\delta > \phi$, the second-best strategy does not depend on the market signal. However, the shareholders learn the market signal from the asset values reported at $t = 0$ and the private signal from the manager's action. Hence, the posterior beliefs regarding the manager's type are exactly as in the proof of Proposition 2 – and so are the manager's incentive compatibility constraints. It follows that the assumed investment rule can be implemented for $\phi \leq \phi^*$ and cannot be implemented for $\phi > \phi^*$. ■

Proof of Proposition 5: Under historical cost accounting, for $\phi \geq \delta$, the best implementable investment strategy depends only on σ , and the shareholders' expected utility is

$$\begin{aligned} EU &= \Pr(\sigma = H) \{ \Pi(0, a_H) + \Pr(\pi = 1 | \sigma = H) \cdot [\Pi(1, a_H) - \Pi(0, a_H)] \} \\ &\quad + \Pr(\sigma = L) \{ \Pi(0, a_L) + \Pr(\pi = 1 | \sigma = L) \cdot [\Pi(1, a_L) - \Pi(0, a_L)] \} \end{aligned} \quad (\text{A19})$$

Using the envelope theorem, we obtain

$$\frac{\partial EU}{\partial \phi} = \frac{1}{2} \left(p - \frac{1}{2} \right) \cdot [\Pi(1, a_H) - \Pi(1, a_L) + \Pi(0, a_L) - \Pi(0, a_H)] > 0. \quad (\text{A20})$$

Thus, if shareholders can choose $\phi \in [0, \bar{\phi}]$ with $\bar{\phi} > \delta$, they choose $\phi = \bar{\phi}$.

For $\phi < \delta$, the best implementable strategy under historical cost accounting depends only on s , and the shareholders' expected utility is independent of ϕ . Thus, for $\bar{\phi} < \delta$, the shareholders are indifferent between any $\phi \in [0, \bar{\phi}]$.

For the case of mark-to-market accounting, we first establish the following Lemma:

Lemma 1 *Under mark-to-market accounting, the shareholders' expected utility is increasing in ϕ for $\phi \in [0, \phi^*]$ and for $\phi \in (\phi^*, 1)$.*

Proof: Under mark-to-market accounting, if $\phi > \phi^*(\delta)$, the best implementable investment strategy depends only on σ . In that case, we know from equation (A20) that the shareholders' expected utility is increasing in ϕ .

In case of $\phi \leq \phi^*(\delta)$, the first-best strategy (which depends on both σ and s) can be implemented. For ease of exposition, we define $p_{\sigma s} \equiv \Pr(\pi = 1 | \sigma, s)$ and $q_{\sigma s} \equiv \Pr(\sigma = \zeta, s = \xi)$ for $(\zeta, \xi) \in \{H, L\} \times \{H, L\}$. Conditional on a signal pair $(\sigma, s) \in \{H, L\} \times \{H, L\}$, the shareholders' expected utility under the first-best investment strategy is

$$g(p_{\sigma s}) \equiv \Pi(0, a_{\sigma s}^*) + p_{\sigma s} \cdot [\Pi(1, a_{\sigma s}^*) - \Pi(0, a_{\sigma s}^*)]. \quad (\text{A21})$$

By the envelope theorem, we have

$$\frac{\partial g(p_{\sigma s})}{\partial p_{\sigma s}} = \Pi(1, a_{\sigma s}^*) - \Pi(0, a_{\sigma s}^*) > 0 \quad (\text{A22})$$

and

$$\frac{\partial^2 g(p_{\sigma s})}{\partial p_{\sigma s}^2} = \left[\frac{\partial \Pi}{\partial a}(1, a_{\sigma s}^*) - \frac{\partial \Pi}{\partial a}(0, a_{\sigma s}^*) \right] \frac{da_{\sigma s}^*}{dp_{\sigma s}} > 0. \quad (\text{A23})$$

Thus, the function $g(\cdot)$ is increasing and convex in $p_{\sigma s}$.

Before σ and s are realized, the shareholders' ex ante expected utility is

$$E[g(p_{\sigma s})] = q_{HH} \cdot g(p_{HH}) + q_{LH} \cdot g(p_{LH}) + q_{HL} \cdot g(p_{HL}) + q_{LL} \cdot g(p_{LL}). \quad (\text{A24})$$

Consider now how the shareholders' ex ante expected utility changes if we increase the informativeness of the market signal from ϕ to $\phi' \in (\phi, \phi^*(\delta)]$. Denoting $\Pr(\pi = 1 | \sigma, s)$ as $p'_{\sigma s}$ and $\Pr(\sigma = \zeta, s = \xi)$ for $(\zeta, \xi) \in \{H, L\} \times \{H, L\}$ as $q'_{\sigma s}$ accordingly, the shareholders' ex ante expected utility is then

$$E[g(p'_{\sigma s})] = q'_{HH} \cdot g(p'_{HH}) + q'_{LH} \cdot g(p'_{LH}) + q'_{HL} \cdot g(p'_{HL}) + q'_{LL} \cdot g(p'_{LL}). \quad (\text{A25})$$

Note that we have

$$p'_{HH} > p_{HH} > p_{LH} > p'_{LH} > p'_{HL} > p_{HL} > p_{LL} > p'_{LL}, \quad (\text{A26})$$

$$q_{HH} \cdot p_{HH} + q_{LH} \cdot p_{LH} = q'_{HH} \cdot p'_{HH} + q'_{LH} \cdot p'_{LH} = \Pr(\pi = 1 | s = H) \cdot \Pr(s = H), \quad (\text{A27})$$

and

$$q_{LL} \cdot p_{LL} + q_{HL} \cdot p_{HL} = q'_{LL} \cdot p'_{LL} + q'_{HL} \cdot p'_{HL} = \Pr(\pi = 1 | s = L) \cdot \Pr(s = L). \quad (\text{A28})$$

