DOI: 10.1111/jbfa.12574

JBFA

ARTICLE

Opacity, liquidity and disclosure requirements

André Stenzel[1,2] | Wolf Wagner[3,4]

[1] Department of Economics, University of Mannheim, Mannheim, Germany

[2] Mannheim Centre for Competition and Innovation (MaCCI), Mannheim, Germany

[3] Department of Finance, Rotterdam School of Management, Rotterdam, The Netherlands

[4] Centre for Economic Policy Research (CEPR), London, UK

Correspondence
André Stenzel, University of Mannheim, 68131 Mannheim, Germany.
Email: andre.stenzel@uni-mannheim.de

Funding information
Deutsche Forschungsgemeinschaft, Grant/Award Numbers: CRC TR 224, Project C3

Abstract

We present a model that links the opacity of an asset to its liquidity. We show that while low-opacity assets are liquid, intermediate levels of opacity provide incentives for investors to acquire private information, causing adverse selection and illiquidity. High opacity, however, benefits liquidity by reducing the value of a unit of private information. The cross-section of bid–ask spreads of US firms is shown to be broadly consistent with this hump-shaped relationship between opacity and illiquidity. Our analysis suggests that uniform disclosure standards may be suboptimal; efficient disclosure can instead be achieved through a two-tier standard system or by subsidizing voluntary disclosure.

KEYWORDS
asymmetric information, disclosure requirements, liquidity, opacity

JEL CLASSIFICATION
G14, M40, M48

1 | INTRODUCTION

Opacity and illiquidity are two central concepts that are, however, rarely distinguished from each other. Both arise from incompleteness of information. An asset can be said to be opaque when agents generally have little knowledge about its payoffs. By contrast, when some agents know more than others about an asset, the asset tends to be illiquid because of adverse selection problems. The difference between opacity and illiquidity thus boils down to whether the incompleteness of information is of a public or private nature.

How can the two be related? At first, one would expect a positive link between opacity and illiquidity. When there is more opacity, there is more scope for agents having different information sets. Adverse selection should then be more pronounced and liquidity low. This reasoning is consistent with common thinking among policymakers, regulators and standard setters that disclosure is beneficial: more public information should deter wasteful private acquisition of information and reduce the potential for information asymmetries among investors.[1]

This argumentation, however, ignores the fact that private information is endogenous. Gathering it is costly; hence it has to be profitable for investors to acquire it. The relationship between opacity and liquidity will thus depend on the scope for private information as well as on the incentives to acquire such information. It is not obvious why the value of information should be higher for opaque assets. Casual observation also throws doubt on an exclusively positive link between opacity and illiquidity. Many opaque assets are frequently traded and have low bid–ask spreads. A case in point is the banking industry. Banking is considered a very opaque business. Nonetheless, the major banks are heavily traded and their stocks display high liquidity.

In this paper, we provide a novel formalization of the opacity of an asset and theoretically analyze the link between opacity and liquidity.[2] We consider an investor who holds an asset that pays in certain states of the world. Opacity is defined as the mass of states where it is (publicly) not known whether the asset pays out. An investor holding the asset has the opportunity to privately acquire information. The investor is able to identify states in which the asset does not pay off at a cost proportional to the number of states. [3] Following this, there is public information that reveals the state of the world. At the same time, the investor may be hit by a liquidity shock that forces him to sell the asset. Illiquidity arises at this stage because market participants anticipate that the investor will sometimes trade opportunistically on his private information.

For a completely transparent asset, there is no scope for private information. Such an asset trades without an adverse selection discount and hence is liquid.[4] At the other extreme, for a very opaque asset the scope for private information is maximal. At the same time, however, we show that the incentives to acquire information are low. Because opaque assets have a low value to the public conditional on favorable public information, opportunistic asset sales based on private information will fetch the investor only a low price, leading to low gains from such information. For a sufficiently high level of opacity, it can be shown that it is never optimal to acquire any information. Complete symmetry of information is preserved and the asset is liquid. At intermediate values of opacity, however, the investor always acquires information and there is adverse selection. [5] A key prediction of the model is thus a hump-shaped relationship between opacity and illiquidity.

In Section 3, we provide an empirical analysis of the cross-section of US firms, which relates dispersion among analyst recommendations as a proxy for opacity to the bid–ask spread as a measure of liquidity.[6] While this exercise should not be taken as a full test of the model, we show evidence consistent with the theoretically predicted nonmonotonic relationship.

[1] For an overview of theoretical justifications for disclosure requirements see Leuz and Wysocki (2008), Bushman and Landsman (2010), Leuz (2010) and Hermalin and Weisbach (2012). The evidence on the benefits of disclosure is however mixed, see, for example, Leuz and Verrecchia (2000).

[2] The notion of liquidity in our analysis is along the lines of, for example, Glosten and Milgrom (1985): An asset is deemed to be illiquid if the price at which it is traded reflects private information concerns.

[3] Information acquisition is therefore by construction targeted to provide insights about states in which the asset does not perform. Examples of this type of information acquisition abound in practice and include, for example, predictions of economic events that cause default of loans or mortgages and information gathered through risk management practices.

[4] A prime example for a completely transparent asset is cash. Cash holdings have been shown to have a positive impact on stock liquidity, see, for example, Charoenwong et al. (2014).

[5] The seminal paper by Grossman and Stiglitz (1980) considers the incentives of agents to learn about the expected payoff of an asset. A lower quality of the signal reduces the incentives to become informed, leading to equilibrium prices reflecting fundamentals less well. While in Grossman and Stiglitz (1980) information incompleteness arises with respect to the expected payoff of the asset (the “fundamentals”), in our analysis of opacity the latter is known. Instead, learning takes place about the mapping between (future) states of the world and payoffs.

[6] Our focus is on cross-sectional differences in liquidity. Other studies have examined heterogeneity in the responses to changes in aggregate liquidity; see Isshaq and Faff (2016).

The main analysis considers an asset of given opacity. However, because opacity affects information acquisition and liquidity, an investor's valuation of an asset will depend on its opacity. This in turn affects the incentives of originators of assets. We turn to the question of how much information an original owner of an asset wants to publicly release, prior to selling to the investor. The issuer's decision is guided by two motives. First, he wants to sell an asset that maximizes value to the investor, as this will benefit him through a higher sale price. Second, he wants to minimize costs associated with releasing information to the public (arising, e.g., because third parties have to be hired to certify information).

Two conclusions can be drawn from the analysis of endogenous opacity. First, it can be (privately and socially) optimal to issue opaque assets in order to deter information acquisition. This may explain why opacity in the financial system has remained high, despite the enormous improvements in information dissemination technologies in recent decades (which should have, by themselves, led to much better public information and lower opacity). It can even be desirable to increase an asset's opacity beyond its natural level (e.g., by drawing up complex securitization structures). Second, issuers may privately choose opacity levels that are higher than the ones that are desirable for the financial system. This occurs because issuers have to fully bear the cost of reducing opacity, but only partially internalize any benefits for other agents.

There are several implications for policy. Uniformly mandated increases in disclosure are not desirable because of the nonmonotonic nature of the relationship between opacity and liquidity (which coincides with welfare in our setting). In principle, a two-class policy where regulators distinguish between assets according to their opacity can achieve efficiency. For assets that are fairly transparent, the standard policy prescription applies that more disclosure increases efficiency. However, assets that are relatively intransparent to start with should not be forced to higher levels of transparency. Such a conditional transparency regime, however, seems informationally demanding for the regulator.[7] A better approach is to provide subsidies for issuers to voluntarily increase disclosure. Subsidies are efficiency-enhancing regardless of a firm's opacity level because they directly address the source of inefficient information choices of issuers (the positive externality of information for other agents in the financial system). They may, for example, take the form of industry bodies sponsoring infrastructure for services that promote transparency, such as public information repositories.

1.1 | Related literature

Our setting is closely related to recent literature that has analyzed how security design affects information acquisition by investors. While the focus in the present paper is on the question of how much information should be released about an asset, the security design literature studies how an asset's payoff streams can be separated into different parts to make information acquisition less attractive. A central theme in this literature is the optimality of debt contracts: because debt has a flat payoff for most of the domain (and otherwise its payoff is determined by limited liability), it minimizes the benefits of acquiring private information.[8] Dang et al. (2013) formally introduce the concept of the *information sensitivity of a security* and show in a model of strategic security design and multiple trading rounds that debt contracts minimize market participants' incentives to acquire information. Using a generalized information structure, Yang (2012) finds standard debt to be least sensitive to private information, irrespective of the composition of the underlying asset pool. Farhi and Tirole (2015) highlight the importance of commonality of information. They show that for an asset to be liquid, it is important that information is symmetric. This can be achieved either by common knowledge or by common ignorance. In our paper, informational symmetry arises either for very transparent assets

[7] Some differentiated disclosure policies exist in practice (e.g., different standards for listed firms).

[8] The literature mostly considers situations where only one party in a potential trade can become informed, in which case information acquisition is welfare-reducing. Farhi and Tirole (2015) study information acquisition on both sides. In this case, information acquisition can improve liquidity as it can increase symmetry across agents.

(common knowledge) or for very opaque assets (because of common ignorance). Intermediate levels of opacity, in contrast, lead to one-sided information and cause adverse selection.

There is a small but growing literature that analyzes asset opacity. Kaplan (2006) examines a bank's choice of whether to release information about assets at an interim stage. The paper shows that it can be efficient for the bank to commit to keep information secret, even though this forces the bank to offer noncontingent deposit contracts *ex-ante*. The reason is that the cost of revealing negative information at an interim stage can outweigh the benefits of positive information. Sato (2014) considers a setup with opacity at the fund and the asset level. He finds that opaque funds invest in opaque assets and that such funds can trade at a premium. The reason is that managers of opaque funds inflate investors' beliefs about future returns by (secretly) overinvesting in opaque assets and levering up.

Pagano and Volpin (2012) analyze a model where investors differ in their ability to process information. Releasing information about assets is subject to a trade-off. On the one hand, information decreases primary market liquidity because it induces a "winner's curse" problem for unsophisticated investors who cannot parse information. On the other hand, information increases secondary market liquidity as information not released by issuers creates scope for private information acquisition and hence leads to adverse selection. The second channel is also present in our model. While in Pagano and Volpin (2012) information is of an all-or-nothing nature, in our model information is continuous. This allows us to show that the value of a unit of information can vary with the asset's level of opacity, which is the source of the opacity benefit in our paper.

Carlin et al. (2013) focus on an issue similar to the differential information processing in Pagano and Volpin (2012). They consider an experimental setting in which the complexity of an asset is varied. Complexity relates to the computational difficulty required to obtain information about the asset's payoff. Carlin et al. (2013) find that when subjects are aware that other subjects are more adept at performing the required calculations, adverse selection becomes pronounced. This is consistent with agents anticipating a lower degree of common information present in markets.

We also relate to papers studying the interaction between public information and private information acquisition incentives; see, for example, Kim and Verrecchia (1994) or Demski and Feltham (1994). Similar to these papers, opacity in our setting affects the incentives of agents to become privately informed. However, we present a different and novel approach of modeling opacity as knowledge about the mapping between states of the world and payoffs, so that different levels of opacity induce differential information acquisition levels given the same public forecast about the future state of the world.

While in our setting there is no social benefit to information, recent papers by Monnet and Quintin (2017) and Dang et al. (2017) have shown that transparency (i.e., more information) can lead to more efficient interim decisions.[9] However, there is also a cost, as investors may be forced to liquidate their positions in response to negative information. In the presence of secondary markets that are not always liquid, the benefits of good interim information cannot be fully capitalized by investors. Transparency is shown to mitigate this problem, at the cost of allocative efficiency.

The remainder of the paper is organized as follows. Section 2 sets up the baseline model for the analysis of the link between opacity and illiquidity. Section 3 examines the cross-section of US firms to see whether it exhibits a hump-shaped relationship. In Section 4, we consider the incentives of asset originators. Section 5 concludes.

2 | THE MODEL

We develop a simple model of information acquisition with the key feature that both cost and value of information depend on an asset's opacity. In the model, an investor can learn about an asset of varying degrees of opacity. This learning is not about the asset's expected payoff (which is the focus of Grossman & Stiglitz, 1980, and several other papers) but about how it pays in different states of the world. This can be likened to an investor (or the risk manager

[9] Boot and Thakor (2001) provide an analysis of disclosure of various types of information that are all beneficial (as it reveals agent's types). They show that in equilibrium firms find it beneficial to disclose all types of information.

of a financial institution) exerting effort in analyzing how an asset performs under several scenarios (e.g., an oil price shock, deflation or an economic downturn). For opaque assets, it will be inherently more costly to reach the same level of information than for transparent assets.

Take for instance the stock of Coca-Cola versus the stock of JP Morgan. The business model of Coca-Cola is simple and transparent; it is hence easy to predict how its stock will perform in a set of circumstances. By contrast, the operations of JP Morgan are extremely complex, involving a wide set of activities (such as trading in derivatives, or holdings of securitization products), which are often difficult to understand even on an individual basis. Learning about how JP Morgan's business will perform under different circumstances is hence difficult and requires substantial effort by investors. Another example is credit products. A mezzanine tranche formed from a portfolio of credits, for instance, is much more opaque than an exposure to a single name. As a result, learning about its payoffs in different states (for instance, its dependence on a clustering of default events in the economy) is more demanding. Conglomerates can also be seen as opaque firms, as opposed to stand-alone firms, as it will be more challenging to understand how they are impacted by shocks.[10]

The economy consists of an investor I and an agent M, representing the market. There are two dates, $t = 1, 2$. The preferences of both agents are linear and given as follows:

- The investor's utility depends on whether she is patient or impatient. If patient (occurring with probability $\pi \in (0, 1)$), the investor can consume at both dates: $U^I = C_1^I + C_2^I$. If impatient, the investor derives only utility from consumption at date 1: $U^I = C_1^I$. The investor privately learns her type (patient or not) at $t = 1$ and this information is not verifiable.
- The market agent consumes at both dates: $U^M = C_1^M + C_2^M$.

