Disclosure and Trading Games in Financial Markets

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I certify that the thesis I have presented for examination for the Ph.D. degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others.

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Part I

Preventing Liquidity Black Holes

Abstract

Financial market runs are the equivalent of a bank run outcome in financial markets. They occur because traders have an incentive to sell when others do so. In our model, traders with market impact who are subject to a loss limit and face uncertainty about market liquidity sell in the fear that other sellers may beat them to the market. The result is a coordinated sell-off that leaves all traders worse off. Using global game techniques, we characterize a unique equilibrium in which this run outcome or liquidity black hole comes into existence. Counter to common intuition, we argue that traders, who are active in the same market and hence expose themselves to identical risks, may overcome these liquidity black holes through sufficiently strong financial interlinkages.

1 Introduction

Recent events in financial markets painfully remind us of the wild swings markets can undergo and the severe consequences that they entail. They are also reminders of the costs associated with crises when these disturbances get out of hand. Episodes of high market distress are often characterized by heavily one-sided order flow, rapid price changes, and financial distress on the part of many market participants. While large price swings occur on a frequent basis, they often revert just as swiftly as they appear. Others however persist and even feed on themselves gaining momentum as they develop. Because of their severity and persistence, practitioners have dubbed such instances "liquidity black holes".

A striking feature of these periods is that they intensify in response to the reactions from market participants. This endogenous feedback loop has the effect of amplifying the initial shock and adding a snowball effect to it. Traders that are subject to strict controls and incentive constraints are particularly prone to act as catalysts for the sell-off in a falling market. Faced with uncertainty about market liquidity, traders must fear the breach of their loss limits caused by the selling pressure on asset prices by other traders who share similar concerns. Anticipating the reaction of other market participants, constrained traders act pre-emptively thereby setting the run in motion.[1] In our paper, we model this scenario quite closely and are able to characterize the financial market run in a unique equilibrium using global game techniques.

The intuition in this paper however applies outside the context of financial markets and in the following we thus try to convey the idea in a simpler and perhaps more familiar setting. Specifically, the run outcome in our story may be likened to the problem faced by two bank robbers.[2] Suppose two individuals contemplate robbing a bank that safeguards a precious asset whose value depreciates over time. If the thieves successfully steal the asset, they hide their loot to collect it at a later stage. If the heist is successful, the bank robbers return later to retrieve the asset. However, there is a chance that the heist fails and that the bank robbers are arrested by the police just after they manage to stow away the asset. Both thieves know that if caught by the police, they will be separated and individually interrogated. If indeed detained, the bank robbers find themselves in a prisoners' dilemma. They will each be given a chance to implicate the other, in which case the "ratter" receives no sentence while the "rattee" receives the harshest possible sentence. If each bankrobber blames the other, both are sentenced to serve in prison long enough to only enjoy the benefits of the remaining undepreciated portion of the asset once released. If both remain silent, each receives a short sentence and can thus enjoy a greater residual amount of the asset. Individual rational behavior then leads the bank robbers to rat on one another spoiling the benefits of the loot for both.

Could the bank robbers do better? The answer to this question may depend on whether the bank robbers could find a way to credibly commit not to blame each other once apprehended. Suppose the bank robbers decided to hide and lock away the asset in such a way that the input of both were needed to retrieve it.[3] Now each thief potentially also has a vested interest in seeing his accomplice go free sooner. By blaming his accomplice, a bankrobber forgoes a larger asset value in exchange for the benefit of serving a shorter sentence. Depending on the relative size of the loot and the length of the sentence, remaining silent may be in the best interest of both thieves. Our model will take this intuition and apply it in the context of a financial market.

Our paper is related to a large literature that has analyzed the implications of an interconnected financial system. On the one hand, it is widely argued that links between financial institutions may have destabilizing or contagious effects by facilitating the spillover of shocks from one institution to another (Allen and Carletti (2008), Allen and Gale (2000), Freixas, Parigi, and Rochet (2000)).[4] A common feature of these models is their reliance on an exogenous shock that causes a crisis to spread into connected institutions. Other explanations of contagion include wealth constraints (Kyle and Xiong (2001)), information spillovers (Aghion, Bolton, and Dewatripont (2000), Dasgupta (2004), Flannery and Kaufman (1996)), liquidity constraints (Kodres and Pritsker (2002)), solvency constraints (Cifuentes, Shin, and Ferrucci (2005)) and incentive schemes of financial intermediaries (Schinasi and Smith (2000)).

A common conclusion of these models is that the failure of individual institutions can have adverse consequences for the system as a whole. An important channel through which these failures induce externalities is through the liquidation prices of assets. If the asset demand is not perfectly elastic, asset sales have the effect of depressing prices, which may in turn harm other market participants. Reasons for asset demand inelasticity are information asymmetry, limited participation or risk absorption capacity on the part of the buyers. The limited capacity of the market to absorb asset sales, an assumption that we use in our setup, has figured prominently in the literature on banking and financial crises (Allen and Gale (2000), Gorton and Huang (2004) and Schnabel and Shin (2004)).

On the other hand, the extant literature holds that links between financial institutions that are exposed to imperfectly correlated risks provide diversification or risk-sharing benefits (Allen and Carletti (2006, 2008)).[5] The evidence on portfolio holdings in the build-up phase of the crisis however suggests that if anything financial institutions held similar, highly correlated assets in addition to various linkages to each other. This is a puzzle for which no explanation has yet been put forward to our knowledge. This paper tries to fill this gap by suggesting that the choice of strong interlinkages by financial institutions that face similar risks may in fact be an optimal arrangement amongst these institutions. In the extreme, this paper suggests that tightly connected institutions may eliminate market sell-offs caused by strategic trading when connected market participants hold similar or identical (perfectly correlated) assets. Recent empirical work suggests that the interbank linkage channel may not be as important in propagating financial difficulties as the extant theoretical literature has indicated so far. Sheldon and Maurer (1998) for Switzerland, Furfine (2003) for the United States, Upper and Worms (2004) for Germany and Wells (2002) for the UK estimate the bilateral exposures among banks finding little potential for failures resulting from interbank linkages.

The closest papers to ours that model financial market runs are Morris and Shin (2004) and Bernardo and Welch (2004). In Bernardo and Welch (2004), the fear of future liquidity shocks produces a collective sell-off by investors to second best users of the asset resulting in depressed prices. In Morris and Shin (2004), financial traders are subject to a loss limit: they are fired when the value of their portfolio falls below a certain threshold. Selling by a critical mass of traders can then harm other traders by pushing their portfolio value through their thresholds causing a collective sell-off in anticipation of the potential breach. A market run ensues with a sharp drop in the asset price. In their model, a trader is uncertain about the loss limit of other traders. In our model, the driving force behind a run is the interplay of traders' trading constraints coupled with their uncertainty about market liquidity, modeled as the limited risk absorption capacity of the market making sector. Again, mimetic actions of investors give rise to externalities, which further stoke and synchronize the actions of market participants.

To address these negative externalities and to minimize the cost of financial crises, the system has responded by introducing regulation. Current regulation takes most prominently place in the form of capital requirements, which force banks to hold a certain amount of capital as a buffer against losses, depending on the riskiness of their assets. While the banking sector is already highly regulated and the authorities are considering extending their regulatory reach to hedge funds, recent events have shown that regulation may not be a panacea either. Proponents of this view argue that current regulation is ineffective in inducing banks to internalize the negative effects of their actions on the system and may potentially even exacerbate the problem (Borio and Drehmann (2008), Repullo and Suarez (2008) and Wagner (2009a)). Perhaps this realization has resulted in a recent proposal by Kashyap, Rajan, and Stein (2008) for a market-based solution, in which the authors put forward the idea of capital insurance contracts that would pay off in states of the world when the banking system is in bad shape. The argument holds that such contracts would provide relief for banks precisely at times when their actions might otherwise cause the greatest harm to the system. In the extension to our base model, we offer a different market-based solution in which financial institutions take steps to self-correct the costly distortions that result from their individually rational but systemically adverse trading behavior.

2 Model

Some of the features of our model are based on Morris and Shin (2004). An asset is traded at two dates, and then liquidated. Time is indexed by three dates: initial, interim and final. The liquidation value of the asset at the final date as viewed from the initial date is given by

$$v + z$$

where z and v are two independent random variables. z is normally distributed with mean zero and variance σ^2, and is realized at the final date. The realization of v is common knowledge in the market at the interim date. Traders then view the liquidation value of the asset as having a normal distribution with mean v and variance σ^2.

Two groups of traders are active in the market. There are two risk-neutral traders in the first group who can be thought of as proprietary traders at financial institutions. Each of them manages 1 unit of the asset. The traders face an incentive contract in which their payoff is proportional to the final liquidation value of the asset. However, they are also subject to a price constraint at the interim date, which may be interpreted as a loss limit. If the price of the asset is pushed through the loss limit at the interim date, the trader is dismissed with a (small) fixed severance payout b. This feature captures the notion that sitting on news and holding the asset in illiquid markets can produce a bad outcome for a trader whose decision horizon is shortened by the constraint. The trading decision of the trader reflects the tradeoff between keeping his position open and reaping the discounted holding gains from the final date against dismissal and the severance pay in the interim. While the price constraint is exogenous to our model, we discuss the contracting tensions that may determine such a constraint later and their relation to the extension of the model.

In the market for this asset, the risk-neutral short-horizon traders face a group of risk-averse long-horizon traders, the market-making sector of the economy. This second group of traders posts the residual demand curve facing the risk-neutral traders as a whole. We represent the market-making sector by means of a representative trader with risk aversion γ who posts limit buy orders in the market at the interim date that coincide with his competitive demand curve. The liquidation value as seen from the interim date is commonly known to have a mean of v and variance σ^2. The Gaussian uncertainty and exponential utility induce the market-making sector to post limit orders that define the linear demand curve

$$d = \frac{v - p}{\gamma\sigma^2}$$

where p is the price of the asset at the interim date. When the aggregate net supply from the risk-neutral traders is s, price at the interim date satisfies

$$p = v - \lambda s \tag{1}$$

where λ, given by $\gamma\sigma^2$, proxies for the risk absorption capacity of the market-making sector. Henceforth, we interchangeably refer to λ as market illiquidity, market depth and absorption capacity. Since the market-making sector is risk averse and requires compensation for assuming the risky asset at the interim date, the asset price falls short of its expected value by an amount λs. A higher λ corresponds to a lower absorption capacity of the market makers so that sales by the risk-neutral traders have a greater price impact: the market becomes illiquid.

2.1 Uncertain market liquidity

In reality, market makers dynamically manage their asset inventory over time and provide prices to the market commensurate with the assessed price risk to their trading book. To prevent adverse market reactions to their trading, market makers have a vested interest in keeping their inventory concealed from public view.

In our model, the absorption capacity of the market-making sector is hidden from the risk-neutral traders when they make their trading decisions leaving them uncertain about the state of liquidity in the market. While the short-horizon traders cannot see the market makers' aggregate trading book, they have access to imperfect information about market liquidity. In particular, at the interim date, each risk-neutral trader observes the realization of a private signal

$$\lambda^i = \lambda + \varepsilon^i \tag{2}$$

where λ has a normal distribution with mean y and precision α. The idiosyncratic noise term of trader i is given by the random variable ε^i, which is normally distributed with mean zero and precision β and independent across traders and of λ.

Based on his private signal about market depth, a short-horizon trader decides whether to hold or sell the asset. The price of the asset is determined by the residual demand curve of the long-horizon traders. The game that unfolds between the two risk-neutral traders yields the following payoffs. For each trader, the payoff to trading the asset depends on the liquidity in the market and potentially the trading decision of the other trader.

If both traders hold the asset, they receive its liquidation value at the final date and value it at its discounted value δv, where $\delta \in (0, 1)$. If one trader sells his asset holdings ($s = 1$) while the other holds, the seller receives the transaction price $v - \lambda$[6] while the trader who attempts to "wait out the storm" is stopped out at b.[7] If both traders sell out, their payoffs are uncertain and driven by a random execution of their sell orders. The traders have no control over the sequence in which orders are executed. We assume that a trader's place in the queue for execution is equally likely to be first or second. The trader who is executed first sells at the transaction price $v - \lambda$ while the trader who comes in second in line fetches b. In the case of a simultaneous sell-off by both traders, any given trader can therefore expect to fetch $\frac{1}{2}(v-\lambda)+\frac{1}{2}b$. We summarize the payoffs in table 1.

		Trader B	
		Hold	Sell
Trader A	Hold	$\delta v,\ \delta v$	$b,\ v-\lambda$
	Sell	$v-\lambda,\ b$	$\frac{1}{2}(v-\lambda)+\frac{1}{2}b,\ \frac{1}{2}(v-\lambda)+\frac{1}{2}b$

Table 1: Payoffs in the two-trader game

2.2 Equilibrium

We now solve for the equilibrium in this trading game. The focus is on the traders' decisions at the interim date. We first analyze the case when market depth is common knowledge among traders. Then, if market illiquidity is extreme, the game has unique outcomes. In particular, if market illiquidity is very high so that the highest possible payoff from selling is less than the lowest possible payoffs from holding, that is when

$$\frac{1}{2}(v-\lambda)+\frac{1}{2}b<b \iff \lambda>v-b$$

holding is the dominant action for both traders. If, on the contrary, market illiquidity is extremely low so that the lowest possible payoff from selling exceeds the highest possible payoff from holding, that is when

$$\frac{1}{2}(v-\lambda)+\frac{1}{2}b>\delta v \iff \lambda<(1-2\delta)\,v+b$$

the traders' optimal action is to sell the asset.

For intermediate values of λ, the game has multiple equilibria and hence we can no longer provide a definitive prediction of the outcome. Specifically, there are two (pure-strategy) equilibria in which both traders either sell or hold the asset. This indeterminacy is largely due to the self-fulfilling nature of a trader's belief in an imminent sell-off. If traders believe that the asset will come under attack, their actions in anticipation of the fall precipitate the sell-off itself. Conversely, if they believe that the asset is not in danger of an attack, their inaction spares the asset from attack, thereby vindicating their initial beliefs. Carlsson and Van Damme (1993) showed how introducing noise into the payoffs of such a game can relax the strong dependence of a player's action on his belief about the actions of others and as a result restore uniqueness of equilibrium. Imperfect information about market liquidity achieves this in our model.

In the two-trader game, each trader decides whether to hold or sell the asset based on his signal λ^i. Trader i's strategy is a function

$$\lambda^i \longmapsto \{hold,\ sell\}$$

that maps the signal realization λ^i to a trading decision. When illiquidity is expected to be extreme, a trader has a dominant action. When illiquidity is expected to be very low (liquidity is high) so that the price impact of a trade is low, a trader's dominant action is to sell. Specifically, selling is a dominant action for trader i who observes a signal $\lambda^i \leq \underline{\lambda}$, where $\underline{\lambda}$ is defined by

$$E\left[\tilde{\lambda}|\underline{\lambda}\right] = (1 - 2\delta)\, v + b$$

Conversely, when illiquidity is expected to be very high so that selling comes at a substantial cost, a trader's dominant action is to hold. This happens when his signal is $\lambda^i \geq \overline{\lambda}$, where $\overline{\lambda}$ is such that

$$E\left[\tilde{\lambda}|\overline{\lambda}\right] = v - b$$

Since both λ and λ^i are normally distributed, a trader's updated belief about λ upon observing signal λ^i is

$$E\left[\tilde{\lambda}|\lambda^i\right] = \frac{\alpha y + \beta\lambda^i}{\alpha + \beta}$$

The critical signal values that determine the dominance regions are then given by

$$\overline{\lambda} = \left(1 + \frac{\alpha}{\beta}\right)(v - b) - \frac{\alpha}{\beta}y$$

and

$$\underline{\lambda} = \left(1 + \frac{\alpha}{\beta}\right)\left[(1 - 2\delta)\, v + b\right] - \frac{\alpha}{\beta}y$$

For intermediate values of a trader's signal that satisfy

$$(1 - 2\delta)\, v + b < E\left[\tilde{\lambda}|\lambda^i\right] < v - b \tag{3}$$

a trader's action depends on the trading decision of the other trader. Condition (3) holds provided

$$\delta v > b \tag{4}$$

Using global game techniques, we can characterize a unique equilibrium in the trading game. A trader's strategy is a rule of action that prescribes an action for every realization of his private signal. We will solve for an equilibrium in threshold strategies where the equilibrium strategy is given by

$$\lambda^i \mapsto \begin{cases} hold & if\ \lambda^i > \hat{\lambda} \\ sell & if\ \lambda^i \leq \hat{\lambda} \end{cases}$$

For trader i who observes private signal λ^i, the expected utilities of holding and selling the asset respectively are given by

$$u^H = \left[1 - q\left(\lambda^i\right)\right] \delta v + q\left(\lambda^i\right) b \tag{5}$$

and

$$u^S = \left[1 - q\left(\lambda^i\right)\right] E\left[v - \tilde{\lambda}|\lambda^i\right] + q\left(\lambda^i\right)\left(\frac{1}{2}E\left[v - \tilde{\lambda}|\lambda^i\right] + \frac{1}{2}b\right) \tag{6}$$

with $q\left(\lambda^i\right) = \Pr\left(\lambda^j \leq \hat{\lambda}|\lambda^i\right)$ where the argument is trader i's signal realization. q denotes trader i's belief that trader j sells conditional on receiving signal λ^i. λ^i has a normal distribution with mean y and variance $\frac{1}{\alpha} + \frac{1}{\beta}$. Using results for conditional distributions, we can derive trader i's belief about trader j's signal having observed signal λ^i as

$$\lambda^j|\lambda^i \sim \mathcal{N}\left(\frac{\alpha y+\beta\lambda^i}{\alpha+\beta}, \frac{\alpha+2\beta}{\beta(\alpha+\beta)}\right) \tag{7}$$

The common threshold $\hat{\lambda}$ used by both traders is such that a trader who observes a signal equal to the threshold is indifferent between holding and selling the asset, that is when

$$\left[1-q\left(\hat{\lambda}\right)\right]\delta v+q\left(\hat{\lambda}\right)b=\left[1-q\left(\hat{\lambda}\right)\right]E\left[v-\tilde{\lambda}|\hat{\lambda}\right]+q\left(\hat{\lambda}\right)\left(\frac{1}{2}E\left[v-\tilde{\lambda}|\hat{\lambda}\right]+\frac{1}{2}b\right) \tag{8}$$

Using (7) and after rearranging (8), we can show that there is a unique solution to the indifference condition, which is illustrated in figure 1.

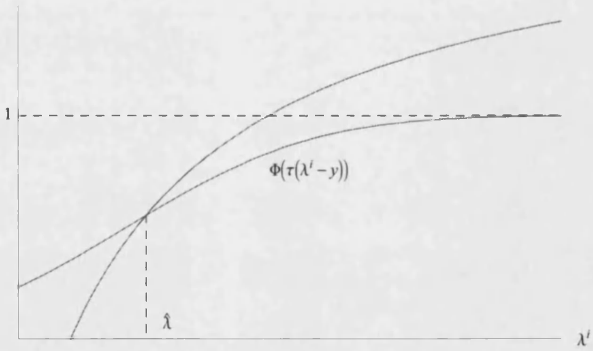


Figure 1: Threshold in unique equilibrium

Proposition 1. *Provided* $\frac{\tau}{\sqrt{2\pi}}<\frac{2\beta[(\alpha+\beta)\delta v-\alpha y]}{[(\alpha+\beta)[(1-2\delta)v+b]-\alpha y]^2}$, *there is an equilibrium in threshold strategies where the threshold* $\hat{\lambda}$ *is given by the unique value* *that solves*

$$\Phi\left(\tau\left(\hat{\lambda}-y\right)\right)=\frac{2\left[(\alpha+\beta)(1-\delta)v-\alpha y-\beta\hat{\lambda}\right]}{(\alpha+\beta)\left[(1-2\delta)v+b\right]-\alpha y-\beta\hat{\lambda}} \tag{9}$$

where $\Phi(\cdot)$ *is the standard normal distribution function and* $\tau=\sqrt{\frac{\alpha}{(\alpha+2\beta)(\alpha+\beta)}}$. *There is no other equilibrium.*

We have shown that if the two traders follow the switching strategy around $\hat{\lambda}$, a trader is indifferent between holding and selling upon observing signal $\hat{\lambda}$. To complete the argument for the equilibrium, we must show that a trader prefers to sell if his signal is below $\hat{\lambda}$ and prefers to hold if his signal is above $\hat{\lambda}$. Figure 2 shows the result graphically.

