Marking to Market and Inefficient Investments

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February 2013

Abstract

We examine how mark-to-market accounting affects investment decisions in an agency model with reputation concerns. Disclosing 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 agent’s actions can be evaluated. However, the fact that market prices are informative about which decision the agent should take can have a perverse effect: the agent may prefer to hide relevant but contradictory private information whose revelation would damage his reputation. Surprisingly, this effect makes mark-to-market accounting less desirable as market prices become more informative.

JEL classification: D81, G31, M41

Keywords: disclosure rules, mark-to-market accounting, historical cost accounting, investment decisions, reputation, agency problem

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1 Introduction

Following 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 are often far away from fundamentals. Therefore, mark-to-market accounting can lead to excessive fluctuations in asset valuations, downward spirals, and contagion. 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 to monitor the management.\

A precondition for these benefits is that market prices contain relevant information about which actions a firm’s management should take. In this paper, we show that precisely this feature can have a perverse effect: managers may prefer to hide contradictory private information. To the extent that optimal decisions depend on both the information contained in market prices and on private information, this makes marking to market less appealing. Surprisingly, this effect is particularly strong if market prices are highly informative. This challenges the commonly-held view that mark-to-market accounting naturally becomes less desirable as market prices become less informative.

In order the aforementioned channel, we consider a principal-agent model with the following features. A principal hires an agent to make an investment decision on her behalf. Which decision maximizes expected profits depends on information conveyed by the current market value of the firm’s assets and on information that is privately available only to the agent. However, while the principal’s objective is to maximize expected profits, the agent strives to maximize his ex-post reputation – for example because of career concerns. We consider two disclosure rules: mark-to-market accounting and historical-cost accounting. The only difference between the two rules in our setting is that under mark-to-market accounting, the market value of the firm’s assets is disclosed in the firm’s financial statements. Under historical cost accounting, the assets’ current market price remains hidden from the principal as asset values

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1 Following the financial crisis, a movement against marking to market has gathered strength both in the US (where the Financial Accounting Standards Board dropped the proposal for mark-to-market accounting of the loan portfolio of banks in January 2011) and in Europe (where the International Accounting Standards Board’s move towards marking to market was opposed by institutional investors because it may lead to a reduction in prudence).

2 See Laux and Leuz (2009) for a detailed discussion.
are reported at historical costs. The idea is that, although markets prices for all assets are available (i.e., prices are public information), the principal does not know the exact nature of the assets managed by the agent. Incidentally, this is the reason why the principal delegates power to the agent in the first place. As a consequence, however, the principal does not know which prices to use in order to produce a market valuation of the firm’s assets.

In a first-best scenario, the principal would like the agent to use all available information to make the investment decision. Hence, the first-best investment is a function both of the information contained in the assets’ current market price and of the agent’s private information. Which investment decision maximizes the agent’s expected reputation, however, depends not only on the information available to the agent but also on the information available to the principal. Thus, whenever the reputation maximizing decision differs from the profit maximizing choice, a conflict of interest arises.

At the heart of this agency problem are the agent’s reputation concerns. In order to manage his reputation, he may try to influence which information becomes available to the principal by distorting the investment decision. This is where the different accounting rules come into play: they determine which information the principal can glean from the firm’s financial statements. On the one hand, greater disclosure can ameliorate the agency problem by limiting the extent to which the agent can hide information from the principal. But on the other hand, it can reduce the agent’s willingness to base the investment decision on relevant private information. This is the channel through which a firm’s disclosure policy interacts with the moral hazard problem.

Using this framework, we then contrast the costs and benefits of the two different accounting rules – marking to market and historical cost accounting – by examining their equilibrium effects on the agent’s investment decision. Our analysis delivers three main results. First, we show that with historical cost accounting the first-best investment is never taken. The intuition for this result is that when the agent invests according to the first-best rule, there is a one-to-one mapping between the information contained in the current market prices, the agent’s private information, and the investment decision. Hence, by observing the investment, the principal learns both the private information and the market prices. In some cases, the investment decision will then reveal to the principal that the agent’s private information diverges from the information contained in the market prices. This, however, is damaging to the agent’s
reputation. The reason is that the private information of skilled agents is more likely to coincide with (rather than to diverge from) the relevant information conveyed by the market prices. Revealing a divergence between the private information and the market information thus leads to a downward revision of the principal’s belief that the agent is of good quality. Since the agent cares about his reputation, it is not in his interest to follow the first-best rule. In equilibrium, the agent will instead invest either based only on his private information or based only on the information contained in the market price. In that case, the principal can only learn the information the agent uses and can never observe any divergence between the two sources of information. Which of these two sources the agent uses simply depends on which one is more informative.

Second, we find that switching from historical cost to mark-to-market accounting makes the principal better or worse off depending on the relative informativeness of the market prices. Surprisingly, more informative market prices can actually render marking to market less attractive. The intuition is as follows. If market prices contain information regarding which investment the agent should take, then publicly revealing this information creates a benchmark against which the agent’s actions can be evaluated. This has two effects. On the one hand, it forces the agent to take the revealed information into account when making the investment decision. On the other hand, however, it creates incentives to hide contradictory private information whose revelation would damage the agent’s reputation. When the information contained in the market prices is relatively uninformative, mark-to-market accounting leads to the first-best investment decisions. In that case the reputation damaging effect of revealing a divergence between the private information and the market information is more than compensated by the expected boost in reputation in case the private information later on turns out to be correct. When instead the market prices become relatively more informative, mark-to-market accounting can become less desirable. The reputational damage of revealing that the private information differs from the market information is then larger, while the chance that the agent’s private information will ex-post turn out to be correct becomes smaller. This increases the agent’s incentives to disregard relevant but contradictory private information. The first-best rule can no longer be implemented, and the agent bases the investment decision solely on the market information.

Third, we emphasize that the choice between the two types of disclosure regimes critically
depends on the relative informativeness of the agent’s private and the market information. When
market prices are more informative than the agent’s private information, the disclosure policy is
irrelevant: under both regimes, the agent will rely only on market prices to make the investment
decision. When instead market prices are much less informative than private information,
mark-to-market accounting dominates historical-cost accounting. In such case, marking to
market leads to the first-best. In the intermediate case in which market prices are informative
but less so than the agent’s private information, historical-cost accounting dominates mark-
to-market accounting. In such case, with mark-to-market accounting the agent follows the
less informative market information, while with historical-cost accounting, he follows the more
informative private information.

We then consider three extensions of the basic model. In the first extension, we examine
how the disclosure regime affects the type of assets that the principal wants the agent to man-
age. Specifically, we consider the choice of the degree of opaqueness of these assets under the
assumption that more opaque assets have less informative market prices. We find that under
historical-cost accounting the choice of assets entirely depends on the relative informativeness
of the market prices of the assets as compared to the agent’s private information. The principal
will want the firm to invest in the most transparent asset if the informativeness of the market
prices for these assets exceeds the quality of the agent’s private information and vice versa.
With mark-to-market accounting, instead, the choice of assets does not depend only on the rel-
ative informativeness of the two signals, because sufficiently opaque assets are associated with
more efficient investment decisions than very transparent assets. This implies that, compared
with historical-cost accounting, the principal has now a preference for opaque assets.

It is often mentioned that a benefit of increased disclosure is a reduction in the cost of
financing.\textsuperscript{3} In a second extension, we thus include a financing stage in the model at which
the agent needs to raise equity from the market in order to make the investment. We assume
that outside investors demand a discount that is increasing in the uncertainty about the firm’s
final payoffs, conditional on the information available at the financing stage. Because mark-to-
market accounting reduces the uncertainty about the final payoffs, we find that the appeal of
mark-to-market accounting increases.

In the final extension of our model, we consider the effect that incentive compensation may

\textsuperscript{3}See, for example, Diamond and Verrecchia (1991) and Leuz and Verrecchia (2000).
have on our findings. To do so, unlike in the rest of the paper, we assume that both the investment decision and the firm’s final payoffs are observable and verifiable. The principal can thus write incentive contracts so that the agent cares not only about his reputation but also about the firm’s profits. We impose the restriction, however, that the agent’s incentive compensation be weakly monotonic in the firm’s payoffs. This restriction is motivated by the observation that the most common forms of incentive compensation used in practice – equity, options, or bonuses – all exhibit this feature. We then show that the results of our analysis are robust to the presence of incentive compensations of this type.

The paper is related to the growing literature on the costs and benefits of marking to market. The more common view is that mark-to-market accounting is costly in periods of crisis. Allen and Carletti (2008) show that marking to market may not be welfare-improving because it can lead to contagion across firms through a cash in the market effect: during liquidity crises, prices no longer reflect fundamentals but rather the amount of cash (liquidity) available to buyers in the market. Plantin, Sapra, and Shin (2008) develop a model that compares the real effects of historical-cost and mark-to-market accounting. Historical-cost accounting may induce short-sighted firms to engage in so called “gains trading”, the selling of assets whose market value exceeds their book value. Marking-to-market overcomes the price insensitivity of book values. However, if markets are illiquid, mark-to-market accounting may lead short-sighted firms to preempt an expected drop in prices by selling their assets and thus amplify the price drop. Through this channel, mark-to-market accounting can add endogenous volatility to prices. This in turn can lead to financial cycles when the assets of financial institutions are marked to market, and financial institutions actively readjust their balance sheets (see, for example, Adrian and Shin (2009)). Heaton, Lucas, and McDonald (2010) also focus on financial institutions and argue that marking to market needs to be combined with procyclical capital requirements.

Unlike these papers, we show that mark-to-market accounting can be associated with costs even in normal times (i.e., even outside periods of crisis). Moreover, instead of focusing on the distortions that may be caused by deviations between prices and fundamentals, we consider an agency problem inside the firm and examine how it is affected by the different disclosure rules. In this setting, marking to market can be detrimental even in normal times because

\footnote{See Leuz and Wysocki (2008) and Sapra (2010) for detailed surveys.}
it changes the firm’s information environment which can exacerbate information based agency problems. In this respect, we borrow from the literature on rational herding. In particular, the mechanism at the basis of our model builds on Scharfstein and Stein (1990), who show how reputation concerns may induce managers to ignore valuable private information, mimicking the investment decision of other managers. An important difference between their and our setting, however, is that we consider two sources of information that differ in quality. Furthermore, our analysis revolves around the question under which conditions a fraction of the available information should be publicly disclosed. Our finding that releasing more information is not necessarily optimal is similar to the point made by Morris and Shin (2002) in the context of coordination games.

The paper is also related to the literature on information disclosure. Prat (2005) shows how increasing transparency can have detrimental effects. Specifically, he shows that greater transparency on consequences is always beneficial, while transparency on actions can have detrimental effects. As in our setup, when actions are observable, the agent faces an incentive to disregard useful private information and to act according to how a good agent is expected to behave a priori. Hermalin and Weisbach (2012) also highlight that disclosure is a two-edged sword. On the one hand, increased information can improve a principal’s ability to monitor her agent. On the other hand, however, the principal must increase the agent’s compensation in exchange for the increase in transparency, while the agent may have incentives to distort the principal’s information.