The endowments of the agents are as follows. At $t = 1$, the investor holds an asset that pays off at date 2. This asset returns one in a subset L (of mass $l \in (0, 1)$) of uniformly distributed states of the world $s \in S = [0, 1]$ and zero otherwise. Given the uniform distribution, the unconditional value of the asset is hence l. While the set L is unknown, its mass l is publicly known. The market agent has a cash endowment of w^M at date 1. We assume $w^M > 1$, which avoids issues arising from constrained endowments.[11] This implies that the cash endowments play no strategic role and allows us to isolate the impact of an asset's opacity on its liquidity. The agents hold no other endowments.

Given the allocation of endowments, it is natural that gains from trade can be realized. If the investor turns out to be impatient at date 1, she can sell the asset to M. However, reaping these gains is complicated by the opportunity for the investor to acquire private information about the asset prior to trading: Acquisition of private information results in adverse selection when trading with the market. The incentives to acquire information, in turn, are affected by the asset's opacity.

Opacity is modeled as follows. There is a set of states O containing the payoff states ($L \subset O$). This set is publicly known. We refer to the mass of this set, o ($\in [l, 1]$), as the asset's opacity. Maximum opacity ($o = 1$) arises when there is no information about the set of payoff states. At the other extreme, if $o = l$, the precise set of payoff states is common knowledge and there is no scope for private information acquisition—the asset is transparent. For $o \in (l, 1)$, opacity is of an intermediate degree and there is incomplete knowledge about payoff states. The more transparent the asset, the smaller o and the more precise is the public information about the location of the payoff states, that is, the circumstances under which the asset pays off. Note that opacity is distinct from the asset's *ex-ante* return and risk: the expected payoff is l and variance of the asset is $l(1 - l)$.

---

[10] Consistent with this, Cohen and Lou (2012) provide evidence that it takes more time for a piece of information to be incorporated in the price of a conglomerate.

[11] One such issue is cash in the market pricing; see, for example, Dang et al. (2017). Introducing constrained endowments does not affect the qualitative results of the analysis. If the market's endowment becomes a limiting factor, this will lower the price at which the investor can (opportunistically) sell the asset. This in turn will generally reduce the incentives to acquire information, however, without (qualitatively) affecting the comparative statics between opacity and liquidity.

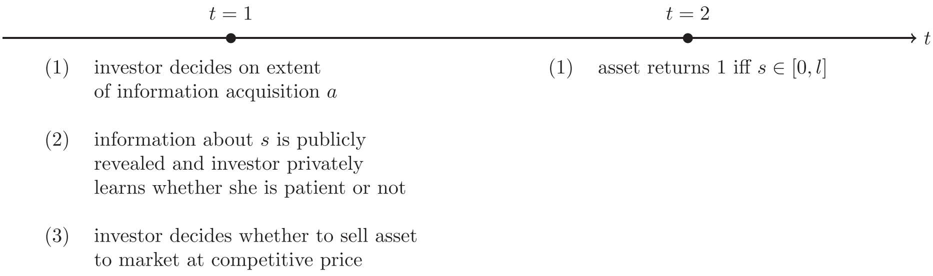

FIGURE 1 Timeline of the baseline model

At the beginning of date 1, the investor has the option to acquire private information. Specifically, she decides on an amount a ($\in [0, o-l]$) of information to acquire. Following this, nature reveals a random subset of states A of mass a from O for which the asset does not pay off. Private information acquisition reduces the size of the set containing the payoff states from o to $o-a$. There are proportional costs of acquiring information $k_I \cdot a$, where $k_I > 0$. We assume that these costs take intermediate values:

Assumption 1.

$$\frac{\pi l(1-\pi)}{1-\pi l} < k_I < \pi. \tag{1}$$

This assumption ensures that information acquisition is nontrivial.[12]

The choice of a as well as the realization of the subset A are private to the investor and are not verifiable. Following the investor's information acquisition decision, the state of the world s becomes available. Subsequently, the investor can sell the asset to the market. For this, we assume that the market posts a competitive price for the asset and the investor decides whether or not to sell at this price.[13]

To focus the analysis, it is convenient to rearrange the states s of the world. Specifically, we reorder states such that the payoff states are on $[0, l]$, the public set of potential payoff states is on $[0, o]$, and the set of potential payoff states privately known to the investor is $[0, o-a]$. In addition, agents no longer observe the exact state, but only the set in which the state falls. If $s > o$, both investor and the market learn that the state of the world falls outside the public set O, and hence that the asset does not pay off. If $s \in (o-a, o]$, the state of the world is in the public set of possible states of the world O, but not in the investor's private set. The investor privately learns that the asset does not pay, while the market learns only that s is within the public set of potential payoff states of mass o. If $s \leq o-a$, both investor and market have incomplete knowledge about the payoff. The investor knows that s is within the private set of payoff states, while the market only observes that the state is within the public set.[14]

The timing of the model is summarized in Figure 1.

2.1 | Trade with the market

To solve for an equilibrium of the game, we first analyze the final stage in which the investor has the opportunity to sell to the market. At this stage, public information about the state s has been revealed. The public set of payoff states

---

[12] If costs are very low, full information would always be acquired, while sufficiently high costs deter information acquisition.

[13] This avoids the use of price as a signal about the asset's quality or the investor's type. A competitive price may, for example, arise if market participants compete by posting bid prices for the asset.

[14] In other words, the market only recognizes states in the set $[o, 1]$, while the investor recognizes states in the set $[o-a, 1]$.

depends on the asset's opacity level and is given by $[0, o]$. Furthermore, the investor has potentially acquired information a; her private set of payoff states is thus $[0, o-a]$. Denote by $\widetilde{a}$ the market's beliefs about how much information the investor has acquired, and by $p(\widetilde{a}, o)$ the competitive price given these beliefs and the opacity level o. Given $\widetilde{a}$, the market forms posterior beliefs about the value of the asset conditional on what drives the selling decision using Bayesian updating.

We first analyze the investor's selling decision for a given price p. To rule out no-trade equilibria, we assume that the investor has a weak preference for selling when she is impatient, and a weak preference for not selling when she is patient. We focus on pure strategy equilibria.[15]

The following cases arise depending on the realization of s. First, there is the trivial case of s being outside the public set ($s > o$). Both the investor and the market know that the asset does not pay off and trade is irrelevant. We can ignore this case for the analysis of the trade equilibrium as trade, if it takes place, occurs at a price of zero.

Consider next the case of s being inside the public set ($s \le o$). If an investor is impatient, she will sell regardless of price (given her weak preference for selling) because there is zero utility from holding on to the asset. For a patient investor, the decision to sell depends on whether the signal is in the private set. If the signal is outside the private set ($s > o-a$), the investor knows that the asset is worthless. She will hence sell at any positive price. If the signal is inside the private set ($s \le o-a$), the investor's expected utility of keeping the asset is $\frac{l}{o-a}$. Taking into account the weak preference for holding on to the asset, she will hence sell the asset if and only if the price p is larger than $\frac{l}{o-a}$. Such a price, however, is inconsistent with market rationality. To see this, note that $\frac{l}{o-a}$ is higher than the value of the asset even without adverse selection $\frac{l}{o}$ (i.e., when the investor only sells when she is impatient). The market can hence never break even at this price and such a price cannot prevail in equilibrium. It follows that when $s \le o-a$ the patient investor does not sell the asset.

We can summarize these results as follows:

Lemma 1. *In equilibrium, the asset is offered to the market (when $s \le o$) if and only if*

(i) the investor is impatient, or

(ii) the investor is patient and s is in her public set but outside her private set ($s \in (o-a, o]$).

We next solve for the price at which an asset is sold (in the case of $s \le o$). Because the price is set competitively, the market breaks even in expectation. The price hence has to be equal to the asset's expected value (given beliefs $\widetilde{a}$) *conditional on being sold*. According to Lemma 1, the asset is sold either when the investor is impatient, or when she is patient and the state is outside her private set. The first case occurs with probability $1-\pi$ and the likelihood of the asset paying off in this case is $\frac{l}{o}$, that is, the ratio of the size of the payoff set l to the size of the public set o. The second case, a patient investor with s outside her private set, is perceived by the market to occur with probability $\pi \cdot \frac{\widetilde{a}}{o}$ ($\frac{\widetilde{a}}{o}$ is the likelihood of the state being outside the private set given beliefs $\widetilde{a}$ about the extent of information acquisition). The asset is worthless in this case. The expected value of the asset (conditional on being sold) is hence $\frac{(1-\pi)\frac{l}{o}}{1-\pi+\pi\frac{\widetilde{a}}{o}}$. Rearranging yields the competitive price $p(\widetilde{a}, o)$ given beliefs $\widetilde{a}$ and opacity level o:

$$p(\widetilde{a}, o) = \frac{1-\pi}{o-\pi(o-\widetilde{a})} l. \tag{2}$$

Note that for $\widetilde{a} = 0$ (that is, if the market believes there is no private information) we have $p(0, o) = \frac{l}{o}$. Furthermore, $\frac{\partial p}{\partial \widetilde{a}} < 0$ because if the market believes that the investor privately acquired more information, it prices in more adverse selection as it becomes more likely that a worthless asset is offered.

[15] Mixed-strategy equilibria exist, but lead to the same amount of information acquisition and welfare (in *expected* terms). The reason for this is twofold. First, at $a^*(o)$ the investor is indifferent about the amount of information acquired. Second, because of linear information acquisition cost, welfare is linear in information acquisition, and hence only depends on the *expected* level of information acquisition.

2.2 | Information acquisition

Consider a candidate for information acquisition a^*, and corresponding market beliefs $\tilde{a}$. For a^* to constitute an equilibrium amount of information acquisition, it has to be the case that a^* maximizes the investor's utility given that the market believes $\tilde{a} = a^*$. We thus have for a^* that

$$a^* = \underset{a \in [0, o-l]}{\operatorname{argmax}}\, u(a, a^*), \tag{3}$$

where $u(a, \tilde{a})$ denotes the investor's expected utility given that she chooses a level of information acquisition a and the market holds beliefs $\tilde{a}$.

We can derive $u(a, \tilde{a})$ as follows. With probability $1 - o$, the state of the world falls outside the public set ($s > o$). In this case, the investor does not derive any utility from owning the asset as it is common knowledge that the asset is worthless. With probability o, the state of the world falls inside the public set ($s \leq o$). The investor then sells whenever she is impatient or when she is patient and the state is outside her private set ($s \in (o - a, o]$). The combined probability for this is $1 - \pi + \pi \cdot \frac{a}{o}$ and she obtains $p(\tilde{a}, o)$ from selling the asset. When she is patient and the state is inside the private set ($s \in [0, o - a]$) she holds onto the asset. This happens with probability $\pi \cdot \frac{o-a}{o}$ and she receives (in expectation) $\frac{l}{o-a}$ from the date-2 return. Together with the information costs $k_I \cdot a$, her utility is thus

$$u(a, \tilde{a}) = o\left(\left(1 - \pi + \pi \frac{a}{o}\right) p(\tilde{a}, o) + \pi \frac{o - a}{o} \frac{l}{o - a}\right) - k_I \cdot a. \tag{4}$$

Note that when beliefs are consistent with actual information acquisition ($\tilde{a} = a$), the above simplifies to $l - k_I \cdot a$.

Differentiating with respect to a, we obtain the marginal gain from acquiring information:

$$\frac{\partial u(a, \tilde{a})}{\partial a} = \pi p(\tilde{a}, o) - k_I. \tag{5}$$

Equation (5) shows that information acquisition trades off marginal benefits $\pi p(\tilde{a}, o)$ with information acquisition costs k_I. The benefits are derived as follows: By acquiring one additional unit of information, the investor reduces her private set by one state. If this state realizes, she knows that the asset is worthless. If she turns out to be patient, she will hence sell and obtain $p(\tilde{a}, o)$, while before she would have held a worthless asset. Note that the incentives to acquire information increase in the asset's price.

The marginal benefits in (5) are constant as they do not depend on the amount of information acquired (a).[16] There are hence three cases to consider. If $\pi p(\tilde{a}, o) - k_I < 0$ (or rearranging, if $p(\tilde{a}, o) < \frac{k_I}{\pi}$), the marginal benefits are always outweighed by the marginal costs. Zero information ($a^* = 0$) thus maximizes investor utility. Likewise, if $\pi p(\tilde{a}, o) - k_I > 0$ ($p(\tilde{a}, o) > \frac{k_I}{\pi}$), the marginal benefits outweigh the marginal costs and the highest possible level of information acquisition ($a^* = o - l$) maximizes utility. Finally, if $p(\tilde{a}, o) = \frac{k_I}{\pi}$, the investor is indifferent as to which level of information acquisition to choose. We can hence summarize for the investor's choice of information given beliefs $\tilde{a}$:

$$\underset{a \in [0, o-l]}{\operatorname{argmax}}\, u(a, \tilde{a}) = \begin{cases} 0 & \text{if } p(\tilde{a}, o) < \frac{k_I}{\pi} \\ [0, o - l] & \text{if } p(\tilde{a}, o) = \frac{k_I}{\pi} \\ o - l & \text{if } p(\tilde{a}, o) > \frac{k_I}{\pi}. \end{cases} \tag{6}$$

This allows us to solve for equilibrium information acquisition. Note that higher opacity reduces the price p for a given belief $\tilde{a}$ and hence the incentives to acquire information; see (2). Define $\underline{o}$ as the critical opacity level, which

[16] This is due to the constant marginal costs of information acquisition k_I. If marginal costs are increasing, the optimal level of information acquisition is uniquely pinned down and all qualitative predictions carry over. We discuss this in detail in Section 2.3.3.