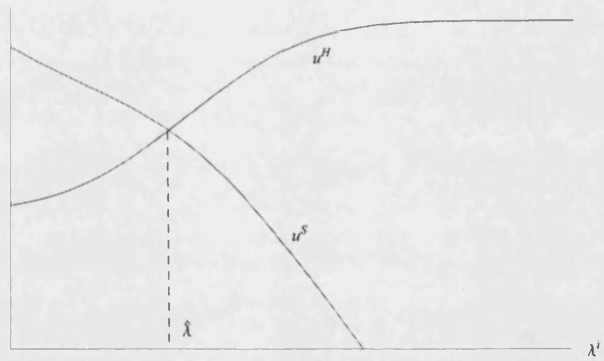


Figure 2: u^H and u^S as a function of trader i's signal λ^i

Since λ^j and λ^i are conditionally independent signals of the common component λ, λ^j and λ^i are positively related. If trader i receives a relatively high (low) signal so will trader j on average. Hence, a higher λ^i reduces the probability that λ^j falls below a given threshold: $q(x)$ is decreasing in x, formally $q'(x)=-\frac{\tau}{\sqrt{2\pi}}\phi(x)<0$. Figure 3 illustrates the idea.

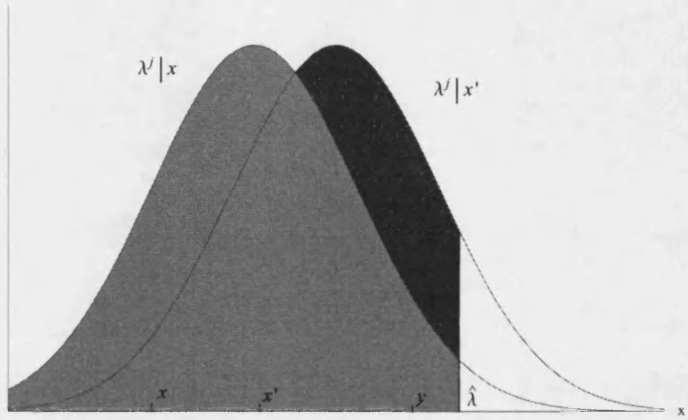


Figure 3: Trader i's beliefs about trader j's sell decision

In the following, we show that u^H is monotonically increasing while u^S is monotonically decreasing in λ^i, a sufficient condition for the uniqueness of the threshold equilibrium.

Trader i's expected utility of holding the asset after observing λ^i is given by (5) and increasing in λ^i given (4)

$$\frac{\partial u^H}{\partial \lambda^i} = -q'\left(\lambda^i\right)\left[\delta v - b\right] > 0$$

His expected utility of selling the asset after observing λ^i, given by (6), is decreasing in λ^i as it is a weighted average with positive weights of terms that are strictly decreasing in λ^i. Formally,

$$\frac{\partial u^S}{\partial \lambda^i} = -\frac{1}{2}\frac{\beta}{\alpha+\beta}\left[\underbrace{2 - q\left(\lambda^i\right)}_{>0} + \underbrace{q'\left(\lambda^i\right)}_{<0}\left[\left(1+\frac{\alpha}{\beta}\right)(v-b) - \frac{\alpha}{\beta}y - \lambda^i\right]\right] < 0$$

where the term in the inner parentheses is positive for small λ^i and receives vanishing weight, $q'(\lambda^i)$, in the expression as λ^i grows larger.

In this game, traders adopt a pre-emptive liquidation strategy. The intuition for this result is that a trader anticipates the adverse consequences of a sale by his opponent. A pre-emptive selling strategy of the other trader must be met by a pre-emptive selling strategy on my part. In equilibrium, both traders adopt a pre-emptive selling strategy because the other does so. The fear of being left holding the hot potato and facing certain dismissal over it drives me to act pre-emptively to keep my chance of staying in the job alive thereby causing the sell-off. While pre-emptive selling is in each trader's best interest individually, the traders harm one another in so doing. If the traders could coordinate on holding the asset, both of them would be better off: holding by both traders is the equilibrium with the highest possible payoffs for both traders if and only if

$$\delta v > \frac{1}{2}\left(v - E\left[\tilde{\lambda}|\hat{\lambda}\right]\right) + \frac{1}{2}b$$

which holds by condition (3) for the lower dominance cutoff since $\hat{\lambda} > \underline{\lambda}$.

Our analysis highlights that it is their inability to credibly commit to one another not to sell that leaves both traders to cause the sell-off. The phenomenon of financial market runs is descriptive of episodes marked by a heavily one-sided order flow, rapid price changes, and financial distress on the part of many of the traders. Such phenomena have also been at the center of much debate in recent months on identifying the factors that helped spread and amplify the effects of the financial crisis. An often cited propagator are the interlinkages among financial institutions. The argument held that while potentially beneficial for the diversification of risks, a closely interlinked system invites the evil of contagion: the more tightly interconnected financial institutions are, the higher the chance that a shock could propagate through the system and bring an otherwise unaffected institution to its knees. Our analysis adds to the debate by demonstrating that benefits of an interconnected financial system may arise even in the case of perfectly correlated risks. In fact, we demonstrate that financial institutions with similar risk exposure may find it optimal to choose a critical degree of interconnectedness to eliminate the adverse consequences of liquidity black holes.

2.3 Cross exposures

In the game with two traders, we see that each trader individually has an incentive to pre-emptively sell the asset if he believes the other trader is likely to do so. Since both traders find themselves in the same situation, they act in concert thereby causing the sell-off. Each trader would be better off if he could credibly commit to the other not to sell. One way to achieve this commitment is to internalize the negative externalities that each trader causes the other by pre-emptively selling the asset. The effect can be achieved if the cost to each trader of selling exceeded the benefit. Then, each trader would no longer have an incentive to sell. We argue that sufficiently strong cross exposures are such a commitment device.

Without cross exposures, the traders are only concerned with maximizing the payoff of the asset. In this case, the trader's benefit of pre-emptively selling is the higher expected exit payoff relative to holding. With cross exposures, the trader's decision is based on his overall portfolio payoff. The trader's decision reflects the trade-off between the benefit of recouping a higher exit price weighed against the cost of a lower value of his cross investment when the asset price is depressed as a result of the sale. When the cross investment is high enough, the cost to selling exceeds the benefit. By assuming a critical level of cross exposure, a trader can thus credibly commit to the other trader that he will hold the asset.

We may think of the cross investment either as a stake in the operation of the other trader or a stake in a mutual investment vehicle set up in the name of both traders. The model may thus provide a novel rationale for the creation of a "toxic asset superfund" or "bad bank" as initially proposed by former U.S. Treasury Secretary, Hank Paulson,[8] and more recently considered by his successor, Timothy Geithner,[9] and the German Ministry of Finance.[10]

In the following, we sketch a stylized extension to the base model that captures the intuition laid out above. Formally, we denote by w_i the cross investment of trader i. At the initial date, we assume that trader i arrives with an exogenously determined position of 1 unit in the asset and chooses his cross investment w_i to maximize his overall portfolio payoff. In this stylized setup, by choosing a stake $w_i \in (0, 1)$, trader i exposes his overall portfolio value to the payoff of his direct asset holdings with weight $(1 - w_i)$ as well as to the payoff of trader j's asset holdings with weight w_i. Table 2 summarizes the traders' portfolio payoffs as a function of their cross holdings.[11]

		Trader B	
		Hold	Sell
Trader A	Hold	$\delta v,\ \delta v$	$(1-w_A)\,b + w_A\,(v-\lambda)\,,\ (1-w_B)\,(v-\lambda) + w_B b$
	Sell	$(1-w_A)\,(v-\lambda) + w_A b,\ (1-w_B)\,b + w_B\,(v-\lambda)$	$\frac{1}{2}\,(v-\lambda) + \frac{1}{2}b,\ \frac{1}{2}\,(v-\lambda) + \frac{1}{2}b$

Table 2: Payoffs in the two-trader game with cross investments

Table 2 shows how the cross holdings may alter the incentive for traders to sell. Conditional on trader B selling, trader A's best response now depends on w_A making holding optimal if

$$w_A\,(v-\lambda) + (1-w_A)\,b \geq \frac{1}{2}\,(v-\lambda) + \frac{1}{2}b \tag{10}$$

or $w_A \geq \frac{1}{2}$. Since the game is symmetric for the two traders, we have $w_B \geq \frac{1}{2}$. This choice of cross holdings results in the elimination of the (*sell*, *sell*) equilibrium leaving (*hold*, *hold*) as the unique (and overall payoff dominant) equilibrium. We assume that when $w_i = \frac{1}{2}, i = A, B$, both traders prefer to hold.

Proposition 2. *There is an equilibrium in which both traders hold the asset and set* $w_i = \frac{1}{2}$*,* $i = A, B$*.*

In the following, we discuss the analysis and its robustness.

3 Discussion

The financial market run in proposition 1 is caused by the incentive of a trader to sell given a sale by his opponent. This coordinated sell-off leaves both traders worse off where the incentive to pre-emptively sell derives from the interplay of their uncertainty about market liquidity and their trading constraints. Such firm-internal controls and other incentive schemes arise as a response to agency problems within a financial institution, and have merit. However, they are no panacea and may even produce "pernicious effects" to use the words of Jean-Claude Trichet, the head of the European Central Bank (see Trichet (2001)).

One shortcoming of such controls is their effect of shortening the decision horizon of the traders. When traders face similar incentive contracts and risk management constraints, their trading behavior becomes more synchronized with the risk of amplifying market outcomes. Changing the internal incentives may therefore appear as a way to mitigate this mimetic trading behavior. However, it is not obvious that firm-internal incentives could eliminate the run outcome and may not shift the problem elsewhere. Within the model, one may argue that sufficiently raising the traders' severance pay b could dampen their incentive to sell. Such a contract however may not be desirable as it would create strong incentives for traders to gamble. Leaving the possibility of a solution by regulatory intervention aside, our analysis suggests that a market-based solution in the form of an optimally interconnected financial system may bring about stability in a particular market environment. The key and surprising message is that sufficiently strong ties between financial institutions that face *similar risks* may achieve the desired outcome by helping them internalize the negative externalities that are otherwise the result of their strategic trading incentives.

A real effect of financial market runs is the shortening of their decision horizon of financial institutions. In future research, we hope to investigate the consequences of cross exposures as an insurance device for the banking sector. In the case of banks, the shortened decision horizon in tuern may feed back into their ex ante investment choice and affect their liquidity transformation role in the economy. That is, banks may shy away from investing in long-dated, potentially illiquid assets if the costs to liquidation in the short run are high. The formation of sufficiently strong interlinkages may thus help reduce the short-run costs by eliminating runs and make banks more willing to act as liquidity transformers in the economy.

The analysis is carried out for the case of two traders. We use this assumption as a stark simplification of real financial markets. Essential to our model is that the traders have an impact on the market price when executing their trades. While Morris and Shin (2004) have shown how liquidity black holes emerge in a market with a continuum of short-horizon traders, allowing such "small" traders to make cross investments would not eliminate the run equilibrium. Using the interpretation of a mutual investment fund, the reason cross holdings lose their effectiveness as a commitment device in that setup is because the size of trader i's stake becomes vanishingly small as the number of co-investors increases (see footnote 11). The type of asset market we have in mind is therefore one that is dominated by a handful of large institutions, such as investment banks, hedge funds and other investment vehicles, which specialize in the trading of a particular asset, such as loans, CDOs or other structured products.

A Appendix

In this appendix, we complete the proof of proposition 1.

Since the left-hand side of (9) takes values between zero and one and the right-hand side is increasing and reaches two as $\hat{\lambda}$ becomes large, a solution exists. Since the functions on both sides of (9) are increasing but nonlinear in $\hat{\lambda}$, we need to provide conditions under which they only intersect once. A necessary and sufficient condition for the uniqueness of $\hat{\lambda}$ is that the highest possible slope of the left-hand side is less than the highest possible slope of the right-hand side. Figure 4 illustrates a case where this condition is not met and multiple equilibria emerge.

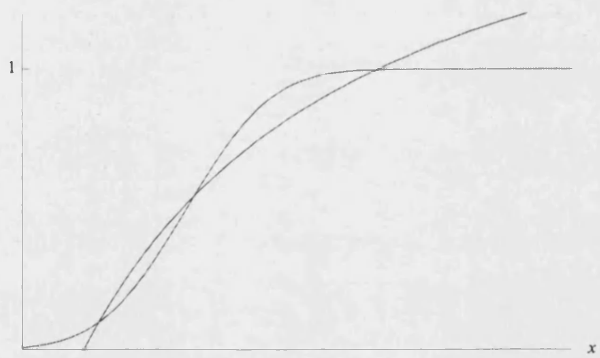


Figure 4: Multiple equilibria

Since the slope of the left-hand side of (9) reaches its maximum at y while the maximal slope of the right-hand side is at zero, the condition for uniqueness of $\hat{\lambda}$ becomes

$$\frac{d}{d\hat{\lambda}}\Phi\left(\tau\left(\hat{\lambda}-y\right)\right)|_{\hat{\lambda}=y}< \frac{d}{d\hat{\lambda}}\frac{2\left[(\alpha+\beta)(1-\delta)v-\alpha y-\beta\hat{\lambda}\right]}{(\alpha+\beta)\left[(1-2\delta)v+b\right]-\alpha y-\beta\hat{\lambda}}|_{\hat{\lambda}=0}$$

This gives the condition in proposition 1. This completes the proof.

Part II

Disclosures, Insider Trading and Incentives

Abstract

This paper models a disclosure-trading game between managers and shareholders. Managers engage in insider trading by optimally divesting their shareholdings in the firm while making disclosures about firm value. Shareholders rationally set the share price based on the information revealed via disclosures and insider trading. Our model endogenizes the decision horizon of managers in a disclosure game with verifiable reports. We investigate under what conditions joint disclosure and insider trading lead to full information revelation. The model is consistent with several empirical findings and has implications for regulation.

"One of the reasons we've got Enron is because we've been increasingly outlawing insider trading, [but] insider trading is the most effective means of making sure a company that does the wrong thing is penalized for doing so."

- Milton Friedman (2003)

B Introduction

One of the main roles of financial markets is the production and aggregation of information. In an efficient market, financial asset prices are driven by and react very swiftly to the arrival of new information. Public information in financial markets however often arrives through the disclosures of interested parties who have a material interest in the reactions of the market to the new information. These parties will seek to exploit their informational advantage when this information affects their objectives.

When shareholders employ managers to run their firm, managers in their role of decision makers inside the firm naturally receive and shape information about the firm first. This information is valuable but not easily credibly communicated to shareholders. The reason is that managers have an incentive to strategically disclose their private information to the market to maximize the stock price of the firm when their compensation is linked to stock price. This incentive is especially pronounced when managers act myopically and the full content of their private information will only eventually come out. As a result, not all available information is immediately revealed and hence not directly reflected in asset prices. The information asymmetry in the market can persist with adverse consequences for shareholders of these firms and for other market participants including managers and shareholders of other firms.

The arrival of timely and precise information is important for shareholders because their decision making depends on this information. For instance, Dow and Gorton (1997), Goldstein and Guembel (2008) and Subrahmanyam and Titman (1999) have argued that managers use the information they learn from stock prices to make better investment decisions. Chen, Goldstein, and Jiang (2007) find empirical support for this hypothesis. Bleck and Liu (2007) point out that more timely information helps shareholders pull the plug on investment projects with deteriorating fundamentals before they are allowed to worsen under the veil of agency conflicts.[12] This finding resonates with the quote by Milton Friedman and the vocal arguments of stakeholders during the Savings & Loans and the recent subprime crises as well as the Enron and Worldcom affairs that suggest that the information about impending trouble could have surfaced much sooner had an adequate mechanism been in place that informed shareholders early on and allowed them to intervene before the crisis occurred.

This paper studies an intuitive and simple mechanism that may provide shareholders with more timely information about the value of the firm. The trading of managers in the securities of their own firm (insider trading) is a key part of this mechanism. To borrow the words of one of the earliest and most outspoken proponents of insider trading, Henry Manne (2005)

"This is not to gainsay that there are also other mechanisms that

> play a significant role in stock pricing, such as the explicit public disclosure of new information, [...] that occurs after some form of market signaling."

In fact, this paper investigates under what circumstances disclosures and insider trading in tandem may produce more information than each mechanism on its own.[13] Under these conditions

> insider trading puts the manager's money where his *report* is

Insiders are not generally interested in revealing their private information. In fact, when outsiders are uncertain about how much information insiders possess, insiders may opportunistically strive to exploit the private information to their advantage.[14] The inevitable manipulability of and inherent leeway in accounting makes this possible and disclosures an imperfect communication device. For instance, Dye (1985) and Shin (2003) show that this leeway coupled with uncertainty about the information endowment of insiders can induce insiders to strategically withhold information. While the resulting disclosures generate stock return patterns that mimic empirical findings (e.g. Black (1976)), it is unclear whether these disclosures would remain unchanged if managers were to simultaneously trade on their private information. In fact, the very attempt to exploit their informational advantage via strategic disclosures may be uncovered as managers try to capitalize on their informational advantage through trading in the firm's securities revealing their private information in the process.[15] In this paper, we examine under what conditions this holds true.

However, concurrent insider trading and disclosures do not always lead to more information revelation when compared to each working on its own. Taken individually, insider trades are just as imperfect a source of information as disclosures are. In our model, trading does not reveal much, if any, information. In particular, when the competition for information in the market is too stiff, trading to reveal information may become too costly for insiders resulting in a lower informativeness of prices.

The model in this paper studies a mechanism that highlights the roles of disclosures and insider trading in revealing information, can shed light on some empirical observations, and has implications for regulation.

First, in the joint mechanism, insider reports inherit their partial effectiveness from their role in isolation and allow the following interpretation: disclosures anchor the market's belief about the trading by managers. When managers may not exaggerate but strategically withhold information furnishing accompanying evidence that will be verified at a later date by a court of law, investors are unable to distinguish uninformed managers from informed managers who withhold information. As a result, investors allow for this uncertainty when setting stock prices. This pooling feeds back into the incentives of the managers. A pooled stock price disadvantages an impatient manager who would like to divest his holdings but is unable to provide evidence that he knows of little or no unfavorable information. To escape this trap of adverse selection, such a manager may signal his ignorance of unfavorable firm prospects to the market by retaining sufficient financial exposure to the firm's value till the verification date. This intuition captures the role of trading in our model. Trading allows the favorably informed manager to add credibility to his disclosure by putting his money where his report is.