The remainder of the paper is organized as follows. In Section 2, we present the setup of the model. The equilibrium is derived in Section 3. Section 4 examines three extensions. Section 5 concludes.

2 Setup

Consider an agency problem with one risk-neutral principal and one risk-neutral agent. The agent’s outside option is normalized to zero, and we assume that the principal has all the bargaining power. There are three dates – \( t = 0, 1, 2 \) – corresponding to the end of a first fiscal period, an intermediate date during the second fiscal period, and the end of the second fiscal period. The timing of events and decisions is as reported in Figure 1.
At $t = 0$, the firm starts out with a set of assets $A$. The agent knows the precise nature of the assets in place and observes their current market price. The principal does not. The value of the assets is reported in the firm’s financial statements 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). In the former case, the current market price of the assets remains unknown to the principal. In the latter case, the principal learns the assets’ current market valuation from the firm’s financial statements. 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 price information that the principal would not be able to obtain otherwise.

At $t = 1$, the agent’s task is to choose an amount $a \geq 0$ of additional investment. This investment is not immediately observable to the principal but its cost $c(a)$ will be reported in the firm’s financial statements at a later point in time. We assume that $c(a)$ satisfies $c(0) = 0, c'(a) > 0, \lim_{a \rightarrow 0} c'(a) = 0$, and $c''(a) > 0$.

At $t = 2$, the firm’s final payoff $\pi$, which is observable but not verifiable, is realized. This payoff depends on the state of the world $\omega \in \{H, L\}$ in the following way:

$$\pi = \begin{cases} A + a & \text{if } \omega = H \\ 0 & \text{if } \omega = L. \end{cases}$$

(1)

In the absence of additional information, the two possible states are equally probable: $\Pr(\omega = L) = \Pr(\omega = H) = 1/2$. However, there exists some relevant information $\gamma \in \{H, L\}$ that is informative about the state of the world in the following sense:

$$\Pr(\gamma = H|\omega = H) = \Pr(\gamma = L|\omega = L) \equiv p \in \left(\frac{1}{2}, 1\right).$$

(2)

We relax this assumption in an extension in Section 4.3.
When deciding on the amount of investment at $t = 1$, the agent has access to two sources of information: a signal $\sigma \in \{H, L\}$ that can be extracted from the market price of the assets in place and a private signal $s \in \{H, L\}$ that is received only by the agent.\(^6\) Both signals may or may not reflect the relevant information $\gamma$. The market signal is either informative (type $\theta_M = i$) or uninformative (type $\theta_M = u$) with probability $\Pr(\theta_M = i) \equiv \phi \in (0, 1)$ which is common knowledge. An informative signal perfectly reveals the relevant information, i.e., $\sigma = \gamma$. An uninformative signal is just noise:

$$\Pr(\sigma = H|\omega = H, \theta_M = u) = \Pr(\sigma = L|\omega = L, \theta_M = u) = \frac{1}{2}. \quad (3)$$

Similar to the market signal, the agent’s private signal may or may not be informative depending on the agent’s type. A good agent (type $\theta_A = g$) receives informative signals: $s = \gamma$. A bad agent (type $\theta_A = b$) does not:

$$\Pr(s = H|\omega = H, \theta_A = b) = \Pr(s = L|\omega = L, \theta_A = b) = \frac{1}{2}. \quad (4)$$

Neither the agent nor the principal know with certainty whether or not the agent’s private signal is informative. However, it is common knowledge that the probability that the private signal reflects the relevant information is $\Pr(\theta_A = g) \equiv \delta \in (0, 1)$.

At $t = 2$, the final payoff $\pi$ is realized. Moreover, the cost of investment $c(a)$ is reported in the financial statements and thus disclosed to the principal. At this point, the principal can learn which level of investment the agent has chosen by inverting the cost function. Thereafter, the principal updates her beliefs regarding the probability that the agent receives relevant signals, i.e., the probability that the agent’s type is good. Finally, the agent derives a benefit $\Omega \cdot \Pr(\theta_A = g|I)$, where $I$ is the information set of the principal and $\Omega > 0$. That is, we assume that the agent derives utility from being considered a good type.\(^7\)

### 3 Equilibrium

We will now examine the equilibrium effects of mark-to-market accounting and historical cost accounting on the agent’s investment decision. First, we will define the first-best investment strategy. Then, we will discuss the agency problem that arises in our setup. Thereafter, we will

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\(^6\)We assume that the historical costs of the assets in place are not informative about the state of the world.

\(^7\)This utility may represent unmodeled career concerns of the agent.
explore whether the first-best strategy can be implemented in equilibrium, considering in turns the case of historical cost accounting and the case of mark-to-market accounting. Finally, we will consider 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 \( a^* \) is given by

\[
    a^* \in \arg \max_{a \geq 0} \{(A + a) \cdot \Pr (\omega = H|\sigma, s) - c(a)\}.
\]

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

\[
    c'(a^*) = \Pr (\omega = H|\sigma, s)
\]

given that the second order condition for a maximum, \( c''(a^*) > 0 \), is satisfied by the fact that \( c(a) \) is convex by assumption. For convenience, we adopt the following notation for the first-best amount of investment:

\[
    a_{HH} \equiv c'^{-1} (\Pr (\omega = H|\sigma = H, s = H))
\]

\[
    a_{LH} \equiv c'^{-1} (\Pr (\omega = H|\sigma = L, s = H))
\]

\[
    a_{HL} \equiv c'^{-1} (\Pr (\omega = H|\sigma = H, s = L))
\]

\[
    a_{LL} \equiv c'^{-1} (\Pr (\omega = H|\sigma = L, s = L))
\]

where \( c'^{-1}(\cdot) \) is the inverse function of \( c'(\cdot) \). Note that there are four possible optimal levels of investment: one for each possible combination of the market signal \( \sigma \) and the private signal \( s \).

3.2 Agency problem

By assumption the principal cannot choose the amount of investment \( a \) directly. The question thus becomes whether or not the agent chooses the investment strategy \( a^* \) which is desired by the principal. Or, in other words, whether or not the first-best strategy is implementable.

Importantly, the agent only cares about the benefit he derives from the principal’s updated beliefs regarding his type.\(^8\) That is, the agent is motivated only by his career concerns and thus

\(^8\)Note that the agent’s outside option is normalized to zero, that the principal has all the bargaining power, and that the final payoﬀs are not verifiable. Thus, the agent does not receive any monetary compensation. We relax these assumptions and consider incentive contracts in Section 4.3.
chooses the action that maximizes the expected posterior beliefs about his type conditional on the information \( I \) that is available to the principal at \( t = 2 \). Thus, the agent chooses \( a \) in order to maximize \( E[\delta(I)] = E[\Pr(\theta_A = g|I)] \).

Depending on the accounting rules and on the agent’s action, \( I \in \{(\omega), (\omega, \sigma), (\omega, s), (\omega, \sigma, s)\} \).

The principal always learns the state of the world \( \omega \) by observing whether or not the final payoff \( \pi \) is positive. She may also learn the market signal \( \sigma \) (as in the second case) or the private signal \( s \) (as in the third case). In the last case, the principal learns everything: the state of the world \( \omega \), the market signal \( \sigma \), and the private signal \( s \). This is the case, for example, if the first-best actions are taken in equilibrium.\(^9\) However, the agent’s objective function – maximizing the expected posterior belief that his type is good – differs from the principal’s objective function – maximizing expected net profits. Thus, it is not clear that the first-best decision rule can always be implemented. Furthermore, because the principal’s information set depends on whether the current market price of the assets’ in place is disclosed 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.

### 3.3 Implementing the first-best strategy

#### 3.3.1 Historical cost accounting

Under historical cost accounting the market price of the assets in place at \( t = 0 \) is not disclosed to the principal. This implies that the principal does not directly learn the market signal \( \sigma \). Of course, she also does not directly observe the agent’s private signal \( s \). If, however, the agent were to follow the first-best investment strategy, his actions would reveal both the market and his private signal ex-post.\(^10\) This is in his interest only if these actions maximize the expected posterior beliefs about his type. As shown in the following proposition, this is not the case. Intuitively, following the first-best strategy reveals (in some cases) a divergence between the market and the private signal. However, because informative signals coincide \( (s = \sigma = \gamma) \),

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\(^9\)In the Appendix, we show that \( \Pr(\omega = H|\sigma, s) \) is a strictly monotone function of \( \sigma \) and \( s \) (with the exception of the special case in which \( \delta = \phi \)). Hence, if chosen in equilibrium, the first-best actions reveal both signals \( \sigma \) and \( s \).

\(^10\)Remember that the cost of investment is reported in the firm’s financial statements at \( t = 2 \), so that the principal can learn the level of investment by inverting the cost function.
revealing divergent signals leads to a lower expected posterior belief about the agent’s type.

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

**Proof:** Assume an equilibrium in which the agent chooses according to the first-best strategy, i.e., the agent chooses as follows:

<table>
<thead>
<tr>
<th>( s = H )</th>
<th>( s = L )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sigma = H )</td>
<td>( a = a_{HH} )</td>
</tr>
<tr>
<td>( \sigma = L )</td>
<td>( a = a_{LH} )</td>
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In that case, the agent’s action reveals both his private signal and the market signal. The state of the world can be learned from the final payoff: \( \pi > 0 \Rightarrow \omega = H \) and \( \pi = 0 \Rightarrow \omega = L \).