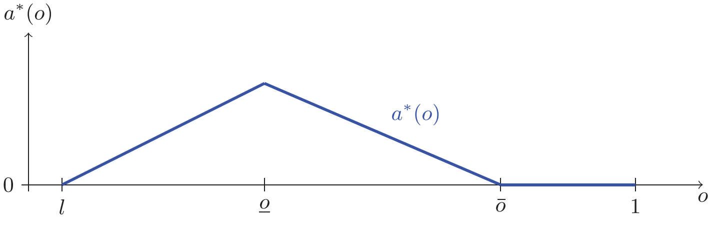

FIGURE 2 Information acquisition as a function of o

just leads to full information acquisition ($a^* = o - l$). Recall that in equilibrium, we have that $a^* = \tilde{a}$. Inserting $\tilde{a} = \underline{o} - l$ into $p(\tilde{a}, \underline{o}) = \frac{k_I}{\pi}$, we obtain after rearranging: $\underline{o} = \pi l + \frac{\pi(1-\pi)l}{k_I}$. Likewise, define $\bar{o}$ as the critical opacity which deters acquisition of any information. We obtain $\bar{o} = \frac{\pi l}{k_I}$ by rearranging $p(0, \bar{o}) = \frac{k_I}{\pi}$. For intermediate values of o, an interior equilibrium arises. By solving for $\tilde{a}$ in the condition $p(\tilde{a}, o) = \frac{k_I}{\pi}$, we obtain for the interior equilibrium that $a^* = \tilde{a} = \frac{(1-\pi)}{\pi}(\frac{\pi l}{k_I} - o)$.

Note that Assumption 1 ensures $\underline{o} < \min\{\bar{o}, 1\}$, which allows to summarize

Proposition 1. *The equilibrium level of information acquisition a^* is*

$$a^*(o) = \begin{cases} o - l & \text{if } o \leq \underline{o} \\ \frac{(1-\pi)}{\pi}\left(\frac{\pi l}{k_I} - o\right) & \text{if } o \in (\underline{o}, \bar{o}) \\ 0 & \text{if } o \geq \bar{o} \end{cases} \tag{7}$$

with $\underline{o} = \pi l + \frac{(1-\pi)\pi l}{k_I}$ *and* $\bar{o} = \frac{\pi l}{k_I}$.

Proof. Follows from the preceding discussion. To see $\underline{o} < \min\{\bar{o}, 1\}$, observe that Assumption 1 states $\frac{\pi l(1-\pi)}{1-\pi l} < k_I \iff \frac{\pi l(1-\pi)}{k_I} < 1 - \pi l$ and $k_I < \pi \iff \frac{\pi}{k_I} > 1$. Thus,

$$\underline{o} = \pi l + \frac{(1-\pi)\pi l}{k_I} < \pi l \underbrace{\frac{\pi}{k_I}}_{>1} + \frac{(1-\pi)\pi l}{k_I} = \frac{\pi l}{k_I} = \bar{o}$$

and

$$\underline{o} = \pi l + \frac{(1-\pi)\pi l}{k_I} < \pi l + (1 - \pi l) = 1.$$

□

Figure 2 shows equilibrium information acquisition $a^*(o)$ as a function of an asset's opacity o. At $o = l$, the asset is fully transparent and it is not possible to acquire information ($a^* = 0$). For values of o between l and $\underline{o}$, the maximum feasible amount of information is acquired ($a^* = o - l$). In this range, opacity increases information acquisition, as higher opacity increases the feasible amount. Beyond $\underline{o}$, however, opacity reduces information acquisition. This is until $\bar{o}$ is reached, at which point no information is acquired. Note that while in the figure we have that $\bar{o} < 1$, this is not necessarily always the case. If not, information will be acquired even at full opacity.

What is the reason why opacity can deter information acquisition? Opaque assets have a lower value when sold to the market. This can be appreciated from the fact that p (for given $\tilde{a}$) is declining in opacity (see equation (2)). In our model this is caused by the fact that the public set is large for opaque assets and hence a realization of s in this set becomes less informative about payoffs. A lower market price p in turn means that learning about a given number of states in the public set is less valuable as opportunistic sales by the investor (occurring when the asset is discovered to be worthless) fetch a lower price.

Note that the nonmonotonic impact of opacity on information acquisition translates also into a nonmonotonic impact on liquidity as well as welfare. The latter immediately follows as information acquisition is only source of welfare losses in our setup.[17] Liquidity in our setup is the difference between the expected value of the asset without information acquisition in case $s < o$ is revealed, $\frac{l}{o}$, and the price offered by the competitive market, which reflects adverse selection concerns, $p(a^*, o)$. This difference is the analogue to the bid–ask spread in canonical models such as Glosten and Milgrom (1985) because of the one-sided nature of transactions in our model (i.e., the insider only *sells*). Formally, we obtain

$$sp(o) = \frac{l}{o} - p(a^*, o) = \begin{cases} \frac{l}{o} \cdot \frac{(o-l)\pi}{o-l\pi} & \text{if } o \leq \underline{o} \\ \frac{l}{o} - \frac{k_I}{\pi} & \text{if } o \in (\underline{o}, \bar{o}) \\ 0 & \text{if } o \geq \bar{o} \end{cases}, \tag{8}$$

Note that $sp(o)$ is continuous in o. Moreover,

$$sp'(o) = \begin{cases} \frac{\pi l}{o^2(o-\pi l)^2}\left(2ol - o^2 - \pi l^2\right) & \text{if } o < \underline{o} \\ -\frac{l}{o^2} < 0 & \text{if } o \in (\underline{o}, \bar{o}) \end{cases}. \tag{9}$$

The spread is hence decreasing in o on $(\underline{o}, \bar{o})$. For $o \leq \underline{o}$ in turn, observe that

$$sp'(o) > 0 \iff 2ol - o^2 - \pi l^2 > 0$$

$$\iff o > l - \sqrt{(1-\pi)l^2} \vee o < l + \sqrt{(1-\pi)l^2}.$$

Because $o \geq l$, we can define $\hat{o} = \min\{l + \sqrt{(1-\pi)l^2}, \underline{o}\}$ and obtain that $sp'(o) > 0$ for $l < o < \hat{o}$ and $sp'(o) < 0$ for $o \in (\hat{o}, \bar{o})$. As such, there is a hump-shaped relationship between the opacity level o and the spread measure $sp(o)$.

2.3 | Robustness

In this section, we discuss several modifications of the model. We focus in particular on different information acquisition technologies.

2.3.1 | Random discovery of the payoff interval

We have considered an information acquisition technology in which the investor eliminates nonpaying states from the set of potential payoff states with certainty. This is based on two assumptions that significantly simplify the analysis. First, information acquisition is deterministic. Second, it is targeted toward privately ruling out states in which the asset does not perform. Toward relaxing these assumptions, we first consider a mode variant in which the outcome

[17] We revisit the welfare implications in Section 4 when endogenizing opacity.

of information acquisition preserves the targeting of nonpayoff states, but is random and sequential. [18] We allow the investor to potentially be "lucky" and discover the payoff interval early on, but she may also be unsuccessful and decide to stop after having acquired a certain amount of information. This implies that the acquired information (and hence also the dead-weight loss from information acquisition) becomes random as well.

We present the analysis of such a technology with random discovery of states in Appendix A. Specifically, we consider the following setup. We introduce a *starting state* for information acquisition, y, which is uniformly distributed on $[l, o]$. The investor is aware of this distribution, but not the realization of y. When the investor acquires information a, there are two potential outcomes. First, if a is such that $y - a > l$, she has ruled out exactly a states as potential payoff states as in the baseline model. Second, if $y - a < l$, the investor discovers the full payoff interval. Importantly, we allow for the investor to sequentially acquire more information; that is, if she initially (unsuccessfully) acquired information about a_1 states, she can subsequently acquire additional information about a_2 states where the new starting point for information acquisition would be $y - a_1$ (which can then be repeated starting at $y - a_1 - a_2$ if unsuccessful).

It is important to note that this sequential information acquisition implies that the expected value of acquiring information about a set a of states depends on how much information has been previously acquired; conversely, any decision to acquire information needs to take into account the subsequent decisions when the payoff interval has not been found. We show that this admits a recursive definition of the value of information and use this to characterize the optimal level of information acquisition by the investor.

Importantly, the results from the baseline model carry over in that information acquisition is first increasing and then decreasing in opacity. There can also be interior equilibrium amounts of information acquisition, where there is a threshold for information acquisition such that an investor acquires information until this threshold is reached or until the payoff interval is discovered.

2.3.2 | Learning about loss states

As a second modification, we invert the targeting by considering a model variant in which—the exact opposite of the baseline model—the asset pays off on $[l, 1]$ but not on $[0, l]$. In addition, suppose that opacity and information acquisition also work in the opposite way: the level of opacity narrows down the set of potential loss states to $[0, o]$, while information acquisition further narrows it to $[0, o - a]$.

A difference to the baseline model is that the investor now benefits from states in which he has *positive* private information about the asset. The intuition for this observation is as follows (Appendix B contains the full analysis). Suppose that selling the asset yields a given price p. Suppose a state s realizes in which the investor knows that the asset pays off but the market does not ($s \in [o - a, o]$). A patient investor will then not sell the asset and thus realize a return of 1, whereas she would have realized p without information acquisition. Suppose next that a state of the world realizes where both investor and market are uncertain about whether there is a payout ($s \in [l, o - a]$). Because the investor also observes that this state is not within her private set of payoff states $[o - a, o]$, she perceives a higher chance—compared to the market agent—that the asset will not pay. This will cause her to sell the asset when patient. However, under symmetric information, the investor would have been indifferent between selling and not selling so that no additional gains are incurred.

Information acquisition makes it more likely that a state realizes where the investor has positive information about the asset. In such a state the investor will refrain from selling the asset, while prior to information acquisition she would have sold the asset. A consequence is that the gains from information acquisition are decreasing in the market price p, the opposite to the case in the baseline model (see (5)). This eliminates the possibility for interior choices of information

[18] Specifically, the preservation of the targeting of nonpayoff states obtains because the investor immediately learns about the entire payoff interval whenever she discovers the first state contained therein.

acquisition. However, as shown in the Appendix, it is still the case that opacity lowers information acquisition at low-opacity levels and that sufficiently high opacity prevents information acquisition.

Overall, this extension highlights that as long as the level of opacity and private information acquisition are targeted in some fashion, irrespective of whether toward loss or payoff states, the model predicts a nonmonotonic relationship between opacity and investor information acquisition.[19] While it is not possible to test the assumption (and direction) of information being targeted, we consider this and in particular the targeting of the baseline model to be sensible. For example, risk management is by nature targeted towards learning about scenarios in which projects (assets) do not perform (do not pay) and are of essential and increasing importance to many firms. Moreover, the empirical assessment in Section 3, while only suggestive and not a direct test of the model, provides evidence in line with the prediction of the baseline model.

2.3.3 | State-dependent information acquisition costs

The baseline model assumes that the cost of acquiring information is proportional to the number of states that are analyzed. Implicit to this is that states have equal information costs. Alternatively, information costs may differ across states. For example, it might be easier to ascertain the value of an asset in the case of an inflationary shock than for instance in the event of a financial crisis. If costs are state-dependent, it becomes optimal for an investor to first analyze cheaper states, resulting in increasing marginal information acquisition costs. Intuitively, increasing costs make it more likely that we obtain an interior equilibrium. Appendix C contains the analysis of increasing marginal costs, that is, where the cost of information acquisition for the investor is not $k_I \cdot a$ but $K_I(a)$ with $K_I'(a) > 0, K_I''(a) > 0$. We show that the qualitative results are same as in the baseline model. In particular, the relationship between opacity and information acquisition still follows a hump shape.

It is critical, however, that the *total* cost of gathering information is higher when more states are analyzed. To see this, suppose to the contrary that any level of information acquisition incurs a fixed cost, independent of how many states are analyzed. The marginal benefit from information once some information has been acquired ($a > 0$) is then strictly positive ($\frac{\partial u(a,\tilde{a})}{\partial a} = \pi p(\tilde{a}, o) > 0$ from equation (5) for $k_I = 0$). Hence, there can no longer be an interior equilibrium. The investor will hence either acquire no information or all information. This case corresponds to the technology of information acquisition considered in Dang et al. (2013, 2017).

2.3.4 | Alternative mechanism

There exists a second, independent reason for why opaque assets may lower information acquisition. It arises when the informational gain from a given amount of information depends on opacity. A unit of information is conceivably less informative if an asset is very opaque as there will then be large uncertainty even after the unit has been acquired. To demonstrate, consider a situation where an asset is valuable to an agent only if it meets a criterion in every state of the world. For instance, agents may have a subsistence requirement; reaching this level of consumption gives a utility of one, if it is not reached, utility will be zero.

