Abstract

A key motivation for disclosure and supervision regulations is the perception that corporations are not as transparent as they could be. Traditional arguments attribute this lack of transparency to agency problems between managers on one side and stakeholders and/or outsiders on the other. We propose an alternative theory founded on the simple idea that agents who invest in long-term projects face a trade-off between information and liquidity. When secondary markets are shallow, more information can reduce the expected payoff of agents who need to liquidate their positions. Even given direct and costless control over information design, these very stakeholders choose to incentivize managers to withhold interim information. In such an environment, imposing transparency can lower investment and welfare.

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1 Introduction

A key motivation for transparency regulations and disclosure rules is the view that corporations tend to withhold news about the quality of the long-term assets they hold. In this sense, they are more opaque than they could be. Traditional arguments attribute this lack of transparency to agency problems between managers and stakeholders. The presumption is that managers have information that would be valuable to stakeholders but that it is too costly to set up incentives for managers to share this information.\footnote{See for instance Milgrom and Roberts (1988) for a review of the traditional literature on agency costs, information, and compensation contracts. They present a canonical model where “[…] it is always optimal for the firm to adjust its promotion criteria and information collection rules from what would otherwise be optimal.” Along related lines, the cheap-talk literature started by Crawford and Sobel (1982) shows that when there is any misalignment of preferences between an informed expert and a principal, all Bayesian-perfect equilibria feature some information loss. Even if the principal can write incentive contracts, full revelation is generally suboptimal. Implementing direct revelation, even when feasible, requires the provision of incentives whose cost can outweigh the benefits. See Krishna and Morgan (2008) for a review of these ideas.}

We propose a different theory that flips this traditional logic on its head: it is optimal for stakeholders to control the flow of information and, therefore, to create incentives for managers to withhold information from them. In other words, the corporations we describe are rationally opaque. Far from being a friction that ought to be mitigated, agency costs may at least in part serve to implement the optimal allocation when information impacts the outside value of long-term projects.

To make this point, we present an environment where more information leads to better scrapping decisions but increases the risk that stakeholders may lose value if they must liquidate their positions. If the key benefit of opacity is in fact to mitigate potential liquidation losses, the tendency of corporations to remain opaque should depend on the depth of secondary markets. In our model, stakeholders choose to limit the revelation of new information on asset quality only when the depth of secondary markets may affect the liquidation value – a situation Allen and Gale (2005) describe as cash-in-the-market pricing. This prediction accords well with the existing empirical evidence.\footnote{Morgan (2002) finds that rating agencies tend to disagree more on financial firms than on other firms suggesting that financial firms tend to be particularly opaque. Since a distinguishing feature of many intermediaries (e.g. banks) is that their stakeholders value liquidity highly, our model suggests that it is rational – even constrained optimal – that financial corporations should be especially opaque. Flannery et al. (2004, 2013) propose various proxies for information availability (bid-ask spreads, the effect of trades on prices…), find little evidence that banks and bank-holding companies are especially opaque during tranquil times but find evidence that the opacity of these intermediaries increases disproportionately during financial crises, especially the 2007-09 period. By predicting that opacity depends on the depth of secondary markets, our model provides a potential explanation for this second empirical regularity as well.}

We develop our argument in a simple model of liquidity needs in the spirit of Diamond
and Dybvig (1983) and Jacklin (1987). Agents can invest in a long-term project but face the risk that they may need to consume at an interim stage, before the project matures. When they need to liquidate their investment early, they can either scrap the project or, instead, sell it to more patient agents as in Jacklin (1987). Our model differs in several key aspects from the canonical Jacklin framework. First, our agents are risk neutral. Second, the long-term project is risky and its probability of success – its *quality* – is drawn at the interim stage. Third, when they make the original investment, agents can design how much information they would like to receive on the project quality at the interim stage. Information is free so that agents can choose at no cost full public information, no information at all, or anything in between these two extremes.

The optimal information design becomes more opaque, in a sense we make precise, as the risk of early liquidation rises. While more information allows investors to scrap early when ex-post efficient, it can also reduce the expected payoff when agents are constrained to liquidate their projects. Indeed, investors may be forced to liquidate at a price that does not reflect the fundamental value of the project when secondary markets are shallow. Therefore, cash-in-the-market-pricing imposes an upper bound on the project’s liquidation value in some states, thus making our risk neutral investors effectively risk averse. Coarser information provides some insurance to those early investors who have to liquidate their project.

Given this logic, it would seem that the optimal situation for investors would be to observe project quality privately at the interim stage in order to make efficient scrapping decisions without incurring the risk of liquidation losses. That intuition turns out to be correct from an individual point of view, but wrong in equilibrium. As in Milgrom and Stokey (1982), all private information is revealed when projects trade in secondary markets. As a result, private information can hurt investors if they cannot commit to restrict it. It is optimal, therefore, for investors to restrict their access to information in some fashion.

One natural way to implement the desired solution is to delegate the project continuation decision to a manager with the right incentives to reveal the correct level of information. A carefully designed compensation scheme that gives the manager a participation in revenues and a severance payment if she chooses to scrap early implements the constrained optimal scrapping policy. Introducing moral hazard whereby the manager can influence the quality of the project does not alter our result. Moral hazard makes transparency more costly and this could lead stakeholders to ask the manager to hold on to the project in more states, even though the project may be of low quality.
Our paper is related to several strands of the literature. Hirshleifer (1972) shows that interim or, in his terminology, “emergent” information can lower the market value of long-term projects unless the project “can be converted into money at a price representing only a time-discount of the value at maturity.” Along different lines, Hirshleifer (1971) shows that the prospect of interim information can make agents with long-term investment and consumption plans worse off by introducing “redistributive risk” once the new information emerges. In either context, as in our paper, the socially or privately optimal information outcome may not be full disclosure. This should be contrasted with Diamond (1984) where, in the tradition of the agency view, opacity is a side effect of any banking activity. There, the bank is opaque because it is too costly for each depositors to monitor the borrowers. More recently, Andolfatto, Berentsen and Waller (2012) show that the threat of undue diligence – the possibility that agents may decide to acquire private information – can influence the socially optimal disclosure policy.

Bolton, Santos and Scheinkman (2011) consider a model of asymmetric information between short and long-term investors with cash-in-the-market pricing. Short-term investors may sell an asset either because of a liquidity shock or because they know the quality of the asset is low. The more short-term investors wait to sell their asset, the more likely they are to receive information about its quality, which leads to an ever increasing discount on the asset price. These investors take the asymmetry of information as given whereas our short-term investors recognize the trade-off they face and devise their information structure in an optimal way.

Diamond and Rajan (2011) and Challes, Mojon and Ragot (2012) argue that distressed banks may hold on to illiquid assets for too long. The mechanism studied in those papers is quite different from ours. In Diamond and Rajan’s model, banks believe that the price of the asset will be much higher in the future so that, conditional on their survival, they are better off keeping them in the hope that they will survive times of distress. In our model, the manager keeps the asset and all fundamental information about it in order to preserve the ability of stakeholders to sell their investment in secondary markets, and this outcome turns out to be optimal from the ex-ante point of view of investors.

Zetlin-Jones (2013) describes a model where, at the optimal contract, more opaque firms tend to emphasize short-term sources of finance. One could think of our result as the converse: corporations whose stakeholders value liquidity highly are more likely to be opaque. Von-Thadden (1995) shows that the possibility of asymmetric interim information between
investors and firms can cause the optimal contract to feature “short-termism” in the sense that short-term investments are preferred to more productive investments. Our model can generate the same outcome, but for other reasons. Kaplan (2006) proposes a model where banks may choose not to reveal the interim information they obtain about the quality of their assets in an environment with consumption risk in the spirit of Diamond and Dybvig (1983). In his model, revealing bad news makes it more costly to induce patient investors to reveal their type.

Another related literature argues that deposit insurance does not give depositors the incentives to monitor the bank’s activity (see for example Calomiris and Khan, 1991 and Kareken and Wallace, 1978). Here we give a reason why, even in the absence of deposit insurance, depositors would not monitor their banks. If depositors were to monitor their banks, they would lose the liquidity services that the bank provides. Through this lens, one could interpret the Federal Reserve’s policy to release liquidity-facility access only with a long delay as an example of the potential role of opacity when dealing with financial intermediaries.

Our implementation of the desired solution via delegation is reminiscent of Aghion, Bolton, and Tirole (2004). They consider a set-up where an entrepreneur can either work or shirk, but will work if he is monitored by an investor. However, the investor may have a need for liquidity at an interim stage. As a result, a trade-off exists between monitoring and liquidity since the investor has private information on the quality of the firm and may use it to his advantage. Instead, we design a mechanism that induces the manager to keep all information to themselves while investors agree to remain uninformed. In this sense, their model seems more applicable to venture capital investors who have direct influence over a firm’s decisions while ours applies more naturally to more mature firms.