Thus, at the end of the second period, the principal learns both signals and the state of the world and forms the following posterior beliefs \( \hat{\delta}(\omega, \sigma, s) = \text{Pr}(\theta_A = g|\omega, \sigma, s) \) regarding the agent’s type (derivation in Appendix A1):

\[
\begin{align*}
\hat{\delta}(\omega = H, \sigma = H, s = H) &= \hat{\delta}(\omega = L, \sigma = L, s = L) \\
&= \frac{2\delta p (1 + \phi)}{2p(\delta + \phi) + (1 - \phi)(1 - \delta)} \tag{11}
\end{align*}
\]

\[
\begin{align*}
\hat{\delta}(\omega = H, \sigma = L, s = H) &= \hat{\delta}(\omega = L, \sigma = H, s = L) \\
&= \frac{2\delta p (1 - \phi)}{2p(\delta - \phi) + (1 - \delta)(1 + \phi)} \tag{12}
\end{align*}
\]

\[
\begin{align*}
\hat{\delta}(\omega = H, \sigma = H, s = L) &= \hat{\delta}(\omega = L, \sigma = L, s = H) \\
&= \frac{2\delta(1 - p)(1 - \phi)}{2(1 - p)(\delta - \phi) + (1 - \delta)(1 + \phi)} \tag{13}
\end{align*}
\]

\[
\begin{align*}
\hat{\delta}(\omega = H, \sigma = L, s = L) &= \hat{\delta}(\omega = L, \sigma = H, s = H) \\
&= \frac{2\delta(1 - p)(1 + \phi)}{2(1 - p)(\delta + \phi) + (1 - \phi)(1 - \delta)}. \tag{14}
\end{align*}
\]

We have (see Appendix A2)

\[
\begin{align*}
\hat{\delta}(\omega = H, \sigma = H, s = H) &> \hat{\delta}(\omega = H, \sigma = L, s = H) \tag{15}
\end{align*}
\]

\[
\begin{align*}
\hat{\delta}(\omega = L, \sigma = H, s = H) &> \hat{\delta}(\omega = L, \sigma = L, s = H) \tag{16}
\end{align*}
\]

and

\[
\begin{align*}
\hat{\delta}(\omega = H, \sigma = L, s = L) &> \hat{\delta}(\omega = H, \sigma = H, s = L) \tag{17}
\end{align*}
\]

\[
\begin{align*}
\hat{\delta}(\omega = L, \sigma = L, s = L) &> \hat{\delta}(\omega = L, \sigma = H, s = L). \tag{18}
\end{align*}
\]
Holding the state of the world fixed, the updated probability that the agent’s type is good is larger if the private and the market signal coincide than if the signals diverge. Thus, irrespective of the true state of the world, the agent always prefers to pretend that both signals coincide. That is, the agent always prefers \( a = a_{HH} \) to \( a = a_{LH} \) and \( a = a_{LL} \) to \( a = a_{HL} \). It follows that the assumed equilibrium does not satisfy the agent’s incentive compatibility constraints in case the private and the market signal do not coincide – the agent never chooses \( a = a_{LH} \) or \( a = a_{HL} \).

3.3.2 Mark-to-market accounting

With mark-to-market accounting the market price of the assets in place at \( t = 0 \) is disclosed to the principal in the firm’s financial statements. This implies that the principal directly learns the market signal \( \sigma \), whereas she does not directly observe the agent’s private signal \( s \). If the agent were to follow the first-best strategy, his actions would reveal his private signal to the principal ex-post. However, as before, this is in his interest only if these actions maximize the expected posterior beliefs about his type.

As shown in the following proposition, the first-best investment rule is implementable only 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, is a negative signal about the quality of the agent – and the more so the more informative the market signal. Hence, we obtain the following result:

**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 \( \phi > \phi^* \).

**Proof:** Assume an equilibrium in which the agent follows the first-best strategy. In that case, the principal forms posterior beliefs \( \delta(\omega, \sigma, s) = \Pr(\theta_A = g|\omega, \sigma, s) \) about the agent’s type based on both signals and the state of the world as outlined in the proof of Proposition 1. Regarding the principal’s out-of-equilibrium beliefs we assume the following: if the market signal is \( \sigma \) and the agent chooses any action \( a \notin \{a_{\sigma H}, a_{\sigma L}\} \) for \( \sigma \in \{H, L\} \), then \( \delta = 0 \). This implies that the agent’s choice is limited to \( a = a_{LH} \) or \( a = a_{LL} \) if \( \sigma = L \), and the agent’s choice is limited to \( a = a_{HL} \) or \( a = a_{HH} \) if \( \sigma = H \).
Consider now the agent’s incentive compatibility constraint in case of $\sigma = L$ and $s = H$.

The agent prefers $a = a_{LH}$ to $a = a_{LL}$ if and only if

$$\hat{\delta} (\omega = H, \sigma = L, s = H) \cdot \Pr (\omega = H|\sigma = L, s = H)$$

$$+ \hat{\delta} (\omega = L, \sigma = L, s = H) \cdot \Pr (\omega = L|\sigma = L, s = H)$$

$$\geq$$

$$\hat{\delta} (\omega = H, \sigma = L, s = L) \cdot \Pr (\omega = H|\sigma = L, s = H)$$

$$+ \hat{\delta} (\omega = L, \sigma = L, s = L) \cdot \Pr (\omega = L|\sigma = L, s = H).$$

Define

$$F (\phi) \equiv \Pr (\omega = H|\sigma = L, s = H) \left[ \hat{\delta} (\omega = H, \sigma = L, s = L) - \hat{\delta} (\omega = H, \sigma = L, s = H) \right]$$

$$+ \Pr (\omega = L|\sigma = L, s = H) \left[ \hat{\delta} (\omega = L, \sigma = L, s = L) - \hat{\delta} (\omega = L, \sigma = L, s = H) \right],$$

so that the above constraint is satisfied for $F \leq 0$ and violated for $F > 0$. $F (\phi)$ is continuous, and we have (see Appendix A3):

$$F (0) < 0$$  \hspace{1cm} (21)

$$F (\delta) > 0$$  \hspace{1cm} (22)

$$\frac{\partial F}{\partial \phi} > 0.$$  \hspace{1cm} (23)

Thus, there exists a unique threshold $\phi^* < \delta$ with $F (\phi^*) = 0$ such that the agent’s incentive compatibility constraint is satisfied for $\phi \leq \phi^*$ and violated for $\phi > \phi^*$. An analogous argument can be made for the case of $\sigma = H, s = L$. In case of $\sigma = s$, the agent’s compatibility constraint is always satisfied. ■

Surprisingly, moving from historical cost accounting to mark-to-market accounting helps implementing the first-best if the quality of the market signal is low but does not do so when the quality of the market signal is high. In that case, the information content of the market signal distorts the action of the agent due to his reputation concerns. Choosing an action that reveals that his private information was different from the (highly informative) market signal damages the agent’s reputation.

### 3.4 Second-best strategy

In this section, we consider which strategies will be implemented when the first-best is not implementable. As before, we will consider in turns the cases of historical cost accounting and
mark-to-market accounting.

Our first step is to reduce the set of possible strategies that need to be considered. To do so, we define a signal revealing strategy as a function \( a(.) \) from the set of signals \((\sigma, s) \in \{H, L\} \times \{H, L\}\) to a subset \( B \) of \( \mathbb{R} \) that can be inverted, so that from any action \( a \in B \) one can infer the pair of signals \((\sigma, s)\). It follows directly from the proofs of Propositions 1 and 2 that if the first-best strategy is not implementable, no other signal revealing strategy can be implemented either.

This implies that if the first-best cannot be implemented, the principal can at best expect the agent to implement investment strategies that are a function of at most one of the two signals. Whether the preferred strategy is a function of the market signal \( \sigma \) or the private signal \( s \) depends on the relative informativeness of the two signals. If the market signal is more informative \((\phi > \delta)\), then the principal prefers the agent to rely on the market signal. Conversely, if the private signal is more informative \((\delta > \phi)\), then the principal prefers the agent to rely on his private signal.

Thus, if \( \delta < \phi \), the second-best strategy is the solution to the following problem:

\[
\max_{a \geq 0} \{(A + a) \cdot \Pr(\omega = H|\sigma) - c(a)\}
\]  

(24)

which implies:

\[
a^{SB} = \begin{cases} 
    a_H & \equiv \ c^{\prime -1} (\Pr(\omega = H|\sigma = H)) \quad \text{if} \quad \sigma = H \\
    a_L & \equiv \ c^{\prime -1} (\Pr(\omega = H|\sigma = L)) \quad \text{if} \quad \sigma = L.
\end{cases}
\]

(25)

If, on the other hand, \( \delta > \phi \), the second-best strategy is the solution to the following problem:

\[
\max_{a \geq 0} \{(A + a) \cdot \Pr(\omega = H|s) - c(a)\}
\]  

(26)

which implies:

\[
a^{SB} = \begin{cases} 
    a_H & \equiv \ c^{\prime -1} (\Pr(\omega = H|s = H)) \quad \text{if} \quad s = H \\
    a_L & \equiv \ c^{\prime -1} (\Pr(\omega = H|s = L)) \quad \text{if} \quad s = L.
\end{cases}
\]

(27)

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

### 3.4.1 Implementing the second-best strategy under historical cost accounting

**Proposition 3** With historical cost accounting, the second-best strategy is implementable.
Proof: Consider first the case in which $\delta < \phi$. In that case, the second-best strategy is:

\[
\begin{array}{c|cc}
  & s = H & s = L \\
\hline
\sigma = H & a = a_{H.} & a = a_{H.} \\
\sigma = L & a = a_{L.} & a = a_{L.} \\
\end{array}
\]

Assuming that this strategy is played in equilibrium, the agent’s action reveals the market signal, but not the private signal. Thus, there is no updating regarding the agent’s private signal because no information about the agent’s private signal is revealed:

$$\hat{\delta} (\omega, \sigma) = \delta \text{ for all } \omega \text{ and } \sigma.$$ (28)

Assuming the out-of-equilibrium beliefs $\hat{\delta} = 0$ if $a \notin \{a_{H.}, a_{L.}\}$, the agent has no reason to deviate from the proposed equilibrium and is indifferent between actions $a_{H.}$ and $a_{L.}$. Hence, the second-best strategy is implemented under the tie-breaking assumption that the agent behaves in the interest of the principal when indifferent.

Conversely, if $\delta > \phi$, the second-best strategy is as follows:

\[
\begin{array}{c|cc}
  & s = H & s = L \\
\hline
\sigma = H & a = a_{H.} & a = a_{L.} \\
\sigma = L & a = a_{H.} & a = a_{L.} \\
\end{array}
\]

Assuming that this strategy is played in equilibrium, the principal learns the private signal from the agent’s action and forms the following posterior beliefs regarding the agent’s type:

$$\hat{\delta} (\omega = H, s = H) = \hat{\delta} (\omega = L, s = L) = \frac{p \delta}{p \delta + \frac{1}{2} (1 - \delta)} > \delta$$ (29)

$$\hat{\delta} (\omega = H, s = L) = \hat{\delta} (\omega = L, s = H) = \frac{(1 - p) \delta}{(1 - p) \delta + \frac{1}{2} (1 - \delta)} < \delta.$$ (30)

Assuming the out of equilibrium beliefs $\hat{\delta} = 0$ if $a \notin \{a_{H.}, a_{L.}\}$, the agent prefers $a = a_{H.}$ to $a = a_{L.}$ if

$$\Pr (\omega = H | \sigma, s) \hat{\delta} (\omega = H, s = H) > \Pr (\omega = H | \sigma, s) \hat{\delta} (\omega = H, s = L)$$

$$+ \Pr (\omega = L | \sigma, s) \hat{\delta} (\omega = L, s = H) > \Pr (\omega = L | \sigma, s) \hat{\delta} (\omega = L, s = L)$$

$$\Pr (\omega = H | \sigma, s) > \Pr (\omega = L | \sigma, s)$$ (31)

which is satisfied for $s = H$ and violated for $s = L$ for all $\sigma$ and $\phi < \delta$. Thus, the assumed rule can be implemented in equilibrium. ■

15
3.4.2 Implementing the second-best strategy under mark-to-market accounting

In 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.