Combined with the fact that $g(\cdot)$ is increasing and convex in $p_{\sigma s}$, this implies

$$q'_{HH} \cdot g(p'_{HH}) + q'_{LH} \cdot g(p'_{LH}) > q_{HH} \cdot g(p_{HH}) + q_{LH} \cdot g(p_{LH}) \quad (\text{A29})$$

and

$$q'_{HL} \cdot g(p'_{HL}) + q'_{LL} \cdot g(p'_{LL}) > q_{HL} \cdot g(p_{HL}) + q_{LL} \cdot g(p_{LL}), \quad (\text{A30})$$

which in turn implies

$$E[g(p'_{\sigma s})] > E[g(p_{\sigma s})]. \quad (\text{A31})$$

The shareholders' expected utility is thus increasing in ϕ for both $\phi > \phi^*(\delta)$ and $\phi \leq \phi^*(\delta)$. ■

We can now show that there exists a $\bar{\delta} \in (0, \bar{\phi})$, such that for $\delta < \bar{\delta}$ the shareholders choose $\phi = \bar{\phi}$ and for $\delta > \bar{\delta}$, the shareholders choose $\phi = \min\{\phi^*(\delta), \bar{\phi}\}$. First, note that it follows from Lemma 1 that the shareholders choose either $\phi = \bar{\phi}$ or $\phi = \phi^*(\delta)$. Second, note that for $\delta = 0$ we obtain $\phi^*(\delta) = 0$, so that the shareholders' expected utility is maximized for $\phi = \bar{\phi}$. Third, for $\delta = \bar{\phi}$, the shareholders' expected utility is maximized for $\phi = \phi^*(\delta)$. To see this, note that $\delta = \bar{\phi}$ implies $\bar{\phi} > \phi^*$. Hence, if the shareholders choose $\phi = \bar{\phi}$, the best implementable strategy is based only on σ . This, however, would lead to the same expected utility as choosing $\phi = 0$ and implementing the optimal strategy based only on s . Consider now the shareholders' expected utility after choosing $\phi = \phi^*(\delta)$. In that case, the best implementable strategy is based not only on s but also on σ . We know that in that case, the shareholders' expected utility is increasing in ϕ . Thus, choosing $\phi = \phi^*(\delta)$ must dominate choosing $\phi = \bar{\phi}$. Finally, note that for $\phi = \phi^*(\delta)$ the shareholders' expected utility is increasing in δ because we have $\partial EU / \partial \delta > 0$ and $\partial \phi^*(\delta) / \partial \delta > 0$. It follows that there exists a unique $\bar{\delta} \in (0, \bar{\phi})$ such that for $\delta < \bar{\delta}$ the shareholders choose $\phi = \bar{\phi}$ and for $\delta > \bar{\delta}$ the shareholders choose $\phi = \min\{\phi^*(\delta), \bar{\phi}\}$. ■

Proof of Proposition 6: Suppose, in case of mark-to-market accounting, the manager can choose to misreport the current market value of the firm's assets at $t = 0$. Consider

the case of $\sigma = H$. (The proof for the case of $\sigma = L$ is symmetric.) Denote the true market signal as σ and the manager's report of the market signal as $\hat{\sigma}$.

First, suppose that $\phi > \phi^*$. In that case, the best implementable investment strategy depends only on the reported market signal, and there is no updating regarding the manager's type: $\hat{\delta}(\pi, \hat{\sigma}) = \delta$ for all π and $\hat{\sigma}$. Hence, the manager is indifferent between reporting $\hat{\sigma} = H$ and $\hat{\sigma} = L$. The shareholders prefer truthful reporting followed by choosing $a = a_H$ to untruthful reporting followed by choosing $a = a_L$ because the firm's expected net profit is larger in the former than in the latter case. Truthful reporting is thus the equilibrium outcome under the tie-breaking assumption that the manager behaves in the interest of the shareholders when indifferent.

Consider now the case of $\phi \leq \phi^*$. In that case, if the manager truthfully reports $\hat{\sigma} = H$, his expected reputation is

$$\Pr(s = H|\sigma = H) \left[\begin{array}{l} \Pr(\pi = 1|\sigma = H, s = H) \hat{\delta}(\pi = 1, \hat{\sigma} = H, s = H) \\ + \Pr(\pi = 0|\sigma = H, s = H) \hat{\delta}(\pi = 0, \hat{\sigma} = H, s = H) \end{array} \right] \quad (\text{A32})$$

$$+ \Pr(s = L|\sigma = H) \left[\begin{array}{l} \Pr(\pi = 1|\sigma = H, s = L) \hat{\delta}(\pi = 1, \hat{\sigma} = H, s = L) \\ + \Pr(\pi = 0|\sigma = H, s = L) \hat{\delta}(\pi = 0, \hat{\sigma} = H, s = L) \end{array} \right]$$

Note that it follows from Proposition 2 that after reporting $\hat{\sigma} = H$, the manager prefers $a = a_{HH}$ to $a = a_{HL}$ if his private signal is $s = H$ and $a = a_{HL}$ to $a = a_{HH}$ if his private signal is $s = L$.