In this sense, our setup also highlights how disclosure regulation and signaling interact. Disclosure regulation enhances the credibility of firms' disclosures by imposing ex-post punitive cost on distorted disclosures. Effective disclosure regulation does not induce a deadweight loss because no firms distort their disclosures in equilibrium: the large ex-post penalty serves as a deterrent and is not actually triggered. In contrast, in a signaling equilibrium, a manager who learns of favorable firm prospects may choose to incur a real (wasteful) cost to reveal his information to the market. The model in this paper shows that when the market for information is not too large, disclosures and signaling work as complements in conveying information to the market. This complementarity obtains when reporting occurs at predetermined disclosures dates that are identical for all firms. Such disclosure schedules (e.g. quarterly and annual reporting dates) serve as a coordinating device. When all firms report at the same time, investors can use the information revealed through the reports to discern firms at a given moment in time. The comparability of firm disclosures is weaker or completely lost when reports do not arrive at the same time.

Second, the model suggests circumstances under which insider trading should be allowed around information-sensitive events, so-called "black-out" periods, which include among other events quarterly and annual earnings reporting dates. It is precisely around information-sensitive events that the information asymmetry between firm insiders and outsiders is at its highest and the potential for reducing it greatest. It is then that insider trading could have the biggest impact. By prohibiting insiders from trading around these events, regulators shut down one channel through which more private information could potentially be brought to light. Regulation hence prolongs the persistence of the information asymmetry in the market and prevents shareholders from learning important information early on to be able to take interventive action in a timely manner.

Third, our results can shed light on several empirical findings. Our model can explain the finding by Roulstone (2007) that insider trades and earnings announcements jointly explain stock returns. Roulstone (2007) documents that insider trades disclosed and executed prior to earnings announcements preempt news in the announcement and have a negative relation with market reactions to the announcement. Moreover, our model results resonate with the findings by Gu and Li (2007), who show that the stock price reaction following a disclosure increases when the disclosure is preceded by insider transactions, indicating that predisclosure trades add credibility to disclosures. Lastly, our results are also consistent with the evidence presented by Nagar, Nanda, and Wysocki (2003), who find supporting evidence for their prediction that stock price-based incentives in the form of stock-based compensation and share ownership incentivize managers to publicly disseminate their private information.

Fourth, the model supports the recent efforts of regulators to set high penalties for accounting fraud (Sarbanes-Oxley Act of 2002). The deterrence of fraudulent accounting through (large) ex-post penalties is what guarantees the partial information revelation through reporting in this model.[16]

C Model

The base disclosure framework, and its description henceforth, is due to Shin (2003) and builds on the binomial tree model that was first introduced in the option pricing literature by Cox, Ross, and Rubinstein (1979).

Consider an economy populated with a large number of firms, each of which is headed by a manager. A firm undertakes N independent and identical projects, the outcome of which cannot be influenced by the manager.[17,18] A project succeeds with probability r and fails with probability $1-r$. A success corresponds to an up-move in the tree that raises the liquidation value of the firm by a factor of u and a failure to a down-move by a factor of d, $u > d > 0$, giving a final firm liquidation value after s successes and $N-s$ failures of

$$u^s d^{N-s} \tag{11}$$

There are three dates - *initial*, *interim* and *final* - indexed by 0, 1 and 2 respectively. At the initial date, nothing is known about the projects besides the setup above. By the interim, the outcome of some but not all projects will be revealed to the manager. That is, with probability θ, identical across projects, the manager learns whether a project succeeded or failed; the probability of learning an outcome is independent across projects. At the final date, all uncertainty is resolved and the realizations of all the projects become common knowledge. The firm is then liquidated.

At the interim date, there is differential information between the managers and the shareholders. A manager's informational advantage is the number of project outcomes he and only he observes. Only the manager knows how many projects in his firm were successful and how many failed while the shareholders (and all other managers) do not. Instead, the only information available to the shareholders is the information revealed through a particular mechanism. We consider three mechanisms in turn: 1) an interim report about firm value sent by the manager, 2) an insider trade of the manager, and 3) a combination of an interim report and an insider trade.

The first mechanism takes the role of a disclosure the manager makes to the shareholders. In this interim report, the manager is free to disclose some or all of what he knows, by exhibiting the project outcomes that have already been revealed to him. However, the manager cannot concoct false evidence. If he knows that a project has failed (succeeded), he cannot claim that it has succeeded (failed). In this sense, although the manager has to tell the truth, he cannot be forced to tell the whole truth. The implicit understanding is that the manager's disclosures are verifiable at a later date by a third party, such as a court, that is able to impose a very large penalty if the earlier disclosure is exposed to be untrue, that is inconsistent with evidence made available by the manager. But how much private information the manager has at the time of disclosure is not verifiable even at a later date. So the manager is free to withhold information if such information is deemed to be unfavorable.[19]

More formally, the information available to the manager at the interim date can be summarized by the pair (s, f), the manager's type, where s is the number of observed successes and f the number of observed failures. Figure (5) shows the private information $s_1 = (s, f)$ the managers observe by T_1 in the case of $N = 2$ projects.

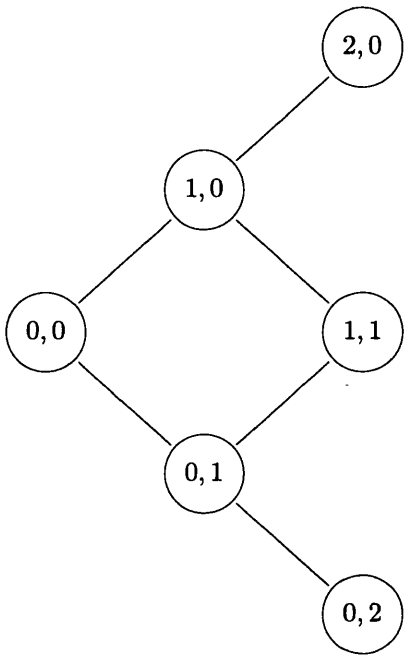


Figure 5: Ex-post Private Signals $s_1 = (s, f)$ at T_1 when $N = 2$

The manager's disclosure strategy $m(\cdot)$ maps his information (s, f) to the pair (s', f'), giving the number of disclosed successes and failures, where the requirement of verifiability imposes the constraint

$$s' \leq s \text{ and } f' \leq f \tag{12}$$

This constraint reflects the requirement that the disclosure takes the form of actually exhibiting a subset of the realized outcomes to the market.[20] This assumption intends to capture the notion that managers have some degree of leeway in their reporting choice. In choosing his disclosure strategy, the objective of the manager is to maximize the interim share price V_1.

The second mechanism is the insider trade of the manager. At the initial date, the manager is given a_0 shares in the company. After receiving the private signal about terminal firm value s_1, the manager has an opportunity to trade shares in the market at the interim date. Any remaining shares the manager retains to the final date will then be paid out of the firm's liquidation proceeds.

We assume the manager is motivated by maximizing the revenue he derives from trading shares in his firm over time. More specifically, the manager's utility is the sum of the cash flow at the interim date, the number of shares traded a_1 at the interim share price V_1, and the discounted cash flow at the final date, the manager's remaining position in the firm's stock $a_0 - a_1$ traded at the expected final-date share price V_2

$$u(a_1; s_1) = a_1 V_1(a_1) + \delta(a_0 - a_1) E[V_2(\tilde{s}_2) | s_1] \tag{13}$$

where $\delta \in (0, 1)$ is a commonly known discount factor for final-date cash flows. The discount factor captures the notion that selling shares in the future at T_2 relative to the present at T_1 is costly. We interpret the discount factor as a holding cost common to all managers.[21]

Together with the differential private information across managers, it is this trading cost that forms the basis for the signaling game played through insider trading. The private information of managers shapes the differential signaling cost of trading through their expectation of terminal firm value. More specifically, a manager who observes s successes and f failures by the interim, that is $s_1 = (s, f)$, values the terminal liquidation value of his firm as seen from the interim date at its expected value computed from the binomial density with success probability r

$$\begin{aligned} E\left[V_2\left(\tilde{s}_2\right) \mid (s,f)\right] &= u^s d^f \sum_{n=0}^{N-s-f} \begin{pmatrix} N-s-f \\ n \end{pmatrix} (ru)^n \left((1-r)\, d\right)^{N-s-f-n} \\ &= u^s d^f \left[ru + (1-r)\, d\right]^{N-s-f} \end{aligned}$$

The third mechanism is a combination of the first two. The manager holds a_0 shares in the company and makes an interim report about the value of the firm to shareholders. We assume the manager's objective is to maximize his share trading revenue over time by choosing his share trade and interim firm value report[22]

$$u\left(a_1, m_1; s_1\right) = a_1 V_1\left(a_1, m_1\right) + \delta\left(a_0 - a_1\right) E\left[V_2\left(\tilde{s}_2\right) |s_1\right] \tag{14}$$

Since the initial and the final share prices of the firm are based on symmetric information, the focus of the analysis will be on the interim price V_1. The interim share price will be the result of the competitive interaction of managers who seek to optimally capitalize on their informational advantage vis-à-vis shareholders via disclosures and/or share trading. The shareholders, however, anticipate the managers' strategies, and price the firms in accordance with the information revealed by the managers' disclosures and/or trading. This gives rise to a game of incomplete information. We will model the shareholders as a player (the "market") in the game who sets the price of the firm to its actuarially fair value based on all the available evidence, taking into consideration the reporting and/or the trading strategies of the manager.

More formally, the shareholders' strategy is the pricing function

$$\Upsilon \mapsto V_1$$

where Υ denotes the particular mechanism considered, that is $\Upsilon \in \{a_1, m_1, (a_1, m_1)\}$. We ensure that the shareholders aim to set the price of the firm to its actuarially fair value by assuming that their objective in the game is to minimize the squared loss function

$$(V_1 - V_2)^2 \tag{15}$$

where V_2 is the (commonly known) liquidation value of the firm at the final date. In other words, the shareholders set V_1 equal to the expected value of V_2 conditional on the information revealed by the disclosure and/or trade of the manager.

The shareholders are assumed to be risk averse with coefficient of relative risk aversion α $(> 0, \neq 1)$. This assumption corresponds to the Von Neumann-Morgenstern utility function $u(c) = \frac{c^{1-\alpha}}{1-\alpha}$. The pricing of the firm thus takes the form of a weighted average of future project outcomes weighted by the state prices. Each state price is proportional to the product of the probability of that state occurring and the marginal utility of consumption $u'(c) = c^{-\alpha}$ in that state, where the constant of proportionality is chosen so that the state prices sum to one. The state price at T_0 for the outcome with

s successes at the final date is

$$\frac{\begin{pmatrix} N \\ s \end{pmatrix} r^s (1-r)^{N-s} \left(u^s d^{N-s}\right)^{-\alpha}}{\sum_{n=0}^{N} \begin{pmatrix} N \\ n \end{pmatrix} r^n (1-r)^{N-n} \left(u^n d^{N-n}\right)^{-\alpha}}$$

Hence the share price at the initial date is given by

$$\begin{aligned}
V_0 &= \frac{\sum_{s=0}^{N} \begin{pmatrix} N \\ s \end{pmatrix} r^s (1-r)^{N-s} \left(u^s d^{N-s}\right)^{1-\alpha}}{\sum_{n=0}^{N} \begin{pmatrix} N \\ n \end{pmatrix} r^n (1-r)^{N-n} \left(u^n d^{N-n}\right)^{-\alpha}} \\
&= \frac{\left[r u^{1-\alpha} + (1-r)\, d^{1-\alpha}\right]^N}{\left[r u^{-\alpha} + (1-r)\, d^{-\alpha}\right]^N} \times \\
&\quad \frac{\overbrace{\sum_{s=0}^{N} \begin{pmatrix} N \\ s \end{pmatrix} \left(\frac{r u^{1-\alpha}}{r u^{1-\alpha} + (1-r)\, d^{1-\alpha}}\right)^s \left(\frac{(1-r)\, d^{1-\alpha}}{r u^{1-\alpha} + (1-r)\, d^{1-\alpha}}\right)^{N-s}}^{=1}}{\underbrace{\sum_{n=0}^{N} \begin{pmatrix} N \\ n \end{pmatrix} \left(\frac{r u^{-\alpha}}{r u^{-\alpha} + (1-r)\, d^{-\alpha}}\right)^n \left(\frac{(1-r)\, d^{-\alpha}}{r u^{-\alpha} + (1-r)\, d^{-\alpha}}\right)^{N-n}}_{=1}} \\
&= \left[\frac{r u^{1-\alpha} + (1-r)\, d^{1-\alpha}}{r u^{-\alpha} + (1-r)\, d^{-\alpha}}\right]^N
\end{aligned}$$

Defining the constant

$$r_\alpha \equiv \frac{ru^{-\alpha}}{ru^{-\alpha} + (1-r)\,d^{-\alpha}} \tag{16}$$

we can write the initial share price as

$$V_0 = \left[r_\alpha u + (1-r_\alpha)\,d\right]^N$$

D Equilibrium

The analysis centers around the question of how and to what extent the disclosure and/or trading games reveal the private information of managers. The analysis is divided into four parts. The first part states the benchmark full-information equilibrium that results when all project outcomes are common knowledge. Parts two to four discuss the asymmetric information cases where the sole source of information is either the disclosure by the manager or his share trade, and where shareholders can potentially infer information from both the disclosure and the share trading by the manager.

D.1 Symmetric information

Suppose all project outcomes are common knowledge. Then there is no information asymmetry and the shareholders perfectly know the manager's type. Neither a disclosure nor insider trading by the manager will reveal any additional information to the market. In this case, disclosure is redundant, and insider trading plays no strategic role; the manager can choose his revenue-maximizing trading policy.

Proposition 3. *When all project outcomes* (s, f) *are common knowledge, every manager divests his entire shareholdings at the interim date setting* $a_1^{FI}(s, f) = a_0$ *for all* s, f *when* $\delta < \frac{\rho_\alpha(s,f)}{\rho(s,f)}$*. The share price equals* $V_1(s, f) = u^s d^f [r_\alpha u + (1 - r_\alpha) d]^{N-s-f}$.

Intuitively, the manager divests all his shares at the interim date when selling shares at the final date is sufficiently costly, that is when $V_1(s, f) > \delta E[V_2(\tilde{s}_2) \mid (s, f)]$ or $\delta < \frac{V_1(s,f)}{E[V_2(\tilde{s}_2)|(s,f)]}$.

When the realized project successes and failures are common knowledge, the full-information share price is computed from the residual uncertainty over the remaining project outcomes given (s, f) by incorporating the risk aversion of shareholders in the form of state prices. Conditional on s realized successes and f realized failures at T_1, the state price for the outcome with $s + k$ successes at the final date is

$$\frac{\begin{pmatrix} N-s-f \\ k \end{pmatrix} r^k (1-r)^{N-s-f-k} \left(u^{s+k} d^{N-s-f-k}\right)^{-\alpha}}{\sum_{n=0}^{N-s-f} \begin{pmatrix} N-s-f \\ n \end{pmatrix} r^n (1-r)^{N-s-f-n} \left(u^{s+n} d^{N-s-f-n}\right)^{-\alpha}}$$

Hence the share price at the interim date conditional on s realized successes and f realized failures equals

$$
\begin{aligned}
V_1(s,f) &= \frac{u^s d^f \sum_{n=0}^{N-s-f} \begin{pmatrix} N-s-f \\ n \end{pmatrix} r^n (1-r)^{N-s-f-n} \left(u^{s+n} d^{N-s-f-n}\right)^{1-\alpha}}{\sum_{n=0}^{N-s-f} \begin{pmatrix} N-s-f \\ n \end{pmatrix} r^n (1-r)^{N-s-f-n} \left(u^{s+n} d^{N-s-f-n}\right)^{-\alpha}} \\
&= u^s d^f \left[\frac{ru^{1-\alpha} + (1-r) d^{1-\alpha}}{ru^{-\alpha} + (1-r) d^{-\alpha}}\right]^{N-s-f}
\end{aligned}
$$

Using the definition of r_α from (16), we can write and denote the full-information interim share price following (s,f) as

$$
\rho_\alpha(s,f) = u^s d^f \left[r_\alpha u + (1-r_\alpha) d\right]^{N-s-f}
$$

where the subscript α indicates the risk aversion parameter of the shareholders. Note that r_α is lower than the success probability r for $\alpha > 0$ and equal to r in the case of risk neutrality, that is when $\alpha = 0$. That is, the risk-averse shareholders attach a lower weight to a successful outcome relative to the case of risk neutrality. Conversely, when all project outcomes are common knowledge and the shareholders are risk neutral, the shareholders place equal weight on the final firm liquidation value as seen from T_1 as the manager. With a slight abuse of notation, we thus write $\rho(s,f) = E\left[V_2(\tilde{s}_2) \mid (s,f)\right]$ for the manager's expectation of firm liquidation value conditional on observing s success and f failures by the interim.

D.2 Asymmetric information

D.2.1 Disclosures

The discussion of the disclosure equilibrium is due to Shin (2003) and we summarize the key features of his analysis in the following.

One immediate conclusion we can draw is that a policy of full disclosure by the manager can never be part of any equilibrium when the only communication device is an interim report. To see this, suppose that the manager always discloses truthfully, so that the disclosure strategy is the identity function

$$m_1(s,f) = (s,f)$$

The best reply by the market is to set V_1 to

$$V_1(s,f) = u^s d^f \left[r_\alpha u + (1-r_\alpha)d\right]^{N-s-f} \tag{17}$$

since there are $N-s-f$ unresolved projects, and the expected value of the firm is

$$\begin{aligned} & u^s d^f \sum_{i=0}^{N-s-f} \begin{pmatrix} N-s-f \\ i \end{pmatrix} (r_\alpha u)^i \left((1-r_\alpha)\, d\right)^{N-s-f-i} \\ = \quad & u^s d^f \left[r_\alpha u + (1-r_\alpha)\, d\right]^{N-s-f} \end{aligned}$$

But then, the manager's disclosure policy is sub-optimal, since the feasible disclosure $(s,0)$ that suppresses all failures elicits the price

$$u^s \left[r_\alpha u + (1-r_\alpha)\, d\right]^{N-s} \tag{18}$$

which is strictly greater than (17) for positive f. Hence, we are led to a contradiction if we suppose that full disclosure can figure in an equilibrium of the disclosure game.

Having ruled out full disclosure, a natural place to turn next is to go the opposite extreme and consider the strategy in which all successes but none of the failures are disclosed. This is the strategy that maps (s, f) to $(s, 0)$. Shin dubs it the *sanitization strategy* in that the disclosure is sanitized by removing the bad news but leaving all the good news. The author then shows that this strategy can, indeed, be supported in equilibrium. Under the constraint of verifiability, the sanitization strategy is optimal for the manager whenever the pricing rule is monotonic in the sense that, if $(s, -f) \geq (s', -f')$ then

$$V_1(s, f) \geq V_1(s', f')$$

Under the sanitization strategy, the manager's disclosure at the interim date still leaves some residual uncertainty about the true value of the firm. The shareholders can only distinguish some firms, those whose sanitized disclosures differ in the number of reported successes. However, the shareholders cannot perfectly distinguish the different firms. Those managers who observed the same number of successful but a different number of failed projects issue identical sanitized reports making it impossible for the shareholders to distinguish them. The shareholders therefore allow for some pooling between managers who are not always fully informed and managers who are withholding information.[23] The market reflects this residual uncertainty in the share price by discounting the potential future successes more heavily.