**Proof:** Consider first the case in which \( \delta < \phi \). In that case, the second-best strategy is:

\[
\begin{array}{|c|c|c|}
\hline
s = H & s = L \\
\hline
\sigma = H & a = a_H. & a = a_H. \\
\sigma = L & a = a_L. & a = a_L. \\
\hline
\end{array}
\]

Assuming that this strategy is played in equilibrium, the agent’s action reveals the market signal but not the private signal. As before, there is no updating regarding the agent’s type because no information about the agent’s signal is revealed: \( \hat{\delta}(\omega, \sigma) = \delta \) for all \( \omega \) and \( \sigma \). Thus, assuming the out-of-equilibrium beliefs \( \hat{\delta} = 0 \) if \( a \notin \{a_H, a_L\} \), the agent has no reason to deviate from the proposed equilibrium and is indifferent between action \( a_H \) and \( a_L \). Hence, the second-best strategy is implemented under the tie-breaking assumption that the agent behaves in the interest of the principal when indifferent.

Conversely, if \( \delta > \phi \), the second-best strategy is as follows:

\[
\begin{array}{|c|c|c|}
\hline
s = H & s = L \\
\hline
\sigma = H & a = a_H & a = a_L \\
\sigma = L & a = a_H & a = a_L \\
\hline
\end{array}
\]

The principal learns the market signal through the disclosure of the market price of the asset at \( t = 0 \) and learns the private signal from the agent’s action. Hence, the posterior beliefs of the agent’s type are exactly as in the proof of Proposition 2 – and so are the agent’s incentive compatibility constraints. It follows that the assumed decision rule can be implemented for \( \phi \leq \phi^* \) and cannot be implemented for \( \phi > \phi^* \). \[\blacksquare\]

**Corollary 1** With mark-to-market accounting, if \( \phi \in (\phi^*, \delta) \), the best implementable strategy is

\[
a^{TB} = a_H \equiv c^{-1}(\Pr(\omega = H | \sigma = H)) \quad \text{if} \quad \sigma = H
\] (33)
and

\[ a^{TB} = a_L, \equiv c^{-1}(Pr(\omega = H|\sigma = L)) \text{ if } \sigma = L. \]  

\( (34) \)

**Proof:** Neither the first-best nor the second-best strategy can be implemented with mark-to-market accounting if \( \phi \in (\phi^*, \delta) \) as is shown in Propositions 2 and 4. The third-best strategy is the solution to

\[
\max_{a \geq 0} \left\{ (A + a) \cdot Pr(\omega = H|\sigma) - c(a) \right\},
\]

which coincides with the second-best strategy in case of \( \delta < \phi \). The proof of Proposition 4 shows that this strategy can be implemented in equilibrium. \( \blacksquare \)

### 3.5 Mark-to-market versus historical cost accounting

Figure 2 summarizes our results in the parameter space \((\delta, \phi)\). When \( \phi > \delta \), there is no difference between mark-to-market and historical cost accounting. In both cases, the first-best strategy is not implementable (as shown in Propositions 1 and 2). The second-best strategy of relying solely on the market signal can be implemented under both accounting rules (as shown in Propositions 3 and 4).

![Figure 2](image)

When \( \phi < \delta \) instead, the two accounting rules lead to different equilibria. If \( \phi \leq \phi^* \), then 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 because under historical cost accounting the agent relies on the (more informative) private signal whereas under mark-to-market accounting the agent relies on the (less informative) market signal.

3.5.1 Accounting rules and firm value

Using the results obtained so far, we can examine which accounting regime maximizes firm value in our setup. As shown in Propositions 1 and 3, 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, however, the first-best decision rule can be implemented if \( \phi \leq \phi^* \) (Proposition 4). In that case, mark-to-market accounting increases the value of the firm compared to historical cost accounting. For \( \phi \in (\phi^*, \delta) \), on the other hand, the second-best strategy is no longer implementable under mark-to-market accounting (Proposition 4). 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.

Given that the agent does not receive any compensation and that all profits accrue to the principal, the principal prefers the accounting regime that maximizes the firm’s value. Thus:

**Corollary 2** The principal prefers mark-to-market accounting for \( \phi \in (0, \phi^*] \) and historical cost accounting for \( \phi \in (\phi^*, \delta) \). The principal is indifferent between the two accounting rules for \( \phi \in [\delta, 1) \).

3.5.2 Accounting rules and information asymmetry

How does the choice between the two accounting regimes affect the information asymmetry between the principal and the agent? While the agent always learns the market signal and his private signal, the principal learns both signals only in case the first-best decision rule can be implemented. Otherwise, the principal learns either the market signal – if the implemented strategy is based on \( \sigma \) – or the private signal – if the implemented strategy is based on \( s \). Thus,
unless the first-best strategy is implemented, there is asymmetric information in the sense that the agent possesses better information about the state of the world than the principal.

We know from the previous analysis, that the first-best decision rule can never be implemented under historical cost accounting (Proposition 1). Mark-to-market accounting, on the other hand, allows for the implementation of the first-best if $\phi \leq \phi^*$ (Proposition 2). It follows that for $\phi \leq \phi^*$ mark-to-market accounting reduces the information asymmetry between the principal and the agent.

For $\phi \in (\phi^*, \delta)$, on the other hand, mark-to-market accounting increases the information asymmetry compared to historical cost accounting. In that case, the first-best strategy cannot be implemented under either accounting rule. However, while historical cost accounting allows for the implementation of the second-best decision rule based on the private signal, mark-to-market accounting only allows the principal to implement strategies based on the less informative market signal. Thus, for $\phi \in (\phi^*, \delta)$ mark-to-market accounting increases the information asymmetry between the principal and the agent relative to historical cost accounting.

Finally, for $\phi \geq \delta$, the degree of information asymmetry between the principal and the agent is not affected by the choice of accounting regime. Either accounting rule allows for the implementation of the second-best strategy (based on $\sigma$), so that the principal learns the market signal but not the agent’s private signal.

Therefore, we can conclude with the following result.

**Corollary 3** A change from historical cost accounting to mark-to-market accounting decreases the information asymmetry between the principal and the agent if $\phi \leq \phi^*$, increases the information asymmetry if $\phi \in (\phi^*, \delta)$, and does not affect the information asymmetry between the principal and the agent if $\phi \geq \delta$.

### 4 Extensions

#### 4.1 Choosing transparent or opaque assets

Up to this point, we have treated the informativeness of the market signal as given. We have assumed that the firm starts out with a given set of assets in place and that the market price of these assets has a given level of informativeness. We then examined the effect of historical cost
accounting and mark-to-market accounting on the agent’s subsequent investment decisions. In this extension, however, we will consider the effect that the different disclosure regimes may have on the type of assets the firm invests in in the first place. Specifically, we will assume that before \( t = 0 \) the principal can choose the asset class in which the firm operates and that different asset classes are distinguished by the informativeness of their market prices. The principal may thus choose to invest in transparent assets whose market prices are relatively more informative, or she may choose to invest in opaque assets with relatively less informative market prices. Using this framework, we obtain the following result for the case of historical cost accounting.

**Proposition 5** Suppose that before \( t = 0 \) the principal can choose \( \phi \in (0, \tilde{\phi}] \) with \( \tilde{\phi} < 1 \) by choosing the class of assets in which the firm invests. Under historical cost accounting, the principal chooses \( \phi = \tilde{\phi} \) for \( \tilde{\phi} \geq \delta \) and is indifferent between any \( \phi \in (0, \tilde{\phi}] \) for \( \tilde{\phi} < \delta \).

**Proof:** Under historical cost accounting, for \( \tilde{\phi} \geq \delta \), the best implementable investment strategy depends only on \( \sigma \), and the principal’s expected utility is

\[
EU = \Pr(\sigma = H) [(A + a_H) \cdot \Pr(\omega = H|\sigma = H) - c(a_H)] \\
+ \Pr(\sigma = L) [(A + a_L) \cdot \Pr(\omega = H|\sigma = L) - c(a_L)].
\]  

(36)

Using the envelope theorem, we obtain

\[
\frac{\partial EU}{\partial \phi} = \frac{1}{2} (a_H - a_L) \left( p - \frac{1}{2} \right) > 0.
\]  

(37)

Thus, if the principal can choose \( \phi \in (0, \tilde{\phi}] \), she chooses \( \phi = \tilde{\phi} \).

For \( \tilde{\phi} < \delta \), the best implementable strategy under historical cost accounting depends only on \( s \), and the principal’s expected utility is independent of \( \phi \). Thus, the principal is indifferent between any \( \phi \in (0, \tilde{\phi}] \).

For the case of mark-to-market accounting, the principal’s choice is as follows.

**Proposition 6** Suppose that before \( t = 0 \) the principal can choose \( \phi \in (0, \tilde{\phi}] \) with \( \tilde{\phi} < 1 \) by choosing the class of assets in which the firm invests. Under mark-to-market accounting, there exists a \( \delta \in (0, \tilde{\phi}) \) such that for \( \delta < \delta \) the principal chooses \( \phi = \tilde{\phi} \) and for \( \delta > \delta \) the principal chooses \( \phi = \phi^*(\delta) < \delta \).

**Proof:** To prove Proposition 6 we first establish the following Lemma.
Lemma 1 Under mark-to-market accounting, the principal’s expected utility is increasing in $\phi$.

Proof: Under mark-to-market accounting, if $\phi > \phi^* (\delta)$, the best implementable investment strategy depends only on $\sigma$. In that case, we know from Proposition 5 that the principal’s expected utility is increasing in $\phi$.

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

$$g (p_{\sigma s}) \equiv (A + a_{\sigma s}) \cdot p_{\sigma s} - c (a_{\sigma s}).$$

By the envelope theorem we have

$$\frac{\partial g (p_{\sigma s})}{\partial p_{\sigma s}} = (A + a_{\sigma s}) > 0 \quad (39)$$

and

$$\frac{\partial^2 g (p_{\sigma s})}{\partial p_{\sigma s}^2} = \frac{\partial a_{\sigma s}}{\partial p_{\sigma s}} = \frac{1}{c'' (c^{-1} (p_{\sigma s}))} > 0. \quad (40)$$

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

Before $\sigma$ and $s$ are realized, the principal’s ex-ante expected utility is

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

(41)

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

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

(42)

Note that we have

$$p'_{HH} > p_{HH} > p_{LH} > p'_{LH} > p_{HL} > p_{LL} > p'_{LL}, \quad (43)$$

$$q_{HH} \cdot p_{HH} + q_{LH} \cdot p_{LH} = q'_{HH} \cdot p'_{HH} + q'_{LH} \cdot p'_{LH} = \Pr (\omega = H|s = H) \cdot \Pr (s = H), \quad (44)$$

and

$$q_{LL} \cdot p_{LL} + q_{HL} \cdot p_{HL} = q'_{LL} \cdot p'_{LL} + q'_{HL} \cdot p'_{HL} = \Pr (\omega = H|s = L) \cdot \Pr (s = L). \quad (45)$$
Combined with the fact that \( g(p_{rs}) \) is increasing and convex in \( p_{rs} \), this implies
\[
q_{HH}' \cdot g'(p_{HH}') + q_{LL}' \cdot g'(p_{LL}') > q_{HH} \cdot g(p_{HH}) + q_{LL} \cdot g(p_{LL})
\] (46)

and
\[
q_{HL}' \cdot g'(p_{HL}') + q_{LL}' \cdot g'(p_{LL}') > q_{HL} \cdot g(p_{HL}) + q_{LL} \cdot g(p_{LL}),
\] (47)

which in turn implies
\[
E \left[ g'(p_{rs}) \right] > E \left[ g(p_{rs}) \right].
\] (48)