We know from Proposition 2 that, for $\phi \leq \phi^*$, the manager prefers $a = a_{LH}$ to $a = a_{LL}$ if $\sigma = L$ and $s = H$. Further, the manager's expected reputation after choosing $a = a_{LH}$

is higher in case of $\sigma = H$ and $s = H$ than in case of $\sigma = L$ and $s = H$:

$$\begin{aligned} & \Pr(\pi = 1|\sigma = H, s = H) \cdot \widehat{\delta}(\pi = 1, \widehat{\sigma} = L, s = H) \\ & + \Pr(\pi = 0|\sigma = H, s = H) \cdot \widehat{\delta}(\pi = 0, \widehat{\sigma} = L, s = H) \\ & > \end{aligned} \tag{A33}$$

$$\begin{aligned} & \Pr(\pi = 1|\sigma = L, s = H) \cdot \widehat{\delta}(\pi = 1, \widehat{\sigma} = L, s = H) \\ & + \Pr(\pi = 0|\sigma = L, s = H) \cdot \widehat{\delta}(\pi = 0, \widehat{\sigma} = L, s = H) \end{aligned}$$

and the manager's expected reputation after choosing $a = a_{LL}$ is lower in case of $\sigma = H$ and $s = H$ than in case of $\sigma = L$ and $s = H$:

$$\begin{aligned} & \Pr(\pi = 1|\sigma = H, s = H) \cdot \widehat{\delta}(\pi = 1, \widehat{\sigma} = L, s = L) \\ & + \Pr(\pi = 0|\sigma = H, s = H) \cdot \widehat{\delta}(\pi = 0, \widehat{\sigma} = L, s = L) \\ & < \end{aligned} \tag{A34}$$

$$\begin{aligned} & \Pr(\pi = 1|\sigma = L, s = H) \cdot \widehat{\delta}(\pi = 1, \widehat{\sigma} = L, s = L) \\ & + \Pr(\pi = 0|\sigma = L, s = H) \cdot \widehat{\delta}(\pi = 0, \widehat{\sigma} = L, s = L) \end{aligned}$$

It follows that if the true market signal is $\sigma = H$, after reporting $\widehat{\sigma} = L$, the manager prefers $a = a_{LH}$ to $a = a_{LL}$ if his private signal is $s = H$.

Further, we know from Proposition 1 that if $\sigma = H$ and $s = L$, the manager prefers $a = a_{LL}$ to $a = a_{HL}$. In that case, the manager also prefers $a = a_{HL}$ to $a = a_{LH}$:

$$\begin{aligned} & \Pr(\pi = 1|\sigma = H, s = L) \cdot \widehat{\delta}(\pi = 1, \widehat{\sigma} = H, s = L) \\ & + \Pr(\pi = 0|\sigma = H, s = L) \cdot \widehat{\delta}(\pi = 0, \widehat{\sigma} = H, s = L) \\ & > \end{aligned} \tag{A35}$$

$$\begin{aligned} & \Pr(\pi = 1|\sigma = H, s = L) \cdot \widehat{\delta}(\pi = 1, \widehat{\sigma} = L, s = H) \\ & + \Pr(\pi = 0|\sigma = H, s = L) \cdot \widehat{\delta}(\pi = 0, \widehat{\sigma} = L, s = H) \end{aligned}$$

It follows that if the true market signal is $\sigma = H$, after reporting $\widehat{\sigma} = L$, the manager prefers $a = a_{LL}$ to $a = a_{LH}$ if his private signal is $s = L$.

Hence, if the manager untruthfully reports $\hat{\sigma} = L$, his expected reputation is

$$\begin{aligned} & \Pr(s = H | \sigma = H) \left[\begin{array}{l} \Pr(\pi = 1 | \sigma = H, s = H) \widehat{\delta}(\pi = 1, \hat{\sigma} = L, s = H) \\ + \Pr(\pi = 0 | \sigma = H, s = H) \widehat{\delta}(\pi = 0, \hat{\sigma} = L, s = H) \end{array} \right] \\ & + \Pr(s = L | \sigma = H) \left[\begin{array}{l} \Pr(\pi = 1 | \sigma = H, s = L) \widehat{\delta}(\pi = 1, \hat{\sigma} = L, s = L) \\ + \Pr(\pi = 0 | \sigma = H, s = L) \widehat{\delta}(\pi = 0, \hat{\sigma} = L, s = L) \end{array} \right] \end{aligned} \quad (\text{A36})$$

Comparing equations (A32) and (A36), it can be shown that the manager prefers to report the assets' market value truthfully if

$$\begin{aligned} & \left[\frac{1}{4} (1 + \phi\delta) + \frac{1}{2} \left(p - \frac{1}{2} \right) (\delta + \phi) \right] \cdot \left[\widehat{\delta}(\pi = 1, \hat{\sigma} = H, s = H) - \widehat{\delta}(\pi = 1, \hat{\sigma} = L, s = H) \right] \\ & + \left[\frac{1}{4} (1 + \phi\delta) - \frac{1}{2} \left(p - \frac{1}{2} \right) (\delta + \phi) \right] \cdot \left[\widehat{\delta}(\pi = 0, \hat{\sigma} = H, s = H) - \widehat{\delta}(\pi = 0, \hat{\sigma} = L, s = H) \right] \\ & \geq \end{aligned} \quad (\text{A37})$$

$$\begin{aligned} & \left[\frac{1}{4} (1 - \phi\delta) + \frac{1}{2} \left(p - \frac{1}{2} \right) (\delta - \phi) \right] \cdot \left[\widehat{\delta}(\pi = 1, \hat{\sigma} = H, s = H) - \widehat{\delta}(\pi = 1, \hat{\sigma} = L, s = H) \right] \\ & + \left[\frac{1}{4} (1 - \phi\delta) - \frac{1}{2} \left(p - \frac{1}{2} \right) (\delta - \phi) \right] \cdot \left[\widehat{\delta}(\pi = 0, \hat{\sigma} = H, s = H) - \widehat{\delta}(\pi = 0, \hat{\sigma} = L, s = H) \right] \end{aligned}$$

which is satisfied for any $\phi\delta > 0$. Hence, the manager prefers to report the market signal truthfully. ■