Finally and closest to our paper is Dang et. al. (2013) who study an environment very similar to ours and also point out that in this class of models withholding information may be optimal. In their model as in ours, markets do not implement the first best allocation because the possibility of bad news cause investors to face liquidation losses. They show that a “bank” that commits not to share its project continuation decisions with late investors and finances early withdrawals by selling information-insensitive securities to these late investors can implement the first best allocation. Their solution to the information design problem is different from ours. We assume that continuation decisions cannot be hidden (that scrapping events are “hard” information), and the solution is then to partially conceal signals about
project quality.\footnote{We also build in various ways on Gorton and Pennachi (1990), Dang, Holmstrom and Gorton (2012) and Siegert (2012).}

The next section presents the environment. Section 3 shows the existence of an equilibrium given an information structure and we proceed to endogenize the information structure in Section 4. There we show that some opacity is typically rational and we discuss the key implications of this result. In Section 5 we consider the case when information can be kept private. Section 6 analyzes implementation by delegating the project and the release of information to a manager.

\section{The environment}

\textbf{Investment opportunities and preferences} Consider an economy with three dates $t = 0, 1, 2$, and equal measures of two types of agents. The first type of agents are early investors who are endowed with one unit of a consumption good at $t = 0$. The second type are late investors who appear at date $t = 1$ with an endowment $A > 0$.

As will soon become clear, the size of the endowment of late investors pins down the size of secondary markets in our model. Therefore, we will think of $A$ as capturing the expected state of secondary markets when early investor select their information disclosure policy. When $A$ is low, secondary markets are shallow, and assets are more likely ex ante to sell at a price that is below their expected payoff, as in Allen and Gale (2005). Our main result will be that this leads early investors to opt for a more opaque information policy. One simplifying assumption we are making here is that $A$ is deterministic. This shortens several of the upcoming arguments but we emphasize that dealing with the stochastic case does not present major technical difficulties or change the nature of our results.\footnote{Our results hold as long as there is a non-zero probability that project prices at date $t = 1$ depend on available resources. One can even assume that the realization of $A$ and project quality are correlated, as long as the correlation is not perfect. See footnote \footnote{11} for more details.}

A fraction $\pi \in [0, 1]$ of early investors and a fraction $1 - \pi$ of late investors have the desire to consume at date 1 while other agents want to consume at date 2. In other words, half of all agents consume at date 1, while the other half want to consume at date 2.\footnote{This symmetric assumption on the risk of early consumption for early and late investors simplifies notation in the upcoming analysis by implying that a mass one of agents want to liquidate their projects a date 1 (namely early investors who turn out to be early consumers) and the same mass of agents are willing to buy projects at date 1 (namely late investors who turn out to be late consumers.) Even though this pins down the number of potential buyers in secondary markets, we can still vary the depth of secondary markets at will}
to \( \pi \) as the liquidity risk for early investors.

As of date \( 0 \), early investors do not yet know whether they will want to consume early or late hence they seek to maximize:

\[
\begin{equation}
\begin{aligned}
u(c_1, c_2; \pi) &\equiv \pi c_1 + (1 - \pi)c_2,
\end{aligned}
\end{equation}
\]

where \( c_1 \) is their expected consumption in period \( t = 1 \) conditional on being an early consumer while \( c_2 \) is expected consumption at \( t = 2 \) conditional on being a late consumer.\footnote{We assume here that a law of large number holds: \( \pi \) is both the fraction of early investors who turn out to be early consumers and the likelihood that a particular early investor will become an early consumer.}

All agents have the option to store the consumption good across dates. Early investors – who receive their endowment at \( t = 0 \) – also have the option to each invest in a long-term and risky project that yields either \( R > 1 \) or nothing at date 2 per unit of the consumption good invested at date 0. As of date 0, early investors know that the success probability \( q \in [0, 1] \) will be drawn at date 1 from a Borel distribution \( F \) with a continuous and strictly positive density in \([0, 1]\). All these projects can be scrapped at date 1 and all have a scrap value \( S \in (0, 1) \) which is independent of \( q \).

For simplicity, we will study the case where all projects have the same success probability. Assuming that the \( q \)'s are perfectly correlated across projects allows us to study one secondary market for all active projects. When \( q \) is potentially different across projects then different interim information messages imply different secondary markets. As long as resources available for buying a specific project are not unbounded with probability one, then the trade-off between information and liquidity is active and our results hold on a project-by-project basis. In that context, a more natural interpretation is the bargaining version of our environment that we study in the appendix.

Parameters could in principle be such that early investors choose to store their endowment, but we focus on the more interesting case where early investors invest in the risky project. Specifically, we assume throughout that

\[
1 < \pi \min \left( A, \int qRdF \right) + (1 - \pi) \int qRdF.
\]

As will become clear below, (2.1) implies that early investors prefer to invest in the risky project than in storage even when they have no information about project quality. Of course by varying \( A \). Doing so, in fact, gives us one of the main comparative statics we establish in this paper, see corollary 4.2.
and as we will discuss at length in this paper, early investors can typically do better by releasing some information about project quality at date 1.

**Market for projects** At date 1, agents can buy or sell risky projects in a Walrasian market. Agents take the project price as given and they trade projects when it raises their expected utility given the information they have. In appendix 8.1 we show that our model with Walrasian trade makes the exact same predictions as a model where early investors who wish to consume early are matched with exactly one late investor who wish to consume late and the former gets to make the latter a take-it-or-leave it offer.

**Information** This paper is principally about what early investors choose to find out about $q$ once it is drawn in period 1. To learn about $q$, early investors who invest in the risky project can choose to activate an information technology. This technology sends a message $m$ once $q$ is realized at date 1. Early investors are free to choose any message function in the following set:

$$
\{ m : [0, 1] \mapsto B([0, 1]) : q \in m(q) \text{ for almost all } q \in [0, 1] \}
$$

where $B([0, 1])$ is the space of Borel subsets of $[0, 1]$. Restricting the choice of message functions to satisfy $q \in m(q)$ is without loss of generality\(^7\) and has the advantage that the technology can be thought of as announcing a subset of $[0, 1]$ to which $q$ belongs. In section 5.1 we will discuss the option for early agents to keep information to themselves and argue that this does not affect any of our results. Finally, restricting our attention to deterministic message functions is also without loss of generality as we will show when we fully characterize the optimal information design choice of early investors\(^8\).

Agents are free to become fully informed about the project quality by setting $m(q) = \{ q \}$ for all $q \in [0, 1]$. One of our main results, however, is that early investors usually opt for much coarser information technology designs, unless they know they will consume late, that is unless $\pi = 0$. Choosing no information -- $m(q) = [0, 1]$ for all $q \in [0, 1]$ -- is always an option as well, but is not optimal either unless $\pi = 1$.

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\(^7\)To see why this is without loss of generality take any Borel-measurable mapping $h$ from $[0, 1]$ to an arbitrary message space. Then the set-valued mapping $m : [0, 1] \mapsto B([0, 1])$ defined for all $q \in [0, 1]$ by $m(q) = h^{-1} \circ h(q)$ has the desired properties and conveys exactly the same information as $h$. In other words, as long as all agents understand the selected design of the information technology, they can invert any message into a subset of $[0, 1]$.

\(^8\)See the proof of proposition 4.1.
Timeline  At date 0, early investors choose the message function. Since they are all alike, they all agree to choose the information design that maximizes their expected payoff as of date 0. Next they decide whether to invest in the long-term project or to store their endowment. At the start of date 1, late investors appear, all consumption types are revealed, and a message \( m \in B([0, 1]) \) becomes available. Agents immediately and correctly translate this message into an expected likelihood of success for the long-term project,

\[
E(q|m) = \frac{\int_m q dF}{\int_m dF}.
\]

Walrasian markets open, projects trade and/or are scrapped. Early consumers consume while late consumers wait until the returns to their investment is realized and consume the proceeds.

3 Equilibrium given an information structure

In this section we define an equilibrium given a message function. The next section will endogenize the choice of message function.

Optimal trading decisions at the Walrasian stage  Let \( p(m(q)) \) be the unit price of a long-term project given \( \pi \in [0,1] \) and \( A > 0 \) when the message \( m(q) \) is issued at the start of period 1. To keep notation simple we do not make explicit the dependence of market prices on the model’s parameters. Early investors who discover that they have to consume early will scrap their project given \( m(q) \) only if \( S \geq p(m(q)) \). As for early investors who do not experience the consumption shock, they sell their project in the market if

\[
p(m(q)) \geq \max\{E(q|m(q))R, S\}.
\]

Given the message technology in place and as of date 0, early investors thus expect payoff:

\[
\pi \int \max\{S, p(m(q))\} dF + (1 - \pi) \int \max(S, E(q|m(q))R, p(m(q))) dF.
\]

Late investors for their part, consume their endowment if they turn out to be early consumers at date 1. Those who are late consumers spend all their endowment on projects if

\[
p(m(q)) \geq \max\{E(q|m(q))R, S\}.
\]

Otherwise they store their endowment. In either case, all late consumers consume their realized wealth at date 2.
Definition  Given a message function $m$, an equilibrium is a set of investment decisions for early investors, a set of scrapping/selling decisions for early investors conditional on their consumption type, a set of trading decisions for late investors conditional on their consumption type, and a Walrasian price schedule $p(m(q))$ for all $q \in (0, 1)$, such that:

1. All decisions are optimal for almost all agents;
2. For $F$-almost all $q \in (0, 1)$, demand for projects equals supply at the Walrasian stage given message $m(q)$.

Since early investors get to select the message function, they select the equilibrium that yields the highest expected payoff to them. That decision is our key concern in this paper, but we must first show that an equilibrium exists and is unique.

Existence  To establish that an equilibrium exists, we show in the appendix that given a message function only one price schedule is compatible with market clearing at the Walrasian stage.