Suppose an agent can acquire information about an asset (=project) before deciding whether to undertake it (the alternative to investment being to store funds to meet subsistence requirements), and that the agent will choose only the asset if the subsistence requirement is fulfilled in every state. This requires the agent to investigate all states. Suppose that there are a discrete number o of opaque states and that in all transparent states it is known that the

[19] This is not the case if information is not targeted. Specifically, let opacity and information acquisition be fully random, that is, for a given opacity level o, there are only $l \cdot o$ payoff states contained in that set, while $l \cdot (1 - o)$ payoff states are publicly known, and that an investor always learns about $l \cdot a$ payoff and $(1 - l) \cdot a$ nonpayoff states. In this case, price without information acquisition in the relevant set ($s \leq o$ so that the true payoff is unknown to the market) is independent of opacity $p(0, o) = l$. But this implies that whether information is acquired at all is independent of opacity.

asset pays at least the subsistence requirement.[20] Let the probability of a payoff in an individual state meeting the subsistence requirement be $q \in (0, 1)$ and let payoffs be independent across states. The likelihood of all states meeting the criterion is then q^o. The expected benefit from acquiring full information is given by $q^o - k_I o$, where k_I is the per-state cost of information acquisition. Dividing by o yields a benefit $\frac{q^o}{o} - k_I$ of acquiring a unit of information. This value of information is decreasing in opacity for two reasons: First, for higher opacity o, the likelihood that the asset will eventually meet the criteria is lower (q^o is lower). Second, for higher o more states have to be inspected, hence the gain per state is lower.

3 | THE CROSS-SECTION OF BID–ASK SPREADS AND OPACITY

The key prediction of our baseline model is that opacity encourages private information only up to a point. Beyond this point, the relationship inverts, and opacity makes information acquisition less attractive (see Figure 2). In this section, we analyze firm-level data to see whether such a pattern is consistent with the data. [21]

Following the theoretical contributions of Glosten and Milgrom (1985) and Kyle (1985), private information leads to higher bid–ask spreads on a firm's stock. Market makers need to be compensated for the risk of trading with an informed party, leading them to widen the bid–ask spread when they expect private information to be more prevalent. Empirically, it is well documented that adverse selection is an important determinant of bid–ask spreads (see, e.g., Huang & Stoll, 1997; Stoll, 1989). We hence proxy the amount of private information on a firm using its stock's (absolute) bid–ask spread.

Opacity of a firm is measured by the extent of disagreement among analysts (following Flannery et al., 2004; Fosu et al., 2017, and others). The idea is that opaque firms exhibit large potential for divergence among analysts, while disagreement is naturally limited for transparent firms.[22] The literature has suggested alternatives to the dispersion proxy, which are however less appropriate for our purpose. For example, Morgan (2002) uses rating splits as measure of firm opacity. While conceptually similar to analyst dispersion, rating splits are not ideal in our context because testing our theory requires a continuous opacity measure that varies over a sufficiently large interval to be able to identify a nonmonotonic relationship (rating splits, in their simplest form, are a binary measure). Another measure of opacity that is used in the literature is the number of analysts following a firm, see, for example, Roulstone (2003). However, this measure does not measure underlying firm opacity itself, but also the extent to which analyst activity alleviates this opacity. We will account for this in our analysis by including the number of analysts following a stock as a control variable.

3.1 | Data

We conduct an analysis of firms listed in the United States by relating their bid–ask spreads to the dispersion in analyst recommendations. In our analysis, we control for factors that may affect bid–ask spreads and which are unrelated to adverse selection.

[20] If the latter is not the case, the asset is known to be worthless and hence there is also no incentive to acquire information about it.

[21] Agarwal (2007) finds a hump-shaped relationship between institutional ownership and liquidity. This is interpreted as the presence of two offsetting effects. On the one hand, higher institutional ownership leads to more informational asymmetries and hence lower liquidity. On the other hand, it leads to more competition (among institutions) which should result in pricing better reflecting information and hence higher liquidity. This exercise differs from ours in that we vary asset characteristics (opacity) rather than characteristics of the holders of the asset.

[22] Suppose that we enrich our model by "analysts" who all randomly learn about different parts of the set of potential payoff states. If polled about the asset value after the state s is revealed, there is a higher chance of divergence among analysts for an opaque asset as it is then more likely that a state of the world materializes in which private information matters.

TABLE 1 Summary statistics

Variable	Mean	SD	Min.	Max.	*N*
Average spread, July 2017 to December 2017	0.989	0.767	0.141	5.197	2033
Market cap, July 2015 (log)	14.919	1.547	9.752	20.46	2033
Price, July 2015	49.883	43.639	5	337.27	2033
Average monthly trading volume, July 2015 to June 2017, scaled by market cap	0.106	0.351	0.002	14.235	2033
SD of daily returns, July 2015 to June 2017	0.024	0.025	0.009	0.581	2033
SD of scaled average monthly trading volume, July 2015 to June 2017	0.489	1.246	0.008	36.235	2033
Average number of analyst recommendations, July 2015 to June 17	12.279	7.857	3	48.708	2033
Average standard deviation of analyst recommendations scaled by mean recommendation, July 2015 to June 2017	0.35	0.088	0.045	0.566	2033

We use the universe of firms contained in the CRSP database. Our measure of the bid–ask spread is the average of a firm's bid–ask spread in CRSP between July and September 2017.[23] In addition, we obtain various controls from CRSP: the (log) of the market capitalization as a measure of firm size and the stock price itself (both as of July 2017); the standard deviation of stock price returns, trading volume and the standard deviation of trading volume averaged over the two years prior to July 2017.

The dispersion measure is obtained from the monthly summary statistics of the I/B/E/S database. Specifically, we calculate dispersion as the average standard deviation of analyst recommendations. Analyst recommendations range from 1 (strong buy) to 5 (strong sell). We calculate this average over two years prior to July 2017 (July 2015 until June 2017) and scale the standard deviation by the mean recommendation. We deliberately choose a long horizon to capture structural disagreement among analysts and to mitigate the impact of any short term events that may cause analysts to diverge or converge in their recommendations, for example, earnings announcements. We also obtain the average number of analysts submitting recommendations following a firm from I/B/E/S.

To be included in our final data set, we require firms to have complete information during each month over which averages are computed and to have at least three analyst recommendations in any month (results are robust to requiring a higher number of analysts). As there are outliers in both spread and dispersion measures, we exclude observations in the 1% tail in either variable. We also drop stocks with an average price of less than $5 because such stocks tend to trade infrequently. We arrive at a final sample of 2033 observations. Table 1 contains the summary statistics for all variables.

3.2 | Results

We first summarize the relationship between spreads and analyst dispersion using rolling windows that sort on dispersion. Figure 3 depicts the results for a window size of 500 (the first data point is the mean spread of the sample of

[23] All results are qualitatively unchanged if we use the one-month average spread (July 2017) or the six-month average spread (July 2017 to December 2017).

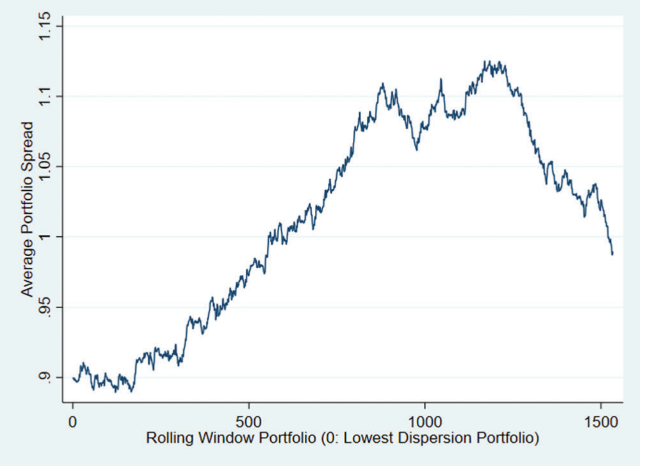

FIGURE 3 Rolling windows analysis of bid–ask spreads

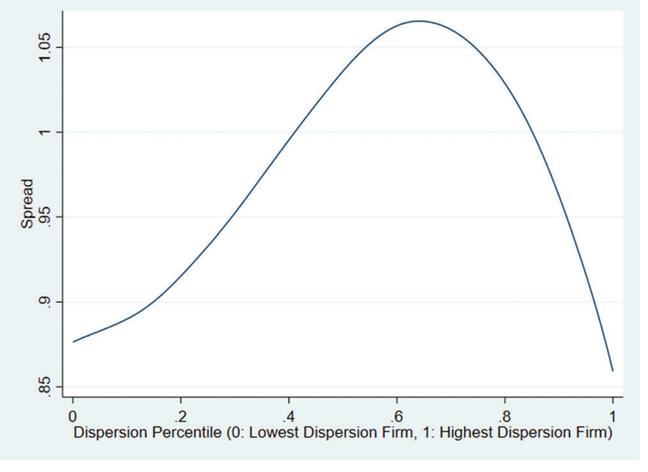

FIGURE 4 Lowess regression for bid–ask spread

firms with the 500 smallest dispersion measure, the second data point is the mean of the firms with a dispersion rank between 2 and 501, etc.). Up to around window 800, there is a clear positive relationship between dispersion and bid–ask spreads. However, for subsequent windows, the bid–ask spread drops significantly. There is thus a nonmonotonic relationship between the two variables, in line with the theoretical predictions.

The rolling window analysis of Figure 3 is based on the raw data and is subject to the disadvantage that for any window information from the observations outside the window are completely ignored. This is an inefficient use of data and, among others, results in a more variable relationship in the figure. In addition, it does not allow inferences for individual-specific dispersion levels, as each data point equally summarizes 500 data points. As an alternative, we analyze the relationship using Lowess smoothing.[24] Figure 4 presents the results, which confirm the rolling windows analysis. In particular, there is a monotonically increasing relationship between dispersion and spreads up to the 60th dispersion percentile of firms, with a clear monotonically decreasing relationship afterwards.

Previous research has indicated that bid–ask spreads reflect other factors besides adverse selection costs. It is thus important to control for these factors in the analysis. Addressing this, we analyze bid–ask spreads that are net of these factors. For this, we first regress bid–ask spreads on a set of controls and obtain residuals from this regression. We proceed to analyze the spread residuals using rolling window portfolios and Lowess smoothing (Cleveland, 1979).

[24] Lowess smoothing (Cleveland, 1979) is based on a series of local regressions that are combined using nonparametric smoothing.

TABLE 2 Control factors in the determination of bid–ask spreads

Coefficient	Spread
Market capitalization (log)	−0.129***
	(0.00829)
Share price	0.0176***
	(0.000372)
Volume (scaled)	−0.0586
	(0.0433)
SD volume	0.00814
	(0.0147)
Volatility	1.605*
	(0.953)
Number of analysts	0.00803***
	(0.00140)
Observations	2,033
R-squared	0.788

Note: This table summarizes results from an ordinary least squares regression where the bid–ask spread is the dependent variable. We report coefficients for the independent variables logged market capitalization, share price, average trading volume scaled by market capitalization, the standard deviation of past daily returns, the standard deviation of scaled past trading volume and the number of analysts giving recommendations. Robust standard errors are in parentheses.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

As a first control, we use size (the log of market capitalization) as larger firms are expected to have smaller spreads independent of adverse selection considerations. Second, we include the stock price, as higher price firms have a tendency to have larger spreads. We also include proxies for inventory costs, as prior literature has emphasized that such costs should result in wider spreads by market makers. The first (and inverse) proxy is trading volume (scaled by market capitalization). Higher trading volume makes it easier for market makers to adjust their inventory and should hence lead to lower spreads (see, e.g., Chordia et al., 2000). The second proxy is the standard deviation of the stock return. This variable captures firm risk, which has the effect of increasing the cost of holding inventory and results in larger spreads. We also include the number of analysts following a stock. Here, a larger number of analysts could be linked both with a higher spread (more analysts are following firms for which private information is an issue), or with a lower spread as analysts effectively reduce private information and thus the spread (see Roulstone, 2003). Finally, we include the standard deviation of the daily trading volume (scaled by market capitalization) as firms with volatile trading volumes require more market depth to provide smooth pricing (Roulstone, 2003).

Table 2 summarizes the results of a regression of the spread on these controls. Market capitalization, price, volatility and number of analysts are the significant controls, and exhibit the expected sign. We calculate the residuals from this regression to separate the components that do not relate to adverse selection. Figure 5 depicts the rolling window analysis of the residuals, using the same approach as in Figure 3 and confirms the pattern from the previous analysis. Figure 6 presents a locally smoothed graph based on Lowess regressions, which plots residual spread against dispersion rank, again showing the hump-shaped relationship.