Proof of Proposition 7: To simplify notation, define

$$\Pr(ijk) \equiv \Pr(\pi = i | \sigma = j, s = k) \quad \text{for } i, j, k \in \{1, 0\} \times \{H, L\} \times \{H, L\} \quad (\text{A38})$$

and

$$\widehat{\delta}(ijk) \equiv \widehat{\delta}(\pi = i, \sigma = j, s = k) \quad \text{for } i, j, k \in \{1, 0\} \times \{H, L\} \times \{H, L\}. \quad (\text{A39})$$

Assume that the compensation contract is restricted by the following three constraints:

(i) the manager has limited liability, (ii) the shareholders have limited liability, and (iii)

the manager's compensation must not be decreasing in the firm's final payoff. Furthermore, assume that the first-best decision rule is implemented in equilibrium. In that case, the shareholders learn σ , s , and π and form posterior beliefs about the manager's type as in the proof to Proposition 1.

Consider first the case of historical cost accounting. We define $b_{\sigma s}^\pi$ as the incentive payment that the manager receives if he has taken action $a_{\sigma s}$ and the existing assets generate cash-flow π . One of the manager's incentive compatibility constraints that must be satisfied in equilibrium is as follows:

$$\begin{aligned} & \Pr(1LH) \left[\Omega \widehat{\delta}(1LH) + b_{LH}^1 \right] + \Pr(0LH) \left[\Omega \widehat{\delta}(0LH) + b_{LH}^0 \right] \\ & \geq \\ & \Pr(1LH) \left[\Omega \widehat{\delta}(1HH) + b_{HH}^1 \right] + \Pr(0LH) \left[\Omega \widehat{\delta}(0HH) + b_{HH}^0 \right]. \end{aligned} \tag{A40}$$

This condition ensures that the manager prefers $a = a_{LH}$ to $a = a_{HH}$ if $\sigma = L$ and $s = H$.

The above constraint can be re-written as

$$\begin{aligned} & \Pr(1LH) \left[b_{LH}^1 - b_{HH}^1 \right] + \Pr(0LH) \left[b_{LH}^0 - b_{HH}^0 \right] \\ & \geq \\ & \Omega \left\{ \Pr(1LH) \left[\widehat{\delta}(1HH) - \widehat{\delta}(1LH) \right] + \Pr(0LH) \left[\widehat{\delta}(0HH) - \widehat{\delta}(0LH) \right] \right\}. \end{aligned} \tag{A41}$$

Further, we have $\Pi(1, a_{HH}) > \Pi(1, a_{LH})$, which implies $b_{HH}^1 \geq b_{LH}^1$ because of the monotonicity constraint on the manager's compensation, and

$$\min \{ b_{LH}^1, b_{HH}^1, b_{LH}^0, b_{HH}^0 \} \geq 0 \tag{A42}$$

because of the manager's limited liability. Therefore, a necessary condition for the incentive compatibility constraint to hold is

$$b_{LH}^0 \geq \Omega \left\{ \widehat{\delta}(0HH) - \widehat{\delta}(0LH) + \frac{\Pr(1LH)}{\Pr(0LH)} \left[\widehat{\delta}(1HH) - \widehat{\delta}(1LH) \right] \right\}. \tag{A43}$$

The shareholders' limited liability, however, implies $b_{LH}^0 \leq \Pi(0, a_{LH})$, so that a necessary condition for the existence of an incentive compatible contract is

$$\Omega \leq \frac{\Pi(0, a_{LH})}{\left\{ \widehat{\delta}(0HH) - \widehat{\delta}(0LH) + \frac{\Pr(1LH)}{\Pr(0LH)} \left[\widehat{\delta}(1HH) - \widehat{\delta}(1LH) \right] \right\}}. \quad (\text{A44})$$

Hence, there exists an Ω^* such that an incentive compatible contract does not exist if $\Omega > \Omega^*$. In particular, if $\Pi(0, a) \leq 0$, i.e., if the firm's final net profit is negative or zero whenever the existing assets generate a low cash flow, then the first-best investment rule cannot be implemented for any $\Omega > 0$.

Suppose instead that the firm follows a mark-to-market rule and consider the case of $\sigma = H$. We define $b_{\sigma s}^\pi(\sigma)$ as the incentive payment that the manager receives if the market signal is σ , he has taken action $a_{\sigma s}$, and the existing assets generate cash-flow π . One of the manager's incentive compatibility constraints is as follows:

$$\begin{aligned} & \Pr(1HL) \left[\Omega \widehat{\delta}(1HL) + b_{HL}^1(H) \right] + \Pr(0HL) \left[\Omega \widehat{\delta}(0HL) + b_{HL}^0(H) \right] \\ & \geq \\ & \Pr(1HL) \left[\Omega \widehat{\delta}(1HH) + b_{HH}^1(H) \right] + \Pr(0HL) \left[\Omega \widehat{\delta}(0HH) + b_{HH}^0(H) \right]. \end{aligned} \quad (\text{A45})$$

This ensures that the manager prefers $a = a_{HL}$ to $a = a_{HH}$ if $\sigma = H$ and $s = L$.