The principal’s expected utility is thus increasing in \( \phi \) for both \( \phi > \phi^* (\delta) \) and \( \phi \leq \phi^* (\delta) \). ■

We can now show that there exists a \( \delta \in (0, \bar{\delta}) \) such that for \( \delta < \delta \) the principal chooses \( \phi = \bar{\phi} \) and for \( \delta > \delta \) the principal chooses \( \phi = \phi^* (\delta) < \delta \). First, note that it follows from Lemma 1 that the principal chooses either \( \phi = \bar{\phi} \) or \( \phi = \phi^* (\delta) \). Second, note that for \( \delta = 0 \) we obtain \( \phi^* (\delta) = 0 \), so that the principal’s expected utility is maximized for \( \phi = \bar{\phi} \). Third, for \( \delta = \bar{\phi} \) the principal’s expected utility is maximized for \( \phi = \phi^* (\delta) \). To see this, note that if the principal chooses \( \phi = \bar{\phi} \), the best implementable strategy is based only on \( s \). 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 principal’s expected utility after choosing \( \phi = \phi^* (\delta) < \delta \). In that case, the best implementable strategy is based on not only on \( s \) but also on \( \sigma \). We know that in that case, the principal’s expected utility is increasing in \( \phi \). Thus, choosing \( \phi = \phi^* (\delta) < \delta \) must dominate choosing \( \phi = \bar{\phi} \). Finally, note that for \( \phi = \phi^* (\delta) \) the principal’s expected utility is increasing in \( \delta \) because we have \( \partial EU/\partial \delta > 0 \) and \( \partial \phi^* (\delta)/\partial \delta > 0 \). It follows that there exists a unique \( \delta \) such that for \( \delta < \delta \) the principal chooses \( \phi = \bar{\phi} \) and for \( \delta > \delta \) the principal chooses \( \phi = \phi^* (\delta) < \delta \). ■

Which type of assets the firm invests in thus depends both on the accounting rules and on the quality of the agent to whom the investment is delegated. Under historical cost accounting, the principal chooses the most transparent asset class if its price informativeness exceeds the informativeness of the agent’s private information. If not, the principal is indifferent between the various asset classes. Under mark-to-market accounting, however, the principal either chooses the asset class with the highest transparency or a more opaque asset class. If the agent’s quality is lower than a given threshold, the most transparent asset class is chosen. If the agent’s quality is higher than the threshold, the principal prefers to invest in more opaque assets. Our analysis
thus suggests that if mark-to-market accounting is mandatory, firms – and in particular those
with skilled managers – may optimally respond by investing in assets with less informative
market prices.

4.2 Informativeness of interim valuations and financing costs

In Section 3, we have derived the optimal investment strategies and examined whether or not
these strategies can be implemented under historical cost or mark-to-market accounting. We
have not, however, considered any effect that the different disclosure rules may have on the cost
of financing the investment. This will be the focus of the following extension.

We assume that before making the investment – in order to finance its costs – the firm must
first raise equity capital against its future payoffs. Furthermore, assume that the capital is raised
from outside investors who are worried about the variability of these payoffs. Specifically, we
assume that the buyers of equity demand a discount \( K/2 \cdot \text{Var}_1 [\pi | I_o] \), where \( I_o \) denotes the
information set of the outside investors at \( t = 1 \). Thus, we assume that the cost of raising capital
increases in the variance of the firm’s future payoffs as perceived by the outside investors. The
parameter \( K \geq 0 \) represents the degree to which the outside investors worry about the variability
of \( \pi \). Using this setup, we are able to derive the following result.

**Proposition 7** The principal prefers marking to market to historical cost accounting for \( \phi \leq \phi^* \)
and for \( \phi \geq \delta \). For \( \phi \in (\phi^*, \delta) \), there exists a \( K^* > 0 \) such that the principal prefers mark-to-
market accounting if \( K > K^* \) and historical cost accounting if \( K < K^* \).

**Proof:** We prove Proposition 7 with the help of Lemmas 2, 3, and 4.

**Lemma 2** The principal prefers mark-to-market accounting to historical cost accounting if the
best implementable strategy under historical cost accounting can also be implemented under
mark-to-market accounting.

**Proof:** For any given strategy \( a = a(\sigma, s) \) and any signal pair \( (\sigma, s) \in \{H, L\} \times \{H, L\} \), the
principal’s expected utility is

\[
EU = E [\pi (a (\sigma, s)) | \sigma, s] - c (a (\sigma, s)) - \frac{K}{2} \text{Var}_1 [\pi (a (\sigma, s)) | I_o]
\]

(49)

with

\[
E [\pi (a (\sigma, s)) | \sigma, s] = (A + a (\sigma, s)) \Pr (\omega = H | \sigma, s)
\]

(50)
and
\[
Var_1[\pi(a(\sigma, s)) | I_o] = (A + a(\sigma, s))^2 \Pr(\omega = H | I_o) \left[ 1 - \Pr(\omega = H | I_o) \right]
\] (51)
where \( I_o \) is the information set of the outside investors at \( t = 1 \). We have \( I_o = \{\emptyset\} \) under historical cost accounting and \( I_o = \{\sigma\} \) under mark-to-market accounting. Note that if the same strategy \( a = a(\sigma, s) \) is implemented both under historical cost accounting and under mark-to-market accounting, the principal’s expected utility is higher under mark-to-market accounting because
\[
Var_1[\pi(a(\sigma, s)) | \sigma] < Var_1[\pi(a(\sigma, s))] \quad \text{for any} \quad \sigma \in \{H, L\}.
\]

**Lemma 3** The principal prefers mark-to-market accounting to historical cost accounting for \( \phi \geq \delta \) and \( \phi \leq \phi^* \).

**Proof:** Consider first the case of \( \phi \geq \delta \). It follows from Propositions 1 and 3 that for \( \phi \geq \delta \) the best implementable strategy under historical cost accounting depends only on the market signal. It follows from Proposition 4 that for \( \phi \geq \delta \) the best implementable strategy under historical cost accounting can also be implemented under mark-to-market accounting. It then follows from Lemma 2 that for \( \phi \geq \delta \) the principal prefers mark-to-market accounting. Consider now the case of \( \phi \leq \phi^* \). It follows from Propositions 1 and 3 that for \( \phi \leq \phi^* \) the best implementable strategy under historical cost accounting depends only on the agent’s private signal. It follows from Proposition 2 that for \( \phi \leq \phi^* \) the best implementable strategy under historical cost accounting can also be implemented under mark-to-market accounting. It then follows from Lemma 2 that for \( \phi \leq \phi^* \) the principal prefers mark-to-market accounting. \[\Box\]

**Lemma 4** For \( \phi \in (\phi^*, \delta) \), there exists a \( K^* > 0 \) such that the principal prefers mark-to-market accounting if \( K > K^* \) and historical cost accounting if \( K < K^* \).

**Proof:** For \( \phi \in (\phi^*, \delta) \), the best implementable strategy under historical cost accounting depends on the agent’s private signal. It follows from Proposition 2 that for \( \phi \in (\phi^*, \delta) \) the best implementable strategy under historical cost accounting cannot be implemented under mark-to-market accounting. It follows from Corollary 1 that for \( \phi \in (\phi^*, \delta) \) the best implementable strategy under mark-to-market accounting depends only on the market signal. For \( \phi \in (\phi^*, \delta) \), there is thus a tradeoff between the two accounting regimes. Mark-to-market accounting is associated with a lower discount for the variability in \( \pi \), but historical cost accounting is associated with more efficient investment.
Note that for $K = 0$ the principal’s objective function in equation (49) is identical to the principal’s objective function in Section 3. We know from Corollary 2 that historical cost accounting is optimal in that case. For $K \to \infty$, however, the principal’s objective function is equivalent to
\[
\max_{a \geq 0} \left\{ -\frac{K}{2} \text{Var}_1 [\pi(a(s)) | I_o] \right\}
\]
which is maximized for $a = 0$ and $I_o = \{\sigma\}$, i.e., under mark-to-market accounting.

Finally, by the envelope theorem, we can see that the principal’s objective function is strictly decreasing in $K$. Hence, as the objective function is continuous in $K$, there exists a unique $K^* > 0$ so that the principal prefers historical cost accounting for $K < K^*$ and mark-to-market accounting for $K > K^*$.

4.3 Incentive compensation

So far, we have assumed that the investment the agent undertakes at $t = 1$ and the firm’s final payoff at $t = 2$ are observable but not verifiable. As a consequence, we have not considered any incentive contracts when assessing under what conditions the first-best decision rule can be implemented. In what follows, we will assume instead that both actions and outcomes are verifiable and consider potential incentive contracts. We are able, however, to derive the following result.

**Proposition 8** Suppose the first-best decision rule cannot be implemented without incentive pay. Then, if (i) the agent has limited liability, (ii) the principal has limited liability, and (iii) the agent’s compensation must not be decreasing in the asset’s final payoff, an incentive contract that induces the agent to follow the first-best decision rule does not exist.

**Proof:** To simplify notation, define
\[
\text{Pr}(ijk) \equiv \text{Pr}(\omega = i | \sigma = j, s = k) \quad \text{for} \quad i, j, k \in \{H, L\} \times \{H, L\} \times \{H, L\}
\]
and
\[
\tilde{\delta}(ijk) \equiv \tilde{\delta}(\omega = i, \sigma = j, s = k) \quad \text{for} \quad i, j, k \in \{H, L\} \times \{H, L\} \times \{H, L\}.
\]
Assume that the compensation contract is restricted by the following three constraints: (i) the agent has limited liability, (ii) the principal has limited liability, and (iii) the agent’s
compensation must not be decreasing in the asset’s final payoff. Furthermore, assume the first-best decision rule is implemented in equilibrium. In that case, the principal learns \( \sigma, s, \) and \( \omega \) and forms posterior beliefs about the agent’s type as in the proof to Proposition 1.

Consider first the case of historical cost accounting. We define \( b'_{\sigma s} \) as the incentive payment that the agent receives if he has taken action \( a_{\sigma s} \), and if state \( \omega \) has been realized. One of the agent’s incentive compatibility constraints that must be satisfied in equilibrium is as follows.

\[
\Pr (HLH) \left[ \Omega \hat{\delta} (HLH) + b'_{LH} \right] + \Pr (LLH) \left[ \Omega \hat{\delta} (LH) + b'_{LH} \right] \geq \Pr (HLH) \left[ \Omega \hat{\delta} (HHH) + b'_{HH} \right] + \Pr (LLH) \left[ \Omega \hat{\delta} (LHH) + b'_{HH} \right].
\]  

(55)

This condition ensures that the agent prefers \( a_{LH} \) to \( a_{HH} \) if \( \sigma = L \) and \( s = H \).