Formally, risk-neutral shareholders value a potential future success at price $q < r$

$$q \equiv \frac{r - \theta r}{1 - \theta r} \tag{19}$$

Higher skepticism, a higher θ, leads to a lower valuation by the market, a lower q. When the shareholders are risk-averse and the manager follows the sanitization strategy, the share price is given by the conditional expected value obtained from a binomial density in which the probability of success of an undisclosed project is q_α

$$V_1(s) = u^s \left[q_\alpha u + (1 - q_\alpha) d\right]^{N-s} \tag{20}$$

where $q_\alpha = \frac{qu^{-\alpha}}{qu^{-\alpha} + (1-q)d^{-\alpha}}$.

Proposition 4. *(Shin (2003)) There is a Sequential Equilibrium in which the manager uses the sanitization strategy. Moreover, in any equilibrium in which the manager uses the sanitization strategy,* $V_1(s) = u^s \left[q_\alpha u + (1-q_\alpha)d\right]^{N-s}$.

In this equilibrium, pooling is the result of the managers' inability to credibly communicate their private information perfectly to the market. This inability hurts managers with more favorable information, who are unable to provide proof that they do not know of much if any bad news, and benefits managers with less favorable information. Given the ubiquity of share-based compensation of managers in reality, the natural incentive of managers with less favorable information is to exploit the information asymmetry in the market (and the overvaluation of their firm's stock) by selling their shares before their true information is eventually and inevitably revealed.

Our model (14) shows that the setup of the disclosure game in Shin (2003), that is the manager's objective of maximizing the interim share price, can be interpreted as assuming that the manager acts myopically and sells all his shares at the interim date. In other words, in Shin (2003) trading is assumed exogenous and identical for all managers. Knowing that his true information will eventually come out, a manager who knows of more favorable prospects for his firm may however be willing to expose the value of his stake in the firm more to firm value in the future. If perceived as credible by the market, having greater exposure to future firm value will then reveal additional information. In the next section, we make explicit the game when managers both disclose information pertinent to firm value and trade on this information. Our model thus endogenizes the trading decision of managers in the model by Shin (2003).

D.2.2 Disclosures and insider trading

In the following, we construct an equilibrium that illustrates the roles of insider trading and disclosures in the disclosure-trading game. We will now show that firm value disclosures and insider trading together may be sufficiently powerful to expose all the private information of managers.

Proposition 5. *There exists a Perfect Bayesian Equilibrium in the disclosure-trading game at T_1 in which the manager follows the sanitization strategy and sells $a_1^{DT}(s,f) = a_0 \prod_{n=0}^{N-s-f-1} \left[\frac{\rho_\alpha(s,f+n+1)-\delta\rho(s,f+n+1)}{\rho_\alpha(s,f+n)-\delta\rho(s,f+n+1)}\right]$ shares at interim share price $V_1\left(a_1^{DT}, m_1^{DT}\right) = u^s d^f \left[r_\alpha u + (1-r_\alpha) d\right]^{N-s-f}$, provided $\delta < \frac{\rho_\alpha(s,f)}{\rho(s,f-1)}$, $N \leq \overline{N}$ and $\rho_\alpha(s,f) > \rho_\alpha(s-1,f-1)$.*

To illustrate the intuition behind the equilibrium, we analyze it in the simplest interesting case of $N = 2$ and later discuss the general case.

The problem of solving for the equilibrium in the presence of $N = 2$ projects can be broken down into $N + 1 = 3$ sub-problems, the structure of which remains the same in each one. The reason for this simplification is the disclosure channel of the game. In this disclosure-trading equilibrium, managers partially separate through their disclosures and fully reveal their type through insider trading. Since all managers report all of their observed successes truthfully, withholding any observed failures, shareholders can only distinguish those managers who report a different number of successes. That is, for any given number of disclosed successes, shareholders are left with residual uncertainty as to exactly how many failures a manager observed. Disclosures thus group managers into sub-sets. Within each set characterized by the same number of reported successes, the incentive of those managers with a lower number of observed failures to separate themselves from those with more bad news gives rise to a game of incomplete information played through insider trading.

In the model with $N = 2$ projects, there are six types of manager as seen in figure 5. The first set is a singleton containing only the manager who observed two successes $(2, 0)$. In equilibrium, he discloses his type truthfully by reporting two successes and divests all his shares at the interim date, that is he sets $\left(a_1^{DT}(2,0) = a_0, m_1^{DT}(2,0) = (2,0)\right)$. Since no other type can mimic his report by the constraint of verifiability, the manager uniquely identifies himself via his disclosure. His trading therefore carries no incremental information and the manager is free to choose his trading unconstrained by any strategic concerns. Divesting his entire shareholdings at the interim is the manager's optimal action given a sufficiently high cost of holding shares to the final date.

The second set contains two types of manager: $(1,0)$ and $(1,1)$. Since the structure of the game in this set is similar but less general compared to the one in the third set, we only present the detailed analysis of the third set here and return to the strategies of types $(1,0)$ and $(1,1)$ afterwards. To ease notation, denote by the superscripts H, M and L the manager types who observe no success and no failure $s_1^H = (0,0)$, no success and one failure $s_1^M = (0,1)$, and no success and two failures $s_1^L = (0,2)$ by the interim.

Suppose that all managers disclose sanitized reports in equilibrium (we will return to the equilibrium choice of disclosures below). An equilibrium that reveals the managers' private information then exists in this case if the managers find it mutually optimal to choose distinct numbers of shares traded and firm value messages $\left(a_1^H, m_1^H\right)$, $\left(a_1^M, m_1^M\right)$ and $\left(a_1^L, m_1^L\right)$, where $m_1^i = (0,0)\,,\, i = H, M, L.$

In order to determine the existence of the share trading component of the disclosure-trading equilibrium, we need to show that every manager, within the set of managers who disclose the same number of successes, finds it optimal to trade a distinct number of shares given the trading of the other managers in this set. Full separation requires that three pairs of incentive compatibility constraints for each pairwise combination of managers be satisfied. However, the number of constraint pairs can be reduced to two since separation between s_1^H and s_1^M and between s_1^M and s_1^L implies separation between s_1^H and s_1^L. The equilibrium share trading then results from solving a manager's maximization program subject to incentive compatibility constraints for the trading of the other two managers in this set. Starting with the manager of type H, his optimal trade maximizes his trading revenue given that managers M and L find it optimal to reveal themselves through trading. Formally,[24]

$$
\begin{aligned}
\max_{a_1^H \in [0,a_0]} \quad & a_1^H \rho_\alpha(0,0) + \delta\left(a_0 - a_1^H\right)\rho(0,0) \\
s.t. \quad & a_1^H \rho_\alpha(0,0) + \delta\left(a_0 - a_1^H\right)\rho(0,1) \\
& \leq \hat{a}_1^M \rho_\alpha(0,1) + \delta\left(a_0 - \hat{a}_1^M\right)\rho(0,1)
\end{aligned}
$$

where $\hat{a}_1^M$ solves

$$
\begin{aligned}
\max_{a_1^M \in [0,a_0]} \quad & a_1^M \rho_\alpha(0,1) + \delta\left(a_0 - a_1^M\right)\rho(0,1) \\
s.t. \quad & a_1^M \rho_\alpha(0,1) + \delta\left(a_0 - a_1^M\right)\rho(0,2) \\
& \leq a_0 \rho_\alpha(0,2)
\end{aligned}
$$

In the first maximization problem, type H's optimal trade $\hat{a}_1^H$ should be such that type M prefers to trade $\hat{a}_1^M$ shares at his full-information share price $\rho_\alpha(0,1)$ rather than a_1^H shares at the higher share price of type H, $\rho_\alpha(0,0)$. At the same time, $\hat{a}_1^M$ should also optimally deter type L from trading a_1^M shares at type M's full-information share price $\rho_\alpha(0,1)$ rather than a_0 shares at his full-information share price $\rho_\alpha(0,2)$. The reason that type L trades a_0 shares is that, given revelation of his type in equilibrium and him being the lowest type in this set, incurring a cost by holding shares to the final date is a waste for him. Type L therefore takes his least-cost action and divests fully at date 1. The solution $\left(\hat{a}_1^H, \hat{a}_1^M, \hat{a}_1^L\right)$ to this program is then given by

$$\left(\hat{a}_1^M \left[\frac{\rho_\alpha(0,1) - \delta\rho(0,1)}{\rho_\alpha(0,0) - \delta\rho(0,1)}\right], \hat{a}_1^L \left[\frac{\rho_\alpha(0,2) - \delta\rho(0,2)}{\rho_\alpha(0,1) - \delta\rho(0,2)}\right], a_0\right)$$

or

$$\left(a_0 \left[\frac{\rho_\alpha(0,1) - \delta\rho(0,1)}{\rho_\alpha(0,0) - \delta\rho(0,1)}\right] \left[\frac{\rho_\alpha(0,2) - \delta\rho(0,2)}{\rho_\alpha(0,1) - \delta\rho(0,2)}\right], a_0 \left[\frac{\rho_\alpha(0,2) - \delta\rho(0,2)}{\rho_\alpha(0,1) - \delta\rho(0,2)}\right], a_0\right)$$

Combining $\hat{a}_1^H$, $\hat{a}_1^M$ and $\hat{a}_1^L$, we notice that

$$0 < \hat{a}_1^H < \hat{a}_1^M < \hat{a}_1^L = a_0$$

since $\frac{\rho_\alpha(0,f+1) - \delta\rho(0,f+1)}{\rho_\alpha(0,f) - \delta\rho(0,f+1)} \in (0,1)$, provided holding shares to the final date is sufficiently costly, that is $\delta < \frac{\rho_\alpha(0,f)}{\rho(0,f+1)}$. Equivalently for the subset of types with one observed success, type $(1,0)$ forces type $(1,1)$ to reveal himself and divest fully by choosing to sell a number of shares equal to

$$\hat{a}_1(1,0) = a_0 \left[\frac{\rho_\alpha(1,1) - \delta\rho(1,1)}{\rho_\alpha(1,0) - \delta\rho(1,1)}\right]$$

Generalizing to the case of $s_1 = (s,f)$, share trading in this disclosure-trading (DT) equilibrium satisfies

$$a_1^{DT}(s,f) = a_0 \prod_{n=0}^{N-s-f-1} \left[\frac{\rho_\alpha(s,f+n+1) - \delta\rho(s,f+n+1)}{\rho_\alpha(s,f+n) - \delta\rho(s,f+n+1)}\right] \tag{21}$$

So far, we fixed the disclosure strategy of the managers as the sanitization strategy. Sanitization is in fact (weakly) optimal in this equilibrium provided $\rho_\alpha(s,f) > \rho_\alpha(s-1,f-1)$. This condition ensures that type (s,f) has no incentive to withhold an observed success. For example, in figure 5, type $(1,1)$ does not find it optimal to report $(0,0)$ given $\rho_\alpha(1,1) > \rho_\alpha(0,0)$. To see the (weak) optimality of sanitized reports, first observe that the disclosed number of observed failures is immaterial given full disclosure of all observed successes and separation via trading. In the separating equilibrium described above, the lowest type in a message set, $(s, N-s)$, divests all his shares thus incurring no signaling cost. Since sending messages is costless, the lowest type is indifferent between withholding any of his observed failures and reporting his type truthfully. In this case, we assume the manager withholds his observed failures in case other set members tremble by disclosing a failure by mistake and selling an insufficient number of shares. This way, the lowest type could threaten to mimic any other type in the set of types with an equal number of observed successes should they not separate through trading. Given the disclosure and trading strategies of the managers, the market responds with the following pricing rule

$$V_1(a_1, m_1) =$$

$$\begin{cases} u^s\left[r_\alpha u + (1-r_\alpha)d\right]^{N-s} \\ \quad if\ \left(\left[0, a_0 \prod_{n=0}^{N-s-1}\left[\frac{\rho_\alpha(s,n+1)-\delta\rho(s,n+1)}{\rho_\alpha(s,n)-\delta\rho(s,n+1)}\right]\right], (s,\forall f')\right) \\ u^s d^f\left[r_\alpha u + (1-r_\alpha)d\right]^{N-s-f} \\ \quad if\ \left(\left(a_0 \prod_{n=0}^{N-s-f}\left[\frac{\rho_\alpha(s,f+n)-\delta\rho(s,f+n)}{\rho_\alpha(s,f+n-1)-\delta\rho(s,f+n)}\right], a_0 \prod_{n=0}^{N-s-f-1}\left[\frac{\rho_\alpha(s,f+n+1)-\delta\rho(s,f+n+1)}{\rho_\alpha(s,f+n)-\delta\rho(s,f+n+1)}\right]\right], (s,\forall f')\right) \end{cases}$$

where the arguments in the conditions should be read as $(a_1 \in \cdot, m_1 = \cdot)$.

In words, within the set of managers who know of no successful project by the interim, managers reveal their private information by retaining "skin in the game" until the final date. This retention effect cascades from the manager with the most favorable information down to the manager with the least favorable information, who divests all his shares. Revelation thus comes at a cost, which is highest for the manager with the best prospects in this set and decreases in firm prospects to zero for the manager with the least favorable information. Therefore, the larger the subset of types who observe the same number of successes is, the more costly it becomes for the types with more favorable information in this set to separate from the other set members. While a (differentially) positive cost is necessary for signaling to work (otherwise holding to the final date is optimal and signaling breaks down), this cost may not be too large as it would otherwise discourage some managers with very good news from separating. Notice also that no restriction on the holding cost (in our setup) is necessary when the market is risk neutral, that is when $\alpha = 0$. However, assuming a risk-averse market expands the parameter set under which this separating equilibrium is played. The reason is that for some parameter values this separating equilibrium is dominated by a pooling equilibrium, which we assume is played in this case. This is because the share price in a pooling equilibrium is lower when the market is risk-averse and decreases in the degree of risk aversion. A lower pooled share price lowers the utility for the types with more favorable information relative to the separating equilibrium inducing play of the pooling equilibrium only under more stringent parameter restrictions.

In the case of $N = 2$, there exists a sequential pooling equilibrium in which managers divest fully and sanitize their reports. The market's pricing rule is given by

$$V_1(a_1, m_1) = \begin{cases} \pi(s; N) & if\ (a_1 = a_0, m_1 = (s, 0)) \\ \rho_\alpha(s, N - s) & if\ (a_1 \neq a_0, m_1 = (s, f \geq 0)) \end{cases}$$

where $\pi(s; N)$ denotes the pooled share price in a type set of s observed successes and N projects, and is given by (20). A necessary condition for this pooling equilibrium to be played is that the payoff in this pooling equilibrium to at least the highest type in a subset with s observed successes dominates this type's payoff in the disclosure-trading equilibrium. This condition is

$$a_1^{DT}(s, 0)\, \rho_\alpha(s, 0) + \delta\left(a_0 - a_1^{DT}(s, 0)\right) \rho(s, 0) \geq a_0 \pi(s; N)$$

or

$$\frac{a_1^{DT}(s, 0)}{a_0} \geq \frac{\pi(s; N) - \delta\rho(s, 0)}{\rho_\alpha(s, 0) - \delta\rho(s, 0)} \tag{22}$$

Satisfying this condition becomes a horserace between a_1^{DT} and π and depends on the underlying parameters. For reasonable parameter values, this condition holds for $N > \overline{N}$, a statement about the size of the market. Condition (22) may not be a sufficient condition for the pooling equilibrium to be played in the general case of N projects. For this to be true, similar conditions may have to hold for other set members. This situation resurfaces in the case of insider trading as the sole source of information.

D.2.3 Insider trading

In this section, we comment on the case when managers do not make disclosures about firm value but only trade in the shares of their firms. We argue that the strategic trading by managers may not reveal all, if any, information. The outcome depends on the dominance of the separating versus the pooling equilibrium and resonates with results from previous research in the market microstructure literature by Grossman and Stiglitz (1980), Kyle (1989) and others. This strand of research has argued that insider trading does not reveal all private information of "insiders" because of the inability of the market to disentangle the insiders' various trading motives, the insiders' trades from the trades of other uninformed market participants, etc. While our model is stylized and excludes more elaborate features of financial markets, the basic idea remains that insider trading alone can be too weak a mechanism to reveal the private information of insiders. In our model, the reason insider trading may fail to reveal information is due to the excessive cost of signaling information to the market when the market is large.

As already described in the previous section, full information revelation via the play of a separating equilibrium may not occur. Note the similarity of the structure of the disclosure-trading and the trading only cases. In the disclosure-trading separating equilibrium, the type space is broken up into subsets of increasing size as the number of observed successes decreases as can be seen in figure 5. In the case of N projects, the largest subset is of size $N+1$. Within each subset (bar the singleton set $\{(N,0)\}$), separation occurs via trading. In the case when managers only trade shares, *all* managers (not just a subset) play a signaling game with one another. That is, in this case, the size of the type set is $\frac{(N+1)(N+2)}{2}$ with N projects. For $N = 2$, all six managers compete against one another in the pure trading context while in the disclosure-trading case three managers play the signaling game in the largest subset with $s = 0$. The analysis of the insider trading game is therefore very similar to the case of the disclosure-trading game. The outcome of play depends on $N < \overline{N}$ and parameter values satisfying conditions such as (22).

E Conclusion

The most important ingredient into decision making is timely and precise information. When shareholders employ managers to run their firm, managers in their role of decision makers inside the firm naturally receive information about the firm first. This information is valuable but not easily credibly communicated to shareholders.

This paper studies an intuitive and simple mechanism that may provide shareholders with more timely information about the value of the firm: the simultaneous use of disclosures and insider trading by managers. We characterize circumstances in which this mechanism may fully reveal the insiders' information and in those conclude that

> insider trading puts the manager's money where his *report* is

When outsiders are uncertain about how much information insiders possess, insiders can exploit the private information to their advantage. The very attempt however may be uncovered as managers try to capitalize on their informational advantage through trading in the firm's securities potentially revealing their private information in the process. As a result, the model offers a mechanism that highlights the roles of disclosures and insider trading in revealing information, can shed light on some empirical observations, and has some implications for regulation.

First, in the joint mechanism, insider reports inherit their partial effectiveness from their role in isolation and allow the following interpretation: disclosures anchor the market's belief about the trading by managers. When managers may not exaggerate but strategically withhold information furnishing accompanying evidence that will be verified at a later date by a court of law, investors are unable to distinguish uninformed managers from informed managers who withhold information. As a result, investors allow for this uncertainty when setting stock prices. This pooling feeds back into the incentives of the managers. A pooled stock price disadvantages an impatient manager who would like to divest his holdings but is unable to provide evidence that he knows of little or no unfavorable information. To escape this trap, such a manager may signal his ignorance of unfavorable firm prospects to the market by retaining sufficient financial exposure to the firm's value till the verification date. This intuition captures the role of trading in our model. Trading allows the favorably informed manager to add credibility to his disclosure by putting his money where his report is.

In this sense, our setup also highlights how disclosure regulation and signaling interact. Disclosure regulation enhances the credibility of firms' disclosures by imposing ex-post punitive cost on distorted disclosures. Effective disclosure regulation does not induce a deadweight loss because no firms distort their disclosures in equilibrium: the large ex-post penalty serves as a deterrent and is not actually triggered. In contrast, in a signaling equilibrium, a manager who learns of favorable firm prospects may choose to incur a real (wasteful) cost to reveal his information to the market. The model in this paper shows that when the market for information is not too large, disclosures and signaling work as complements in conveying information to the market. This complementarity obtains when reporting occurs at predetermined disclosures dates that are identical for all firms. Such disclosure schedules (e.g. quarterly and annual reporting dates) serve as a coordinating device. When all firms report at the same time, investors can use the information revealed through the reports to discern firms at a given moment in time. The comparability of firm disclosures is weaker or completely lost when reports do not arrive at the same time.