Proposition 3.1. Given a message function $m$, an equilibrium exists and is generically unique. Furthermore, at the Walrasian stage and for almost all $q \in [0, 1]$,

$$p(m(q)) = \max \{S, \min \{E(q|m(q))R, A\}\}.$$  

There is an equilibrium only if early investors who consume late hold on to their projects, as otherwise supply exceeds demand. They do so if the price is not too high relative to their expectation for the project’s payoff. In addition, late investors will bid for the project as long as its expected return is higher than its price and as long as they have the means to buy it. In particular, if the signal is positive, then late investors might want to buy many projects. However they have limited resources and the maximum they can spend is their endowment. Therefore the price cannot exceed $A$ and must equal the project’s expected payoff otherwise. If the expected payoff falls below the scrap value, then holders of the project scrap it and the only possible market price is $S$ in this case.

The argument is illustrated in figure [1]. The price must fall between $S$ and the expected payoff $E(q|m(q))R$ given the message. As long as the price is the expected payoff, late investors who want to consume late are willing to spend their entire endowment on projects making demand (drawn in dashed blue) the entire interval between 0 and $\frac{\pi A}{p} = \frac{\pi A}{E(q|m(q))R}$. To move
beyond that demand level, the price must fall and demand becomes \( \pi_A \frac{p}{p} \) for \( p \in (0, E(q|m(q))R) \). Supply, shown in solid red, is \([0, \pi]\) when \( p = S \), is exactly \( \pi \) when \( p \in (S, E(q|m(q))R) \) and becomes \([\pi, 1]\) when \( p = E(q|m(q))R \) since in that case even late consumers with projects are willing to sell.

The figure shows the case where there are not enough resources to purchase all the projects at fair value, that is when \( \frac{\pi_A}{E(q|m(q))R} < \pi \). Then the only equilibrium price is \( p = A \). In other words, the price is dictated by the resources available in the market rather than the project’s expected payoff. This is a situation Allen and Gale (2005) describe as cash-in-the-market pricing. On the other hand, if \( \frac{\pi_A}{E(q|m(q))R} \geq \pi \), then the equilibrium price is the expected payoff. We will show that cash-in-the-market pricing implies a trade-off between information and liquidity.

We assume that that \( A \) is fixed but \( q \) varies while Allen and Gale (2005) assume the reverse. We need \( q \) to vary to create an interesting information problem. The key aspect of both environments, however, is that projects may sell at a discount when \( A \) is small relative to \( q \). We keep \( A \) fixed for simplicity but making both \( q \) and \( A \) stochastic is easy and does not alter any of our results.

Observe also that the payoff early investors obtain when projects trade is the same as when early investors who experience liquidity shocks are matched with one late investor who wishes to consume late and make a take-it or leave-it offer to these agents. It follows that all the results we establish below regarding the rational choice of information technology hold in a simple search environment exactly as they do in a Walrasian environment. In appendix 8.1 we also show that proportional bargaining does not change the qualitative nature of our results.

4 Rational Opacity

We are now in a position to characterize the information design decisions of early investors. It will be instructive to first consider a parametric example where the trade-off between information and liquidity is transparent. We will then characterize the general solution to our information problem.

\footnote{A similar alternative is to assume that the measure of late investors who desire early consumption is stochastic.}
4.1 An illustrative parametric example

Assume that technological parameters are such that
\[
\int \max(S, \min(qR, A)) dF < A < \int qR dF. \tag{4.1}
\]

In this particular part of the parameter space, there is cash-in-the-market pricing in secondary markets when no information is provided as the price cannot be above \(A\), as we explained above. The first inequality means that information reduces the sellers’ expected payoff from secondary markets since late investors are already willing to pay \(A\) when no information is provided. In other words, the Walrasian price is as shown in figure 2 for the two polar information cases: full information and no information. In this specific case, information cannot have any positive effect on liquidation value but, if \(q\) is low, the news is bad and can have a negative effect on secondary market prices.

To make clear the resulting trade-off between information and liquidity, observe that if early investors opt for no information, their ex-ante payoff is
\[
\pi A + (1 - \pi) \int_{0}^{1} qR dF. \tag{4.2}
\]
Indeed, they can sell their project for $A$ in secondary markets when they must consume early and, if they turn out to be late consumers then they keep their project to maturity, as no new information becomes available at date 1. If on the other hand early investors opt for full information, their expected payoff is

$$\pi \left( \int_0^{\frac{S}{R}} SdF + \int_{\frac{S}{R}}^{\frac{A}{R}} qRdF + \int_{\frac{A}{R}}^1 AdF \right) + (1 - \pi) \left( \int_0^{\frac{S}{R}} SdF + \int_{\frac{S}{R}}^1 qRdF \right).$$  \hspace{1cm} (4.3)

Information is valuable ex-post for late consumers because it enables them to make efficient scrapping decisions, thus obtaining a higher expected payoff,

$$\int_0^{\frac{S}{R}} SdF + \int_{\frac{S}{R}}^1 qRdF > \int qRdF,$$

but it is costly for early consumers because it reduces the expected liquidation value of the project at date 1:

$$\int_0^{\frac{S}{R}} SdF + \int_{\frac{S}{R}}^{\frac{A}{R}} qRdF + \int_{\frac{A}{R}}^1 AdF < A.$$  \hspace{1cm} (4.4)

A trivial consequence of these observations is that given only a choice between full information
and no information, early investors would only opt for full information if their liquidity risk is low enough.

We can say much more. Assume that agents can design the message function in any way they wish. Revealing information cannot improve early investors’ payoff if they must consume early, as condition (4.1) implies that their payoff is already at its maximum if they do not receive any information. The only point of revealing some information, then, is to induce a better scrapping decision when early investors are not constrained to sell. It follows directly that there is no need for the message function to partition $[0, 1]$ in more than two subsets: scrap or hold. While late consumers would like to be informed when $qR < S$, there is no value in having more information than just $q \geq \frac{S}{R}$. To summarize, while the value of marginal information in $[\frac{S}{R}, 1]$ is non-positive, revealing that information could reduce early investors’ payoff when they have to consume early.\(^{10}\)

These simple observations give us the first source of opacity. It is not rational for early investors to reveal any information beyond what is strictly necessary to induce efficient scrapping decisions. Late investors, for their part, would value finer information, but they have no means to induce the original investors to provide it.

We will show in full generality below that the two subsets, scrap and hold, are non-overlapping intervals. We can thus restrict our search for optimal message functions to the following class of functions, indexed by $\bar{q} \in [0, 1]$: for $q \in [0, 1]$,

$$m(q) = \begin{cases} [0, \bar{q}] & \text{if } q < \bar{q} \\ (\bar{q}, 1] & \text{otherwise.} \end{cases}$$

At date zero then, early investors need only choose $\bar{q}$. We refer to $\bar{q}$ as the scrapping threshold. An obvious possibility is to set $\bar{q} = \frac{S}{R}$ which would enable late consumers to always make the ex-post efficient scrapping choice. In this case, the message is designed to convey the most information subject to the constraints we have outlined above. This design, however, turns out to be optimal only when $\pi = 0$ and early investors know they will consume late.

To characterize the optimal design, notice that the early investors’ payoff is

$$V(\bar{q}) = \pi \left( \int_0^{\bar{q}} SdF + \int_{\bar{q}}^1 AdF \right) + (1 - \pi) \left( \int_0^{\bar{q}} SdF + \int_{\bar{q}}^1 qRdF \right).$$

\(^{10}\)A formal proof of this claim as well as other claims we make in this intuitive discussion are provided in the next section where we take on the optimal design problem in full generality.
Since $V$ is continuous on a compact set, an optimal $\bar{q}$ exists for all $\pi \in [0, 1]$. While the payoff function is not necessarily concave in the scrapping threshold for arbitrary density functions, it is hill-shaped with a single peak so that the optimal threshold is in fact unique. Furthermore, $V$ is strictly submodular: the early investor’s marginal payoff is decreasing in $\pi$. Therefore, the higher the liquidity risk, the greater the cost of increasing the scrapping threshold. Intuitively, there is a tradeoff between the desire to scrap when it is efficient to do so and the fact that better information can lower the project’s resale value. This implies that investors who face a relatively low liquidity risk will choose a higher scrapping threshold. And inversely, investors facing a high liquidity risk will prefer a lower scrapping threshold and possibly no information at all. In this simple parametric case, one can show\(^{12}\) that the optimal scrapping cut-off is

$$\bar{q} = \max \left\{ \frac{S - \pi A}{(1 - \pi)R}, 0 \right\}. $$

Indeed, we argue below that if the optimal scrapping solution is interior it must satisfy the following first order condition:

$$\pi A + (1 - \pi)\bar{q}R = S. $$

Any $q > \bar{q}$ such that the left hand side of the equality exceeds the right-hand side should be included in the holding message, as it dominates scrapping. Of course, consistency requires that the holding strategy be optimal for late consumers given the message. But (4.1) guarantees that they are willing to hold the project if no new information is revealed, so they remain willing to do so upon learning the good news that $q \geq \bar{q}$. For the same reason, since late investors are willing to pay $A$ before hearing that $q \geq \bar{q}$, this remains true after learning the message.