The above constraint can be re-written as

$$\begin{aligned} & \Pr(1HL) \left[b_{HL}^1(H) - b_{HH}^1(H) \right] + \Pr(0HL) \left[b_{HL}^0(H) - b_{HH}^0(H) \right] \\ & \geq \\ & \Omega \left\{ \Pr(1HL) \left[\widehat{\delta}(1HH) - \widehat{\delta}(1HL) \right] + \Pr(0HL) \left[\widehat{\delta}(0HH) - \widehat{\delta}(0HL) \right] \right\}. \end{aligned} \quad (\text{A46})$$

Further, we have $\Pi(1, a_{HH}) > \Pi(1, a_{HL})$, which implies $b_{HH}^1(H) \geq b_{HL}^1(H)$ because of the monotonicity constraint on the manager's compensation, and

$$\min \{ b_{HL}^1(H), b_{HH}^1(H), b_{HL}^0(H), b_{HH}^0(H) \} \geq 0 \quad (\text{A47})$$

because of the manager's limited liability. Therefore, a necessary condition for the incentive compatibility constraint to hold is

$$b_{HL}^0(H) \geq \Omega \left\{ \widehat{\delta}(0HH) - \widehat{\delta}(0HL) + \frac{\Pr(1HL)}{\Pr(0HL)} \left[\widehat{\delta}(1HH) - \widehat{\delta}(1HL) \right] \right\}. \quad (\text{A48})$$

The shareholders' limited liability, however, implies $b_{HL}^0(H) \leq \Pi(0, a_{HL})$, so that a necessary condition for the existence of an incentive compatible contract is

$$\Omega \leq \frac{\Pi(0, a_{HL})}{\left\{ \widehat{\delta}(0HH) - \widehat{\delta}(0HL) + \frac{\Pr(1HL)}{\Pr(0HL)} \left[\widehat{\delta}(1HH) - \widehat{\delta}(1HL) \right] \right\}}. \quad (\text{A49})$$

Hence, there exists an Ω^{**} such that an incentive compatible contract does not exist if $\Omega > \Omega^{**}$. In particular, if $\Pi(0, a) \leq 0$, i.e., if the firm's final net profit is negative or zero whenever the existing assets generate a low cash flow, then the first-best investment rule cannot be implemented for any $\Omega > 0$. ■

Proof of Proposition 8: To prove Proposition 8, we first establish the following Lemma.

Lemma 2 *For a given strategy, denote the set of actions from which a good manager chooses with Σ_G and the set of actions from which a bad manager chooses with Σ_B . Any strategy that can be implemented in equilibrium must be such that $\Sigma_G = \Sigma_B$.*

Proof: Consider an equilibrium in which we have $\Sigma_G \neq \Sigma_B$. Then, there must exist at least one action a_R such that either $a_R \in \Sigma_G$ but $a_R \notin \Sigma_B$ or $a_R \in \Sigma_B$ but $a_R \notin \Sigma_G$. If $a_R \in \Sigma_G$ but $a_R \notin \Sigma_B$, choosing $a = a_R$ reveals that the manager is good. In that case, choosing an action $a \in \Sigma_B$ cannot be incentive-compatible for the bad type: choosing $a = a_R$ dominates choosing $a \in \Sigma_B$. If $a_R \in \Sigma_B$ but $a_R \notin \Sigma_G$, choosing $a = a_R$ reveals that the manager is bad. In that case, choosing $a = a_R$ cannot be incentive compatible for the bad type: choosing $a \in \Sigma_G$ dominates choosing $a = a_R$. Thus, the assumed equilibrium cannot satisfy the bad type's incentive compatibility constraints. ■

The first-best strategy in case the manager knows his type specifies a different set of investment levels for the good manager than for the bad manager. Lemma 2 implies that this strategy cannot be implemented.

Consider now the second-best strategy. Under historical cost accounting, if the manager chooses according to this strategy, the shareholders' posterior beliefs regarding the manager's type are

$$\begin{aligned} \Pr(\theta_A = g | \pi = 1, a = a_H^{SB}) &= \Pr(\theta_A = g | \pi = 0, a = a_L^{SB}) \\ &= \frac{\frac{1}{2}p\delta}{\frac{1}{2}p\delta + [\frac{1}{2} + \phi(p - \frac{1}{2})](1 - \delta)} \end{aligned} \quad (\text{A50})$$

and

$$\begin{aligned} \Pr(\theta_A = g | \pi = 0, a = a_H^{SB}) &= \Pr(\theta_A = g | \pi = 1, a = a_L^{SB}) \\ &= \frac{\frac{1}{2}(1 - p)\delta}{\frac{1}{2}(1 - p)\delta + [\frac{1}{2} - \phi(p - \frac{1}{2})](1 - \delta)} \end{aligned} \quad (\text{A51})$$

It follows that both types of manager prefer $a = a_H^{SB}$ to $a = a_L^{SB}$ if $\Pr(\pi = 1 | \sigma, s) > \Pr(\pi = 0 | \sigma, s)$. Further, a good manager is indifferent between $a = a_H^{SB}$ and any other investment level that indicates $s = H$ and between $a = a_L^{SB}$ and any other investment level that indicates $s = L$. Similarly, a bad manager is indifferent between $a = a_H^{SB}$ and any other investment level that indicates $\sigma = H$ and between $a = a_L^{SB}$ and any other investment level that indicates $\sigma = L$. Thus, under the tie-breaking assumption that the manager behaves in the interest of the shareholders when indifferent, the second-best strategy can be implemented under historical cost accounting: A good manager chooses $a = a_H^{SB}$ if $s = H$ and $a = a_L^{SB}$ if $s = L$, and a bad manager chooses $a = a_H^{SB}$ if $\sigma = H$ and $a = a_L^{SB}$ if $\sigma = L$.

Consider instead the case of mark-to-market accounting and assume that $\sigma = L$. If the manager follows the proposed strategy, then choosing $a = a_H^{SB}$ reveals that the

manager's type is good. Thus, it is not incentive-compatible for the bad manager to choose $a = a_L^{SB}$. It follows that the second-best strategy cannot be implemented under marking to market.