Second, the model suggests circumstances under which insider trading should be allowed around information-sensitive events, so-called "black-out" periods, which include among other events quarterly and annual earnings reporting dates. It is precisely around information-sensitive events that the information asymmetry between firm insiders and outsiders is at its highest and the potential for reducing it greatest. It is then that insider trading could have the biggest impact. By prohibiting insiders from trading around these events, regulators shut down one channel through which more private information could potentially be brought to light. Regulation hence prolongs the persistence of the information asymmetry in the market and prevents shareholders from learning important information early on to be able to take interventive action in a timely manner.

Third, our results can shed light on and explain several empirical findings. Our model can explain the finding by Roulstone (2007) that insider trades and earnings announcements jointly explain stock returns. Roulstone (2007) documents that insider trades disclosed and executed prior to earnings announcements preempt news in the announcement and have a negative relation with market reactions to the announcement. Moreover, our model results resonate with the findings by Gu and Li (2007), who show that the stock price reaction following a disclosure increases when the disclosure is preceded by insider transactions, indicating that predisclosure trades add credibility to disclosures. Lastly, our results are also consistent with the evidence presented by Nagar, Nanda, and Wysocki (2003), who find supporting evidence for their prediction that stock price-based incentives in the form of stock-based compensation and share ownership incentivize managers to publicly disseminate their private information.

Fourth, the model supports the recent efforts of regulators to set high penalties for accounting fraud (Sarbanes-Oxley Act of 2002). The deterrence of fraudulent accounting through (large) ex-post penalties is what guarantees the partial information revelation through reporting in this model.

Finally, we admit that the above conclusions should be interpreted with caution as our model is a stylized formulation. First, the choice of a continuous variable for share trading complicates the analysis and may eliminate otherwise interesting insights. Second, while the base model is very intuitive, its formulation in terms of discrete types also contributes importantly to our conclusions. These points underscore the difficulty inherent in the analysis of games with incomplete information.

Part III

Market Transparency and the Accounting Regime[1]

[1]This chapter is joint work with my former PhD colleague Xuewen Liu with equal contribution by both co-authors. This chapter was subsequently published in the *Journal of Accounting Research* (see Bleck and Liu (2007)).

Abstract

We model the interaction of financial market transparency and different accounting regimes. This paper provides a theoretical rationale for the recently proposed shift in accounting standards from historic cost accounting to marking to market. The paper shows that marking to market can provide investors with an early warning mechanism while historical cost gives management a "veil" under which they can potentially mask a firm's true economic performance. The model provides new explanations for several empirical findings and has some novel implications. We show that greater opacity in financial markets leads to more frequent and more severe crashes in asset prices (under historic cost accounting). Moreover, our model indicates that historic cost accounting can make the financial market more rather than less volatile, which runs counter to conventional wisdom. The mechanism shown in the model also sheds light on the cause of many financial scandals in recent years.

F Introduction

Market transparency is generally believed to be a key mechanism that reduces the information asymmetry among market participants thereby guaranteeing market efficiency. In fact, the opacity of markets was blamed for the cause of many recent scandals such as Enron, Worldcom and Fannie Mae. In cases like these, investors and regulators often discover pertinent information too late to be able to take measures to prevent a potential crisis from happening. The Sarbanes-Oxley Act of 2002 may be seen as a direct response of regulators to such criticism. Moreover, as a central piece of the infrastructure of financial markets aimed at enhancing market transparency, accounting standards have become a key area of proposed reform over the last couple of years. One such proposal and central issue of the debate is the shift of the accounting regime from historic cost (HC) accounting to marking to market (MTM) with the objective of improving market transparency.

However, there are many voices against such a reform. The main reason for the objections focuses on the infeasibility of implementing the marking-to-market regime. That is, the so-called "fair value" is seldom available in reality. Ideally, if the true value of an asset or liability could be observed, we would use this as the accounting measure. Marking to market would then lead to first-best efficiency. In reality, however, market frictions prevent us from determining a fair value. Most markets are too illiquid to allow for timely and accurate valuation. The debate does not put into question whether marking to market *itself* is optimal. The issue is rather whether it is possible to implement such a regime. That is, the center of the debate is the *feasibility* of marking to market, not its *validity*. Plantin, Shin, and Sapra (2008) (hereafter PSS) write

> "[...] a rapid shift to a full mark-to-market regime may be detrimental [...]. This is not to deny that such a transition is a desirable long-run aim. In the long run, large mispricings in relatively illiquid secondary markets would likely trigger financial innovations in order to attract new classes of investors. This enlarged participation would in turn enhance liquidity, a situation in which our analysis shows that marking to market becomes more efficient."

The difficulty or infeasibility of *fully* implementing a marking-to-market scheme makes a mixed compromise unavoidable, whereby some items are recorded at historic cost while others are marked to market. The decision by the European Commission last November to endorse a mixed reporting scheme is evidence of a similar thought process.[25] The prerequisite for finding an *optimal* compromise, however, is to understand the advantages and disadvantages of different accounting regimes and their effects on market transparency. While understanding that the main difficulty of marking to market lies in its *infeasibility*, both academics and practitioners are not yet very clear about what the problems of historic cost accounting and the mechanisms are by which these problems are produced. The main motivation for this paper is to investigate these problems and their mechanisms.

In studying the accounting regimes and their economic implications, the first natural question to ask is what the difference between the accounting regimes is and why the shift from one regime to another matters. In fact, although the proposal to shift the accounting regime to MTM is a recent one, various forms of MTM accounting have already been practiced for centuries, particularly in the form of the so-called lower-of-cost-or-market (LCM) rule.

However, the implementation of the conservative principle like LCM, which is a "rule" rather than a "law", depends on several factors: industry, market and country. First, LCM is seldom used in the financial industry, which has been a particular target of accounting regulation in recent years. Even in the manufacturing industry, the LCM rule is not applicable to long-term, illiquid assets. For other assets, LCM is not implemented with high frequency (e.g. only seasonally or annually). In the interim, it is still pure HC accounting that is used. Second, a liquid market is necessary for the implementation of LCM, a rare situation in reality. In fact, the lack of liquidity is the very source of difficulty of implementing MTM in the first place. Third, as Ball, Robin, and Sadka (2008) show, the conservative accounting practice varies across countries. In many countries, it is hard to strictly implement LCM. In order to highlight and study the difference between MTM and HC accounting, HC accounting in this paper is interpreted as HC accounting in the strict sense (that is without the LCM element).[26]

The main insight of this paper is that marking to market can provide investors with an early warning mechanism while historical cost gives the manager a "veil" to potentially mask the firm's true performance. That is, historical cost accounting is equivalent to granting a free call option to the manager. If the firm's performance is good (that is its market price is high), the manager can choose to sell making the book value reflect the asset's market price. On the contrary, if the asset's market value is low, he can hold the asset and report a book value equal to the asset's initial cost. Hence, however low the market value is, the manager has a "floor" in the book value - the project's initial cost. At the same time, he can fully benefit from the project's upside. This "convexity" in the book value is the typical feature of a call option. In practice, as accounting-value-based compensation, such as profit-based bonuses, is widely used, the manager has an incentive to maximize the accounting numbers. Hence he has an incentive to use his free option. We will essentially show that historic cost accounting will not only "incentivize" but also "enable" the manager to mask the firm's performance. The manager has an incentive because he would like to keep a bad project "alive" in order to secure the convex payoff next period. He is also able to because he can hide the project's poor performance by setting the book value equal to the asset's initial cost.

Our main findings are two. First, our model implies a relationship between market transparency and asset price crashes under historic cost accounting. Myers and Jin (2006) document that countries where firms are more opaque to outside investors have a higher frequency of crashes in asset prices. Our model can provide an explanation for such evidence. The idea is as follows: in a more transparent market, the shareholder is able to distinguish good from bad projects and hence achieve a first-best outcome by liquidating poor projects. However, in more opaque financial markets, the shareholder may have to let a poor project continue as the manager can use historic cost accounting to pool good with bad projects. Failure of the shareholder to discriminate good from bad projects at an early stage allows bad projects to be kept alive and to potentially worsen in quality over time. The poor performance of these projects can thus accumulate and only eventually materialize at their final maturity leading to a crash in the asset price. This theory also sheds light on the cause of many recent financial scandals and their link to the different accounting regimes. In fact, such a link has already been suggested by a recent report of the Bank of England. As an example, the author cites the crisis of US Savings and Loans, which

> "[...] stemmed in part from the fact that the (variable) interest rates on their deposit liabilities rose above the (fixed) rates earned on mortgage assets. The application of traditional accounting meant that this showed up initially only gradually through negative annual net interest income. While it eventually became clear that many S&Ls were insolvent, a fair value approach would have highlighted much earlier that, as a result of changes in interest rates, the true economic value of their fixed-rate mortgage assets was below that of their deposit obligations. Had fair value accounting been used, it is likely that the S&Ls' difficulties would have been recognised and addressed earlier, and perhaps at lower fiscal cost." - Michael (2004)

Second, our model will help clarify the debate about the effect of different accounting regimes on asset price volatility. Opponents of a marking-to-market regime often claim that this accounting regime would lead to greater asset price fluctuations than would be the case under historic cost accounting. At first glance, this statement might seem consistent with intuition. But is this statement necessarily true? To the best of our knowledge, no theoretical model or empirical evidence has so far been presented that shows the impact of accounting regimes on asset price volatility. As our model will show, the claim that a historic cost accounting regime makes financial markets less volatile is not strictly true. Historic cost accounting indeed stabilizes asset prices in the short term. Under the veil of this apparent stability, volatility actually accumulates only to hit the market at a later date. Put differently, historic cost accounting not only transfers volatility across time but also increases asset price volatility overall. This result sits in stark contrast with the common opinion about historic cost accounting's effect on volatility.

Moreover, the model can, to some extent, provide a new explanation for the "Black" effect (Black (1976)). Under the historic-cost-accounting regime, we show that a low book value will be followed by high uncertainty and hence high volatility of the next-period return.

Despite the current hot debate and the practical importance of the issue of accounting reform, there has been surprisingly little theoretical and empirical work done on the economic consequences of different accounting regimes for the financial market. The leading article on this topic is the PSS paper. The authors study the basic trade-off between historic cost accounting and marking to market. In their model, the main problem of marking to market comes from the illiquidity of the secondary market. In such a market, the asset price is endogenous and the true and fair value of the asset is hence unavailable. The paper mainly concentrates on the position of a financial institution. It sheds light on why the opposition of marking to market has been led by the banking and insurance industries. While we agree with PSS on the main problem of marking to market being its infeasibility, our paper mainly concentrates on the modeling of the economic consequences of the historic-cost-accounting regime, particularly its effect on asset prices, its link to market crashes and its interplay with market transparency. Other papers that study the effects of marking to market on financial institutions include Burkhardt and Strausz (2009) and Freixas and Tsomocos (2003).

Myers and Jin (2006) is one of the few papers to model the relationship between market transparency and asset price crashes as well as stock-price co-movement while providing evidence in support of their theory. In their paper, using different proxies for transparency, the authors find that countries where firms are more opaque to outside investors exhibit a higher frequency of crashes. In comparison with their model, our paper builds on quite different premises and provides a new theory that explains the existing empirical evidence. Moreover, besides making explicit the effect of market transparency on crashes, our paper models the relationship between the accounting regime and asset price crashes.

Bushman, Piotroski, and Smith (2004) examine the factors that determine corporate transparency at the country level. They find that financial transparency is lower in countries with a high share of state-owned enterprises. In addition, their findings show that corporate governance is more transparent in countries with higher levels of judicial efficiency and a common-law background as well as in countries where stock markets are more active and well developed.

Morck, Yeung, and Yu (2000) and Campbell, Lettau, Malkiel, and Xu (2001) study the relationship between the characteristics of financial markets and stock price variation. They show that R^2 and other measures of stock-market synchronicity are higher in countries with relatively low per-capita gross domestic product (GDP) and less-developed financial markets. Bushee and Noe (2000) analyze the link between corporate disclosure and stock price volatility. Compared with this literature, our paper analyzes the effect of the accounting regime on asset price volatility.

G Model

G.1 The firm

Consider a firm that is owned by one representative shareholder. The shareholder employs the manager to run the firm. The firm has only one exogenously given project (or asset). The project lasts two periods from T_0 until T_2 when it will be liquidated by the shareholder. The whole life of the project spans across the dates T_0, T_1, T_{2-} to T_2. T_{2-} slightly precedes T_2. We use T_{2-} to model our assumption that the manager is shorter-lived than the firm.[27] The initial acquisition cost (or the market value at T_0) of the project is normalized to unity. The project yields no intermediate cash flows over its life. However, the manager can choose to sell any proportion of the project at T_1 and T_{2-}.[28] The selling price is the market value of the project at those dates. The market value at T_1 for the whole project is equal to $1 \cdot (1 + \widetilde{g}_1)$, where $\widetilde{g}_1$ denotes the project's growth rate over the first period. Similarly, the market value at T_2 (or T_{2-}) is given by $1 \cdot (1 + \widetilde{g}_1) \cdot (1 + \widetilde{g}_2)$, where $\widetilde{g}_2$ is the growth rate in the second period. Moreover, we assume that the growth rates $\widetilde{g}_1$ and $\widetilde{g}_2$ are positively autocorrelated. Specifically, the setup for $\widetilde{g}_1$

and $\widetilde{g}_2$ is $\widetilde{g}_1 = \widetilde{\varepsilon}_1$ and $\widetilde{g}_2 = \rho\widetilde{g}_1 + \widetilde{\varepsilon}_2$, where $\widetilde{\varepsilon}_1$ and $\widetilde{\varepsilon}_2$ are independent and both follow uniform distributions: $\widetilde{\varepsilon}_1 \sim Unif\ [-a, a]$ and $\widetilde{\varepsilon}_2 \sim Unif[-b, b]$ with $a > 0,\ b > 0,\ \rho > 0$.

Two remarks about the growth rates $\widetilde{g}_1$ and $\widetilde{g}_2$ deserve mention. First, they are private information. The project is firm specific. Its intrinsic worth, and hence its market value, is only known to the manager; it is hidden from the outsider or only available to him at a prohibitive cost. Secondly, we use the assumption of positive autocorrelation mainly to illustrate the feature that the firm's performance in the first period is a signal of its performance in the following period.[29]

G.2 The agents

There are two types of agents in our model: the shareholder and the manager. The first assumption about the manager is that he is shorter-lived than the project. Upon receiving his compensation at T_{2-}, he resigns and leaves the firm while the project remains alive until T_2. We believe the manager's shorter life relative to that of the project is a fundamental reason for the inefficiency caused by historic cost accounting. Since the project will be liquidated at the later date T_2, its market value is unobservable to the outsider (including the shareholder) when the manager leaves the firm at T_{2-}. Hence market-value-based compensation is not available to incentivize the manager to maximize firm value (the shareholder's objective). Conversely, suppose the manager was longer-lived than the project. Then the shareholder would be able to offer a compensation scheme linking the project's liquidation value to the manager's pay. In this case, first-best efficiency can be achieved.[30]

Second, we assume that the manager is risk-averse with CARA utility defined over wealth at time T_2 given by $U(\widetilde{W}) = 1 - e^{-k \cdot \widetilde{W}}$, where k denotes the coefficient of risk aversion. The shareholder is assumed to be risk-neutral for simplicity.

G.2.1 The information structure

The agency problem in this model arises from the information asymmetry between the shareholder and the manager. The manager as the insider knows the intrinsic value[31] of the project at any point in time even if the project is not brought to the market to be sold. However, the shareholder as the outsider knows the intrinsic value of the project only when it is liquidated in the market at T_2. Prior to liquidation, the shareholder must rely on the firm's book value from the manager's accounting report, which depends on the particular accounting regime used, to infer the firm's market value. Under historic cost accounting, the firm's book value contains two parts. The portion of the project the manager chooses to sell is transferred to cash and therefore shown at its market price. The remaining part of the project that the manager chooses to hold is recorded at its initial cost. However, under marking to market, the book value of the firm is the market price of the whole project. If there exists a deep and liquid secondary market for the project, as we assume, its market price is exogenous (that is the firm will be a price-taker unlike in the setup of the PSS model). In this case, first-best efficiency can be achieved under the marking-to-market regime since the book value is just equal to the market value of the firm. There is no information asymmetry between the manager and the shareholder.

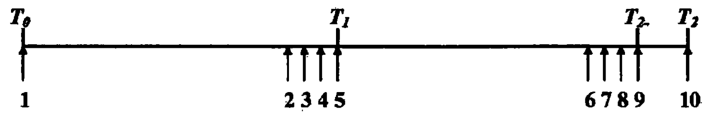
G.2.2 The compensation structure

The objective function of the shareholder is to maximize the final liquidation value of the project at T_2. As for the manager's compensation structure, we consider different schemes. At this stage, we assume that the manager's objective is to maximize the book value at T_{2-}. We show later on that this objective is equivalent to the manager being given accounting-number-based compensation—a base salary plus a profit bonus (the profit at T_{2-} is the book value at T_{2-} less the book value at T_0 (the initial cost of the asset)).[32] We believe the assumption of accounting-number-based compensation, particularly profit-based compensation, to be quite reasonable.[33] In fact, such compensation structures are widely used in practice, particularly in firms outside the United States. This is partly due to market inefficiency and illiquidity of some stock markets. Equity-based compensation may therefore cause even greater inefficiency not only in these countries. Even in the United States, where equity-based compensation is common, we still have good reason to believe that the stock price is significantly affected by accounting information. The assumption that the manager tries to maximize the accounting value does therefore not appear extreme.[34] Besides the monetary compensation, we assume that the manager derives some private benefit from running the project. Hence he prefers to continue operating to liquidating the project, all else equal. This assumption is the same in spirit as in Jensen (1986). The manager prefers to have more and bigger projects despite their being value destroying (negative net present value).

G.2.3 The agents' actions

In this model, the manager's action is to choose $\alpha\,(\in[0,1])$, the proportion of the project he decides to sell at T_1 and T_{2-}. At T_1, conditional on the specific α the manager chooses, the book value of the project is equal to $BV_1 = \alpha\cdot(1+g_1)+(1-\alpha)\cdot 1 = 1+\alpha\cdot g_1$, where g_1 is the realized growth rate of the project in the first period. The first term $\alpha\,(1+g_1)$ is the book value of the part of the project that the manager chooses to sell, which equals its market price. The second term $(1-\alpha)$ is the book value of the remaining part of the project the manager chooses to hold, which is recorded at its initial cost. Based on the book value BV_1, the shareholder makes the decision to either continue with or liquidate the whole project by trying to infer the fundamentals g_1. That is, the shareholder's action is $action^S$, where $action^S \in \{liquidate, continue\}$. Suppose the shareholder decides to continue with the project at T_1. Then the manager has another round of trading at T_{2-} just before leaving. Again, he can choose to sell any proportion of the remaining project at that date. The reason that we limit the shareholder's action to liquidating or continuing is because the manager's action is unverifiable and hence noncontractable. That is, the shareholder cannot force the manager to hold or sell a certain amount of the project. He can only passively choose to continue or liquidate the whole project.