This result implies in particular that the optimal $\bar{q}$ is zero on $\left(\frac{S}{A}, 1\right]$ and decreases strictly on $[0, \frac{S}{A}]$. More liquidity-minded early investors thus opt to reveal less information. It also

\(^{11}\)This simple example also illustrates how our results can easily be extended to the stochastic case. Suppose that $A$ is stochastic but remains in the bounds implied by assumption \(^{4.1}\). Then the expected payoff of early investors remains strictly submodular in $(\pi, \bar{q})$ and this section’s argument goes through unchanged. More generally, as long as there is a positive probability that the price of projects in secondary market is $A$ when $\bar{q} = \frac{S}{\pi}$, then some opacity will be optimal and the extent of opacity will increase with $\pi$. In other words, as long as cash-in-the-pricing is a possibility, our results hold.

\(^{12}\)For a concrete example, assume that $F$ is uniform. Then

$$V(\bar{q}) = \bar{q}S + \pi(1 - \bar{q})A + \frac{(1 - \pi)R}{2} (1 - \bar{q}^2). $$

This function is strictly concave in $\bar{q}$ and its derivative vanishes at $\frac{S - \pi A}{(1 - \pi)R}$.  

15
suggests that deeper secondary markets—a higher \( A \)—causes early investors to opt for more opacity. But, as will now see, this only holds on the particular part of the parameter space on which this section focuses. The relationship between the depth of secondary markets and opacity turns out to be more complicated than this simple example would suggest. To see this, we now turn to the general solution of the information design problem.

4.2 The general solution

This section provides the general solution to our problem. Intuitively and as discussed in the example above, a trade-off only exists between liquidity and information when projects sell at a price below their expected value. Otherwise, it is never optimal to withhold information. Capturing this idea is the main direction in which we need to generalize the example. To shorten the exposition, we will proceed assuming that \( \pi \in (0, 1) \) and that \( A > S \).

As we mentioned, a key quality cutoff in the analysis is the threshold \( \tilde{q}(A) \) past which, if the message \( q \geq \tilde{q}(A) \) is emitted at date 1, projects sell at price \( A \), below their expected value. This threshold is defined by

\[
\tilde{q}(A) = \max \left\{ \tilde{q} \in [0, \frac{S}{R}] : E(qR|q \geq \tilde{q}) \leq A \right\}
\]

(4.5)

with the understanding that \( \tilde{q}(A) = 0 \) if \( E(qR) > A \).

**Proposition 4.1.** Given \( \pi \in (0, 1) \) and \( A > S \), the optimal information design consists of a scrapping message and a holding message. The scrapping message is in—essentially an interval \([0, \tilde{q}(\pi, A)]\) where

\[
\tilde{q}(\pi, A) = \max \left\{ \frac{S - \pi A}{(1 - \pi)R}, \tilde{q}(A) \right\}
\]

(4.6)

The proof consists of several steps. First we show that we can restrict the search for the optimal message function to binary functions—scraps or hold—and that these functions are two non-overlapping intervals with no gaps. This implies the existence of a scrapping threshold \( \tilde{q} \) such that agents receive the scrapping message whenever \( \tilde{q} < q \) and the holding message otherwise. Second, we show that \( \tilde{q} \geq \tilde{q}(A) \). Otherwise, and given (4.5), raising \( \tilde{q} \) would

\[\text{When } A \leq S \text{ or } \pi = 0 \text{ secondary market can play no role and early investors opt for full information. If } \pi = 1, \text{ information has no value and choosing no information is always optimal.}\]
strictly raise the early investors’ expected payoff. Therefore their problem is to maximize their expected payoff (4.4) subject to \( \bar{q} \geq \bar{q}(A) \), which yields (4.6). Finally, we show that random messages would not help early investors in achieving a higher expected payoff.

Cash-in-the-market pricing – the possibility that market price may depend on available resources on the demand side for projects – plays a critical role in our results. It introduces a cap on the early consumer’s payoff, thus making their payoff function non-linear in \( m(q) \). As a consequence, even though agents are risk neutral, liquidity concerns can make them behave as if they were risk-averse.

4.3 Key implications

This general result has several immediate consequences. First, it yields the main comparative statics results we seek to establish in this paper.

**Corollary 4.2.** At the optimal information design:

1. \( \bar{q}(\pi, A) \) decreases weakly with \( \pi \), strictly so if and only if \( \bar{q}(\pi, A) \in (\bar{q}(A), \frac{S}{R}) \).

2. \( \bar{q}(\pi, A) \) is U-shaped in \( A \). Given \( \pi \in [0, 1] \), there exists \( \bar{A}(\pi) \leq \int_{\frac{S}{R}}^{1} qRdF \) such that \( \bar{q}(\pi) = \frac{S}{R} \) if \( A \leq S \) or \( A \geq \bar{A}(\pi) \), and the optimal scrapping thresholds first decreases and then increases on \([S, \bar{A}(\pi)]\).

**Proof.** The first item is obvious. As for the second item, note first that if \( A \) is sufficiently high, \( \bar{q}(A) = \frac{S}{R} \), and the optimal threshold is \( \frac{S}{R} \). As \( A \) falls \( \bar{q}(A) \) falls below \( \frac{S}{R} \), the threshold initially traces \( \bar{q}(A) \) an increasing function of \( A \). As \( A \) falls further, it starts tracing \( \frac{S - \pi A}{(1 - \pi)^{\frac{R}{S}}} \) instead, a decreasing function, until that function becomes exactly \( \frac{S}{R} \) which occurs at \( A = S \). \( \square \)

The first item states that more liquidity-concerned investors choose a lower scrapping threshold. The negative relationship between the liquidity risk and information revelation comes from the basic trade-off between liquidity and information we discussed earlier. The second item says that the trade-off is only operative when the market price of projects is affected by the endowment of late investors. It should be clear scrapping low quality projects is always optimal when \( A \leq S \). Hence, in this case \( \bar{q}(\pi, A) = \frac{S}{R} \). At the opposite end, when \( A \) is so large that projects always sell at their expected payoff, information cannot affect liquidation value and there is no need to take the risk of holding the project when it would be efficient to scrap, so that again \( \bar{q}(\pi, A) = \frac{S}{R} \). In between these two thresholds, there is
cash-in-the-market pricing in secondary markets and the scrapping threshold does depend on $A$.

Notice that a lower threshold $\bar{q}(\pi, A)$ is equivalent to an increase in opacity: as the threshold decreases, the set of project quality for which all investors receive the same information is larger. Hence opacity tends to rise when there is cash-in-the-market pricing. This prediction accords well with the dominant message of the empirical literature prompted by the findings of Morgan (2002) or Flannery et al. (2013): various proxies for opacity tend to increase during periods where secondary markets are under stress or illiquid.

We emphasize yet again that the assumption that $A$ is deterministic hence independent of project quality is made only for convenience and plays no role in these comparative statics. The key assumption is that when early investors select the optimal information design, they attach positive probability to the event that secondary market prices will be determined by market depth rather than by project quality. All that matters for our purposes, therefore, is that market depth and project quality not be perfectly correlated. Credit freezes and more generally financial crises are natural examples of events that affect secondary markets beyond what changes in fundamental project quality alone would justify.

Proposition 4.1 also implies that equilibria can be inefficient. In cases where $\bar{q}(\pi, A) < \frac{\tilde{\pi}}{\tilde{R}}$, early investors choose a scrapping threshold that induces them to keep the project in some states of the world when they should not. Therefore, total expected output is strictly below what would prevail under full information as is, therefore, aggregate expected consumption. The inefficiency arises from the fact that ignorance is bliss for those agents who must sell their project. In summary:

**Corollary 4.3.** The equilibrium allocation under rational information design can be Pareto inefficient.

Finally, an important result is that while information distortions may lower expected output below its potential, this does not imply that imposing transparency necessarily causes output to rise. In fact, yet another consequence of proposition 4.1 is that doing so may lead to a decrease in expected output.

**Corollary 4.4.** Imposing full information can lead early investors to opt for storage rather than the risky project. In particular, it can cause expected output and expected consumption to fall.
Proof. Assume that parameters satisfy:

\[ S < \int \max(S, \min(qR, A))dF < 1 < A < \int qRdF. \]  

(4.7)

In other words, the expected payoff from fully informed secondary markets is dominated by the storage payoff, but it continues to be the case that selling to uninformed secondary markets dominates storage. Now consider early investors with a high liquidity risk. If \( \pi \) is high enough, constraining early investors to provide full information will cause them to opt for storage, thus causing a decline in investing activity since those same agents would choose to invest if they could opt for no (or, more generally, less) information.

As in Andolfatto et. al. (2012) therefore, more transparency can imply less investment and hence destroys surplus. Here, this occurs because imposing full information lead liquidity-minded investors to opt for less productive projects with safer short-term returns.

Von-Thadden (1995) also presents a model where the possibility of asymmetric interim information between investors and firms can cause the optimal contract to feature “short-termism” in the sense that short-term investments are preferred to more productive investments. The mechanism behind this aspect of our model is quite different however: stakeholders are concerned about their ability to liquidate their investment at a good price and transparency, therefore, can reduce the value of entering into long-term investment projects.

4.4 Constrained optimality

We have characterized the information design solution that would obtain in a decentralized version of the environment. Could a social planner propose a different information arrangement at date 0 that improves the lot of agents alive at that date and implement that arrangement via carefully designed sets of transfers across agents? The answer turns out to be no as long as the planner cannot exclude agents from entering into side-trades and must abide by the resulting participation constraints.