The nonmonotonic relationship between spreads and dispersion is robust to various considerations. First, the length of the rolling window can be modified within reasonable ranges without fundamentally modifying the observed pattern; similarly, results are robust to variations in the bandwidth for the Lowess regression. Second, trading volume (which we use here as a control) arguably can be considered as a measure of liquidity itself. We hence rerun Figure 5 excluding trading volume in stage 1, with results unchanged. Furthermore, the results are robust to exclusion of the

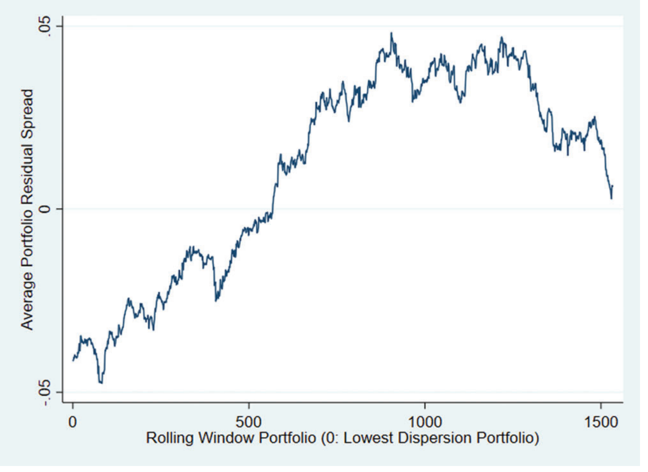

FIGURE 5 Rolling windows analysis of bid–ask spreads residuals

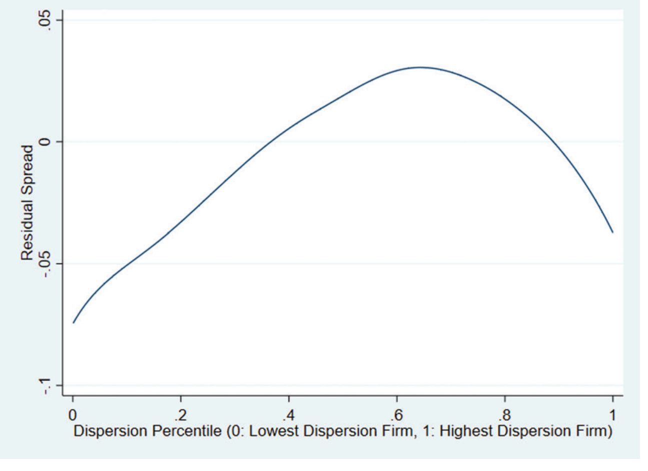

FIGURE 6 Lowess regression of bid–ask spread residual

number of analysts as control. The analysis is also robust to requiring a high number of analysts following a firm (i.e., a minimum requirement of 5, 7 or 10 analysts following the firm). Results are also robust to different outlier treatments, such as including stocks with a price of less than \$5 and extending the tail cutoff for the spread and dispersion measures. Finally, the same patterns appear in an earlier working paper version of this paper, which uses data from 2011 to 2013.

We finish this section by stressing that this empirical exercise should not be taken as a full test of the model. For one, opacity itself may be in endogenous variables. In addition, the proxies for opacity and liquidity are crude and may capture also other asset characteristics. Nonetheless, it is noteworthy that the data are broadly consistent with the predictions of our model, in particular because our priors would have probably led us to expect a monotonic relationship between opacity and liquidity.

4 | THE INCENTIVES OF ASSET ORIGINATORS

In this section, we endogenize several characteristics of the asset held by the investor. For this, we consider an original owner of the asset who can influence an asset's characteristics before selling it on to the investor. We first analyze

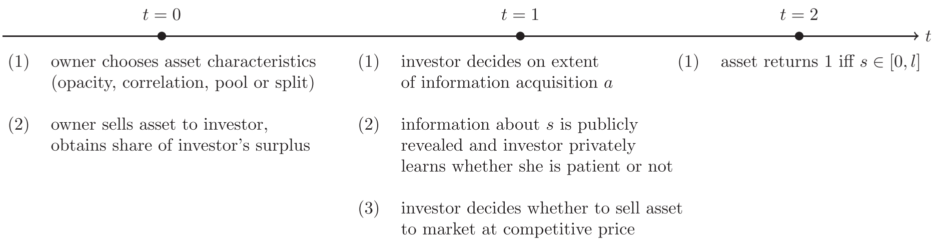

FIGURE 7 Timeline of extended model

the question of how much information an owner wants to release about an asset prior to the sale. Following this, we consider implications for which assets should be sold and how to sell them. Often originators (which may for instance be banks) have several assets for sale. In this case, they can decide whether to sell them together or separately, and when they sell them together, which assets to include in the bundle.

To analyze these questions, let us assume that there is an original owner of the asset, O. Prior to selling the asset to the investor, the owner can choose (some) characteristics of the asset. The choice of these characteristics affects future information acquisition by the investor, and through this, the price at which the owner can sell in the primary market.

Incorporating the owner, the economy now consists of three agents: an owner O, an investor I, and the market M. There are three dates ($t = 0, 1, 2$) of which dates 1 and 2 are identical to the baseline model. The preferences of agents are as follows:

- The owner derives utility from consumption at date 0 only: $U^O = C_0^O$.
- The investor can now also consume at date 0. His utility when patient is hence $U^I = C_0^I + C_1^I + C_2^I$ and $U^I = C_0^I + C_1^I$ when impatient.
- The utility of the market is unchanged: $U^M = C_1^M + C_2^M$.

At date 0, the owner is endowed with the asset. The owner has no other endowment besides the asset. The investor has an endowment of w^I at date 0 and the market still has an endowment of w^M at date 1. As before, we assume that the endowments are sufficient to avoid issues arising because endowments are constrained. Sufficient for this is $w^I > I$ and $w^M > 1$.

The owner first decides on the characteristics of the asset. Following this, he can sell the asset to the investor. For this, we assume that the owner and the investor bargain and that the owner captures a fraction $\delta \in (0, 1]$ of the investor's surplus. Following this, actions proceed as in the baseline model. Figure 7 depicts the timeline.

4.1 | Opacity

We first analyze the owner's choice of opacity. We assume that the owner is perfectly informed about the states in which the asset pays off. Before selling to the investor, he decides how much of this information to release. Specifically, he discloses a set of states of measure o which contain the payoff states. Releasing information comes at a cost for the owner: reducing opacity from 1 to o incurs a proportional cost of $k_O \cdot (1 - o)$ ($k_O > 0$).[25] Such costs arise because it is costly to collect information about an asset and to convey it credibly to the other agents in the economy.

[25] A richer model could allow assets to differ with respect to *fundamental* opacity, that is, the level of opacity before any efforts by the owner to reduce opacity.

4.1.1 | Efficient opacity

Because the owner does not capture the full surplus whenever $\delta < 1$, his choice of opacity may differ from the welfare maximizing one. We first solve for the welfare-maximizing opacity level and subsequently contrast it with the owner's opacity choice.

From date 1 onward, the setup is identical to the model of fixed opacity; trading and information acquisition are still characterized by Lemma 1 and Proposition 1. We now analyze the level of opacity that maximizes welfare. Given linearity of utility, (utilitarian) welfare is simply the expected sum of resources in the economy that are available for consumption. Welfare thus consists of the endowments, $w^I + w^M$, the asset's expected payoff, l, minus the cost of reducing opacity $k_O \cdot (1 - o)$, minus the cost of acquiring information $k_I \cdot a^*(o)$:

$$W(o, a^*(o)) = w^I + w^M + l - k_O \cdot (1 - o) - k_I \cdot a^*(o). \tag{10}$$

Welfare is hence maximized by minimizing the sum of the two costs in the economy.

The opacity choice has two effects on welfare. There is the direct cost of opacity reduction $k_O \cdot (1 - o)$ incurred by the owner. Furthermore, opacity affects date-1 information acquisition $a^*(o)$ and hence the information acquisition costs. Two cases arise. If $\bar{o} \leq 1$, information acquisition can be deterred by leaving the asset fully opaque, that is setting $o = 1$ (see Proposition 1). As this induces neither information acquisition (and associated costs) nor costs of opacity reduction, the first best is reached.

If $\bar{o} > 1$, this is not possible. In this case, the problem can be broken down as follows. First, choosing an opacity level that leads to partial information acquisition (i.e., choosing an o on $[\underline{o}, 1)$) such that $a^*(o) \in (0, o - l)$ is never optimal. A completely opaque asset ($o = 1$) would dominate this choice as it would entail less information acquisition (recall that information acquisition is decreasing in opacity in the interior range) and also no opacity reduction cost. Second, when an opacity level of $[l, \underline{o})$ is chosen, all possible information is acquired ($a^*(o) = o - l$) and welfare is given by

$$W(o, a^*(o)) = w^I + w^M + l - k_O \cdot (1 - o) - k_I \cdot (o - l). \tag{11}$$

Equation (11) shows that optimal opacity depends on which cost parameter is larger. If information is more costly than the cost of opacity reduction, $k_I > k_O$, welfare is maximized by choosing the smallest opacity in the considered range $(l, \underline{o})$: $o = l$. If this is not the case, $k_I \leq k_O$, the optimal choice would be to choose the largest opacity in the range: $o = \underline{o}$. However, as previously discussed, $\underline{o}$ is dominated by a completely opaque asset ($o = 1$).

It follows that to find the optimal opacity level o whenever $\bar{o} > 1$ and $k_I > k_O$, one has to compare welfare for a fully transparent and a fully opaque asset ($o = l$ vs. $o = 1$). This boils down to comparing the cost of fully eliminating opacity, $k_O \cdot (1 - l)$, with the cost of investor information acquisition that arises for an entirely opaque asset, $k_I \cdot a^*(1)$. Note that $k_I < k_O$ ensures that $k_I \cdot a^*(1) < k_O \cdot (1 - l)$ due to $a^*(1) \leq 1 - l$.

Summarizing yields the following proposition.

Proposition 2. *Selling an opaque asset ($o^* = 1$) maximizes welfare if*

(i) this deters information acquisition ($\bar{o} \leq 1$), or
(ii) $k_I \cdot a^*(1) < k_O \cdot (1 - l)$. $k_I < k_O$ is sufficient to ensure this.

Otherwise, selling a fully transparent asset maximizes welfare ($o^* = l$).

There are three important messages. First, it can be optimal to sell a fully opaque asset—independent of the magnitude of opacity reduction costs k_O. This is because under certain conditions, full opacity prevents any information acquisition by the investor. Second, intermediate degrees of opacity are undesirable as such opacity levels induce the investor to acquire costly information. Third, if the costs of opacity reduction are sufficiently small, it can be optimal for the owner to sell a fully transparent asset, which precludes information acquisition.

Adverse selection costs: Even though there is adverse selection at the trading stage (because a patient investor sells when he has negative private information), there are no direct welfare consequences of this in our model. This is because the impatient investor and the market have identical marginal utilities of consumption. A lower market price resulting from adverse selection thus does not affect the gains from trade (the equation for welfare does not contain the price). If an impatient investor were to have higher marginal utility than the market, this neutrality no longer obtains. Appendix D analyzes this case, showing that information acquisition then has an additional, negative, effect on welfare through its effect on the equilibrium price. This, however, does not affect the key results. In particular, the hump-shaped relationship between opacity and information acquisition is still obtained.

4.1.2 | The owner's choice of opacity

The owner maximizes the price at which he can sell the asset to the investor, minus any cost incurred by him. Given that the investor's surplus is $l - k_I \cdot a^*(o)$, the owner maximizes

$$W_O(o, a^*(o)) = \delta\big(l - k_I \cdot a^*(o)\big) - k_O \cdot (1 - o). \tag{12}$$

The owner thus minimizes a combination of costs of opacity reduction and information acquisition costs. However, his objective function is not identical to the social one as he only internalizes a fraction δ of the investor's information acquisition costs.

Similar to the previous section, the solution can be derived as

Proposition 3. *The owner sells a fully opaque asset ($o = 1$) if*

(i) this deters information acquisition ($\bar{o} \leq 1$), or
(ii) $\delta k_I \cdot a^*(1) < k_O \cdot (1 - l)$.

Otherwise, he sells a fully transparent asset ($o^* = l$).

Proof. The owner's opacity choice mirrors the one in the baseline model. If $1 > \bar{o}$, information acquisition can be deterred and the owner can avoid costs entirely by choosing full opacity ($o = 1$). If this is not the case, he chooses either full opacity or full transparency. The respective utilities from these choices are $W_O(1, a^*(1)) = \delta(l - k_I \cdot a^*(1))$ and $W_O(l, a^*(l)) = \delta l - k_O \cdot (1 - l)$. He hence chooses full opacity if and only if $\delta k_I \cdot a^*(1) < k_O \cdot (1 - l)$. □

This yields the following corollary.

Corollary 1. *The owner chooses an opacity level that is inefficiently high if and only if $\bar{o} > 1$ and $\delta k_I \cdot a^*(1) < k_O \cdot (1 - l) < k_I \cdot a^*(1)$. Otherwise his choice of opacity is efficient.*

Proof. Follows from comparing condition (ii) in Propositions 2 and 3. □

The intuition is clear. Because the owner incurs transparency costs fully but only internalizes a fraction of the investor's information acquisition costs, he has comparatively lower benefits from outcomes where transparency is high and information acquisition low.[26] He hence may not sell a transparent asset even when transparency maximizes welfare.[27]

Policy implications: Regulation of information disclosure by firms has a long tradition and takes many forms. Examples are requirements for listed companies to publish certified accounts at specified intervals or to disclose material information in a timely fashion. Prior to the crisis of 2007–2009, disclosure policies were predominantly targeted at protecting investors in standard securities (debt and equity). Following the breakdown of trade in various classes of asset-backed securities, a new focus of regulation is on the transparency of assets issued by financial institutions. For example, the Dodd–Frank act requires disclosure of information about asset-backed securities.

Disclosure policies typically take the form of minimum standards. Issuers are obliged to follows these standards, but are free to implement higher standards of transparency. In light of our results, this is not necessarily a desirable approach to regulation. Specifically, Proposition 2 establishes that fully opaque assets may indeed be optimal provided that they are sufficiently opaque as to deter information acquisition.

More generally, we have shown that transparency reduces adverse selection only when transparency is sufficiently large, while increasing it otherwise. Consider Figures 3 and 4, which depict the (smoothed) cross-sectional relationship between opacity and bid–ask spreads at the firm level. The turning point at which transparency reduces asset liquidity is around the 40th percentile in both figures, suggesting that a mandated increase in transparency may increase bid–ask spreads for a large share of the population of firms. Because higher transparency brings about costs for issuers, the net effect of uniformly higher transparency may hence easily be negative.[28] Note that this does not imply that disclosure regulation per se is undesirable as actual opacity levels already reflect existing efforts to enhance transparency.