It is important to emphasize that the outsider can only observe the total book value $1+\alpha\cdot g_1$. He cannot observe its two components separately: the sold part $\alpha\cdot(1+g_1)$ and the unsold part $\alpha\cdot g_1$. In fact, no outsider, including the shareholder, can discern the project's growth rate g_1 by telling



Event	*Description*
1	The exogenous project is given.
2, 6	The manager observes the project's market value.
3, 7	The manager decides how much to sell or hold.
4, 8	The book value is disclosed.
5	The shareholder decides whether to continue or liquidate the whole project.
9	The manager receives compensation and then leaves the firm.
10	The whole project is liquidated.

Figure 6: Timeline

apart the cash $\alpha(1 + g_1)$ from the noncash item $(1 - \alpha)$. We use this setup to capture the fundamental difference between historic cost accounting and marking to market, namely that the shareholder cannot perfectly infer the market value from the book value.[35] Otherwise, there would be no difference between historic cost accounting and marking to market and the choice of which accounting regime is employed becomes irrelevant. If this is the case, there is no need to debate the accounting regime reform.[36]

G.3 The timeline of events

G.4 The decision rules

Our analysis will mainly concentrate on the agents' decisions at time T_1. Figure 7 describes the agents' decision rules at date T_1. Figure 7 also summarizes all the key information of the setup outlined so far.

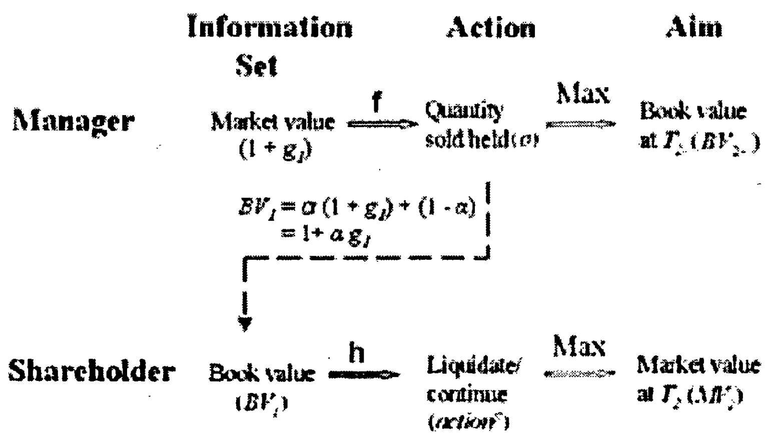


Figure 7: The agents' decision rules at time T_1

The manager observes the market value of the project. Based on this information, he decides how much to sell/hold to maximize his payoff linked to the book value at time T_2. However, when making his decision, the manager also needs to take the shareholder's possible response to his action into account. If the manager's action (forming a book value) results in the shareholder's decision to liquidate the whole project, the manager is no longer able to go ahead with the project and hence cannot maximize his payoff based on the book value at time T_2. He is then remunerated based on the liquidation value at time T_1. The shareholder uses the book value, which is a function of the fundamentals g_1 as well as the manager's action, as an (imperfect) signal to infer the firm's true performance g_1. Hence he makes the decision whether to continue or liquidate the whole project. His aim is to maximize the market value of the project at time T_2.

G.5 The financial market

In our model, different financial markets are characterized by different degrees of transparency. To each financial market corresponds an "uninformed window" as shown in figure 8. The more transparent the financial market is, the smaller the "uninformed window" will be. In our setup, where the project's return is uniformly distributed over the interval $[-a, a]$, we define the uninformed window as the subset $[-a', a']$ $(0 < a' < a)$. We assume that the outsider can perfectly observe the true value of states in the case of extreme return realizations (very high or very low) that fall outside the uninformed window. However, any given ex-post return sampled inside the uninformed window, the shareholder cannot distinguish from other returns in the uninformed window. The shareholder thus has to rely on the manager's accounting report for more information. The idea of defining an uninformed window can be described as follows. In every financial market, we can classify two kinds of communication channels between shareholders and management: accounting and non-accounting reports. The non-accounting channel is more powerful in transparent markets than in opaque ones. In fact, in more transparent financial markets like the United States, there is a greater analyst and media coverage through such institutions as investment banks and rating agencies for instance. All these non-accounting channels make the shareholder less dependent on the manager's accounting report. Hence, the uninformed window, within which the shareholder has to rely on the manager's accounting report, is shorter.[37] We also use figure 8 to illustrate the setup of the financial market. Without loss of generality, we

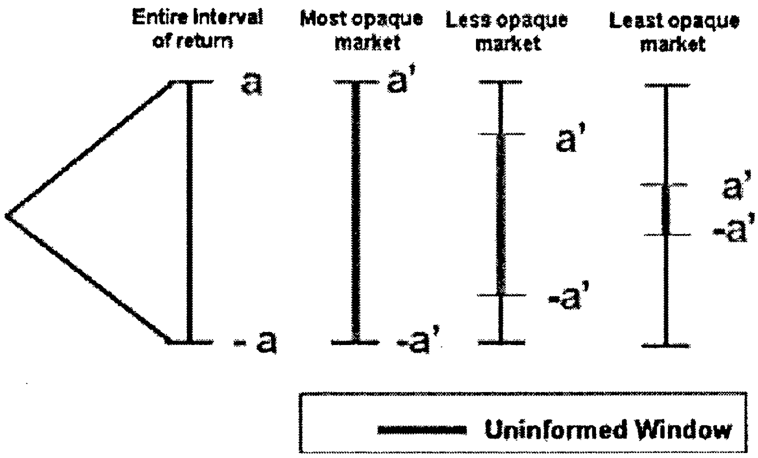


Figure 8: The financial market with different degrees of transparency
For the same project whose return is uniformly distributed in the interval $[-a, a]$, the less opaque financial market has a shorter uninformed window $[-a', a']$, within which the shareholder has to rely on the accounting statement (the book value). Outside the uninformed window, the shareholder knows the true state.

normalize the riskfree interest rate in the economy to zero.

H Equilibrium

As figure 7 shows, the agents' actions are not independent but there indeed exists a strategic dimension to their decision-making process. In fact, the interplay of their actions constitutes a sequential game between the shareholder and the manager. Solving for the equilibrium of the game is equivalent to finding the equilibrium strategy profile of the agents (f, h). We formalize the agents' strategies in definition 6.

Definition 6. (Strategies) The manager's strategy at time T_1 is the function

f, which is a map from the first period's return g_1 to the proportion of the asset he chooses to sell α, that is $\alpha = f(g_1)$. The shareholder's strategy is given by the function h, which maps the book value at time T_1 to the set $\{liquidate, continue\}$. That is, $action^S = h(BV_1)$, where $action^S \in \{liquidate, continue\}$.

It is important to note that the equilibrium does not only depend on the accounting scheme but also on the degree of transparency of the financial market. The degree of transparency determines the length of the uninformed window, which in turn determines the manager's capability to mask the firm's true performance. Recall that the shareholder is perfectly informed, that is, his action does not depend on the disclosure of accounting information, when the economic fundamentals are recorded outside the uninformed window. Theorem 7 states the first type of equilibrium - a pooling equilibrium, which occurs in sufficiently opaque financial markets where the uninformed window is large. The proof of the theorem is provided later on.

Theorem 7. *(Pooling Equilibrium) When $a' > a^*(b, \rho, k)$, the strategy profile $s = (f, h)$ at time T_1 constitutes a Nash Equilibrium, where f and h satisfy*

$$f(g_1) = \begin{cases} \underset{\alpha \in [0,1]}{\arg\max} E\left[U\left(\max\left\{1 + \alpha g_1, \alpha(1+g_1) + (1-\alpha)(1+g_1)(1+\widetilde{g}_2)\right\}\right)\right] & when\ g_1 \geq 0 \\ 0 & when\ g_1 < 0 \end{cases}$$

and

$$h(BV_1) = \begin{cases} continue & when\ BV_1 \geq 1 \\ liquidate & when\ BV_1 < 1 \end{cases}$$

In this equilibrium, the manager sells nothing (that is $f(g_1) = 0$) if and only if g_1 falls in two extreme intervals, that is $g_1 \in [-a', \underline{a}] \cup [\overline{a}, a']$. In the middle interval $[\underline{a}, \overline{a}]$, the manager partially liquidates the project, where $a^* = \left[\frac{3}{4}\left(\overline{a}^2 - \underline{a}^2\right) + \frac{1}{2}\left(\overline{a}^3 - \underline{a}^3\right)\right]^{\frac{1}{3}}$, $\overline{a}$ solves $\left\{e^{-k(1+\overline{a})(1+\rho\overline{a}+b)} \cdot [1 + k(1+\overline{a})(\overline{a}\rho + b)] - e^{-k(1+\overline{a})(1+\rho\overline{a}-b)} \cdot [1 + k(1+\overline{a})(\overline{a}\rho - b)]\right\} \times \frac{1}{2bk(1+\overline{a})} = 0$ and $\underline{a}$ satisfies

$$-k\underline{a}e^{-k\frac{\rho\underline{a}^2+(1+\rho)\underline{a}-b(1+\underline{a})}{2b(1+\underline{a})}} + \frac{1}{2bk(1+\underline{a})}[e^{-k(1+\underline{a})(1+\rho\underline{a}+b)} - e^{-k} + k(1+\underline{a})(\rho\underline{a}+b) \cdot e^{-k(1+\underline{a})(1+\rho\underline{a}+b)} + k\underline{a} \cdot e^{-k}] = 0.$$

It is worth noting that the pooling equilibrium here is to be interpreted in the sense that the shareholder always continues the project, as opposed to the result in theorem 8 below where the firm is efficiently liquidated when $g_1 < 0$. The basic idea of the pooling equilibrium can be explained as follows. When the project's return in the first period g_1 is non-negative, the manager does not need to worry that the shareholder will liquidate the project. The manager can maximize his own expected utility without giving any consideration to the shareholder's interference. However, when the project's return g_1 is negative, the manager knows that the shareholder will definitely liquidate the whole project if the manager sells only a tiny fraction. It is thus optimal for the manager to set $\alpha = 0$. This is the manager's strategy. As for the shareholder, if he observes a book value strictly higher (lower) than unity, he can perfectly infer the project's return being positive (negative). Hence his dominant strategy is to continue (liquidate). Observing a book value of unity, he knows the project could be either very good or very bad. But if the uninformed window is sufficiently large (that is $a' > a^*(b, \rho, k)$), as we assume in theorem 7, the gain of continuing potentially good projects will dominate the loss of not liquidating bad projects. The shareholder's optimal strategy is then to continue resulting in bad and good projects being pooled. In summary, the shareholder will continue the whole project if the book value is not less than unity. Otherwise he is going to liquidate the project.

Before proceeding to the proof of theorem 7, we use some diagrams created via numerical simulations of the agents' optimal strategies to help us understand the intuition behind the equilibrium. First, consider the manager's strategy. In figure 9, the bottom diagram represents the manager's strategy, the optimal sale α as a function of the fundamentals g_1. This is a non-monotonic function. The manager sets $\alpha = 0$ (that is holds everything) when g_1 is very low or very high selling partially when g_1 is fairly high. It is worth noting that the optimal α is the result of two different considerations by the manager. When $g_1 \geq 0$, α is the solution to the manager's utility maximization problem. In this case, he needs not be concerned with the shareholder's liquidating the firm as we will show later. When $g_1 < 0$, the manager's decision to sell nothing is given by his strategic consideration. The reason for his action is that he must otherwise fear the firm's forced liquidation by the shareholder, which would thwart the manager's chance of upside compensation at time T_{2-}. Following the manager's action (that is choosing α), the shareholder can access the firm's accounting statements and observe its book value as shown in the top diagram of figure 9. Note that the book value is a bell-shaped function of the fundamentals. The book value is just a simple function of the manager's action (that is $BV_1 = \alpha(1+g_1)+(1-\alpha) = 1+\alpha g_1$). In this diagram, we can see a pattern similar to the "Black" effect. That is, the higher the first-period expected

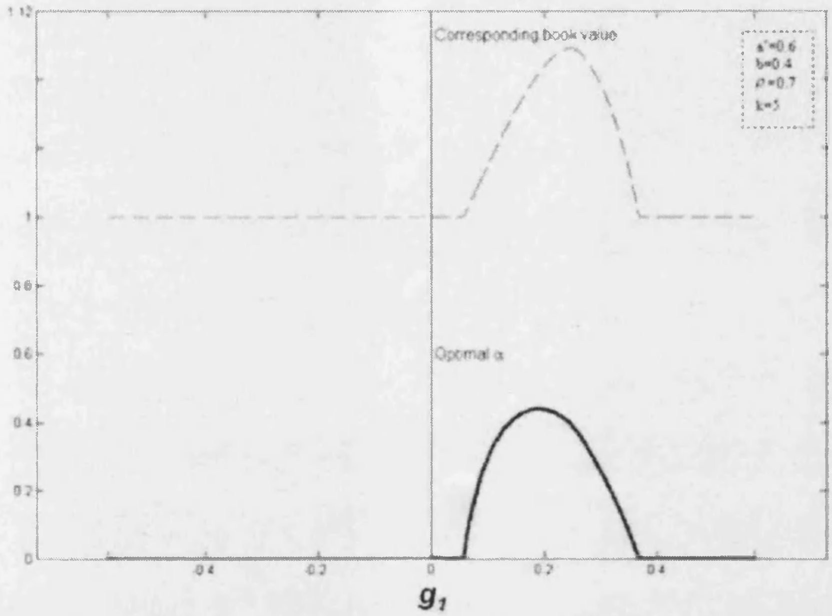


Figure 9: The manager's strategy in the pooling equilibrium

return, the higher the volatility (uncertainty) of the next-period return. The shareholder uses the book value information to try to infer the fundamentals, that is, $g_1 = f^{-1}(BV_1)$. For a book value (y-axis) greater than unity, there are two corresponding values of g_1 (x-axis). As the book value decreases, the distance between the two g_1, which measures the uncertainty of the fundamentals, increases. Particularly, at a book value equal to unity, the corresponding g_1 falls into two intervals. At this point, the shareholder's uncertainty is at its highest.

Next consider the shareholder's strategy. Conditional on the book value he observes, the shareholder is uncertain about the economic fundamentals. The top diagram in figure 10 plots his position. Particularly when he observes a book value of unity, the fundamental value may be any $g_1 \in [-a', \underline{a}] \cup [\overline{a}, a']$. This degree of uncertainty makes the shareholder's optimal strategy not obvious. The bottom diagram in figure 10 depicts the shareholder's payoffs of the two alternative choices (liquidate or continue) as functions of the fundamentals. Suppose the shareholder knows that the return falls inside $[0, \underline{a}] \cup [\overline{a}, a']$. In this case, his strategy to continue with the project dominates the decision to liquidate the firm early. However, if g_1 falls in the interval $[-a', 0]$, liquidation is the dominant strategy. Faced with uncertainty, the shareholder's strategy is to compare the potential gain (the area $\triangle$DHIE $+\triangle$ABC) with the potential loss (the area $\triangle$ALM) of a given strategy. The result of the comparison depends on the length of uninformed window. The bigger the uninformed window (a') is, the higher the possibility that *continue* becomes the dominant strategy. a^* is the threshold. If $a' > a^*$, the shareholder will let the project continue, which corresponds to the pooling equilibrium in the sense that both bad and good projects are kept alive. If the shareholder observes a book value different from unity, continuation is the shareholder's dominant strategy as the diagram shows.

The above explanation forms the basic intuition for the pooling equilibrium in theorem 7. Now we can proceed with the formal proof.

Proof. In essence, proving that the strategy profile (f, h) constitutes a Nash Equilibrium is equivalent to proving that the strategy of each agent is the best response to that of the other agent (that is f and h are the best mutual responses). To aid comprehension, we organize the proof into a number of steps.

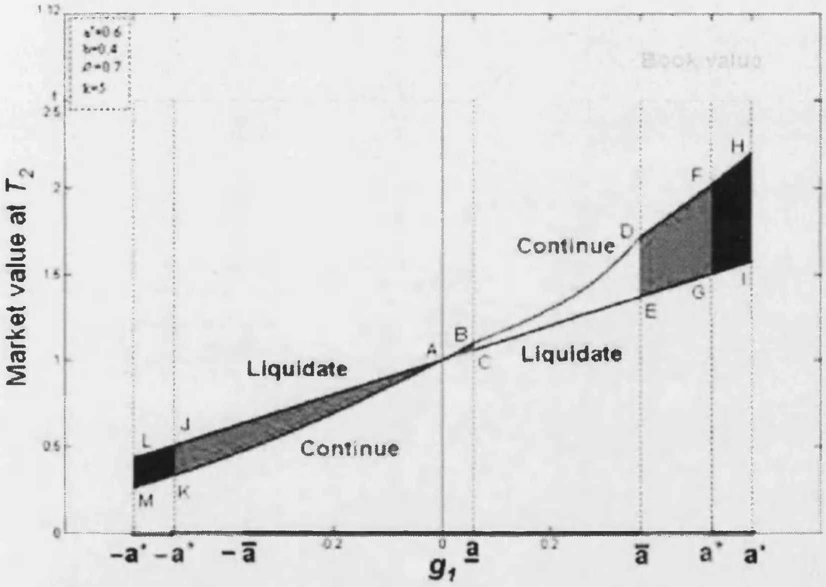


Figure 10: The shareholder's strategy in the pooling equilibrium

Step 1: If g_1 doesn't fall into the uninformed-window (that is, $g_1 \in [-a, -a'] \cup [a', a]$), the shareholder knows g_1 perfectly. Hence, there is no inefficiency due to market opaqueness or the accounting regime. Hence, it suffices to focus the discussion only on $g_1 \in [-a', a']$.

Step 2: Consider the shareholder's strategy. Essentially the shareholder's decision to continue or liquidate is about the trade-off between liquidating the project at date T_1 and delaying liquidation until time T_2. Thus he needs to compare the time-T_1 market value of the project with its expected time-T_2 market value. The project's market value at T_1 is $MV_1 = 1 \cdot (1 + g_1) = 1 + g_1$. If the manager delays liquidation until time T_2, the project's T_2-market value includes two parts. The first part is the portion of the project the manager liquidated at T_1. This is in the form of cash, which was converted before T_{2-}. Its value is $\alpha (1 + g_1)$. The other part is the one the manager chooses to hold. Its value at T_2 is $(1 - \alpha)(1 + g_1)(1 + \widetilde{g}_2)$. Hence the total market value at T_2 is $MV_2 = \alpha (1 + g_1) + (1 - \alpha)(1 + g_1)(1 + \widetilde{g}_2)$. Therefore, the expectation of the difference in payoff between the two alternative choices is

$$
\begin{aligned}
E[MV_2 - MV_1] &= E[(1 - \alpha)(1 + g_1)\widetilde{g}_2] \\
&= (1 - \alpha)(1 + g_1)\rho g_1 \qquad (23)
\end{aligned}
$$

From equation (23), we can see that the shareholder's decision exclusively depends on the fundamentals g_1. However, while the manager knows the fundamental value of the firm, the shareholder merely receives some information about it through the disclosure of accounts (that is the book value). The book value thus serves as a signal of the fundamentals. It reflects the decision of the manager, which in turn is a function of the fundamentals. Specifically, the book value is given by

$$BV_1 = \alpha (1 + g_1) + (1 - \alpha) = 1 + \alpha g_1 \tag{24}$$

Now we can discuss the shareholder's strategy, the function $action^S = h(BV_1)$. There are three cases for BV_1: i) $BV_1 > 1$, ii) $BV_1 < 1$ and iii) $BV_1 = 1$. In cases i) and ii), the shareholder can perfectly infer the sign of the economic fundamentals from the book value. Given that α is non-negative, we have

$$BV_1 > 1 \Longrightarrow g_1 > 0 \tag{25}$$

$$BV_1 < 1 \Longrightarrow g_1 < 0 \tag{26}$$

Substituting (25) and (26) into (23) and considering the manager's equilibrium strategy $\alpha = f(g_1) \neq 1$, we obtain

$$BV_1 > 1 \Longrightarrow E[MV_2 - MV_1] > 0 \tag{27}$$

$$BV_1 < 1 \Longrightarrow E[MV_2 - MV_1] < 0 \tag{28}$$

From (27) and (28), we can get the shareholder's optimal strategy (that is his best response to the manager's strategy) in cases i) and ii). That is, *continue* $= h(BV_1)$ when $BV_1 > 1$ and *liquidate* $= h(BV_1)$ when $BV_1 < 1$.