To see this, consider a social planner who seeks to maximize the ex-ante welfare of early investors. We assume throughout that parameters are such that the planner is better off investing all date 0 resources in the risky project. Once a message function is set and given a message \( m \), the planner chooses the consumption of early investors if they turn out to be early consumers, \( c^E_1(m) \), the consumption of late investors who are early consumers, \( c^L_1(m) \),
the expected consumption of early investors who turn out to be late consumers, \( c_2^E(m) \), and
the expected consumption of late investors who are late consumers, \( c_2^L(m) \). The planner also
chooses what fraction \( x(m) \in [0,1] \) of projects to scrap given \( m \) at date 1 and a quantity
\( k(m) \geq 0 \) of resources to store at date 1. These choices must first be resource feasible at date
1, for all possible messages \( m \):

\[
\pi c_1^E(m) + (1 - \pi) c_1^L(m) + k(m) \leq A + x(m)S. \tag{4.8}
\]

Indeed, the only resources available for consumption at date 1 are the endowment of late
investors and the proceeds from scrapping long-term projects. Likewise, the expected payoffs
for late consumers given \( m \) must be feasible:

\[
(1 - \pi)c_2^E(m) + \pi c_2^L(m) = (1 - x(m))E(qR|m) + k(m) \tag{4.9}
\]

Since late investors can always consume their endowment immediately or store it, the plan
must also satisfy the following participation constraints:

\[
c_1^L(m), c_2^L(m) \geq A \tag{4.10}
\]

Finally we require that early investors who are early consumers be willing to participate in
the arrangement upon discovering their consumption type. We assume that types are either
unverifiable or unobservable so that any agent can claim either \( c_1^E(m) \) or \( c_2^E(m) \). Hence, early
consumers who pretend to be late consumers can always sell claims to \( c_2^E(m) \) to late investors.
An early investor who chooses to sell her individual claims to late investors must offer at least
the same return as the one offered by the planner, namely

\[
r(m) \equiv \frac{c_2^L(m)}{A} - 1.
\]

Therefore the planner faces the additional constraint that an early investor should not be bet-
ter off by selling his claim to late consumption rather than taking the proposed consumption
for early consumers:

\[
c_1^E(m) \geq \frac{c_2^E(m)}{1 + r(m)}. \tag{4.11}
\]

Here, a key observation is that while the planner must internalize aggregate resource con-
straint \([4.8]\) in establishing a consumption vector for all agents, individual deviators are not
constrained in that fashion. In particular, since each early investor is small, she would face unbounded demand for claims to late consumption remunerated at a transformation rate infinitesimally higher than the social planner.

Then, given a message function $m : [0, 1] \mapsto \mathcal{B}[0, 1]$, the planner solves:

$$SP(m) = \max \pi \int c_1^E(m(q))dF + (1 - \pi) \int c_2^E(m(q))dF$$

subject to (4.8), (4.9), (4.10) and (4.11). We will now show that the message strategy which early investors select in the decentralized environment maximizes $SP(m)$, hence is constrained-efficient.

**Proposition 4.5.** The messaging strategy early investors select in the decentralized environment is constrained-efficient.

Given any message strategy $m$, we show in the appendix that the decentralized allocation we characterize in section 3 gives early investors a payoff of exactly $SP(m)$. If follows that date-0 investors always select a messaging strategy that attains $SP(m)$ and, as a result, is constrained-efficient. Because early investors can enter into side-trades, the planner must deliver the same consumption to all late consumers, whether they were early or late investors. Hence, although the planner does not value the welfare of late investors, they still receive consumption when they consume late, and that consumption must be higher than what they would obtain from storing their endowment. It follows that the marginal return to raising $c_2^E(m) \geq A$ is below the implied resource cost. On the other hand, while the marginal return to raising early consumption $c_1^E(m)$ equals its marginal resource cost, early consumption cannot be higher than the available resources $A$. At any optimum therefore, if $A$ is relatively low – i.e. when $S < A < E(qR|m)$ – then the planner would like but cannot increase the early consumption of early investors beyond $A$, and so $c_1^E(m) = A$. If $A$ is high – i.e. when $A > E(qR|m) > S$ – then the planner can shift consumption towards early consumers until the constraint on late consumption binds, so that $c_2^E(m) = A$. But this is exactly what the decentralized solution delivers, and the result follows.
5 Private information

So far we have assumed that if information is made available to some agents, then it is public information. Our results suggest that early investors would prefer to observe project quality privately at date 1 to make efficient scrapping decisions without incurring the risk of liquidation losses. This section shows that this intuition is wrong. While it is true that each investor has an incentive to be better informed than other agents, this is true for all agents, and general equilibrium arguments imply that acquiring private information can only hurt investors. Since they are unable to commit not to act on their private information, their willingness to trade in secondary markets will make public any private information. Therefore private information can only hurt investors if they cannot commit to restrict it.

5.1 Investors always observe the signal

Assume that early investors always observe the interim signal perfectly but privately. In that case, as long as late investors observe the supply of projects, the Walrasian market reveals all private information which means that the equilibrium allocation is the same as in the full information case.

**Proposition 5.1.** If early investors observe project quality privately then the only equilibrium allocation is the full information equilibrium allocation.

**Proof.** Consider a candidate price schedule \( p(q) \) for projects on island at date 1 where, in the context of this proof, the premise is that \( q \) is only observed by early investors. We know that \( p(q) \geq S \) in any equilibrium and for almost all \( q \). If \( S < p(q) < qR \) then only early consumers supply their projects and, upon observing that demand, potential buyers infer that \( q \) is distributed with strictly positive continuous density over \([p(q), 1]\). It follows that demand for projects is \( \pi \frac{A}{p(q)} \). The only case in which this is an equilibrium, therefore, has \( p(q) = 1 \) and \( qR > 1 \). If \( p(q) > qR \) then all potential sellers sell, from which buyers infer that \( q \) is distributed with strictly positive continuous density over \([0, p(q)]\) so that demand is zero, which can not be an equilibrium. The only equilibrium, then, has \( p(q) = \min(S, qR) \) if \( qR < A \) and \( p(q) = 1 \) if \( qR \geq A \) exactly as in the full information case. \( \square \)

This result should not come as a surprise: agents’ willingness to trade at the interim stage reveals all private information in this environment as in Milgrom and Stokey (1982). Since unbridled access to private information can lead to an inferior allocation from the ex-ante
point of view of early investors, they have an incentive to observably commit to remaining ignorant. Section 5.2 explores this possibility.

5.2 Observable private information design

Assume now that agents can make the design of private information they select observable to late investors, or, equivalently, that they can somehow commit to it. In this case, late investors observe what information design early investors selected. At the trading stage, late investors can infer all information early investors received and, therefore, the equilibrium is the same as when the signal is public.

Proposition 5.2. If the design of the information technology is observable, the rational information design choice is the same regardless of whether the message is private or public.

Proof. The argument is the same as in the proof of proposition 5.1 with \( E(q|m(q))R \) playing the role of \( qR \).

Put another way, all the results we established in the previous section go through unaffected when information is private rather than public. In addition, this section says that investors who must confront liquidity risk have incentives to observably commit to reveal any information they have (say, via delegated monitoring) or to not trade on the basis of that information (say via regulations that ban trading on the basis of undisclosed information.)

6 Implementation by delegation

The analysis above suggests that agents have an incentive to find ways to commit to ignore, or at least not to act upon their private information. In this section we show that a natural way to implement the desired solution is to delegate the project continuation to a risk-neutral representative agent (e.g. a manager) with the right incentives. In a second part, we introduce a moral hazard problem to evaluate the traditional argument that opacity fosters fraud.

6.1 The basic delegation problem

Assume that the coalition of early investors hire an agent with no holdings in the project and give her the authority to scrap the project at date 1. Assume further that only this agent is given full access to the signal at date \( t = 1 \).
Consider then the class of compensation scheme whereby the manager receives a fixed payment $M > 0$ if the project is scrapped – think of it as a severance payment – and, if the project is continued, receives a payment $\alpha R$ if the project succeeds—think of this part of her compensation as a participation in revenues. For simplicity, we assume that the manager has no mass so that, in particular, the payment she receives does not affect the expected surplus generated by the project. We now have:

**Proposition 6.1.** Let $\bar{q}(\pi)$ be an optimal scrapping threshold on island $\pi \in [0, 1]$. Let the manager’s compensation scheme $(M, \alpha)$ be such that

$$M = \alpha \bar{q}(\pi) R.$$ 

Then the manager implements the optimal scrapping policy and, correspondingly, early investors expect the constrained-efficient payoff.

*Proof.* Assume that the (fully but privately informed) manager observes that $q < \bar{q}(\pi)$. Then, since $\alpha q R < M$, she chooses to scrap, as desired. The converse holds by the exact same logic and the compensation scheme, therefore, leads to exactly the desired policy. \qed

Stakeholders can implement the ex-ante optimal allocation and information design by creating ex-post conflict of interests between a manager and at least some of the stakeholders. Late consumers would prefer upon discovering their type that all information be revealed. By committing to delegation with a carefully designed set of incentives, stakeholders are committing to the ex-ante optimal information environment. Far from being a friction that ought to be addressed as it is in traditional models, agency costs serve to implement the constrained optimal solution.