The limited liability constraints for the principal and the agent imply \( b'_{LH} = b'_{HH} = 0 \), so that the above constraint can be re-written as:

\[
b'_{HH} - b'_{LH} \leq \Omega \left\{ \hat{\delta} (HLH) - \hat{\delta} (HHH) + \frac{\Pr (LLH)}{\Pr (HLH)} \left[ \hat{\delta} (LH) - \hat{\delta} (LHH) \right] \right\}.
\]  

(56)

Combined with the restriction that the agent’s pay must not be decreasing in the asset’s final payoff, \( b'_{HH} \geq b'_{LH} \), this implies that we must have

\[
\Omega \left\{ \hat{\delta} (HLH) - \hat{\delta} (HHH) + \frac{\Pr (LLH)}{\Pr (HLH)} \left[ \hat{\delta} (LH) - \hat{\delta} (LHH) \right] \right\} \geq 0.
\]  

(57)

However, we know that \( \hat{\delta} (HLH) < \hat{\delta} (HHH) \) and \( \hat{\delta} (LH) < \hat{\delta} (LHH) \), so that this condition is always violated.\(^{11}\)

Suppose that instead of historical cost accounting the firm follows a mark-to-market rule and consider the case of \( \sigma = H \). We define \( b'_{\sigma s} (\sigma) \) as the incentive payment that the agent receives if the market signal is \( \sigma \), he has taken action \( a_{\sigma s} \), and if state \( \omega \) has been realized. One of the agent’s incentive compatibility constraints is as follows.

\[
\Pr (HHL) \left[ \Omega \hat{\delta} (HHL) + b'_{HL} (H) \right] + \Pr (LHL) \left[ \Omega \hat{\delta} (LHL) + b'_{HL} (H) \right] \geq \Pr (HHL) \left[ \Omega \hat{\delta} (HHH) + b'_{HH} (H) \right] + \Pr (LHL) \left[ \Omega \hat{\delta} (LHH) + b'_{HH} (H) \right].
\]  

(58)

This ensures that the agent prefers \( a_{HL} \) to \( a_{HH} \) if \( \sigma = H \) and \( s = L \).

Limited liability for the principal and the agent implies \( b'_{HH} (H) = b'_{HL} (H) = 0 \). We can thus re-write the agent’s incentive compatibility constraint as follows:

\[
b'_{HH} (H) - b'_{HL} (H) \leq \Omega \left\{ \delta (HHL) - \delta (HHH) + \frac{\Pr (LHL)}{\Pr (HHL)} \left[ \hat{\delta} (LHL) - \hat{\delta} (LHH) \right] \right\}.
\]  

(59)

\(^{11}\)See the proof of Proposition 1.
The assumption that the agent’s compensation must not be decreasing in the asset’s final payoff implies
\[ b_{HH}^H (H) - b_{HL}^H (H) \geq 0, \] (60)
so that a necessary condition for the existence of an incentive compatible contract is
\[ \hat{\delta} (HHL) - \hat{\delta} (HHH) + \frac{Pr (LHL)}{Pr (HHL)} \left[ \hat{\delta} (LHL) - \hat{\delta} (LHH) \right] \geq 0. \] (61)
However, we know from the proof of Proposition 2 that this condition is violated if \( \phi > \phi^* \).

**Corollary 4** Under mark-to-market accounting and for \( \phi \in (\phi^*, \delta) \), if (i) the agent has limited liability, (ii) the principal has limited liability, and (iii) the agent’s compensation must not be decreasing in the asset’s final payoff, an incentive contract that induces the agent to follow the second-best decision rule does not exist.

**Proof:** Under mark-to-market accounting and for \( \phi \in (\phi^*, \delta) \), the second-best strategy reveals the agent’s private signal to the principal. It follows from the proof of Proposition 8 that such a strategy cannot be implemented in equilibrium.

Thus, if compensation contracts between the principal and the agent must satisfy (i) limited liability for the agent, (ii) limited liability for the principal, and (iii) compensation that is not decreasing in the asset’s final payoff, then verifiable actions and outcomes will not help the principal to implement the first-best decision rule. Furthermore, for \( \phi \in (\phi^*, \delta) \), historical cost accounting continues to dominate mark-to-market accounting.

## 5 Conclusion

We have examined how mark-to-market accounting affects the investment decisions of an agent 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, disclosing the current market value of a firm’s assets plays a disciplining role in this setting. The information contained in the market prices provides a benchmark against which the agent’s actions can be evaluated, and in equilibrium the agent is forced to take this information into account when making the investment decision. However, precisely the fact that market prices are informative about which decision the agent should take has a negative side
effect: the agent may prefer to hide contradictory private information whose revelation would damage his reputation. Surprisingly, this effect makes mark-to-market accounting less desirable as market prices become more informative.

When contrasting mark-to-market accounting with historical cost accounting, we find that which disclosure rule is preferable crucially depends on the relative informativeness of the market prices and the agent’s private information. If market prices are not too informative (relative to the agent’s private information), marking to market is preferable because it leads to the first-best investment. Historical cost accounting, however, is preferable once market prices become more informative but are still less so than the agent’s private information. In that case, historical cost accounting allows the agent to base his decisions solely on his private information. Under mark-to-market accounting the agent instead bases his decisions only on the less informative market information. In case market prices are more informative than the agent’s private information, both disclosure rules lead to the same investment.

This analysis has important normative implications. First, there is no optimal form of disclosure. Depending on the informativeness of the public signal and the private information, marking to market or historical-cost accounting may be preferable (or the disclosure regime may be irrelevant). Hence, one-size-fits-all disclosure rules are not optimal. Second, in contrast with the commonly held view that more informative prices make mark-to-market accounting naturally more appealing, we find that for more informative market prices historical cost accounting may actually be preferable. Marking to market dominates historical cost accounting only when market prices are not too informative. This suggests that it may be optimal to mandate mark-to-market accounting precisely when assets are more opaque and thus more difficult to value, and not do so when assets are more transparent and thus easier to value.
References


Appendix

A1. Posterior beliefs about the agent’s type

For $\hat{\delta}(\omega = H, \sigma = H, s = H)$ we have

$$
\hat{\delta}(\omega = H, \sigma = H, s = H) = \frac{\Pr(\omega=H,\sigma=H,s=H|\theta_A=g) \cdot \Pr(\theta_A=g)}{\Pr(\omega=H,\sigma=H,s=H|\theta_A=g)+\Pr(\omega=H,\sigma=H,s=H|\theta_A=b) \cdot \Pr(\theta_A=b)}
$$

(A1)

with

\[
\Pr(\omega = H, \sigma = H, s = H|\theta_A=g) = \Pr(\omega = H, \sigma = H, s = H|\theta_M=i, \theta_A = g) \cdot \Pr(\theta_M = i) + \Pr(\omega = H, \sigma = H, s = H|\theta_M=u, \theta_A = g) \cdot \Pr(\theta_M = u)
\]

\[
= \frac{1}{2} \cdot p \cdot \phi + \frac{1}{2} \cdot \frac{1}{2} \cdot p \cdot (1 - \phi)
\]

\[
= \frac{1}{4} p (1 + \phi)
\]  

(A2)

and

\[
\Pr(\omega = H, \sigma = H, s = H|\theta_A=b) = \Pr(\omega = H, \sigma = H, s = H|\theta_M=i, \theta_A = b) \cdot \Pr(\theta_M = i) + \Pr(\omega = H, \sigma = H, s = H|\theta_M=u, \theta_A = b) \cdot \Pr(\theta_M = u)
\]

\[
= \frac{1}{2} \cdot p \cdot \frac{1}{2} \cdot \phi + \frac{1}{2} \cdot \frac{1}{2} \cdot \frac{1}{2} \cdot (1 - \phi)
\]

\[
= \frac{1}{4} \left[ \frac{1}{2} + \phi \left( p - \frac{1}{2} \right) \right]
\]

(A3)

We obtain:

$$
\hat{\delta}(\omega = H, \sigma = H, s = H) = \frac{\frac{1}{4} p (1 + \phi) \cdot \delta}{\frac{1}{4} p (1 + \phi) \cdot \delta + \frac{1}{4} \left[ \frac{1}{2} + \phi \left( p - \frac{1}{2} \right) \right] \cdot (1 - \delta) + \frac{1}{2} p (1 + \phi)}
$$

$$
= \frac{2\delta p (1 + \phi)}{2p (\delta + \phi) + (1 - \phi) (1 - \delta)}
$$

(A4)

For $\hat{\delta}(\omega = L, \sigma = L, s = L)$ we obtain by analogy:

$$
\hat{\delta}(\omega = L, \sigma = L, s = L) = \frac{2\delta p (1 + \phi)}{2p (\delta + \phi) + (1 - \phi) (1 - \delta)}
$$

(A5)

For $\hat{\delta}(\omega = H, \sigma = L, s = H)$ we have

$$
\hat{\delta}(\omega = H, \sigma = L, s = H) = \frac{\Pr(\omega=H,\sigma=L,s=H|\theta_A=g) \cdot \Pr(\theta_A=g)}{\Pr(\omega=H,\sigma=L,s=H|\theta_A=g)+\Pr(\omega=H,\sigma=L,s=H|\theta_A=b) \cdot \Pr(\theta_A=b)}
$$

(A6)
with
\[
\Pr(\omega = H, \sigma = L, s = H|\theta_A = g) = \Pr(\omega = H, \sigma = L, s = H|\theta_M = i, \theta_A = g) \cdot \Pr(\theta_M = i)
+ \Pr(\omega = H, \sigma = L, s = H|\theta_M = u, \theta_A = g) \cdot \Pr(\theta_M = u)
= \frac{1}{2} \cdot 0 \cdot \phi + \frac{1}{2} \cdot \frac{1}{2} \cdot p \cdot (1 - \phi)
= \frac{1}{4} p (1 - \phi)
\] (A7)

and
\[
\Pr(\omega = H, \sigma = L, s = H|\theta_A = b) = \Pr(\omega = H, \sigma = L, s = H|\theta_M = i, \theta_A = b) \cdot \Pr(\theta_M = i)
+ \Pr(\omega = H, \sigma = L, s = H|\theta_M = u, \theta_A = b) \cdot \Pr(\theta_M = u)
= \frac{1}{2} \cdot (1 - p) \cdot \frac{1}{2} \cdot \phi + \frac{1}{2} \cdot \frac{1}{2} \cdot \frac{1}{2} \cdot (1 - \phi)
= \frac{1}{4} \left[ \frac{1}{2} - \phi \left( p - \frac{1}{2} \right) \right]
\] (A8)