The more complicated part is case iii) when the book value equals unity. In this case, there are two things that can happen, either $g_1 = 0$ or $\alpha = 0$. In fact, whatever the fundamentals are, the book value will equal unity if the manager holds fully. The shareholder cannot perfectly infer the fundamentals. However, given the manager's strategy, the shareholder knows that the manager chooses $\alpha = 0$ if and only if $g_1 \in [-a', \underline{a}] \cup [\overline{a}, a']$. Hence, the expected net payoff from continuing the project conditional on a book value of unity is

$$\begin{aligned} & E[MV_2 - MV_1 \mid BV_1 = 1] \\ = \quad & E[(1+g_1)\rho g_1 \mid BV_1 = 1] \\ = \quad & \tfrac{1}{2a'+\underline{a}-\overline{a}} \left(\int_{g_1=-a'}^{g_1=\underline{a}} (1+g_1)\rho g_1 dg_1 + \int_{g_1=\overline{a}}^{g_1=a'} (1+g_1)\rho g_1 dg_1 \right) \\ = \quad & \tfrac{1}{2a'+\underline{a}-\overline{a}} \left[\tfrac{2}{3}a'^3 - \tfrac{1}{3}\left(\overline{a}^3 - \underline{a}^3\right) - \tfrac{1}{2}\left(\overline{a}^2 - \underline{a}^2\right) \right] \end{aligned} \tag{29}$$

From (29), we get the condition for the manager to continue the project conditional on the book value equal to unity. That is,

$$E[MV_2 - MV_1 \mid BV_1 = 1] > 0 \Longleftrightarrow a' > a^* \tag{30}$$

where $a^* = \left[\frac{3}{4}\left(\overline{a}^2 - \underline{a}^2\right) + \frac{1}{2}\left(\overline{a}^3 - \underline{a}^3\right)\right]^{\frac{1}{3}}$.

In theorem 7, we assume $a' > a^*$, hence the shareholder will continue with the project, which results in the pooling equilibrium. So far, we have shown that $action^S = h(BV_1)$ is indeed the shareholder's best response to the manager's strategy.

Step 3: Now consider the manager's strategy. The manager's information is the fundamental return g_1. Suppose the realized return is non-negative $g_1 \geq 0$, then the book value $BV_1 = 1 + \alpha g_1$ will be greater or equal to unity since α is non-negative. The analysis shows that the book value will be at least unity whatever the non-negative α the manager chooses when $g_1 \geq 0$. Considering that the shareholder's strategy is to continue the project if the book value is not less than unity, the manager needs not be concerned with the shareholder's liquidation of the project. The manager's objective is equivalent to maximizing expected utility, which is a function of his bonus at T_{2-}. The bonus is proportional to the firm's profit, which is the difference between the book value at T_{2-} and T_0 (that is the initial cost). We begin by analyzing the book value at T_{2-}, denoted BV_{2-}. As we have already shown in step 2, the market value of the project at T_2 is $MV_2 = \alpha(1 + g_1) + (1 - \alpha)(1 + g_1)(1 + \widetilde{g}_2)$. Moreover, we know that the market value of the project at T_{2-} is $MV_{2-} = MV_2$. We must have

$$\begin{aligned} BV_{2-} &= \max\{BV_1, MV_{2-}\} \\ &= BV_1 + \max\{0, MV_{2-} - BV_1\} \end{aligned} \tag{31}$$

The intuition behind equation (31) is as follows. At T_{2-} when the manager leaves the firm, he has another opportunity to trade. He can choose to sell or hold the remainder of the project that is still "alive" (that is the portion of project that was not liquidated at T_1). At that date, if he chooses not to sell, the book value BV_{2-} will equal the book value at the previous date (that is BV_1). This means the manager can report a book value at T_{2-} of at least BV_1. This is his "floor". The manager chooses not to sell at T_{2-} when the market value at that date, MV_{2-}, is lower than BV_1. It is then optimal for him to hold everything. Alternatively, if the market value MV_{2-} is higher than BV_1, he will sell the remainder of the project to realize its market value. Hence we can express the book value BV_{2-} as shown in equation (31). This equation also highlights the feature that the historic-cost-accounting regime gives the manager a free call option (that is a floor plus a call option). The idea behind the option feature of historic cost accounting is as in our analysis above: the manager can choose to sell (that is exercise the option) to make the book value reflect the market value when the market price is high. In addition, he can choose to hold (that is not exercise the option) to keep the book value unchanged when the market price is low.

Substituting MV_{2-} and BV_1 into (31), we obtain

$$\begin{aligned} BV_{2-} &= \max\{BV_1, MV_{2-}\} \\ &= \max\{1+\alpha g_1, \alpha(1+g_1)+(1-\alpha)(1+g_1)(1+\widetilde{g}_2)\} \quad (32) \end{aligned}$$

Therefore, the profit of the firm at T_{2-} is

$$\begin{aligned} PF_{2-} &= BV_{2-} - BV_0 \\ &= \max\{1+\alpha g_1, \alpha(1+g_1)+(1-\alpha)(1+g_1)(1+\widetilde{g}_2)\} - 1 \quad (33) \end{aligned}$$

Since we are concerned with the situation $g_1 \geq 0$, from (33) we have

$$PF_{2-} \geq 0 \tag{34}$$

It is worth noting that the compensation structure has the characteristic of "limited liability", which means that the shareholder cannot pay a negative bonus in the case of a loss. Fortunately, however, we can see from (34) that the profit is always non-negative in our model. Hence the limited-liability constraint is never binding.

Suppose the manager's bonus is a proportion $\beta > 0$ of the profit. The bonus is then equal to

$$BN = \beta \cdot PF_{2-} = \beta \cdot [\max \{1 + \alpha g_1, \alpha(1 + g_1) + (1 - \alpha)(1 + g_1)(1 + \widetilde{g}_2)\} - 1] \tag{35}$$

Substituting (35) into the manager's utility function, we obtain his expected utility

$$\begin{aligned} EU &= E[U(BN)] \\ &= E[U(\beta \cdot PF_{2-})] \\ &= E[U(\beta \cdot [\max \{1 + \alpha g_1, \\ &\quad \alpha(1 + g_1) + (1 - \alpha)(1 + g_1)(1 + \widetilde{g}_2)\} - 1])] \end{aligned} \tag{36}$$

Recall that the manager's utility function is $U(\widetilde{W}) = 1 - e^{-k \cdot \widetilde{W}}$. In order to save parameters, we can use an equivalent optimization scheme to replace the original one by replacing k with $k\beta$

$$\max_{\alpha\in[0,1]} EU$$
$$\Longleftrightarrow$$
$$\max_{\alpha\in[0,1]} E\left[U\left(\beta\cdot\left[\max\left\{1+\alpha g_1, \alpha(1+g_1)+(1-\alpha)(1+g_1)(1+\widetilde{g}_2)\right\}-1\right]\right)\right]$$
$$\Longleftrightarrow$$
$$\max_{\alpha\in[0,1]} E\left[U\left(\beta\cdot\max\left\{1+\alpha g_1, \alpha(1+g_1)+(1-\alpha)(1+g_1)(1+\widetilde{g}_2)\right\}\right)\right] \quad (37)$$

where k is scaled up by β.

Basically, equation (37) shows that the manager's maximizing utility based on his bonus is equivalent to his maximizing utility based on book value. Hence we obtain the optimal strategy for the manager when $g_1 \geq 0$, that is, $f(g_1) = \arg\max_{\alpha\in[0,1]} E\left[U\left(\max\left\{1+\alpha g_1, \alpha(1+g_1)+(1-\alpha)(1+g_1)(1+\widetilde{g}_2)\right\}\right)\right]$ when $g_1 \geq 0$.

Finally, we need to show that the manager's optimal strategy is to sell nothing when $g_1 < 0$. By $BV_1 = 1+\alpha g_1$, if the manager sets α to be positive, $BV_1 < 1$. Following the argument in step 2, the shareholder will liquidate the firm immediately after observing $BV_1 < 1$. If this situation happens, the market value of the firm is realized and the manager's bonus will be paid based on the firm's liquidation value. The liquidation value however is $MV_1 = 1 + g_1 < 1$, which means that the manager will receive no bonus. This is not the manager's optimal strategy. In fact, he can do better by setting $\alpha = 0$, which makes the book value at T_1 equal unity. In this case, the shareholder lets the project continue according to his optimal strategy. The manager prefers this strategy of holding (that is $\alpha = 0$) for two reasons. First, if he can make the shareholder continue with the project, the manager receives a valuable "call option" and his bonus will be non-negative. The option comes from the fact that there is a positive probability of the project's "recovery" at date T_{2-}. If recovery does occur, the manager can sell the project at that date thus making a profit and earning a bonus. Even if "recovery" does not transpire and the firm's performance worsens, the shareholder can choose to hold the project at T_{2-} setting the book value to at least unity. Therefore, the manager has an incentive to keep the project "alive". The second reason follows from the assumption that the manager derives some private benefit from continuing the project. This means that even though the manager knows perfectly that the project will not recover and may even worsen, he still prefers not to divest the project early since he can reap the private benefit in this case. He will also be employed for another year and receive his guaranteed base salary. In sum, the manager's strategy is to set $\alpha = 0$ when $g_1 < 0$, that is, $f(g_1) = 0$ when $g_1 < 0$.

Step 4: In this step, we will show $\underline{a}$ and $\overline{a}$ do exist so that the manager indeed holds fully when g_1 is high enough (that is $g_1 > \overline{a}$) and will sell partially when g_1 is fairly high. That is, we need to show there do exist such optimal αs that make the book value a bell-shaped function of g_1. The mechanism can be explained as follows. As we showed in step 2, the manager holds fully when $g_1 < 0$ due to his strategic concern that the shareholder would liquidate the project if he was to sell. However, we would ideally like to know the intuition for his choice to hold fully even when the return is very high. There are two reasons. One is the growth opportunity. The high return in first period means that the expected return in the second period will be high. Second, as we argued in step 3, the manager has an option at date T_{2-}. However only if he holds the project can he keep this option alive. Hence he has an incentive to hold the project. However, why does the manager prefer to sell partially rather than hold fully when the fundamentals are fairly good? This is due to another two factors that will make the decision tend in the opposite direction (that is favor selling). One is that the manager is risk-averse. His decision to hold or sell is equivalent to making a portfolio choice. Selling the asset will increase his position in the risk-free asset (that is cash) while holding the project is analogous to investing in the risky asset. The standard trade-off induces the manager to sell partially (that is investing some amount in the risk-free asset) when g_1 (the expected return of the risky asset) is not very high. The second force, which makes the manager sell a bit more, is the "floor", which is analyzed in step 3. The more the manager sells, the higher the book value the manager will have at T_1. This increases the floor in the book value at T_{2-}, which is valuable to the manager.

This concludes the proof of theorem 7. $\square$

Theorem 7 presents the pooling equilibrium that occurs in less transparent markets. However, the more transparent the financial market is, the more independent the shareholder will be of the manager's accounting report. The manager will have less opportunity to mask the firm's performance by pooling the bad with the good project. This change could lead to the second kind of equilibrium - a separating equilibrium. We state this result in theorem 8.

Theorem 8. *(Separating Equilibrium) When $\overline{a} < a' \leq a^*(b,\rho,k)$, the strategy profile $s = (f,h)$ constitutes a Nash Equilibrium, where f and h are given by*

$$f(g_1) = \begin{cases} \max\left\{ \underset{\alpha\in[0,1]}{\arg\max} E\left[U\left(\max\left\{1+\alpha g_1, \alpha(1+g_1)+(1-\alpha)(1+g_1)(1+\widetilde{g}_2)\right\}\right)\right], \varepsilon \right\} \\ \quad when \quad g_1 > 0 \\ 0 \quad when \quad g_1 \leq 0 \end{cases}$$

and

$$h(BV_1) = \begin{cases} continue \quad when\ BV_1 > 1 \\ liquidate \quad when\ BV_1 \leq 1 \end{cases}$$

where ε is a small positive number infinitely close to zero (we can also define it by $\frac{1}{\varepsilon} = +\infty$), $a^* = [\frac{3}{4}(\overline{a}^2 - \underline{a}^2) + \frac{1}{2}(\overline{a}^3 - \underline{a}^3)]^{\frac{1}{3}}$, $\overline{a}$ solves $\left\{ \begin{array}{c} e^{-k(1+\overline{a})(1+\rho\overline{a}+b)} \cdot [1+k(1+\overline{a})(\overline{a}\rho+b)] - \\ e^{-k(1+\overline{a})(1+\rho\overline{a}-b)} \cdot [1+k(1+\overline{a})(\overline{a}\rho-b)] \end{array} \right\} \times \frac{1}{2bk(1+\overline{a})} = 0$ *and $\underline{a}$ satisfies* $-k\underline{a}e^{-k\frac{\rho\underline{a}^2+(1+\rho)\underline{a}-b(1+\underline{a})}{2b(1+\underline{a})}} + \frac{1}{2bk(1+\underline{a})}[e^{-k(1+\underline{a})(1+\rho\underline{a}+b)} - e^{-k} + k(1+\underline{a})(\rho\underline{a}+b)e^{-k(1+\underline{a})(1+\rho\underline{a}+b)} + k\underline{a}e^{-k}] = 0$.

The emergence of the separating equilibrium is due to the uninformed window being shorter now. The manager can no longer pool the bad with the good project. It is worth noting that both the shareholder's strategy and the manager's strategy will change in the separating equilibrium compared with their actions in the pooling equilibrium. As for the shareholder, he is going to liquidate rather than continue the project after observing a book value of unity. The manager changes his strategy to selling a tiny proportion of the project to signal to the shareholder that the project is good when it is indeed good.

Figure 11 describes the result of the separating equilibrium. The top diagram is the shareholder's book value information. Suppose the manager still adopts his optimal strategy from the pooling equilibrium (that is sending no signal to the shareholder). The book value then corresponds to the dashed line in the diagram. If this is the case, conditional on the book value of unity, the shareholder's potential gain from continuation (the area of $\triangle$ABC plus $\triangle$DEFG) is dominated by the potential loss from early liquidation (the area $\triangle$AJK). This is due to the uninformed window being shorter now ($a' \leq a^*$). Note that a^* is the threshold (that is $\triangle\text{ABC} + \triangle\text{DHIG} = \triangle\text{ALM}$). Therefore, the shareholder's optimal strategy is to liquidate the project conditional on a book value of unity. The manager's strategy will change as well. He will signal to the shareholder by showing a book value infinitesimally higher than unity when the economic fundamentals are positive. The solid line in the top diagram represents the manager's signal in terms of the book value. Now the shareholder can perfectly distinguish the bad from the good project and first-best efficiency can be achieved.

Proof. The proof of theorem 8 is rather easy as we only need to compare the agents' strategies in the separating equilibrium with those in the pooling equilibrium. The change of the shareholder's strategy in the separating equilibrium is his action deviation when he observes a book value of unity. Since the uninformed window is shorter now (that is $a' \leq a^* (b, \rho, k)$), condition (30) is no longer satisfied. The shareholder will liquidate the project anyhow. The idea behind this argument is as follows. Although the shareholder knows

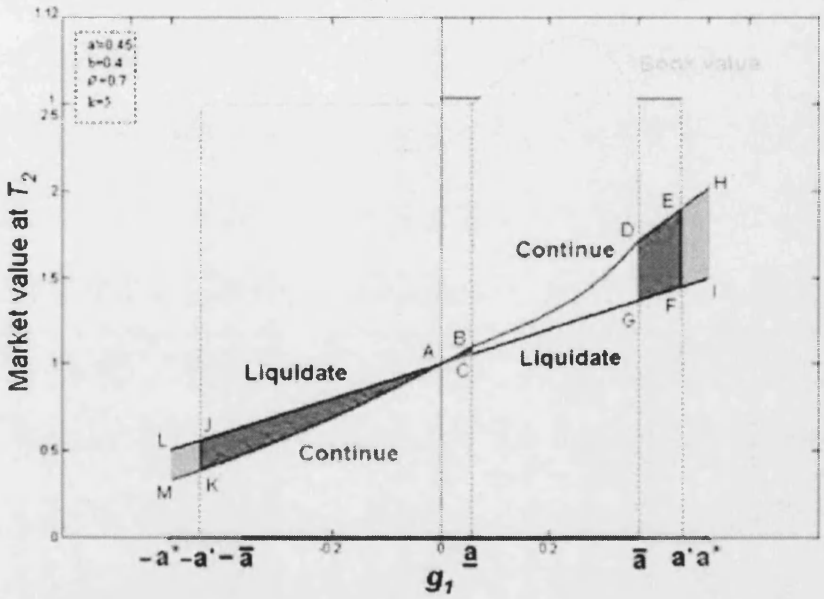


Figure 11: The shareholder's strategy in the separating equilibrium

the project may be very good conditional on a book value of unity, the loss from a poor project dominates the gain from a promising project. Hence, it is optimal for the shareholder to liquidate the project. It is very important to note that the manager's strategy also changes when the shareholder's strategy does. Conditional on the manager's selling nothing giving rise to a book value of unity, the manager knows that the shareholder will liquidate the project even if there is chance of it being good. Hence the manager will have to adapt his strategy in order to maximize his payoff: he will send an inimitable signal to the shareholder that the project is good when indeed the economic fundamentals are good by selling a tiny fraction ε of the project to push the book value slightly above unity. Hence the $f(g_1)$ is the best response of the manager to the shareholder's strategy. Now we can go back and check that the shareholder's strategy is still the best response to the manager's updated strategy. This is in fact obvious. Given the manager's strategy, the shareholder knows the book value equals unity if and only if $g_1 < 0$. Now it is even more certain that the shareholder will liquidate the project in this case. $\square$

I Implications

In this section, we analyze the model implications by a series of propositions. From theorems 7 and 8, we know that in more opaque financial markets the manager is better able to use historic cost accounting to pool bad with good projects. This hinders the shareholder from discerning the bad project at an early stage. The bad project can then potentially worsen in quality over time. The poor performance can accumulate and only eventually surface leading to a big crash in the asset price. This is the relationship between market transparency and the asset price crash.

Proposition 9. *Under the historic-cost-accounting regime, a higher degree of opaqueness leads to more frequent and more severe asset price crashes.*

The result of proposition 9 is consistent with the findings in Myers and Jin (2006). Our contribution is that we provide a new mechanism that explains the cause of the empirical evidence. In other words, the historic cost accounting regime can provide a tool for the manager to hide the firm's true performance, a scenario that can potentially lead to a crash.

Figure 12 gives a numerical example. On the horizontal axis we plot a' (that is the width of the uninformed window) and on the vertical axis $\triangle s$ (that is the degree of the crash in the book value). The graph shows that more opaque financial markets exhibit a higher intensity of book value crashes, both in frequency and magnitude.