Note that the proposition does not pin down the level of the compensation scheme so that in principle, the entire one-dimensional space of schemes that satisfies the desired property implement the optimal policy. Since the manager has no mass, investors are indifferent across such schemes as long as they involve finite payments. In the next section, we introduce moral hazard and we show that – among other insights – doing so provides a natural way to pin down the level of the optimal compensation scheme.
6.2 Delegation with moral hazard

The delegation scheme we have considered so far assumes that the manager has no impact on the project’s outcome. Assume instead and more realistically that success requires a certain level of attention, or effort, on the part of the manager. In this section, we show that, counter-intuitively, opacity about asset quality may lower the cost of inducing managers to expend the optimal level of effort on the project they oversee.

Precisely, we assume the manager can affect the quality of the project by exerting an unobservable effort \( e \in [0, 1] \) before nature draws the quality of the project. If she exerts effort \( e \) and nature draws quality \( q \) then the probability the project succeeds is \( e.q \in [0, q] \). Therefore, we can think of the manager’s action as affecting the distribution from which nature draws a level of quality. To make the problem interesting, we assume that effort is costly and the per unit cost of effort for the manager is \( B \). Notice that the structure of the economy is the same as the one we have already studied when \( e = 1 \).

Since the effort level is unobservable and unverifiable, agents who observe \( e.q \) are unable to distinguish \( e \) from \( q \). Therefore, given effort \( e \), the analysis proceeds as before: agents select a liquidation threshold \( \bar{q}_h \) and, when if \( eq < \bar{q}_h \), then the delegate scraps the project, while if \( eq \geq \bar{q}_h \) then the project is held to maturity. Agents need to design a compensation scheme such that (1) the delegate chooses to liquidate the project if and only if \( eq < \bar{q}_h \), and (2) the manager chooses to the optimal level of effort. In appendix 6.2, we show that the unique compensation scheme that satisfies both requirements belongs in the class of schemes we have used before: the manager receives a fixed severance payment or, when the project is held to maturity, a participation in revenues. In particular then, the manager gets paid a positive amount whenever he has to scrap the project and this gives him an incentive to shirk, since in that case pay is unaffected by effort. Hence, transparency – in the sense of a higher \( \bar{q}_h \) – will increase the cost of maintaining the manager’s incentives to work. Summarizing this discussion, we have established the following:

**Proposition 6.2.** With moral hazard, more transparency is costly, as it requires a higher severance payment and a higher share of the project’s revenue to incentivize the manager to work.

Notice that the contracting problem bears a strong resemblance to the standard costly

\[\text{14Assuming that the other agents incur no cost of exerting effort, or that the minimum } \pi \text{ is high enough that agents always exert efforts.} \]
state verification problem of Townsend (1979), with scrapping playing the same role in our problem as audit does in Townsend’s. However, the payment structure is essentially reversed: it is debt when the manager scraps the project and equity otherwise. This occurs because outsiders cannot tell whether nature selected a low $q$ or whether the manager shirked.

7 Conclusion

In this paper we argue that curtailing the flow of interim information about expected payoffs can be a rational choice for long-term investors because there is a natural trade-off between information and liquidity. A natural way to restrict their own access to information is for stakeholders to delegate the management of their interests to agents whose compensation provides them with incentives that differ from the ex-post incentives of stakeholders. In our model therefore and far from being a friction that ought to be addressed, agency costs serve to implement the constrained optimal solution. Another direct implication of our theory is that imposing transparency requirements can lead to short-termism, whereby shareholders prefer to invest in short- rather than long-maturity projects, even though that is constrained inefficient.

Our framework clearly applies to financial corporations which rely heavily on highly liquid sources of finance and, as our model would predict, tend to be especially opaque when secondary markets are under stress as Flannery et. al. (2004) document. But the mechanism we study is bound to be operative for most corporations.

We made strong assumptions (short-lived agents, for one) to make the model tractable but the basic economic mechanism we articulate should survive relaxing most of these. One critical assumption we make is that divesting decisions are public information. If, instead, we allow project managers to hide scrapping decisions, to store scrapping proceeds when they are positive, and compensate that manager with a carefully chosen fraction of proceeds at maturity, then it is easy to show that the manager will scrap when and only when $q \leq S_R$, as needed to maximize surplus. In that environment, secondary markets always pay the no-information price – scrapping decisions, since they are unobserved, have no consequences on liquidation values – exactly as in Dang et al. (2013). While low-quality projects may have been scrapped, secondary markets buyers only discover that they bought bad projects when proceeds are distributed at maturity.

The trade-off between liquidity and information thus introduces incentives to hide actions
if possible. Since stakeholders do not have that option in our model, they choose instead to curtail the flow of information about projects which leads to inefficient continuation decisions. Our implementation delivers the constrained-optimal allocation by introducing agency problems between managers and stakeholders. As in Sobel and Crawford (1982) this effectively results in managers opting for a coarse message.

8 Appendix

8.1 Bargaining

Here we analyze the case where early consumers and newborn are bilaterally matched in period 1 and bargain over the project following the realization of the public signal $m(q)$. To shorten the analysis, we focus on the parametric example considered in Section 4.1.

Assume that agents split the surplus from trade using proportional bargaining. We denote by $\theta$ the share of the surplus of early consumers. Since $m$ is public, all agents expect the long-term project to return $\max[E(q|m)R; S]$. Let $p(m) \leq A$ be the agreed transfer of resources between the early consumers and the newborn. With proportional bargaining, $p(m)$ has to satisfy

$$(1 - \theta) [p(m) - S] = \theta \{\max[E(q|m)R; S] - p(m)\}$$

and arranging, together with the resource constraint $p(m) \leq A$, we have

$$p(m) = \min \{\theta \max[E(q|m)R; S] + (1 - \theta)S; A\}$$

As usual in the context of proportional bargaining, newborns extract more of the surplus as their bargaining power $1 - \theta$ increases, in which case the transfer decreases to $S$. Agents then expect payoff

$$\pi \int p(m(q))dF + (1 - \pi) \int \max[S, E(q|m(q))R]dF.$$

If agents choose to reveal nothing, then their payoff is:

$$\pi \min \left\{\theta \int qRdF + (1 - \theta)S, A\right\} + (1 - \pi) \int qRdF. \tag{8.1}$$
If they choose to provide full information, then their payoff is:

$$\pi \left\{ \int_0^{\bar{q}} SdF + \int_{\bar{q}}^{1} \left[ \theta qR + (1 - \theta)S \right] dF + \int_{\bar{q}}^{1} AdF \right\} + (1 - \pi) \left\{ \int_0^{\frac{S}{R}} SdF + \int_0^{\frac{S}{R}} qRdF \right\}. \quad (8.2)$$

With take-it or leave-it offers from early consumers (i.e., $\theta = 1$) we obtain the same expressions as in main text. As before then, given a choice only between full information and no information, early investors choose the former if and only if their liquidity risk is below a certain threshold.

More generally, consider now the same general class of messages as in the main text. At date zero then, agents of type $\pi \in [0, 1]$ choose $\bar{q}$.

**Proposition 8.1.** The optimal information level $\bar{q}(\pi, \theta)$ for agents of type $\pi \in [0, 1]$ decreases strictly with $\pi$ and $\theta$. Furthermore, $\bar{q}(0, \theta) = \bar{q}(\pi, 0) = \frac{S}{R}$ and $\bar{q}(1, \theta) = 0$ for all $\theta > 0$.

**Proof.** Fix $\pi \in [0, 1]$. Given $\bar{q} \leq \frac{S}{R}$ the agent’s payoff is:

$$\pi \left\{ \int_0^{\bar{q}} SdF + \int_{\bar{q}}^{1} \min \left\{ \theta E[qR|q \geq \bar{q}] + (1 - \theta)S; A \right\} dF \right\} + (1 - \pi) \left\{ \int_0^{\bar{q}} SdF + \int_0^{1} qRdF \right\}. \quad (8.3)$$

Differentiating this expression with respect to $\bar{q}$ yields

$$Sf(\bar{q}) - \pi \min \left\{ \theta E[qR|q \geq \bar{q}] + (1 - \theta)S; A \right\} f(\bar{q})$$

$$-\mathbb{I}_{\{\theta E[qR|q \geq \bar{q}] + (1 - \theta)S < 1\}} \theta \pi \int_0^{1} \bar{q}Rf(\bar{q})dF - (1 - \pi)\bar{q}Rf(\bar{q}).$$

where $\mathbb{I}$ is an indicator function. Since $\min \left\{ \theta E[qR|q \geq \bar{q}] + (1 - \theta)S; A \right\} > S$, this expression is strictly negative when $\bar{q} = \frac{S}{R}$ unless $\pi = 0$. Therefore only when $\pi = 0$ do agents choose to reveal the efficient level of information. If $\pi = 1$ then (8.3) is strictly negative even if $\bar{q} = 0$ so that no information is revealed. Also, since $\bar{q} < \frac{S}{R}$ for all interior $\pi$ the derivative is uniformly decreasing as $\pi$ rises through $(0, 1)$ which implies that $\bar{q}$ decreases strictly, as claimed. Turning to the effect of $\theta$, when $\theta = 0$ the derivative is strictly positive if $\bar{q} < \frac{S}{R}$ and strictly negative if $\bar{q} > \frac{S}{R}$. Therefore, the maximum is attained at $\bar{q} = \frac{S}{R}$, and all agents prefer more information when they have no bargaining power. The case with $\theta = 1$ is as in the text. Finally, the derivative is uniformly decreasing as $\theta$ rises through $(0, 1)$ which implies that $\bar{q}$ decreases strictly.