The third-best level of investment, a_σ^{TB} , is given by

$$\frac{\partial \Pi}{\partial a}(0, a_\sigma^{TB}) + \Pr(\pi = 1|\sigma) \cdot \left[\frac{\partial \Pi}{\partial a}(1, a_\sigma^{TB}) - \frac{\partial \Pi}{\partial a}(0, a_\sigma^{TB}) \right] = 0 \quad \text{for } \sigma \in \{H, L\} \quad (\text{A52})$$

and can be implemented under mark-to-market accounting. If the manager follows this strategy, the shareholders' posterior beliefs are $\hat{\delta} = \delta$ in all cases and do not depend on the manager's action. Thus, the third-best strategy can be implemented under the tie-breaking assumption that the manager behaves in the interest of the shareholders when indifferent. ■

Mixed strategies under mark-to-market accounting

We now show that in case the first-best strategy cannot be implemented under mark-to-market accounting, mixed strategies in which the manager's investment decision reveals partial information about his private signal cannot be implemented either. To simplify the notation, we define

$$\Pr(ijk) \equiv \Pr(\pi = i | \sigma = j, s = k) \quad \text{for } i, j, k \in \{1, 0\} \times \{H, L\} \times \{H, L\}, \quad (\text{A53})$$

$$\Pr(jk) \equiv \Pr(\sigma = j, s = k) \quad \text{for } j, k \in \{H, L\} \times \{H, L\}, \quad (\text{A54})$$

and

$$\widehat{\delta}(ijk) \equiv \widehat{\delta}(\pi = i, \sigma = j, s = k) \quad \text{for } i, j, k \in \{1, 0\} \times \{H, L\} \times \{H, L\}. \quad (\text{A55})$$

Case 1: Randomization both after $s = H$ and after $s = L$

Suppose the market signal is $\sigma = H$. (The case of $\sigma = L$ is symmetric). Consider the following mixed strategy: If the manager has observed $s = H$, he chooses an investment a_H with probability $\alpha \in (0, 1)$ and an investment a_L with probability $1 - \alpha$. If the manager has observed $s = L$, he chooses an investment a_H with probability $\beta \in (0, 1)$ and an investment a_L with probability $1 - \beta$. That is, the manager randomizes between the two investment levels a_H and a_L . Note that this strategy is equivalent to announcing $\widehat{s} = H$ with probability $\alpha \in (0, 1)$ and $\widehat{s} = L$ with probability $1 - \alpha$ after observing $s = H$ and announcing $\widehat{s} = H$ with probability $\beta \in (0, 1)$ and $\widehat{s} = L$ with probability $1 - \beta$ after observing $s = L$.

The firm's shareholders observe σ , \widehat{s} , and π . Suppose, for example, $\sigma = H$, $\widehat{s} = H$, and $\pi = 1$. In that case, the shareholders form the following posterior belief about the

manager's type:

$$\begin{aligned} \Pr(\theta_A = g | \pi = 1, \sigma = H, \hat{s} = H) &= \Pr(\theta_A = g, s = H | \pi = 1, \sigma = H, \hat{s} = H) \\ &+ \Pr(\theta_A = g, s = L | \pi = 1, \sigma = H, \hat{s} = H). \end{aligned} \quad (\text{A56})$$

We have

$$\begin{aligned} \Pr(\theta_A = g, s = H | \pi = 1, \sigma = H, \hat{s} = H) &= \Pr(\theta_A = g | \pi = 1, \sigma = H, s = H, \hat{s} = H) \\ &\cdot \Pr(s = H | \pi = 1, \sigma = H, \hat{s} = H) \\ &= \Pr(\theta_A = g | \pi = 1, \sigma = H, s = H) \\ &\cdot \Pr(s = H | \pi = 1, \sigma = H, \hat{s} = H), \end{aligned} \quad (\text{A57})$$

where the second equality follows from the fact that \hat{s} does not provide any additional information about the manager's type conditional on π , σ , and s . We can therefore write

$$\begin{aligned} \Pr(\theta_A = g | \pi = 1, \sigma = H, \hat{s} = H) &= \hat{\delta}(1HH) \cdot \Pr(s = H | \pi = 1, \sigma = H, \hat{s} = H) \\ &+ \hat{\delta}(1HL) \cdot \Pr(s = L | \pi = 1, \sigma = H, \hat{s} = H). \end{aligned} \quad (\text{A58})$$

The shareholders' posterior beliefs after observing $\pi = 0$ and/or $\hat{s} = L$ can be constructed analogously.

Suppose now that the manager has observed $s = H$. In that case, his expected utility from announcing $\hat{s} = H$ is

$$\begin{aligned} EU[\hat{s} = H | \sigma = H, s = H] &= \Pr(1HH) \cdot \Pr(\theta_A = g | \pi = 1, \sigma = H, \hat{s} = H) \\ &+ \Pr(0HH) \cdot \Pr(\theta_A = g | \pi = 0, \sigma = H, \hat{s} = H) \end{aligned} \quad (\text{A59})$$

The manager's expected utilities after observing $s = L$ and/or announcing $\hat{s} = L$ can be constructed analogously.

For the manager to randomize between announcing $\hat{s} = H$ and $\hat{s} = L$ after observing

$s = H$ and $s = L$ we must have

$$EU[\widehat{s} = H|\sigma = H, s = H] = EU[\widehat{s} = L|\sigma = H, s = H] \quad (\text{A60})$$

and

$$EU[\widehat{s} = H|\sigma = H, s = L] = EU[\widehat{s} = L|\sigma = H, s = L]. \quad (\text{A61})$$

Solving the above system leads to the following condition:

$$\begin{bmatrix} \Pr(1HL) \\ -\Pr(1HH) \end{bmatrix} \cdot \begin{bmatrix} \widehat{\delta}(1HH) \\ -\widehat{\delta}(1HL) \end{bmatrix} \cdot \begin{bmatrix} \Pr(s = H|\pi = 1, \sigma = H, \widehat{s} = H) \\ -\Pr(s = H|\pi = 1, \sigma = H, \widehat{s} = L) \end{bmatrix} = 0. \quad (\text{A62})$$

Hence, for $\delta \neq 0$, the manager is willing to randomize between announcing $\widehat{s} = H$ and $\widehat{s} = L$ if and only if

$$\Pr(s = H|\pi = 1, \sigma = H, \widehat{s} = H) = \Pr(s = H|\pi = 1, \sigma = H, \widehat{s} = L), \quad (\text{A63})$$

i.e., if the manager's announcement does not provide any new information about his private signal.