Nonetheless, Corollary 1 provides a clear rationale for regulation: issuers do not internalize the full cost of opacity for other agents in the economy and may hence choose inefficiently low disclosure. Firm-specific disclosure standards which take into account that optimal opacity is heterogeneous are in principle welfare-enhancing. However, the extent to which transparency is optimal depends on deep parameters such as the cost of information to firms and investors. Regulation that conditions on these parameters seems practically infeasible.

A less demanding approach is to provide subsidies (implicit or explicit) to issuers for reducing opacity. From the previous analysis, we know that issuers sometimes choose inefficient opacity because they only take into account a fraction $\delta < 1$ of the full cost of opacity, $k_I \cdot a^*(1)$. Consider therefore a subsidy S paid whenever she instead issues a fully transparent asset, $o = l$. Under such a subsidy scheme, the issuer chooses a transparent asset if $\bar{o} > 1$ and the direct cost of full transparency is less than the internalized loss due to illiquidity arising from investor information acquisition. Formally, the issuer chooses $o = l$ if

$$k_O(1 - l) - S \geq \delta k_I \cdot a^*(1),$$

where it is immediate that for $S = (1 - \delta)k_I a^*(1)$ this simplifies to

$$k_O(1 - l) \geq k_I \cdot a^*(1),$$

which is the same condition as for the welfare-maximizing opacity level characterized in Proposition 2. A subsidy of $(1 - \delta)k_I \cdot a^*(1)$ for each issuer can hence implement efficiency. It is important to note that this specific subsidy is sufficient because the issuer only considers fully opaque and fully transparent assets; see Proposition 3. Alternatively,

[26] This resembles the holdup problem: The originator has an opportunity to increase the rents available to both investor and himself by reducing opacity. However, he is only able to extract parts of the benefits, which potentially does not suffice to compensate her for the (noncontractible) costly opacity reduction, which may lead to social inefficiency in the unregulated equilibrium.

[27] Note that a sharing of rents between the investor and the market in the secondary trading stage does not lead to any bias in the owner's opacity choice as it does not create a wedge with the welfare maximizing level of opacity.

[28] Kurlat and Veldkamp (2015) provide an alternative reason for why disclosure can reduce welfare. The channel is based on a general equilibrium effect. Disclosure makes assets less risky. This, in turn, will result in assets commanding a lower return in equilibrium.

the regulator could also obtain the welfare-maximizing outcome via a subsidy scheme that conditions on the opacity choice of the issuer, that is, a negative Pigouvian tax. Specifically, a subsidy of $(1-\delta)k_l a^*(1+l-o)$ would implement this and ensure that the issuer does not receive a subsidy when choosing an opaque asset, $(1-\delta)k_l a^*(1+l-1) = (1-\delta)k_l a^*(l) = 0$, while the required subsidy is paid when a fully transparent asset is issued, $(1-\delta)k_l a^*(1+l-l) = (1-\delta)k_l a^*(1)$.

Finally, when the regulator has incomplete knowledge about the size of externalities posed by individual issuers, he can still implement a welfare-improving policy through a subsidy that is equal to the minimum of $(1-\delta)k_l \cdot a^*(1)$ across all firms (in this case, transparency will be optimally increased at some firms—without leading to any increases in transparency that are welfare-reducing at other firms).

A subsidy could, for example, take the form of a government-sponsored rating agency that allows issuers (at their discretion) to obtain free ratings. In addition, publicly run information repositories could help reduce the costs of providing transparency to issuers. It is crucial, however, that participation is left to the discretion of the issuers—compulsory participation suffers from the same problem as mandatory disclosure requirements.

Finally, it is important to bear in mind potentially beneficial effects of private information acquisition that may be reduced by such policy interventions. Within our model, information acquisition is innately wasteful and provides no social benefit. In practice, it can however also help to increase the efficiency of resource allocation, see, for example, Dow and Gorton (1997). Our analysis and policy recommendations thus predominantly apply to settings where the adverse effect from socially wasteful private information acquisition due to rent-seeking motives dominates these considerations.

Fundamental and effective opacity: One concern with the "all-or-nothing" result in Proposition 3 is that it may at first glance seem incompatible with the cross-sectional variations of the opacity measure in Section 3. However, it is important to distinguish between the fundamental and effective opacity of an asset.

The effective opacity of an asset (i.e., the opacity of an asset when sold to the investor) will in practice consist of two factors. First, it consists of the fundamental opacity of the asset, determined by its business characteristics. This was the focus of the analysis in the baseline model. For example, firms in certain industries are intrinsically more opaque. Large and complex firms will also have a fundamental tendency toward higher opacity. Second, there is the opacity choice of the owner (which we focused on in this section). This choice can be understood as efforts by the owner to reduce opacity below its fundamental opacity. In cases where such efforts are not taking place, effective opacity may approximate fundamental opacity. In addition, reaching a certain level of transparency will be more costly when initial opacity is high. Incorporating this type of convex costs of opacity reduction into the analysis would leave the qualitative predictions of the model unchanged, but allow for interior levels of opacity to be optimal.[29] Overall, the model is thus consistent with wide levels of effective opacity prevailing in practice, with higher levels typically corresponding to a higher fundamental opacity.

4.2 | Correlation

Suppose an owner wants to sell a number of assets, for instance, through a securitization. Should he include correlated or uncorrelated assets in the sale? And does this decision depend on the characteristics of the assets available?

To analyze this in a stylized fashion, we consider the following modification of the model. At $t = 0$, the owner is endowed with two pools of assets, each containing x ($x \geq 2$) assets of fixed opacity o. The assets in each pool are individually identical to that of the baseline model: an asset pays 1 in a mass l states of the world and zero otherwise. The investor can narrow down the set of payoff states for each individual asset by incurring cost a. The only difference between the two pools is that in the first (correlated) pool, assets are identical and pay off in exactly the same states of the world. In the second (uncorrelated) pool, the payoff states are independently distributed across assets.

[29] This is similar to the analysis of increasing marginal costs of information acquisition presented in Appendix C.

At $t = 0$ the owner decides which pool of assets to sell. This choice is public information. At $t = 1$ the investor can acquire information about each asset in the pool and subsequently sell assets to the market. We assume that assets are sold individually to market participants and that each market participant cannot observe how many assets in total the investor is selling. To focus the analysis, we analyze in the following the case of $\delta = 1$, in which case there is no conflict between the owner's incentives and the welfare maximizing outcome.

Suppose first that the owner chooses to sell the pool consisting of correlated assets. At the trading stage, the investor has to decide for each individual asset whether to sell it. The market has formed beliefs about information acquisition and because assets are identical, these beliefs boil down to a single parameter $\tilde{a}$ about the investor's private information set $[o - \tilde{a}, o]$. The decision whether to sell is identical to the baseline model, but now applies to x-assets at the same time. That is, the investor will sell all assets whenever she is impatient or when she privately knows that the assets are worthless ($s \in [o - a, o]$).

At the beginning of $t = 1$, the investor decides how much information to acquire about each asset. Because assets are perfectly correlated, it is strictly optimal to acquire information about one asset only. The investor thus has a single choice a, as in the baseline model. However, acquiring information about one asset now provides additional benefits: Because of perfect correlation, the investor learns about several assets at the same time. Similar to equation (4), we can write the utility of the investor as

$$u(a, \tilde{a}) = x \cdot o\left(\left(1 - \pi + \pi \frac{a}{o}\right) p(\tilde{a}, o) + \pi \frac{o - a}{o} \frac{l}{o - a}\right) - k_l \cdot a. \tag{13}$$

From this we can derive the investor's optimal information acquisition.

Proposition 4. *The equilibrium level of information acquisition for the correlated pool of assets is*

$$a_C^* = \begin{cases} o - l & \text{if } o \leq \underline{o}_C \\ (1 - \pi)\left(x \frac{l}{k_l} - \frac{o}{\pi}\right) & \text{if } o \in (\underline{o}_C, \bar{o}_C) \\ 0 & \text{if } o \geq \bar{o}_C \end{cases} . \tag{14}$$

with $\underline{o}_C = \pi l + x \frac{\pi(1-\pi)l}{k_l}$ *and* $\bar{o}_C = x \frac{l\pi}{k_l}$.

Proof. Analogous to Proposition 1. □

Compared to the sale of a single asset, information acquisition now tends to be higher. First, the threshold opacity level above which the investor does not acquire information is higher ($\bar{o}_C > \bar{o}$). Second, information acquisition in the interior cases is always higher ($a_C^* > a^*$ for given o). The reason for this is because information can be applied to several assets, it becomes more attractive to acquire information.

Suppose next that the owner has sold uncorrelated assets. At the trading stage the market will again have beliefs $\tilde{a}$ about the level of private information for each asset. These beliefs will be asset-independent due to symmetry of the setup. The trading stage for each asset is hence the same as in the baseline case. Consequently, information acquisition for each individual asset is also unchanged and given by a as laid out in Proposition 1. Total information acquisition, however is $x \cdot a^*$.

We can now turn to the owner's choice of which assets to sell. Because the owner consumes only at $t = 0$, he does not care about the assets that are retained.[30] He will hence sell the pool that obtains the highest price, which will be the one with the lowest information cost. The owner's problem is thus to identify the pool that induces the lowest amount of private information. This choice will be subject to a basic trade-off. The incentives to acquire information for an

[30] If the owner could also consume at $t = 2$, he would still be indifferent as to which assets are retained as both pools have the same expected payoff.

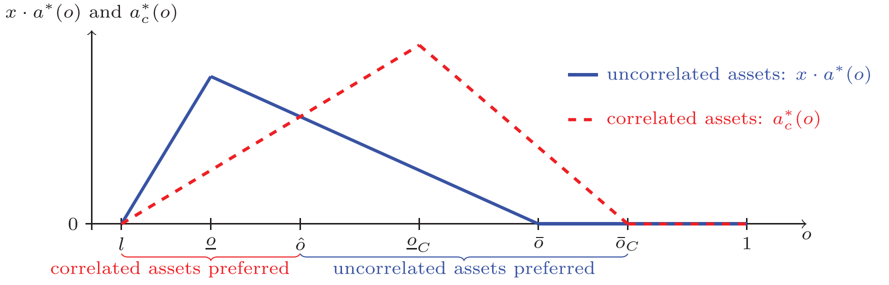

FIGURE 8 Information acquisition as a function of o

individual asset are stronger in the correlated pool, as shown above. This speaks for the uncorrelated pool. However, for a given amount of information acquired about an asset, total costs are higher in the uncorrelated pool because information is then acquired about each asset individually.[31]

The consequences for the owner's decision are as follows. When information acquisition is sufficiently unattractive ($o \geq \bar{o}_C$), there will be no information acquisition for either pool and the owner is indifferent between the pools. When $\bar{o} < o < \bar{o}_C$, there will be information acquisition in the correlated pool only; hence the uncorrelated pool is preferred. For lower levels of opacity ($o < \bar{o}$), information is acquired in both pools. In this case the above trade-off comes into play. If $o > \underline{o}_C$ (i.e., there is incomplete information acquisition in the correlated pool), an uncorrelated pool still maximizes welfare. This can be seen by noting that interior information acquisition in the correlated pool, $a_C^* = (1-\pi)(x\frac{l}{k_l} - \frac{o}{\pi})$, is always higher than in the uncorrelated pool, $xa^* = x(1-\pi)(\frac{l}{k_l} - \frac{o}{\pi})$. However, for o that is sufficiently below $\underline{o}_C$, information costs in the uncorrelated pool dominate (information acquisition in the correlated pool even decline because they are then already at their maximum feasible level, $o - l$). The critical opacity level at which this happens is determined by the condition $o - l = xa^*(o)$. Rearranging yields:

$$\hat{o} = \frac{x(1-\pi)\frac{\pi}{k_l} + 1}{x(1-\pi) + 1} l. \tag{15}$$

Figure 8 illustrates the different cases. We can summarize

Proposition 5. *Consider the owner's choice to sell a correlated or uncorrelated pool of assets.*

1. *If $o \leq \hat{o}$, the owner prefers to sell a correlated pool of assets.*
2. *If $o \in (\hat{o}, \bar{o}_C)$, the owner prefers to sells an uncorrelated pool of assets.*
3. *If $o \geq \bar{o}_C$, the owner is indifferent between both pools.*

In their review of securitization practices, Gorton and Metrick (2013) identify the lack of diversification as one of the main puzzles: "The choice of loans to pool and sell to the SPV also remains a puzzle. Existing theories cannot address why securitized loan pools are homogeneous—all credit cards or all prime mortgages, for example. The existing theory suggests that credit card receivables, auto receivables, mortgages, and so on should be in the same pool—for diversification, but this never happens." Proposition 5 shows that selling homogeneous (or correlated) assets can be beneficial for the originator. The reason is that this lowers the total cost of private information acquisition because

[31] Dang et al. (2017) also analyze the impact of diversification on the incentives for information acquisition. They show that selling a diversified portfolio discourages private information acquisition by hiding private information. They do this in a setting where the cost of acquiring information is independent of the security design. Our model of endogenous information acquisition shows that while incentives to acquire information are indeed lower in the case of uncorrelated assets, correlated pools avoid duplicating private information production and may thus be preferred.

information acquisition costs do not need to be spent on each individual asset—as information acquisition is ultimately self-defeating, lower information costs imply more rent, which can be extracted in the primary market.