28
We leave aside the case with bargaining under private information as it is substantially more difficult.

8.2 Proof of Proposition 3.1

Proof. We begin by proving that \( p \) must have the form posited above in any equilibrium. Take any \( q \) and associated message \( m(q) \). If \( p(m(q)) > E(q|m(q))R \) then all early investors would sell their projects at date 1 while there are no buyers. If, on the other hand, \( S < p(m(q)) < E(q|m(q))R \) then only early investors who need to consume early sell their projects. In that case, all late investors who need to consume at date 2 buy as many projects as they can afford, namely \( \frac{A}{p(m(q))} \) so that demand equals supply if and only if

\[
\pi \frac{A}{p(m(q); \pi, A)} = \pi \iff p(m(q); \pi, A) = A.
\]

Finally, if \( E(q|m(q))R \leq S \) then the optimal strategy for a project holder is to scrap it. Therefore we must have \( p(m(q)) = S \) so that all agents are indifferent between buying or selling the project. This proves the second part of the proposition.

Having so characterized the shape of the Walrasian price schedule, we can now simplify early investor’s expected payoff given a message function \( m \). If project quality \( q \) is drawn at date 1, all agents rightly infer from the message \( m(q) \) they receive that the likelihood of success is \( E(q|m(q)) \). The agent’s payoff, then, is given by:

\[
\pi \int p(m(q); \pi, A)dF + (1 - \pi) \int \max(S, E(q|m(q))R) dF.
\]

To understand the second integral, recall that agents always have the option to scrap their project and observe that agents who do not experience a consumption shock are always at least as well off keeping their projects as selling them and may be strictly better off doing so when \( p(m(q); \pi, A) = A \). Finally, it is easy to see that as long as assumption [as1] holds it is uniquely optimal for agents born at date zero to invest all their endowment in risky projects.
8.3 Proof of Proposition 4.1

Proof. To ease the exposition in the context of this proof, we will dispense with all “$F$—essentially” qualifiers. Statements we make below about various subsets of project quality levels are understood to apply except possibly on sets of $F$-measure zero.

We will first characterize the solution under the assumption that the messages must be deterministic but will then argue that this assumption can be dropped without changing the solution. When the message function is deterministic, information takes the form of a partition of the interval (namely the range of the inverse of the message function) and we can assume that for all possible $q$ the message is a subset $m(q)$ of $[0, 1]$ that contains $q$ itself.

Consider any solution to the early investors’ information design problem (i.e. consider any optimal message function.) Let $\mathcal{H}$ be the union of messages $m \subset [0, 1]$ that induce late consumers to hold their project with probability one, while $S$ is the complement set, i.e. the union of messages that induce scrapping with strictly positive probability. The expected payoff for early investors given this messaging strategy can be written as:

$$\pi \left\{ F(S)S + \int_{\{q:m(q)\subset\mathcal{H}\}} \min (E(qR|m(q)), A) dF \right\} + (1 - \pi) \left\{ F(S)S + F(\mathcal{H})E(qR|\mathcal{H}) \right\}$$

To understand this expression, note that the project is scrapped with positive probability by late consumers only if $E(qR|m) \leq S$. Given the same message then, secondary markets are willing to pay no more than $S$ for the project, so that the expected payoff is the same whether the project is sold or scrapped by early investors. If the project is held on the other hand, late consumers get as payoff the expected date 2 revenue. Early consumers get $\min (E(qR|m(q)), A)$ from secondary markets. But note that

$$\int_{\{q:m(q)\subset\mathcal{H}\}} \min (E(qR|m(q)), A) dF \leq \min \left( \int_{\{q:m(q)\subset\mathcal{H}\}} E(qR|m(q))dF, F(\mathcal{H})A \right)$$

$$= F(\mathcal{H}) \min (E(qR|\mathcal{H}), A)$$

so that merging all messages that lead late consumers to hold into one hold message can only raise the expected payoff of early investors. Henceforth then we can restrict our search for the optimal message functions to binary functions: hold or scrap.

Next we show that $S$ is an interval that contains the origin. If this is not the case then there are two sets $M_1$ and $M_2$ of equal and strictly positive $F$-mass such that the first set is in
\(H\), the second set is in \(S\), and \(M_1 < M_2\). Moving \(M_2\) to \(H\) and \(M_1\) to \(S\) leaves the scrapping part of the expected payoff unchanged but, since the \(q\)'s are higher in \(M_2\) than in \(M_1\), this strictly raises the payoff conditional on holding. If follows, then, that we must have \(S = [0, \bar{q}]\) and \(H = (\bar{q}, 1]\) for some \(\bar{q} \in [0, 1]\).

Next assume (yet again by way of contradiction) that \(\bar{q} < \bar{q}(A)\) which implies, in particular, that \(\bar{q} < \frac{S}{R}\). Then secondary markets pay \(E(qR|H)\) when the hold message is issued. Indeed, the definition of \(\bar{q}(A)\) implies that when \(\bar{q} < \bar{q}(A)\), \(E(qR|q \geq \bar{q}) < A\) so that projects trade at their expected value in secondary markets when the hold message is issued. It follows that the ex-ante expected payoff for date-0 agents is

\[
\int_0^{\bar{q}} SdF + \int_0^1 E(qR|q \geq \bar{q})dF.
\]

But since the scrapping threshold is such that \(\bar{q} < \frac{S}{R}\) so that \(\bar{q}R < S\), raising \(\bar{q}\) marginally would strictly increase the payoff, contradicting the premise that the messaging strategy was optimal.

These results, taken together, imply that the optimal scrapping threshold maximizes:

\[
V(\bar{q}; A) \equiv \pi \left\{ \int_0^{\bar{q}} SdF + \int_0^1 AdF \right\} + (1 - \pi) \left\{ \int_0^{\bar{q}} SdF + \int_0^1 qRdF \right\}
\]

subject to:

\(\bar{q} \geq \bar{q}(A)\).

The unconstrained maximizer of \(V\) is easily seen to be \(\max \left\{ \frac{S - \pi A}{(1 - \pi)R}, 0 \right\}\). If the constraint does bind, the solution is \(\bar{q}(A)\) instead.

To complete the proof, we now need to argue that the suggested information design remains optimal even if random messages are allowed. Consider then general message functions \(h\) defined from \([0, 1]\) to the set of probability distributions on a given message space \(\mathcal{M}\) that includes at least the set of all Borel measurable subsets of \([0, 1]\) so that, in particular, the optimal deterministic solution remains feasible. We will require that \(h\) be such that for any subset \(\mathcal{P}\) of \(\mathcal{M}\) that has a positive mass in the distribution induced by \(F \circ h\), \(E(qR|\mathcal{P})\) is well defined. The same Jensen inequality argument as in the deterministic case implies that we may restrict our attention to a binary message space, scrap or hold, and we denote each message as before by \(S\) and \(H\), respectively. The complication is that date-0 agents may now
randomize over those two possibilities for a set of $q \in [0, 1]$.

Assume, first, that at the optimal messaging policy $E(qR|\mathcal{H}) > A$ but that there is a set of positive mass in $[0, \max \left\{ \frac{S - \pi A}{(1 - \pi)R}, 0 \right\})$ such that the probability that $\mathcal{H}$ is emitted given almost any $q$ in that set is strictly positive. Take a subset of those $q$’s sufficiently small that $E(qR|\mathcal{H}) > A$ continues to hold even if we change the message to scrap for those $q$’s. Since $\pi A + (1 - \pi)qR < S$ by construction for those quality levels, the ex-ante payoff for date-0 agents rises strictly when we do make that policy change. This implies that $q$’s in $[0, \max \left\{ \frac{S - \pi A}{(1 - \pi)R}, 0 \right\})$ must trigger the scrap message with probability one as before. The same argument implies that if $E(qR|\mathcal{H}) > A$, $q$’s in $(\max \left\{ \frac{S - \pi A}{(1 - \pi)R}, 0 \right\}, 1]$ trigger the hold message with probability one. If $E(qR|\mathcal{H}) > A$ then, the messaging policy is deterministic.

If $E(qR|\mathcal{H}) < A$ then early investors expect the same payoff regardless of whether they turn out to be early or late consumers. In that case, if the scrapping policy is not the full-information one, the payoff can be strictly raised by changing the message policy as above, without perturbing the fact that $E(qR|\mathcal{H}) < A$, a contradiction. In particular, the message policy is once again deterministic.

Finally, conditional on $E(qR|\mathcal{H}) = A$, it is easy to see that the payoff is at its highest possible level when messages are deterministic and $\bar{q} = \bar{q}(A)$.

These three scenarios for $E(qR|\mathcal{H})$ cover all possibilities and, in all cases, the message function is deterministic. This completes the proof.

8.4 Proof of Proposition 4.5

Proof. Given a message function, we will show that the allocation described in section 3 is feasible for the planner and achieves $SP(m)$. Since the planner seeks to maximize the welfare of early investors and $c^E_1(m)$ only matters through its effect on available resources, any solution must feature $c^E_1(m) = A$ so that (4.8) becomes $\pi c^E_1(m) + k(m) \leq A + x(m)S$.