Case 2: Randomization either after $s = H$ or after $s = L$

Subcase A: Consider an equilibrium in which the manager always announces $\widehat{s} = H$ after observing $s = H$. After observing $s = L$, the manager announces $\widehat{s} = H$ with probability $\beta \in (0, 1)$ and announces $\widehat{s} = L$ with probability $1 - \beta$. In equilibrium, conditional on having observed $s = L$, the manager must be indifferent between announcing $\widehat{s} = L$ and $\widehat{s} = H$. Thus, we must have

$$EU[\widehat{s} = L|\sigma = H, s = L] = EU[\widehat{s} = H|\sigma = H, s = L]. \quad (\text{A64})$$

Note that announcing $\widehat{s} = L$ perfectly reveals $s = L$, so that

$$EU[\widehat{s} = L|\sigma = H, s = L] = \Pr(1HL)\widehat{\delta}(1HL) + \Pr(0HL)\widehat{\delta}(0HL) \quad (\text{A65})$$

for all $\beta \in [0, 1)$. We further have

$$\begin{aligned} EU [\widehat{s} = H | \sigma = H, s = L] &= \Pr(1HL) \Pr(\theta_A = g | \pi = 1, \sigma = H, \widehat{s} = H) \\ &+ \Pr(0HL) \Pr(\theta_A = g | \pi = 0, \sigma = H, \widehat{s} = H), \end{aligned} \quad (\text{A66})$$

which can be re-arranged to

$$\begin{aligned} EU [\widehat{s} = H | \sigma = H, s = L] &= \widehat{\delta}(0HL) + \Pr(1HL) \left[\widehat{\delta}(1HL) - \widehat{\delta}(0HL) \right] \\ &+ \frac{\Pr(1HH) \Pr(HH) \Pr(1HL) [\widehat{\delta}(1HH) - \widehat{\delta}(1HL)]}{\Pr(1HH) \Pr(HH) + \Pr(1HL) \Pr(HL) \beta} \\ &+ \frac{\Pr(0HH) \Pr(HH) \Pr(0HL) [\widehat{\delta}(0HH) - \widehat{\delta}(0HL)]}{\Pr(0HH) \Pr(HH) + \Pr(0HL) \Pr(HL) \beta} \end{aligned} \quad (\text{A67})$$

using

$$\begin{aligned} \Pr(\theta_A = g | \pi = 1, \sigma = H, \widehat{s} = H) &= \widehat{\delta}(1HH) \Pr(s = H | \pi = 1, \sigma = H, \widehat{s} = H) \\ &+ \widehat{\delta}(1HL) \Pr(s = L | \pi = 1, \sigma = H, \widehat{s} = H), \end{aligned} \quad (\text{A68})$$

$$\begin{aligned} \Pr(\theta_A = g | \pi = 0, \sigma = H, \widehat{s} = H) &= \widehat{\delta}(0HH) \Pr(s = H | \pi = 0, \sigma = H, \widehat{s} = H) \\ &+ \widehat{\delta}(0HL) \Pr(s = L | \pi = 0, \sigma = H, \widehat{s} = H), \end{aligned} \quad (\text{A69})$$

$$\Pr(s = H | \pi = 1, \sigma = H, \widehat{s} = H) = \frac{\Pr(1HH) \Pr(HH)}{\Pr(1HH) \Pr(HH) + \Pr(1HL) \Pr(HL) \beta}, \quad (\text{A70})$$

and

$$\Pr(s = H | \pi = 0, \sigma = H, \widehat{s} = H) = \frac{\Pr(0HH) \Pr(HH)}{\Pr(0HH) \Pr(HH) + \Pr(0HL) \Pr(HL) \beta}. \quad (\text{A71})$$

It follows that

$$EU [\widehat{s} = H | \sigma = H, s = L] = EU [\widehat{s} = H | \sigma = H, s = L] \quad (\text{A72})$$

if and only if

$$\beta = \frac{\Pr(0HH) \Pr(HH) \left\{ \frac{\Pr(0HL) [\widehat{\delta}(0HL) - \widehat{\delta}(0HH)]}{\Pr(1HL) [\widehat{\delta}(1HH) - \widehat{\delta}(1HL)]} - 1 \right\}}{\Pr(0HL) \Pr(HL) \left\{ 1 - \frac{\Pr(0HH) [\widehat{\delta}(0HL) - \widehat{\delta}(0HH)]}{\Pr(1HH) [\widehat{\delta}(1HH) - \widehat{\delta}(1HL)]} \right\}} \quad (\text{A73})$$

Note, however, that $\phi > \phi^*$ implies

$$\frac{\Pr(0HL) [\widehat{\delta}(0HL) - \widehat{\delta}(0HH)]}{\Pr(1HL) [\widehat{\delta}(1HH) - \widehat{\delta}(1HL)]} < 1, \quad (\text{A74})$$

so that $\beta > 0$ if and only if

$$\frac{\Pr(0HH) [\widehat{\delta}(0HL) - \widehat{\delta}(0HH)]}{\Pr(1HH) [\widehat{\delta}(1HH) - \widehat{\delta}(1HL)]} > 1 \quad (\text{A75})$$

which is always violated. Hence, for $\phi > \phi^*$, no $\beta \in (0, 1)$ exists for which the manager is indifferent between announcing $\widehat{s} = L$ and $\widehat{s} = H$ after observing $s = L$.