We obtain:
\[
\hat{\delta}(\omega = H, \sigma = L, s = H) = \frac{\frac{1}{4} p (1 - \phi) \cdot \delta}{\frac{1}{4} p (1 - \phi) \cdot \delta + \frac{1}{4} \left( p - \frac{1}{2} \right) \cdot (1 - \phi)}
= \frac{2 \delta p (1 - \phi)}{2 \delta p (1 - \phi) + (1 - \delta) (1 + \phi)}
\] (A9)

For \( \hat{\delta}(\omega = L, \sigma = H, s = L) \) obtain by analogy:
\[
\hat{\delta}(\omega = L, \sigma = H, s = L) = \frac{2 \delta p (1 - \phi)}{2 \delta p (1 - \phi) + (1 - \delta) (1 + \phi)}
\] (A10)

For \( \hat{\delta}(\omega = H, \sigma = H, s = L) \) we have:
\[
\hat{\delta}(\omega = H, \sigma = H, s = L) = \frac{\Pr(\omega = H, \sigma = H, s = L|\theta_A = g) \cdot \Pr(\theta_A = g)}{\Pr(\omega = H, \sigma = H, s = L|\theta_A = g) \cdot \Pr(\theta_A = g) + \Pr(\omega = H, \sigma = H, s = L|\theta_A = b) \cdot \Pr(\theta_A = b)}
\] (A11)

with
\[
\Pr(\omega = H, \sigma = H, s = L|\theta_A = g) = \Pr(\omega = H, \sigma = H, s = L|\theta_M = i, \theta_A = g) \cdot \Pr(\theta_M = i)
+ \Pr(\omega = H, \sigma = H, s = L|\theta_M = u, \theta_A = g) \cdot \Pr(\theta_M = u)
= \frac{1}{2} \cdot 0 \cdot \phi + \frac{1}{2} \cdot \frac{1}{2} \cdot (1 - p) \cdot (1 - \phi)
= \frac{1}{4} (1 - p) (1 - \phi)
\] (A12)
We obtain:

$$\hat{\delta} (\omega = H, \sigma = H, s = L) = \frac{\frac{1}{4} (1 - p) (1 - \phi) \cdot \delta}{\frac{1}{4} (1 - p) (1 - \phi) \cdot \delta + \frac{1}{4} \left[ \frac{1}{2} + \phi \left( p - \frac{1}{2} \right) \right] \cdot (1 - \delta)}$$

$$= \frac{2\delta (1 - p) (1 - \phi)}{2(1 - p) (\delta - \phi) + (1 - \delta) (1 + \phi)}$$

(A14)

For $\hat{\delta} (\omega = L, \sigma = L, s = H)$ obtain by analogy:

$$\hat{\delta} (\omega = L, \sigma = L, s = H) = \frac{2\delta (1 - p) (1 - \phi)}{2(1 - p) (\delta - \phi) + (1 - \delta) (1 + \phi)}$$

(A15)

For $\hat{\delta} (\omega = H, \sigma = L, s = L)$ we have:

$$\hat{\delta} (\omega = H, \sigma = L, s = L) = \frac{\Pr(\omega = H, \sigma = L, s = L|\theta_M = i, \theta_A = g) \cdot \Pr(\theta_M = i) + \Pr(\omega = H, \sigma = L, s = L|\theta_M = u, \theta_A = g) \cdot \Pr(\theta_M = u)}{\Pr(\omega = H, \sigma = L, s = L|\theta_M = i) \cdot \Pr(\theta_M = i) + \Pr(\omega = H, \sigma = L, s = L|\theta_M = u) \cdot \Pr(\theta_M = u)}$$

(A16)

with

$$\Pr(\omega = H, \sigma = L, s = L|\theta_A = g) = \Pr(\omega = H, \sigma = L, s = L|\theta_M = i, \theta_A = g) \cdot \Pr(\theta_M = i)$$

$$+ \Pr(\omega = H, \sigma = L, s = L|\theta_M = u, \theta_A = g) \cdot \Pr(\theta_M = u)$$

$$= \frac{1}{2} \cdot (1 - p) \cdot \phi + \frac{1}{2} \cdot \frac{1}{2} \cdot (1 - p) \cdot (1 - \phi)$$

$$= \frac{1}{4} (1 - p) (1 + \phi)$$

(A17)

and

$$\Pr(\omega = H, \sigma = L, s = L|\theta_A = b) = \Pr(\omega = H, \sigma = L, s = L|\theta_M = i, \theta_A = b) \cdot \Pr(\theta_M = i)$$

$$+ \Pr(\omega = H, \sigma = L, s = L|\theta_M = u, \theta_A = b) \cdot \Pr(\theta_M = u)$$

$$= \frac{1}{2} \cdot (1 - p) \cdot \frac{1}{2} \cdot \phi + \frac{1}{2} \cdot \frac{1}{2} \cdot \frac{1}{2} \cdot (1 - \phi)$$

$$= \frac{1}{4} \left[ \frac{1}{2} - \phi \left( p - \frac{1}{2} \right) \right]$$

(A18)

We obtain:

$$\hat{\delta} (\omega = H, \sigma = L, s = L) = \frac{\frac{1}{4} (1 - p) (1 + \phi) \cdot \delta}{\frac{1}{4} (1 - p) (1 + \phi) \cdot \delta + \frac{1}{4} \left[ \frac{1}{2} - \phi \left( p - \frac{1}{2} \right) \right] \cdot (1 - \delta)}$$

$$= \frac{2\delta (1 - p) (1 + \phi)}{2(1 - p) (\delta + \phi) + (1 - \phi) (1 - \delta)}$$

(A19)
For \( \delta(\omega = L, \sigma = H, s = H) \) we obtain by analogy
\[
\delta(\omega = L, \sigma = H, s = H) = \frac{2\delta(1-p)(1+\phi)}{2(1-p)(\delta + \phi) + (1-\phi)(1-\delta)} \tag{A20}
\]

### A2. Comparison of posterior beliefs about the agent’s type

We have
\[
\hat{\delta}(\omega = H, \sigma = H, s = H) > \hat{\delta}(\omega = H, \sigma = L, s = H) \tag{A21}
\]
and
\[
\hat{\delta}(\omega = L, \sigma = L, s = L) > \hat{\delta}(\omega = L, \sigma = H, s = L) \tag{A22}
\]
if
\[
\frac{2\delta p(1+\phi)}{2p(\delta + \phi) + (1-\phi)(1-\delta)} > \frac{2\delta p(1-\phi)}{2p(\delta - \phi) + (1-\delta)(1+\phi)}
\]
\[
(1+\phi)[2p(\delta - \phi) + (1-\delta)(1+\phi)] > (1-\phi)[2p(\delta + \phi) + (1-\phi)(1-\delta)]
\]
\[
1 > p \tag{A23}
\]
which is satisfied by assumption.

We have
\[
\hat{\delta}(\omega = L, \sigma = H, s = H) > \hat{\delta}(\omega = L, \sigma = L, s = H) \tag{A24}
\]
and
\[
\hat{\delta}(\omega = H, \sigma = L, s = L) > \hat{\delta}(\omega = H, \sigma = H, s = L) \tag{A25}
\]
if
\[
\frac{2\delta (1-p)(1+\phi)}{2(1-p)(\delta + \phi) + (1-\phi)(1-\delta)} > \frac{2\delta (1-p)(1-\phi)}{2(1-p)(\delta - \phi) + (1-\delta)(1+\phi)}
\]
\[
(1+\phi)[2(1-p)(\delta - \phi) + (1-\delta)(1+\phi)] > (1-\phi)[2(1-p)(\delta + \phi) + (1-\phi)(1-\delta)]
\]
\[
1 > 1-p
\]
\[
p > 0 \tag{A26}
\]
which is satisfied by assumption.
A3. $F(\phi)$ and $\phi^*$

We have

$$F(\phi) \equiv \Pr(\omega = H|\sigma = L, s = H) \left[ \delta(\omega = H, \sigma = L, s = L) - \delta(\omega = H, \sigma = L, s = H) \right]$$

$$+ \Pr(\omega = L|\sigma = L, s = H) \left[ \delta(\omega = L, \sigma = L, s = L) - \delta(\omega = L, \sigma = L, s = H) \right]$$

We have

$$\Pr(\omega = H|\sigma = L, s = H) = \frac{\Pr(\sigma = L, s = H|\omega = H) \cdot \Pr(\omega = H)}{\Pr(\sigma = L, s = H|\omega = H) \cdot \Pr(\omega = H) + \Pr(\sigma = L, s = H|\omega = L) \cdot \Pr(\omega = L)}$$

with

$$\Pr(\sigma = L, s = H|\omega = H) = \Pr(\sigma = L, s = H|\omega = H, \theta_M = i, \theta_A = g) \cdot \Pr(\theta_M = i, \theta_A = g)$$

$$+ \Pr(\sigma = L, s = H|\omega = H, \theta_M = i, \theta_A = b) \cdot \Pr(\theta_M = i, \theta_A = b)$$

$$+ \Pr(\sigma = L, s = H|\omega = H, \theta_M = u, \theta_A = g) \cdot \Pr(\theta_M = u, \theta_A = g)$$

$$+ \Pr(\sigma = L, s = H|\omega = H, \theta_M = u, \theta_A = b) \cdot \Pr(\theta_M = u, \theta_A = b)$$

$$= 0 \cdot \phi \cdot \delta + \frac{1}{2} \cdot \phi \cdot (1 - \delta)$$

$$+ \frac{1}{2} \cdot p \cdot (1 - \phi) \cdot \delta + \frac{1}{2} \cdot \frac{1}{2} \cdot (1 - \phi) \cdot (1 - \delta)$$

$$= \frac{1}{2} \left[ \frac{1}{2} (1 - \phi \delta) - \left( p - \frac{1}{2} \right) (\phi - \delta) \right]$$

and

$$\Pr(\sigma = L, s = H|\omega = L) = \Pr(\sigma = L, s = H|\omega = L, \theta_M = i, \theta_A = g) \cdot \Pr(\theta_M = i, \theta_A = g)$$

$$+ \Pr(\sigma = L, s = H|\omega = L, \theta_M = i, \theta_A = b) \cdot \Pr(\theta_M = i, \theta_A = b)$$

$$+ \Pr(\sigma = L, s = H|\omega = L, \theta_M = u, \theta_A = g) \cdot \Pr(\theta_M = u, \theta_A = g)$$

$$+ \Pr(\sigma = L, s = H|\omega = L, \theta_M = u, \theta_A = b) \cdot \Pr(\theta_M = u, \theta_A = b)$$

$$= 0 \cdot \phi \cdot \delta + p \cdot \frac{1}{2} \cdot \phi \cdot (1 - \delta)$$

$$+ \frac{1}{2} \cdot (1 - p) \cdot (1 - \phi) \cdot \delta + \frac{1}{2} \cdot \frac{1}{2} \cdot (1 - \phi) \cdot (1 - \delta)$$

$$= \frac{1}{2} \left[ \frac{1}{2} (1 - \delta \phi) + \left( p - \frac{1}{2} \right) (\phi - \delta) \right]$$