4.3 | Splitting and pooling

Information acquisition also has consequences for whether an owner should sell cash flows individually or in a pool. To this end, consider that the owner has at date 0 an asset that pays x in I states and zero otherwise. The owner has the option to sell this asset in its entirety. Alternatively, he can split the asset into x smaller assets (each paying 1 in I states) and sell them to x separate investors. Assume that per-state information costs are k_I regardless of the size of the asset. In addition, assume that investors cannot credibly reveal information to each other (otherwise, one investor could obtain the information and sell them to all other investors) and that the market cannot observe how many investors are selling assets (this would reveal the private information of investors).

Consider first the sale of the asset in one piece. This case is identical to that of a correlated pool in the previous section. While for a correlated pool information acquisition for one asset applied to x assets of size 1, it now applies to one asset of size x. Information acquisition is hence a_C^* as given by Proposition 4. Consider next the sale of split assets to different investors. Each investor is in the same situation as in the baseline model: he can decide to acquire information about an asset of size 1. Thus, the results from the baseline model apply. However, because there are now x investors in total, overall information costs are $x \cdot a^*$, identical to the case of an uncorrelated pool.

The decision whether to split the asset thus creates the same trade-off as the decision whether to sell a correlated pool. We can conclude:

Proposition 6. *Consider the owner's choice to split an asset for sale.*

1. *If $o \leq \hat{o}$, the owner prefers not to split.*
2. *If $o \in (\hat{o}, \bar{o}_C)$, the owner prefers to split.*
3. *If $o \geq \bar{o}_C$, the owner is indifferent.*

The intuition behind the trade-off is as follows. On the one hand, the incentives to acquire information for an investor who has bought the entire asset are high because private information can then be applied to an asset that pays off $x > 1$. On the other hand, when investors who have bought the split assets acquire information, information acquisition is duplicated because each individual investor will acquire information. This means that in cases where there are large incentives to acquire information, the owner should sell the entire asset in order to avoid duplication of a large amount of information.

5 | CONCLUSION

How does opacity affect liquidity when investors can acquire information about an asset? This paper proposes a novel formalization of opacity and targeted private information acquisition, which suggests that the link between the two is nonmonotonic. Both very transparent and very opaque assets preserve commonality of information. While full transparency directly precludes information asymmetries, sufficiently large opacity deters acquisition of private information by making learning about an asset more costly. Assets with either very low or very high opacity can hence be expected to be liquid. Assets that display intermediate degrees of opacity, in contrast, are prone to information acquisition. These assets may suffer from adverse selection problems when they need to be traded. An empirical analysis of the cross-section of listed US firms strongly supported this hump-shaped relationship between opacity and illiquidity.

Our analysis points to a significant benefit to opacity, which may help understand the phenomenon that issuers often choose to sell surprisingly opaque assets, as for instance observed in the case of securitization products. Policymakers thus have to be careful in equating opacity with inefficiencies. The results also have implications for disclosure regulation. In particular, our analysis suggests that uniform disclosure requirements are not desirable. This is simply because they may increase adverse selection for the more opaque assets in the economy. Rather, a more appropriate policy is to subsidize the provision of information by issuers. This can help internalizing the externalities associated with opacity, while allowing issuers to optimally preserve heterogeneous transparency levels.

ACKNOWLEDGMENTS

We thank participants of the Annual Meeting of the EFA 2014, the ESEM 2014, the ESWM 2014, as well as the ENTER Jamboree 2015, and seminar audiences at Cambridge Judge, ULB-ECARES, Leicester, Rotterdam, Mannheim and Tilburg. We are grateful to Jacques Crèmer, Paolo Conteduca, Raphael Levy, Volker Nocke, Yuki Sato, Nicolas Schutz and Ernst-Ludwig von Thadden for valuable comments. Funding by the German Research Foundation (DFG) via the CRC TR 224 (Project C3) is gratefully acknowledged.

Open Access funding enabled and organized by Projekt DEAL.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from Wharton Research Data Services (WRDS). Restrictions apply to the availability of these data, which were used under license for this study. Data are available from the authors with the permission of WRDS.

ORCID

André Stenzel https://orcid.org/0000-0002-6443-6810

REFERENCES

Agarwal, P. (2007). *Institutional ownership and stock liquidity* (Working Paper). Cornell University. https://doi.org/10.2139/ssrn.1029395

Boot, A. W., & Thakor, A. V. (2001). The many faces of information disclosure. *Review of Financial Studies*, *14*(4), 1021–1057.

Bushman, R., & Landsman, W. R. (2010). The pros and cons of regulating corporate reporting: A critical review of the arguments. *Accounting and Business Research*, *40*(3), 259–273.

Carlin, B., Kogan, S., & Lowery, R. (2013). Trading complex assets. *Journal of Finance*, *68*(1), 1937–1960.

Charoenwong, C., Chong, B. S., & Yang, Y. C. (2014). Asset liquidity and stock liquidity: International evidence. *Journal of Business Finance & Accounting*, *41*(3-4), 435–468.

Chordia, T., Roll, R., & Subrahmanyam, A. (2000). Commonality in liquidity. *Journal of Financial Economics*, *56*(1), 3–28.

Cleveland, W. (1979). Robust locally weighted regression and smoothing scatterplots. *Journal of the American Statistical Association*, *74*(1), 829–836.

Cohen, L., & Lou, D. (2012). Complicated firms. *Journal of Financial Economics*, *104*(2), 383–400.

Dang, T., Gorton, G., & Holmström, B. (2013). *The information sensitivity of a security* (Working Paper). http://www.columbia.edu/

Dang, T. V., Gorton, G., Holmström, B., & Ordonez, G. (2017). Banks as secret keepers. *American Economic Review*, *107*(4), 1005–1029.

Demski, J. S., & Feltham, G. A. (1994). Market response to financial reports. *Journal of Accounting and Economics*, *17*(1–2), 3–40.

Dow, J., & Gorton, G. (1997). Stock market efficiency and economic efficiency: Is there a connection? *Journal of Finance*, *52*(3), 1087–1129.

Farhi, E., & Tirole, J. (2015). Liquid bundles. *Journal of Economic Theory*, *158*, 634–655.

Flannery, M., Kwan, S., & Nimalendran, M. (2004). Market evidence on the opaqueness of banking firms' assets. *Journal of Financial Economics*, *71*(3), 419–460.

Fosu, S., Ntim, C. G., Coffie, W., & Murinde, V. (2017). Bank opacity and risk-taking: Evidence from analysts' forecasts. *Journal of Financial Stability*, *33*, 81–95.

Glosten, L., & Milgrom, P. (1985). Bid, ask and transaction prices in a specialist market with heterogeneously informed traders. *Journal of Financial Economics*, *14*(1), 71–100.

Gorton, G., & Metrick, A. (2013). Securitization. In G. M. Constantinides, M. Harris, & R. M. Stulz (Eds.), *Handbook of the economics of finance* (Vol. 2, pp. 1–70). Elsevier.

Grossman, S. J., & Stiglitz, J. E. (1980). On the impossibility of informationally efficient markets. *American Economic Review*, *70*, 393–408.

Hermalin, B. E., & Weisbach, M. S. (2012). Information disclosure and corporate governance. *Journal of Finance*, *67*(1), 195–233.

Huang, R. D., & Stoll, H. R. (1997). The components of the bid–ask spread: A general approach. *Review of Financial Studies*, *10*(4), 995–1034.

Isshaq, Z., & Faff, R. (2016). Stock liquidity risk and the cross-sectional earnings-returns relationship. *Journal of Business Finance & Accounting*, *43*(9–10), 1121–1141.

Kaplan, T. (2006). Why banks should keep secrets. *Economic Theory*, *27*(2), 341–357.

Kim, O., & Verrecchia, R. E. (1994). Market liquidity and volume around earnings announcements. *Journal of Accounting and Economics*, *17*(1–2), 41–67.

Kurlat, P., & Veldkamp, L. (2015). Should we regulate financial information? *Journal of Economic Theory*, *158*, 697–720.

Kyle, A. (1985). Continuous auctions and insider trading. *Econometrica*, *53*, 1315–1335.

Leuz, C. (2010). Different approaches to corporate reporting regulation: How jurisdictions differ and why. *Accounting and Business Research*, *40*(3), 229–256.

Leuz, C., & Verrecchia, R. E. (2000). The economic consequences of increased disclosure. *Journal of Accounting Research*, *38*, 91–124.

Leuz, C., & Wysocki, P. D. (2008). Economic consequences of financial reporting and disclosure regulation: A review and suggestions for future research. *Journal of Accounting Research*, *54*, 525–622.

Monnet, C., & Quintin, E. (2017). Rational opacity. *Review of Financial Studies*, *30*(12), 4317–4348.

Morgan, D. (2002). Rating banks: Risk and uncertainty in an opaque industry. *American Economic Review*, *92*(4), 874–888.

Pagano, M., & Volpin, P. (2012). Securitization, transparency, and liquidity. *Review of Financial Studies*, *25*(8), 2417–2453.

Roulstone, D. T. (2003). Analyst following and market liquidity. *Contemporary Accounting Research*, *20*(3), 552–578.

Sato, Y. (2014). Opacity in financial markets. *Review of Financial Studies*, *56*(1), 3–28.

Stoll, H. R. (1989). Inferring the components of the bid–ask spread: Theory and empirical tests. *Journal of Finance*, *44*(1), 115–134.

Yang, M. (2012). *Optimality of securitized debt with endogenous and flexible information acquisition* (Working Paper No. 019-2011). https://doi.org/10.2139/ssrn.1881156

How to cite this article: Stenzel A, Wagner W. Opacity, liquidity and disclosure requirements. *J Bus Fin Acc*. 2022;*49*:658–689. https://doi.org/10.1111/jbfa.12574

APPENDIX A: RANDOM DISCOVERY OF THE PAYOFF INTERVAL

This analyzes a stochastic information acquisition technology. While in the baseline model information acquisition started at the upper end of the interval $[l, o]$, we now consider a random starting point. Specifically, we denote the *starting state* for information acquisition with y and assume that it is uniformly distributed on $[l, o]$. The distribution of the starting state is known by the investor, but not its realization.

As before, the investor learns about an interval of mass a when choosing a level of information acquisition a. For given starting state y, the investor thus learns about the interval $[y - a, y]$). If a is such that $y - a > l$, she learns that the interval $[y - a, y]$ does not contain payoff states, as in the baseline model. If a is sufficiently large such that $y - a \leq l$, she "discovers" the payoff interval. In this case, she ends up with complete knowledge about the distribution of payoff states.

We allow information acquisition to take place sequentially, that is, the investor can first decide to obtain information about a certain mass of states, and following this decide whether to analyze more states (and so on). Note that because the investor does not know the realization of y, she does not know in advance whether a certain amount of information acquisition will lead to discovery of the payoff interval.

It is easy to see that the modification in the information technology does not alter the investor's incentives to sell to the market at date 1 (Lemma 1): she will offer the asset if impatient; otherwise she will offer the asset only if she knows that the asset is worthless. The price of the asset will again depend on the market's belief about information acquisition. These beliefs, however, are no longer necessarily characterized by a single parameter because information acquisition can become stochastic (for instance, depending on y, investor may discover the payoff interval early on and stop). Let us denote the market price with $\widetilde{p}$ to indicate its dependence on beliefs.

We start with the analysis of the investor's incentives to acquire information. When deciding about information, the investor takes as given the price $\widetilde{p}$ at which she can sell to the market. We consider information acquisition that takes place by acquiring knowledge about (small) intervals of size $b > 0$ (we later consider the limit of b tending to zero).

Consider first that the investor has already discovered the payoff interval. She then has complete information about the asset, and hence will not acquire any further information.

Consider next the decision of an investor to acquire information about an interval b given that she has already acquired an amount $a \geq 0$ of information and has not yet discovered the payoff interval. Two cases arise. First, if a is sufficiently large such that $o - a - b \leq l$, the investor knows that the payoff interval will be discovered with certainty with the next information acquisition. The discovery will benefit the investor when a state of nature s materializes that falls in the interval $[l, o - a]$ and when she is impatient. The probability of this is $(o - a - l)\pi$, in which case she is able to sell at price $\widetilde{p}$ rather than holding onto a worthless asset. Her expected gains from additional information acquisition are thus

$$u(l, \widetilde{p}) - u(a, \widetilde{p}) = (o - a - l)\pi\widetilde{p} - bk_l. \tag{A1}$$

These gains are identical to equation (5) in the baseline model—except that an interval of size $o - a - l$ is discovered by incurring costs for b ($\geq o - a - l$) states. A1 shows that information acquisition is beneficial whenever $(o - a - l)\pi\widetilde{p} > bk_l$. We can hence define the *option value* of information acquisition in this case as $\max\{(o - a - l)\pi\widetilde{p} - bk_l, 0\}$.

Second, we have the case of $o - a - b > l$. In this case, the investor does not know whether the next information acquisition will discover the payoff interval—it depends on the starting state y. While the realization of y is unknown to the investor, she infers from not having discovered the payoff interval up to now that $y \in [l + a, o]$. The impact of information acquisition in this case is as follows. When $y > l + a + b$, she does not discover the payoff interval. In this case, she can rule out an interval of mass b as containing payoff states. When $y \leq l + a + b$, she discovers the payoff interval. She then rules out in total a mass of $o - a - l$ states. The likelihood of nondiscovery and discovery is $1 - \frac{b}{o-a-l}$ and $\frac{b}{o-a-l}$, respectively. We hence have for the total expected mass of loss states discovered $b(1 + \frac{o-l-a-b}{o-a-l})$. Recalling that the investor benefits from knowledge about loss states when impatient, we obtain for the total expected gains from acquiring information:

$$u(a + b, \widetilde{p}) - u(a, \widetilde{p}) = b\left((1 + \frac{o - l - a - b}{o - a - l})\pi\widetilde{p} - k_l\right) + \left(1 - \frac{b}{o - a - l}\right)V(a + b), \tag{A2}$$

where $V(a + b)$ is the option value from acquiring further information when the payoff interval has not been discovered.