Subcase B: Consider an equilibrium in which the manager always announces $\widehat{s} = L$ after observing $s = L$. After observing $s = H$, the manager announces $\widehat{s} = H$ with probability $\alpha \in (0, 1)$ and announces $\widehat{s} = L$ with probability $1 - \alpha$. In equilibrium, conditional on having observed $s = H$, the manager must be indifferent between announcing $\widehat{s} = H$ and $\widehat{s} = L$. Thus, we must have

$$EU[\widehat{s} = H | \sigma = H, s = H] = EU[\widehat{s} = L | \sigma = H, s = H]. \quad (\text{A76})$$

Note that announcing $\widehat{s} = H$ perfectly reveals $s = H$, so that

$$EU[\widehat{s} = H | \sigma = H, s = H] = \Pr(1HH) \widehat{\delta}(1HH) + \Pr(0HH) \widehat{\delta}(0HH) \quad (\text{A77})$$

for all $\alpha \in [0, 1)$. We further have

$$\begin{aligned} EU[\widehat{s} = L | \sigma = H, s = H] &= \Pr(1HH) \Pr(\theta_A = g | \pi = 1, \sigma = H, \widehat{s} = L) \\ &\quad + \Pr(0HH) \Pr(\theta_A = g | \pi = 0, \sigma = H, \widehat{s} = L), \end{aligned} \quad (\text{A78})$$

which can be re-arranged to

$$\begin{aligned} EU[\widehat{s} = L | \sigma = H, s = H] &= \Pr(1HH) \widehat{\delta}(1HL) + \Pr(0HH) \widehat{\delta}(0HL) \\ &\quad + \frac{\Pr(1HH) \Pr(HH)(1-\alpha) \Pr(1HH) [\widehat{\delta}(1HH) - \widehat{\delta}(1HL)]}{\Pr(1HH) \Pr(HH)(1-\alpha) + \Pr(1HL) \Pr(HL)} \\ &\quad + \frac{\Pr(0HH) \Pr(HH)(1-\alpha) \Pr(0HH) [\widehat{\delta}(0HH) - \widehat{\delta}(0HL)]}{\Pr(0HH) \Pr(HH)(1-\alpha) + \Pr(0HL) \Pr(HL)} \end{aligned} \quad (\text{A79})$$

using

$$\begin{aligned} \Pr(\theta_A = g | \pi = 1, \sigma = H, \hat{s} = L) &= \widehat{\delta}(1HH) \Pr(s = H | \pi = 1, \sigma = H, \hat{s} = L) \\ &\quad + \widehat{\delta}(1HL) \Pr(s = L | \pi = 1, \sigma = H, \hat{s} = L), \end{aligned} \quad (\text{A80})$$

$$\begin{aligned} \Pr(\theta_A = g | \pi = 0, \sigma = H, \hat{s} = L) &= \widehat{\delta}(0HH) \Pr(s = H | \pi = 0, \sigma = H, \hat{s} = L) \\ &\quad + \widehat{\delta}(0HL) \Pr(s = L | \pi = 0, \sigma = H, \hat{s} = L), \end{aligned} \quad (\text{A81})$$

$$\Pr(s = H | \pi = 1, \sigma = H, \hat{s} = L) = \frac{\Pr(1HH) \Pr(HH) (1 - \alpha)}{\Pr(1HH) \Pr(HH) (1 - \alpha) + \Pr(1HL) \Pr(HL)} \quad (\text{A82})$$

and

$$\Pr(s = H | \pi = 0, \sigma = H, \hat{s} = L) = \frac{\Pr(0HH) \Pr(HH) (1 - \alpha)}{\Pr(0HH) \Pr(HH) (1 - \alpha) + \Pr(0HL) \Pr(HL)}. \quad (\text{A83})$$

Thus we have

$$EU[\hat{s} = L | \sigma = H, s = H] = EU[\hat{s} = H | \sigma = H, s = H] \quad (\text{A84})$$

if and only if

$$1 - \alpha = \frac{\Pr(HL) \Pr(1HL) \left\{ \frac{\Pr(1HH) [\widehat{\delta}(1HH) - \widehat{\delta}(1HL)]}{\Pr(0HH) [\widehat{\delta}(0HL) - \widehat{\delta}(0HH)]} - 1 \right\}}{\Pr(HH) \Pr(1HH) \left\{ 1 - \frac{\Pr(1HL) [\widehat{\delta}(1HH) - \widehat{\delta}(1HL)]}{\Pr(0HL) [\widehat{\delta}(0HL) - \widehat{\delta}(0HH)]} \right\}} \quad (\text{A85})$$

Note, however, that $\phi > \phi^*$ implies

$$\frac{\Pr(1HL) [\widehat{\delta}(1HH) - \widehat{\delta}(1HL)]}{\Pr(0HL) [\widehat{\delta}(0HL) - \widehat{\delta}(0HH)]} > 1 \quad (\text{A86})$$

so that $\alpha < 1$ if and only if

$$\frac{\Pr(1HH) [\widehat{\delta}(1HH) - \widehat{\delta}(1HL)]}{\Pr(0HH) [\widehat{\delta}(0HL) - \widehat{\delta}(0HH)]} < 1 \quad (\text{A87})$$

which is always violated. Hence, for $\phi > \phi^*$, no $\alpha \in (0, 1)$ exists for which the manager is indifferent between announcing $\hat{s} = H$ and $\hat{s} = L$ after observing $s = H$.