Thus we obtain

$$\Pr(\omega = H|\sigma = L, s = H) = \frac{1}{2} + \frac{\left( p - \frac{1}{2} \right) (\delta - \phi)}{1 - \delta \phi}$$
For \( \Pr (\omega = L|\sigma = L, s = H) \) we have

\[
\Pr (\omega = L|\sigma = L, s = H) = 1 - \Pr (\omega = H|\sigma = L, s = H) = 1 - \frac{1}{2} \frac{(p - \frac{1}{2}) (\delta - \phi)}{1 - \delta}\phi
\]

For \( \phi = 0 \), we obtain

\[
\Pr (\omega = H|\sigma = L, s = H) = \frac{1}{2} + \delta \left( p - \frac{1}{2} \right) \tag{A33}
\]

\[
\Pr (\omega = L|\sigma = L, s = H) = \frac{1}{2} - \delta \left( p - \frac{1}{2} \right) \tag{A34}
\]

\[
\hat{\delta} (\omega = H, \sigma = L, s = H) = \hat{\delta} (\omega = L, \sigma = L, s = H) = \frac{2\delta (1 - p)}{2 (1 - p) \delta + (1 - \delta)} \tag{A35}
\]

and therefore

\[
F (\phi = 0) = \left[ \frac{1}{2} + \delta \left( p - \frac{1}{2} \right) \right] \left[ \frac{2\delta (1 - p)}{2 (1 - p) \delta + (1 - \delta)} - \frac{2\delta p}{2p\delta + (1 - \delta)} \right] + \left[ \frac{1}{2} - \delta \left( p - \frac{1}{2} \right) \right] \left[ \frac{2\delta p}{2p\delta + (1 - \delta)} - \frac{2\delta (1 - p)}{2 (1 - p) \delta + (1 - \delta)} \right]
\]

\[
= \frac{-8\delta^2 (1 - \delta) \left( p - \frac{1}{2} \right)^2}{[2 (1 - p) \delta + (1 - \delta)] \cdot [2p\delta + (1 - \delta)]}
\]

\[
< 0 \tag{A37}
\]

For \( \phi = \delta \) we have

\[
\Pr (\omega = H|\sigma = L, s = H) = \Pr (\omega = L|\sigma = L, s = H) = \frac{1}{2} \tag{A38}
\]

\[
\hat{\delta} (\omega = H, \sigma = L, s = L) = \frac{2\delta (1 - p) (1 + \delta)}{4 (1 - p) \delta + (1 - \delta)^2} \tag{A39}
\]

\[
\hat{\delta} (\omega = H, \sigma = L, s = H) = \frac{2\delta p}{1 + \delta} \tag{A40}
\]

\[
\hat{\delta} (\omega = L, \sigma = L, s = L) = \frac{2\delta p (1 + \delta)}{4p\delta + (1 - \delta)^2} \tag{A41}
\]

\[
\hat{\delta} (\omega = L, \sigma = L, s = H) = \frac{2\delta (1 - p)}{1 + \delta} \tag{A42}
\]

and thus

\[
F (\phi = \delta) = \frac{1}{2} \left[ \frac{2\delta p (1 + \delta)}{4p\delta + (1 - \delta)^2} - \frac{2\delta p}{1 + \delta} + \frac{2\delta (1 - p) (1 + \delta)}{4 (1 - p) \delta + (1 - \delta)^2} - \frac{2\delta (1 - p)}{1 + \delta} \right] \tag{A43}
\]
Furthermore, using
\[
\frac{2\delta p (1 + \delta)}{4p\delta + (1 - \delta)^2} - \frac{2\delta p}{1 + \delta} = 2\delta p \left\{ \frac{(1 + \delta)}{4p\delta + (1 - \delta)^2} - \frac{1}{1 + \delta} \right\}
\]
\[
= 2\delta p \left\{ \frac{(1 + \delta)^2}{4p\delta + (1 - \delta)^2} [1 + \delta] - \frac{4p\delta + (1 - \delta)^2}{4p\delta + (1 - \delta)^2} [1 + \delta] \right\}
\]
\[
= \frac{8\delta^2 p (1 - p)}{4p\delta + (1 - \delta)^2} (1 + \delta)
\]
\[
> 0
\]
we obtain
\[
F(\phi = \delta) > 0
\]
(A44)

and
\[
\frac{2\delta (1 - p) (1 + \delta)}{4 (1 - p) \delta + (1 - \delta)^2} - \frac{2\delta (1 - p)}{1 + \delta} = \frac{8\delta^2 p (1 - p)}{4 (1 - p) \delta + (1 - \delta)^2} (1 + \delta)
\]
\[
> 0
\]
(A45)

we obtain
\[
F(\phi = \delta) > 0
\]
(A46)

Now consider \( \frac{\partial F}{\partial \phi} \). Taking the derivative of \( F \) with respect to \( \phi \) we obtain
\[
\frac{\partial F}{\partial \phi} = \Pr (\omega = H | \sigma = L, s = H) \left[ \frac{\partial \tilde{\delta}(\omega = H, \sigma = L, s = L)}{\partial \phi} - \frac{\partial \tilde{\delta}(\omega = H, \sigma = L, s = H)}{\partial \phi} \right]
\]
\[
+ \Pr (\omega = L | \sigma = L, s = H) \left[ \frac{\partial \tilde{\delta}(\omega = L, \sigma = L, s = L)}{\partial \phi} - \frac{\partial \tilde{\delta}(\omega = L, \sigma = L, s = H)}{\partial \phi} \right]
\]
\[
+ \frac{\partial \Pr (\omega = H | \sigma = L, s = H)}{\partial \phi} \left[ \tilde{\delta} (\omega = H, \sigma = L, s = L) - \tilde{\delta} (\omega = H, \sigma = L, s = H) \right]
\]
\[
+ \frac{\partial \Pr (\omega = L | \sigma = L, s = H)}{\partial \phi} \left[ \tilde{\delta} (\omega = L, \sigma = L, s = L) - \tilde{\delta} (\omega = L, \sigma = L, s = H) \right]
\]
(A47)

with
\[
\frac{\partial \tilde{\delta}(\omega = L, \sigma = L, s = L)}{\partial \phi} = \frac{\partial \tilde{\delta}(\omega = H, \sigma = L, s = H)}{\partial \phi} = \frac{-4p(1-p)\delta(1-\delta)}{[2p(\delta-\phi)+(1-\delta)(1+\phi)]^2} < 0
\]
(A48)

\[
\frac{\partial \tilde{\delta}(\omega = L, \sigma = L, s = H)}{\partial \phi} = \frac{\partial \tilde{\delta}(\omega = H, \sigma = L, s = L)}{\partial \phi} = \frac{-4p(1-p)\delta(1-\delta)}{[2(1-p)\delta(\delta+\phi)+(1-\delta)(1+\phi)]^2} < 0
\]
(A49)

\[
\frac{\partial \tilde{\delta}(\omega = H, \sigma = L, s = H)}{\partial \phi} = \frac{\partial \tilde{\delta}(\omega = L, \sigma = L, s = H)}{\partial \phi} = \frac{4p(1-p)\delta(1-\delta)}{[2(1-p)\delta(\delta+\phi)+(1-\delta)(1+\phi)]^2} > 0
\]
(A50)

\[
\frac{\partial \tilde{\delta}(\omega = L, \sigma = L, s = L)}{\partial \phi} = \frac{\partial \tilde{\delta}(\omega = H, \sigma = L, s = H)}{\partial \phi} = \frac{4p(1-p)\delta(1-\delta)}{[2p(\delta+\phi)+(1-\phi)(1+\phi)]^2} > 0
\]
(A51)

and
\[
\frac{\partial \Pr (\omega = H | \sigma = L, s = H)}{\partial \phi} = -\frac{(p - \frac{1}{2}) (1 - \delta^2)}{(1 - \phi \delta)^2} < 0
\]
(A52)

\[
\frac{\partial \Pr (\omega = L | \sigma = L, s = H)}{\partial \phi} = -\frac{\partial \Pr (\omega = H | \sigma = L, s = H)}{\partial \phi}
\]
(A53)
We have
\[
\frac{\partial F}{\partial \phi} = \Pr (\omega = H|\sigma = L, s = H) \left[ \frac{\partial \delta (\omega = H, \sigma = L, s = L)}{\partial \phi} - \frac{\partial \delta (\omega = H, \sigma = L, s = H)}{\partial \phi} \right] + \Pr (\omega = L|\sigma = L, s = H) \left[ \frac{\partial \delta (\omega = L, \sigma = L, s = L)}{\partial \phi} - \frac{\partial \delta (\omega = L, \sigma = L, s = H)}{\partial \phi} \right] + \frac{\partial \Pr (\omega = H|\sigma = L, s = H)}{\partial \phi} \left[ \frac{\delta (\omega = H, \sigma = L, s = L) - \delta (\omega = L, \sigma = L, s = L)}{\partial \phi} - \frac{\delta (\omega = H, \sigma = L, s = H) - \delta (\omega = H, \sigma = L, s = H)}{\partial \phi} \right] > 0
\]

(A54)

**A4. Useful probabilities**

The probabilities for the different combinations of private and market signals are as follows:

\[
\Pr (s = H) = \Pr (\sigma = H) = \frac{1}{2} \quad \text{(A55)}
\]

\[
\Pr (\sigma = H, s = H) = \Pr (\sigma = L, s = L) = \frac{1}{4} (1 + \delta \phi) \quad \text{(A56)}
\]

\[
\Pr (\sigma = H, s = L) = \Pr (\sigma = L, s = H) = \frac{1}{4} (1 - \delta \phi) \quad \text{(A57)}
\]

The probabilities for the different states of the world conditional on the private and the market signals are as follows:

\[
\Pr (\omega = H|s = H) = \Pr (\omega = L|s = L) = \frac{1}{2} + \delta \left( p - \frac{1}{2} \right) \quad \text{(A58)}
\]

\[
\Pr (\omega = H|\sigma = H) = \Pr (\omega = L|\sigma = L) = \frac{1}{2} + \phi \left( p - \frac{1}{2} \right) \quad \text{(A59)}
\]

\[
\Pr (\omega = H|\sigma = H, s = H) = \frac{1}{2} + \frac{(p - \frac{1}{2}) (\delta + \phi)}{1 + \phi \delta} \quad \text{(A60)}
\]

\[
\Pr (\omega = H|\sigma = L, s = H) = \frac{1}{2} + \frac{(p - \frac{1}{2}) (\delta - \phi)}{1 - \phi \delta} \quad \text{(A61)}
\]

\[
\Pr (\omega = H|\sigma = H, s = L) = \frac{1}{2} - \frac{(p - \frac{1}{2}) (\delta - \phi)}{1 - \phi \delta} \quad \text{(A62)}
\]

\[
\Pr (\omega = H|\sigma = L, s = L) = \frac{1}{2} - \frac{(p - \frac{1}{2}) (\delta + \phi)}{1 + \phi \delta} \quad \text{(A63)}
\]