Next, if $S \geq E(qR|m)$, setting $x(m) = 1$, $c^E_1(m) = c^E_2(m) = A$, and $c^E_1(m) = c^E_2(m) = S$, which is the decentralized solution, obviously solves the social planner’s problem. Likewise, if $A < S$, the presence of late investors is irrelevant and the proposition holds trivially.

So assume henceforth that $S < E(qR|m)$ and that $S < A$. In that case $x(m) = 0$ is easily seen to be optimal which means that (4.8) becomes $c^E_1(m) \leq A$. But this, together with (4.11), implies

$$A(1 + r) \geq c^E_2(m) \iff c^E_1(m) \geq c^E_2(m).$$
This inequality is the linchpin of the proof. It says that the fact that early investors can enter into side trades ends up implying that even though he does not value their welfare directly – the planner has to deliver a payoff to late investors who are late consumers that is as high as that of original stakeholders. If the planner tries to reduce the rate of transformation late investors receive in the arrangement, individual deviators can offer them a better deal.

To conclude the proof, observe that (4.8) and (4.9), together with the fact that \( x(m) = 0 \), and the fact that \( c^L_1(m) = A \) imply that

\[
(1 - \pi)c^E_2(m) + \pi c^E_1(m) \leq \pi A - \pi c^L_2(m) + E(qR|m).
\] (8.4)

Now we only need to consider two simple subcases. If \( A > E(qR|m) > S \), the decentralized solution calls for a hold for early investors who are late consumers and for a sale of the project at price \( E(qR|m) \) for early investors who are early consumers. Late investors who are late consumers expect payoff \( E(qR|m) \) at date 2. That allocation satisfies all of the planner’s constraints and makes \( SP(m) = E(qR|m) \) which, given (8.4) and the fact that \( c^L_2(m) \geq A \), is the highest payoff the planner can achieve in this case.

If \( S < A < E(qR|m) \), the decentralized solution calls once again for a hold for early investors who are late consumers and for a sale of the project at price \( A \) for early investors who are early consumers. Late investors who are late consumers expect payoff \( E(qR|m) \) at date 2. That allocation is feasible for the planner and makes \( (1 - \pi)c^E_2(m) + \pi c^E_1(m) = (1 - \pi)E(qR|m) + \pi A \). We will show that this payoff cannot be beat by the planner. Since we must have \( c^E_1(m) \leq A \), the only way to beat it is to have \( c^E_2(m) > E(qR|m) \). Since \( c^L_2(m) \geq c^E_2(m) \), that would imply \( c^E_2(m) < A \). But in that case it feasible to reduce both \( c^L_2(m) \) and \( c^E_2(m) \) by a marginal \( \epsilon > 0 \), increase \( c^E_1(m) \) by \( \frac{\epsilon}{\pi} \), which changes the objective by \(-\pi \epsilon \) which completes the proof.

8.5 Proof of Proposition 6.2

Proof. We now consider the incentives of the manager to exert the right amount of effort, given \( \bar{q} \). Consider a payment scheme \( P(eq, \rho, a) \) where \( e \) is the intermediary’s effort, \( q \) is the quality of the project known only to the intermediary, \( \rho \in \{s, f\} \) is the outcome of the project (success or failure) and \( a \in \{S, H\} \) is the interim announcement of the intermediary (scrap, S or hold, H). Since the project should be scrapped whenever \( eq \leq \bar{q} \), the payment cannot be conditioned.
on the final outcome of the project, success or failure, so that \( P(eq, \rho, S) = P(eq, S) \) for all \( eq \leq \bar{q} \). Truth-full revelation of \( eq \) in the range \([0, \bar{q}]\) implies that \( P(eq, S) = P(S) \), as otherwise the intermediary would always choose to reveal the quality \( eq \) that gives him the highest payoff. In particular, notice that \( P(S) \) does not depend on the effort level chosen by the intermediary.

We now turn to the case where \( eq > \bar{q} \). In this case the project should be kept to maturity, so that the payoff can depend on the outcome \( s \) or \( f \). Now, for any \( eq > \bar{q} \), the intermediary has to prefer to say just \( H \) than revealing another \( q' \in [\bar{q}, 1] \) as otherwise the payment scheme would not satisfy the requirement that it is optimal that the intermediary only communicates scrap or hold, \( S \) or \( H \). Hence, the payment scheme has to satisfy for any \( eq, q' \in [\bar{q}, 1] \),

\[
\begin{align*}
\text{eq}P(eq, s, H) + (1 - \text{eq})P(eq, f, H) &= \text{eq}P(q', s, H) + (1 - \text{eq})P(q', f, H),
\end{align*}
\]

i.e. whatever \( q \) nature draws, the intermediary is indifferent between revealing any \( q' \) as long as it implies \( H \). Therefore, combining the incentive compatibility constraint to reveal \( eq \) instead of any \( q' \) as well as the constraint to reveal \( q' \) instead of \( eq \) we obtain

\[
(eq - q')(P(eq, s, H) - P(q', s, H)) = (eq - q')(P(eq, f, H) - P(q', f, H))
\]

Hence, \( P(eq, s, H) - P(q', s, H) = P(eq, f, H) - P(q', f, H) \). As it would be more expensive to compensate the intermediary more in one case than in another\(^\text{15}\) we conclude that \( P(eq, s, H) = P(q', s, H) = P(s, H) \), and \( P(eq, f, H) = P(q', f, H) = P(f, H) \).

Finally, we need to insure that the intermediary announces \( S \) (scrap) for all \( eq < \bar{q} \) and \( H \) (hold) otherwise. That is the payment scheme should satisfy,

\[
eq P(s, H) + (1 - \text{eq})P(f, H) \geq P(S), \text{ if } eq > \bar{q},
\]

and

\[
P(S) \geq \text{eq}P(s, H) + (1 - \text{eq})P(f, H), \text{ if } eq < \bar{q}.
\]

Since the payoff function when \( H \) is increasing in \( eq \) whenever \( P(s, H) > P(f, H) \) and decrea-

\(^{15}\)If \( P(eq, s, H) = P(q', sH) \) yields the desired result, then there is no reason to incur the additional cost of setting \( P(eq, s, H) > P(q', sH) \).
ing otherwise, we need to set $P(s, H) > P(f, H)$. Finally, payment is minimized whenever

$$P(S) = \bar{q}P(s, H) + (1 - \bar{q})P(f, H). \quad (8.5)$$

We can now derive the incentive constraint on the effort level. Given $\bar{q}$, the bank’s payoff of exerting effort $e$ is simply

$$\int_0^{q/e} P(S)dF(q) + \int_{q/e}^1 [eqP(s, H) + (1 - eq)P(f, H)]dF(q) - Be$$

which is convex in $e$ as $P(s, H) > P(f, H)$, that is the marginal payoff is

$$\int_{q/e}^1 q[P(s, H) - P(f, H)]dF(q) - B$$

which is negative at $e = 0$ and increasing in $e$. Hence, the intermediary will choose either $e = 0$ or $e = 1$. In other words, the intermediary exerts effort if and only if

$$\int_0^\bar{q} P(S)dF(q) + \int_{\bar{q}}^1 [qP(s, H) + (1 - q)P(f, H)]dF(q) - B \geq P(S)$$

on the left hand side of this incentive constraint is the payoff when $e = 1$ while on the right-hand side is the payoff when $e = 0$. In this case notice that the intermediary always gets $P(S)$, as the project is always scrapped. Arranging terms and using (8.5) we can rewrite this incentive constraint as

$$\int_{\bar{q}}^1 \{(q - \bar{q})P(s, H) + (\bar{q} - q)P(f, H)\}dF(q) \geq B$$

As $\bar{q} < q$ in the range of integration, it is optimal to set $P(f, H) = 0$ and $P(s, H)$ such that

$$P(s, H) = \frac{B}{\int_\bar{q}^1 (q - \bar{q})dF(q)} \quad (8.6)$$

Notice that the payment is increasing in $\bar{q}$. Therefore, more transparency (in the sense of a higher $\bar{q}$) is costly, as it requires a higher compensation scheme to incentivize the manager.

When, as in the text, we set $P(s, H) = \alpha R$ for a given $\alpha$ then the intermediary exerts
effort if and only if
\[
\int_{\bar{q}}^{1} (q - \bar{q})dF(q) \geq \frac{B}{\alpha R} \tag{8.7}
\]
On the left-hand side is the gains from working, while on the right-hand side is the relative gains from shirking. Notice that the left-hand side is decreasing in $\bar{q}$ and there is a pair $\hat{q}(\alpha)$ and $\alpha$ such that (8.7) is satisfied for all $\bar{q} \leq \hat{q}(\alpha)$. Hence, agents will choose $\bar{q}$ to maximize
\[
V(\bar{q}; \pi) \equiv \int_{0}^{\bar{q}} SdF + \int_{\bar{q}}^{1} qRdF - \pi \int_{\bar{q}}^{1} (qR - A) dF, \tag{8.8}
\]
subject to (8.7) and $\bar{q} \leq \hat{q}(\alpha)$. Therefore moral hazard will increase opacity (weakly), as by decreasing $\bar{q}$ the agent decreases the region where the intermediary gets paid $\alpha qR$ while exerting no effort.

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References


University of Minnesota Press, Minneapolis, pp 26-47.