Proof. See Appendix I. □

Now consider what happens if the marking-to-market regime can be implemented (in sense that the fair value is observable). In this case, the shareholder can see through the firm's performance. He will liquidate the firm if $\varepsilon_1 = -a'$ and no crash can happen. Yet there is a crash under historic cost accounting if the financial market is sufficiently opaque. This is proposition 10: the relationship between the accounting regime and the asset price crash.

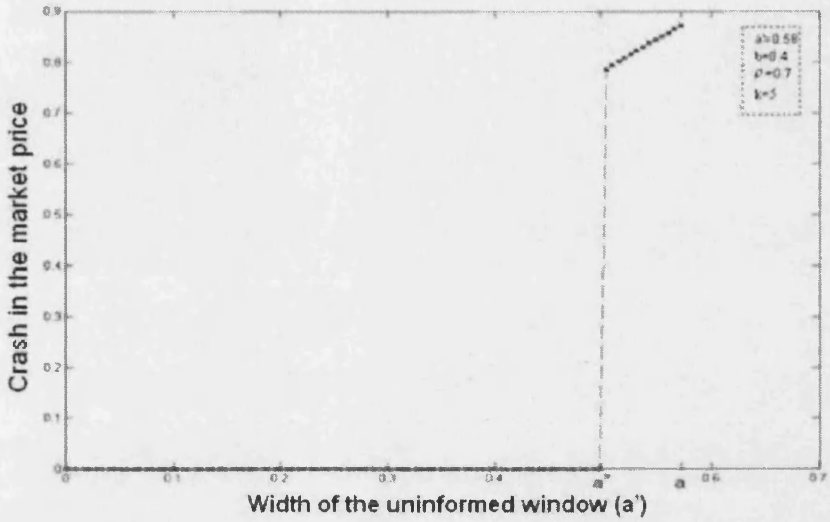


Figure 12: The crash in the asset price.

Proposition 10. *In an opaque financial market (that is $a' > a^*$), more severe and more frequent asset price crashes result under historic cost accounting than under marking to market.*

Proposition 10 is in the same spirit as proposition 9. We therefore omit its proof.

In fact, some practitioner reports have provided evidence in support of the implication of proposition 10. As a Bank of England survey states, under historic cost accounting the shareholder cannot distinguish the bad from the good project at an early stage and hence is unable to prevent a bad project from being kept alive and potentially worsening in quality. This is the reason for the crash under the historic cost accounting regime while no such crash can happen under marking to market. The above argument underlines the intuition of proposition 10.

As marking-to-market can lead to more efficient liquidation, the bad project will have a lower probability to survive over time. The asset price at T_2 is less volatile under marking to market than under historic cost accounting.

Proposition 11. *The unconditional volatility of the asset price at T_2 is higher under historic cost accounting than under marking to market.*

Moreover, the historic-cost-accounting regime not only increases the asset price volatility overall but it also transfers it across time in a pattern similar to the "Black" effect. As figure 9 shows, under historic cost accounting, the lower (higher) the book value at T_1, the higher (lower) the uncertainty (volatility) about the liquidation value at T_2.

Proposition 12. *Under historic cost accounting, the asset price exhibits a pattern similar to the "Black" effect in the book value.*

J Conclusion and discussion

This paper analyzes the economic consequences of historic cost accounting for the financial market. Using a theoretical model we can (partially) answer the following two questions: what kind of inefficiency can a historic-cost-accounting regime cause and what is the mechanism that produces these inefficiencies? Our model shows that under historic cost accounting the opaqueness of the financial market can lead to the inefficient continuation of the project by the shareholder, which in turn leads to more pronounced asset price crashes, both in frequency and magnitude. However, under the marking-to-market regime, if the fair value is indeed available, these crashes will not happen. Our model also shows that historic cost accounting can change the asset price volatility. In fact, it transfers asset price volatility across time while increasing volatility overall. The mechanism of historic cost accounting to produce the above effects lies in the book value's convexity in the economic fundamentals. However low the market price is, the manager can make the book value equal to the initial cost (the floor) by holding the asset. At the same time, he can participate in the upside of the market valuation by selling. The convexity in the book value is equivalent to granting the manager a free call option. When accounting-value-based compensation is used (which is quite common in reality), the manager has both the capability and the incentive to use this option. This will lead to inefficiencies.

Finally, we admit that our results should be interpreted with caution since our results are based on a specific setup. It is impossible for us to explore all aspects of the features of historic cost accounting and all aspects of the effects of historic cost accounting. Notably, in the analysis of the equilibria and their implications, we assume that the manager's compensation structure is composed of a base salary plus a profit-based bonus. We use this assumption because such compensation structure is widely used in practice, particularly in some industries like financial services. One of the most important reasons why many firms do not use market-value-based compensation under historic cost accounting in reality is that the market may be not very liquid, which makes the fair value unavailable. In this case, market-price-based compensation may cause more inefficiency. Also, the market price is likely to be very volatile and the market not efficient. Nevertheless, if the shareholder implements a very complicated compensation structure, this may reduce some inefficiency of the historic cost accounting regime.[38]

However, our argument is that many theoretical compensation structures are hardly feasible in reality, particularly given the illiquidity and inefficiency of many financial markets. In order to highlight and model the effects of historic cost accounting on a market with such features, we have abstracted away from the complicated optimal compensation design by using the compensation structure that is most common in reality. We believe our main findings are robust.

Appendix

Proof of Proposition 9

Consider the change in the share price between T_1 and T_2 in different financial markets. Here we suppose that the ex-post returns in period 1 and 2 are $\varepsilon_1 = -a'$ and $\varepsilon_2 = -b$ respectively, that is, the lowest returns are realized. We consider this situation for the purpose of exploring the asset price change in extreme cases (that is the worst outcome). Note that when ε_1 falls outside the uninformed window (e.g. $-a < \varepsilon < -a'$), the shareholder can observe the return. Hence the lowest ex-post return that the shareholder cannot observe is $\varepsilon_1 = -a'$.

A transparent financial market: $a' \leq a^*$. In such a market, the whole project will be liquidated at T_1. Hence there is no change in the share price between T_1 and T_2.

$$\triangle s = s_1 - s_2 = 0 \tag{38}$$

Here we assume that if the project is liquidated early at T_1, the firm value at T_2 equals its liquidation value (e.g. all the cash generated from liquidation is retained within the firm until date T_2). Therefore, the firm value does not change in the second period.

An opaque financial market: $a' > a^*$. In such a market, the manager is able to pool bad with good projects by exploiting the shareholder's ignorance of the project's true quality leading the shareholder to potentially continue both types of projects. The book value is unity. Hence the share price is the discounted expected market value of the firm at T_2 conditional on the book value at T_1 being unity, that is,

$$
\begin{aligned}
s_1 &= E\left[MV_2 \mid BV_1 = 1\right] \\
&= E\left[(1+g_1)(1+\rho g_1 + \widetilde{\varepsilon}_2) \mid BV_1 = 1\right] \\
&= \frac{1}{2a' + \underline{a} - \overline{a}} \cdot \left[\int_{-a'}^{\underline{a}} (1+g_1)(1+\rho g_1)\, dg_1 + \int_{\overline{a}}^{a'} (1+g_1)(1+\rho g_1)\, dg_1\right] \\
&= \frac{1}{2a' + \underline{a} - \overline{a}} \cdot \left\{ \begin{array}{c} \left[\frac{1}{3}\rho \underline{a}^3 + \frac{1}{2}(1+\rho)\underline{a}^2 + \underline{a}\right] - \left[-\frac{1}{3}\rho a'^3 + \frac{1}{2}(1+\rho) a'^2 - a'\right] \\ + \left[\frac{1}{3}\rho a'^3 + \frac{1}{2}(1+\rho) a'^2 + a'\right] - \left[-\frac{1}{3}\rho \overline{a}^3 + \frac{1}{2}(1+\rho)\overline{a}^2 - \overline{a}\right] \end{array} \right\}
\end{aligned}
$$

The share price at T_2 is the firm's liquidation value at that date given by

$$
s_2 = \left(1 - a'\right)\left(1 - \rho a' - b\right)
$$

Therefore, the price change is equal to

$$
\begin{aligned}
\triangle s &= s_1 - s_2 = \frac{1}{2a' + \underline{a} - \overline{a}} \cdot \left\{ \begin{array}{c} \left[\frac{1}{3}\rho \underline{a}^3 + \frac{1}{2}(1+\rho)\underline{a}^2 + \underline{a}\right] \\ - \left[-\frac{1}{3}\rho a'^3 + \frac{1}{2}(1+\rho) a'^2 - a'\right] \\ + \left[\frac{1}{3}\rho a'^3 + \frac{1}{2}(1+\rho) a'^2 + a'\right] \\ - \left[-\frac{1}{3}\rho \overline{a}^3 + \frac{1}{2}(1+\rho)\overline{a}^2 - \overline{a}\right] \end{array} \right\} \\
&\quad - \left(1 - a'\right)\left(1 - \rho a' - b\right) \qquad (39)
\end{aligned}
$$

Putting (38) and (39) together, we obtain $\triangle s$, which measures the extent of the asset price crash, as a function of a', which measures the degree of market opaqueness:

$$\triangle s = l\left(a'\right) = \begin{cases} 0 & a' \in [0, a^*] \\ \frac{1}{2a'+\underline{a}-\overline{a}} \cdot \left\{ \begin{array}{c} \left[\frac{1}{3}\rho \underline{a}^3 + \frac{1}{2}\left(1+\rho\right)\underline{a}^2 + \underline{a}\right] \\ -\left[-\frac{1}{3}\rho a'^3 + \frac{1}{2}\left(1+\rho\right)a'^2 - a'\right] \\ +\left[\frac{1}{3}\rho a'^3 + \frac{1}{2}\left(1+\rho\right)a'^2 + a'\right] \\ -\left[-\frac{1}{3}\rho \overline{a}^3 + \frac{1}{2}\left(1+\rho\right)\overline{a}^2 - \overline{a}\right] \end{array} \right\} & a' \in (a^*, a] \\ -\left(1-a'\right)\left(1-\rho a' - b\right) & \end{cases}$$

With the setup of the parameters in our model, $\triangle s$ is an increasing function of a' when the crash occurs (that is $a' \in (a^*, a]$), which means that the more opaque financial market will display more severe crashes. Moreover, $\triangle s$ is a discontinuous function of a' in the whole interval $[0, a]$. When $a' < a^*$, there is no crash at all. This discontinuity means that opaqueness will not only lead to more severe but also more frequent asset price crashes. This idea will become clearer if we consider the case of multiple projects. Suppose there are many projects in each financial market, the length of the uninformed window of these projects in the same financial market is different but centered around a' of their own financial market. Hence we can expect that the financial market with a higher a' will have more projects falling within the interval $(a^*, a]$, resulting in a higher frequency of crashes.

Notes

[1]The seminal paper on bank runs is due to Diamond and Dybvig (1983).

[2]The attentive reader will notice that the game structures in our setup and the bankrobber case are not the same. Our setup as expained later is a coordination game while the bankrobber example has a prisoners' dilemma structure. We use the outcome of the familiar prisoners' dilemma only to intuitively illustrate the forces at work that produce a run outcome.

[3]A possible interpretation of the asset could be short-lived information that requires the input of both parties to decipher and reveal its value.

[4]Other papers argue that bank fragility may not be entirely undesirable as it disciplines managers (Calomiris and Kahn (1991), Flannery and Kaufman (1996), Diamond and Rajan Diamond and Rajan (2000, 2001a,b,c)). For a comprehensive literature survey on bank failures see Wagner (2009b).

[5]However, even with uncorrelated risks, a level of diversification that is optimal for a single institution may be suboptimal for the system (Wagner (2008, 2009a)).

[6]We choose the parameters of the distribution of λ to minimize the probability of a negative asset price.

[7]The breach of the price constraint may be due to additional supply of the asset by noise traders who sell upon observing a price drop. We abstract away from the micro foundations that could give rise to the fixed payout b.

[8]See for instance Financial Times, November 13, 2008.

[9]See The Economist, March 26, 2009.

[10]See Bloomberg, March 19, 2009.

[11]When interpreting cross investments in terms of stakes in a mutual investment fund, the correct exposure of trader i in the fund is his relative stake given by $\frac{w_i}{(1-w_j)+w_i}$.

[12]The tone in this paper may suggest to the reader that we view more information as desirable for shareholders. The literature has identified circumstances when more information is not necessarily desirable. While this paper does not take a stance on this, one reason why shareholders may prefer more information is the opportunity to take corrective action that increases firm value when managers have not acted in the best interest of

shareholders.

[13]Bushman and Indjejikian (1995) also consider corporate disclosures and insider trading but differ from our model in that they introduce information acquisition. Fan (2007), John and Lang (1991) and Gomes (2000) study two-dimensional signaling models of insider trading and dividend announcements/earnings management/resource diversion.

[14]Bergstresser and Philippon (2006) find evidence that managers whose compensation is more sensitive to share price manipulate earnings more, and sell large quantities of shares after manipulating their earnings upward.

[15]A number of papers has shown that corporate insider trades are associated with subsequent stock returns, which indicates that insiders trade upon private information not reflected in stock price (e.g. Givoly and Palmon (1985), Lakonishok and Lee (2001), Piotroski and Roulstone (2002, 2005), Seyhun (1986), Roze and Zaman (1998)).

[16]One may interpret the disclosure setup as misstatements by the manager (in the sense of presenting more good or bad news than is known to him) receiving an infinite penalty ex post. Kartik (2008) studies communication games with finite lying costs.

[17]The outcome of a project can be interpreted as the profitability of a division within a firm.

[18]This assumption allows us to study the information revelation role of disclosures and insider trading in isolation of any incentive effects related to investments.

[19]Disclosure models with verifiable reports were introduced by Grossman (1981) and Milgrom (1981), and generalized by Seidmann and Winter (1997).

[20]Imposing this constraint is equivalent to assuming a less restrictive message space and an infinite cost of lying (reporting more successes or failures than were actually observed). It is in this sense that the verifiable reports game is a (degenerate) version of a signaling game.

[21]Our holding cost is similar to the transaction cost in the signaling game of DeMarzo and Duffie (1999). Alternative interpretations of the discount factor are the time and in particular the risk preferences of managers. The qualitative predictions of the model should be similar. The model by Leland and Pyle (1977) is based on this assumption. Since a large fraction of a manager's wealth is closely tied to and positively correlated

with firm value through his human capital, portfolio theory predicts that managers prefer to divest their holdings in the firm to diversify. Costly incomplete diversification through the retainer of an equity stake can thus signal positive information about the firm. In such signaling models, the signaling cost is determined by managerial risk aversion, an unobservable parameter. Since the discount factor in our model is assumed to be common knowledge and identical across managers, we prefer the interpretation of a holding cost.

[22]We abuse notation here by suppressing the mutual dependence of the share trade and the firm value message.

[23]Pooling of this kind has also been studied by Lewis and Sappington (1993), Austen-Smith (1994) and Shin (1994).

[24]We rule out short selling and share purchases. Short selling by insiders is prohibited in the United States under SEC Rule 16 (c). We believe excluding share purchases does not alter our results. Share purchases would not occur in equilibrium for instance for a sufficiently low holding cost.

[25]*The Economist,* 23-29 October 2004, p.83.

[26]In fact, even if we don't interpret HC accounting as its pure form, HC accounting with LCM still differs from MTM; they have quite different economic consequences. HC accounting with LCM can only reveal a decrease and not an increase in the asset value (conservative principle). Specifically, a company (and its investors) may well consider a project that earns a low positive return a failure. The investors may want it liquidated and have the resources redeployed. However, under HC accounting with LCM, the investors cannot distinguish a low positive return from a very high positive return. Hence they would not be able to tell that the asset is earning a sub-standard return. With MTM accounting, they would be able to. In other words, even if LCM is applied stringently, it provides managers a veil in some cases whereas MTM never does.

[27]At the same time, this timing setup highlights the fact that a longer-dated model is unsuitable for our purposes (we will explain the last two points later on). This timing setup is thus the most tractable one.

[28]We assume this project is divisible. Take the example of a supermarket chain that operates outlets in different locations. Should the company decide to part with some or

all of its branches, the latter could be sold off as a whole, in groups or individually. An outsider would only be able to see the total transaction value but be unable to put a price on the individual branches. He would simply lack the expertise (firm-specific project) or find it uneconomical to do so (high cost).

[29]The assumption of positive autocorrelation can also be justified by empirical evidence (e.g. GDP growth, as an aggregate performance measure of numerous small projects, over the business cycle) and on theoretical grounds (e.g. stage financing in the venture capital industry as an optimal contract due to sequential information revelation).

[30]The shorter lifetime of the manager is also one of the reasons for the inefficiency of historic cost accounting in Plantin, Shin, and Sapra (2008).

[31]The intrinsic value is the value realized if the project is liquidated in the market.

[32]In the extension part of this paper, we are going to consider share-price-based compensation.

[33]However, if the shareholder decides to liquidate the whole project at T_1, we assume that the manager is paid based on the profit at T_1, which equals the liquidation value less the initial cost.

[34]The PSS paper also assumes that the agent's aim is to maximize the accounting value.

[35]It is worth noting that even if these two items could be disentangled on the balance sheet, this can only occur when $\alpha \neq 0$. Therefore, if the manager's strategy in the equilibrium is to choose $\alpha = 0$ for a very low g_1, then shareholders cannot infer g_1 even under the assumption that the balance sheet reports cash separately.

[36]In our context, the unobservability of the project's market value for the shareholder is due to its firm-specific nature and the heterogeneity of its parts. Take the example of the supermarket chain. In the case of a sale of a number of outlets that are regionally dispersed, for instance, the unit sale values are not known to the outsider, only the total sale value is. Although the outlets are likely to be identically equipped, the location factor is likely to drive a wedge between their individual sale values. Knowing or determining these values is not realistically possible for the outsider or only at a prohibitive cost. The inseparability of the proportion of the project sold and its growth rate, and thus the unobservability of the project's market value, is the crucial difference between historic

cost accounting and marking to market. If the outsider could observe the growth rate and the proportion of the project sold individually, historic cost accounting would be just as informative as marking to market, making them identical.

[37]Further, as the referee pointed out, we can also interpret the opaqueness measure a' as an LCM hurdle under historic cost accounting regime in reality.

[38]Our basic argument is that under historic cost accounting, share-price-based compensation is more efficient than accounting-value-based compensation if the stock market is sufficiently efficient. However under marking to market, accounting-value-based compensation is an improvement over share-price-based compensation if the stock market is not liquid enough. Basically, given two accounting schemes and two compensation schemes, there are four pairwise combinations between the accounting regime and the compensation scheme: (1) historic cost accounting regime and accounting-value-based compensation, (2) historic cost accounting regime and share-price-based compensation, (3) marking to market and accounting-value-based compensation, (4) marking to market share-price-based compensation. We argue that combinations (2) and (3) are more efficient than (1) and (4). Intuitively, (1) and (4) make the performance measure endogenous. Since the manager can influence the performance measure, which determines his pay, higher inefficiency ensues. Combination (1) is the focus of our paper. As we show, historic cost accounting provides the manager with a free option to increase the book value without requiring any effort from the manager. If the manager is remunerated based on book value, he has an incentive to use this free option. This will lead to inefficiency. A similar story holds for combination (4). If marking to market and a share-price-based measure are used to determine compensation, the share price will not longer be exogenous. This is so because the manager can influence the share pice to some degree himself. If his remuneration is simultaneously based on the share price, the manager has an incentive to inflate the share price to increase his compensation, which also leads to inefficiency.

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