The value of information acquisition can hence be recursively defined as

$$V(a) = \begin{cases} \max\{b\left(\left(1 + \frac{o-l-a-b}{o-a-l}\right)\pi\widetilde{p} - k_l\right) + \left(1 - \frac{b}{o-a-l}\right)V(a + b), 0\} & \text{if } a < o - l - b \\ \max\{(o - a - l)\pi\widetilde{p} - bk_l, 0\} & \text{if } a \in [o - l - b, o - l) \\ 0 & \text{if } a \geq o - l \end{cases}. \tag{A3}$$

Note that $f(a) := b((1 + \frac{o-l-a-b}{o-a-l})\pi\widetilde{p} - k_l)$ is decreasing in a. This implies that the value of acquiring information about an interval of size b is declining in the amount of information already acquired. The reason is as follows. While the likelihood of discovering the payoff interval ($\frac{b}{o-a-l}$) is increasing in a, the expected gains conditional on discovery are decreasing. The latter is because the mass of states ruled out by discovery, $o - l - a - b$, falls in a. Because of this latter effect, the gains from information acquisition are ultimately decreasing.

It follows that $f(a) \leq 0$ implies $f(a+b) < 0$. In addition, we can conclude that when $a \in [o-l-b, o-l)$ (i.e., when the next information acquisition discovers the payoff interval with certainty) we have $f(a-b) > (o-a-l)\pi\tilde{p} - bk_I$. From this it follows that whenever $f(a) \leq 0$, the option value of information acquisition beyond the next interval is zero ($V(a+b) = 0$). Thus, $V(a) = 0$ whenever $f(a) \leq 0$. The consequence is that an investor will acquire information as long as $f(a) > 0$, and will stop when $f(a) \leq 0$ or when the payoff interval is discovered.

An equilibrium strategy for information acquisition is hence defined by a threshold $a^* \in (0, o-l)$ such that $f(a^*) \leq 0$, but $f(a^*+b) > 0$. For arbitrarily small intervals of information acquisition ($b \to 0$), we find that $f(a) = 0$ precisely when

$$\tilde{p} = \frac{k_I}{2\pi}. \tag{A4}$$

This condition is almost identical to the condition for an interior equilibrium in the baseline model ($\tilde{p} = \frac{k_I}{\pi}$). The difference arises because information acquisition is now more effective as it can result in the discovery of the payoff interval, in which case the entire distribution becomes known (in the baseline model, it only allowed us to proportionally narrow down the set of payoff states). In order for the gains from information acquisition to be identical to the costs k_I, the price at which the asset can be sold when information is of use to the investor hence has to be lower.

We next derive the break-even market price $\tilde{p}$ as a function of beliefs about information acquisition. Recall that the investor's strategy can be summarized by a threshold value a^*. The market's beliefs can hence be summarized by a single parameter $\tilde{a}$. Note that even though information discovery is stochastic, it has only two possible outcomes: either the investor finds the payoff interval or she reaches $\tilde{a}$ and stops. Given that the starting point y is distributed on $[l, o]$, the probability of the payoff interval being discovered is simply

$$\pi_0 = \frac{\tilde{a}}{o-l}. \tag{A5}$$

The investor will offer the asset if either she is impatient or if she is patient and privately knows the asset will not pay out. The probability of the latter is $\frac{o-l}{o}$ when she has discovered the payoff interval and $\frac{\tilde{a}}{o}$ when she has not discovered the payoff interval. The total probability of offering is thus

$$1-\pi+\pi\left(\pi_0\frac{o-l}{o}+(1-\pi_0)\frac{\tilde{a}}{o}\right). \tag{A6}$$

An offered asset only has a positive expected value if the investor is impatient (occurring with probability $1-\pi$), in which case the expected value to the market is $\frac{l}{o}$. We can then use (A5) and (A6) to express the expected value (and hence the price) of the asset conditional on being offered as

$$p(\tilde{a}, o) = \frac{1-\pi}{(1-\pi)o+\pi\left(\tilde{a}\left(2-\frac{\tilde{a}}{o-l}\right)\right)}l. \tag{A7}$$

Combining (A4) and (A7) to eliminate $p(\tilde{a}, o)$, and solving for $a^* = \tilde{a}$ yields

$$a^* = (o-l) - \sqrt{(o-l)\left((o-l)-(1-\pi)\left(\frac{2l}{k_I}-\frac{o}{\pi}\right)\right)}. \tag{A8}$$

Differentiating with respect to o gives

$$\frac{\partial a^*}{\partial o} = 1 - \frac{(o-l)\left(2-\frac{1-\pi}{\pi}\right)-(1-\pi)\left(\frac{2l}{k_I}-\frac{o}{\pi}\right)}{2\sqrt{(o-l)\left((o-l)-(1-\pi)\left(\frac{2l}{k_I}-\frac{o}{\pi}\right)\right)}} < 0. \tag{A9}$$

Information acquisition (in an interior equilibrium) is hence declining in opacity o, as in the baseline model.

The cases of no and full information acquisition are straightforward to analyze. No information acquisition results if at $a = 0$ we have $f(a) \leq 0$. Noting that zero information acquisition implies $p = \frac{l}{o}$, we can obtain from $f(a) = 0$ a critical threshold opacity of $\bar{o} = 2\frac{l\pi}{k_I}$, such that an opacity level of $o \geq \bar{o}$ deters information acquisition. Full information acquisition arises when $f(o-l) \geq 0$ (as $b \to 0$, we can ignore the case of $a \in [o-l, o-l+b]$). Equation (A7) yields for $a^* = o - l$ that $p = \frac{(1-\pi)l}{o-\pi l}$. Combining with $f(o-l) = 0$ and rearranging gives a critical threshold $\underline{o} = \pi l + \frac{(1-\pi)\pi l}{2k_I}$. For $o \leq \underline{o}$ we hence have a full information acquisition equilibrium.

We can summarize

Proposition A1. *The equilibrium threshold for information acquisition $a^*(o)$ is given by*

$$a^*(o) = \begin{cases} o - l & \text{if } o \leq \bar{o} \\ (o-l) - \sqrt{(o-l)\Big((o-l) - (1-\pi)\Big(\frac{2l}{k_I} - \frac{o}{\pi}\Big)\Big)} & \text{if } o \in (\underline{o}, \bar{o}) \\ 0 & \text{if } o \geq \underline{o} \end{cases} \tag{A10}$$

with $\underline{o} = \pi l + \frac{(1-\pi)\pi l}{2k_I}$ and $\bar{o} = 2\frac{\pi l}{k_I}$.

APPENDIX B: LEARNING ABOUT LOSS STATES

Assume that the asset pays 1 if nature selects a state $s \in [l, 1]$ and zero otherwise. Increasing transparency and information acquisition each narrow down the potential set of states where the asset does not pay off. In particular, for transparency choice o and information acquisition a, the public knows the set of nonpaying (loss) states to be on the interval $[0, o]$, while the investor knows that the loss states are distributed on $[0, o-a]$.

For given beliefs about private information acquisition, $\tilde{a}$, the trading decision of the investor is as follows. When $s \geq o$, both investor and market know that the asset will certainly pay. Its price will hence be 1. An impatient investor will sell the asset, while a patient investor will not sell given the assumptions we made about the investor's actions whenever indifferent. When $s \in [o-a, o]$, the investor knows that the asset will certainly pay off but the market has only imperfect knowledge about the payoff. The investor has thus positive private information about the asset. If she is patient, she will hence not sell. If impatient, the investor will still sell. Finally, when $s \in [0, o-a]$, both investor and market are uncertain about the payoff. However, the investor observes that s is not in her private set of payoff states $[o-a, o]$. She thus has negative private information. She will hence sell, regardless of whether she is patient (the expected value of the asset is $\frac{o-a-l}{o-a}$ in this case). The market price of the asset (conditional on $s < o$) can hence be derived as

$$p(\tilde{a}, o) = \frac{o - l - \tilde{a}\pi}{o - \tilde{a}\pi}. \tag{B1}$$

Note that for $\tilde{a} = 0$, this simplifies to $p = \frac{o-l}{o}$, which is the expected value of the asset conditional on $s < o$. Note also that $\frac{\partial p(\tilde{a},o)}{\partial \tilde{a}} < 0$ because of adverse selection.

Similar to equation (4), we can derive the investor's utility given market beliefs $\tilde{a}$:

$$u(a, \tilde{a}) = 1 - o + o\Big(\frac{a}{o}(\pi + (1-\pi)p(\tilde{a}, o) + \frac{o-a}{o}p(\tilde{a}, o)\Big) - k_I \cdot a. \tag{B2}$$

The derivative with respect to a is

$$\frac{\partial u(a, \tilde{a})}{\partial a} = \pi(1 - p(\tilde{a}, o)) - k_I. \tag{B3}$$

It is useful to contrast this with the marginal benefit of information acquisition in the baseline model ($\frac{\partial u(a,\tilde{a})}{\partial a} = \pi p(\tilde{a}, o) - k_I$). Private information benefits the investor whenever it causes her to modify her selling decision. In the baseline model, the investor learns that the asset will *not* pay off in certain states. A patient investor will then sell the asset if such a state materializes; and hence benefits from a higher market price. In the extension considered here, the investor learns about states in which the asset *does* pay off. She thus does not sell the asset if such a state materializes. Her gains hence decline in the market price (which she would otherwise obtain by selling the asset). This has a consequence: Because more information acquisition leads to lower prices in equilibrium, the gains from information will now be increasing in the amount of information acquired (formally, we have that $\frac{\partial u(a,\tilde{a})}{\partial a}|_{a=\tilde{a}}$ is increasing in a).

Two cases arise. Consider first that $\frac{\partial u(a,\tilde{a})}{\partial a}|_{a=\tilde{a}} > 0$ at $a = 0$. This implies that at a conjectured equilibrium with no information acquisition, the marginal gains from information acquisition are positive. Because we know that $\frac{\partial u(a,\tilde{a})}{\partial a}|_{a=\tilde{a}}$ is increasing in a, the marginal gains from information acquisition are hence also positive for any $a > 0$. The unique equilibrium is hence full information acquisition: $a^* = o - l$. Consider next that $\frac{\partial u(a,\tilde{a})}{\partial a}|_{a=\tilde{a}} < 0$ at $a = 0$. In this case, the gains from information acquisition at an equilibrium with no information acquisition are negative. Hence, no information acquisition is an equilibrium ($a^* = 0$). Because $\frac{\partial u(a,\tilde{a})}{\partial a}|_{a=\tilde{a}}$ is increasing in a, there might also be a second equilibrium with positive information acquisition. However, this equilibrium would be pareto-dominated by no information acquisition (which involves no information cost) and we hence rule it out.

Whether full or no opacity is chosen thus depends on the sign of $\frac{\partial u(a,\tilde{a})}{\partial a}|_{a=\tilde{a}}$. Using equation (B3) one can find that this derivative is zero when $o = \frac{\pi l}{k_I}$. We can hence state

Proposition B1. *When the investor learns about loss states, the equilibrium level of information acquisition a^* is*

$$a^*(o) = \begin{cases} o - l & \text{if } o < \bar{o} \\ 0 & \text{if } o \geq \bar{o} \end{cases} \tag{B4}$$

with $\bar{o} = \frac{\pi l}{k_I}$.

APPENDIX C: INCREASING COST OF INFORMATION ACQUISITION

To analyze increasing costs of information acquisition, let the total cost of acquiring information about a mass of a states be $K_I(a)$ with $K_I(0) = 0, K_I'(a) > 0, K_I''(a) > 0$.

Differentiating the investor's utility $u(a, \tilde{a})$ (equation (4), after replacing $k_I \cdot a$ with the new information cost function) with respect to a yields

$$\frac{\partial u(a, \tilde{a})}{\partial a} = \pi p(\tilde{a}, o) - K_I'(a). \tag{C1}$$

Equation (C1) determines a new threshold for zero information acquisition $\bar{o}$. Rearranging $\pi p(0, o) - K_I'(0) = \pi \frac{l}{o} - K_I'(0) = 0$ gives $\bar{o} = \frac{\pi l}{K_I'(0)}$. Because $K_I'(0) > 0$, there is hence a unique $\bar{o}$ above which no information is acquired. Likewise, $\underline{o}$ is uniquely pinned down by the condition $\pi p(o - l, o) - K_I'(o - l) = \pi \frac{1-\pi}{1-\pi\frac{l}{o}} \frac{l}{o} - K_I'(o - l) = 0$. This yields $\underline{o} = \pi l + \frac{(1-\pi)\pi l}{K_I'(o-l)}$. Finally, we can write down the condition for the interior equilibrium: $\pi p(a^*, o) - K_I'(a^*) = \frac{\pi(1-\pi)l}{o-\pi(o-a^*)} - K_I'(a^*) = 0$. Totally differentiating with respect to o and rearranging gives

$$a^{*\prime}(o) = -\frac{(1-\pi)K_I'(a^*(o))}{\pi K_I'(a^*(o)) + ((1-\pi)o + \pi a^*(o)))K_I''(a^*(o))} < 0. \tag{C2}$$

Thus, opacity reduces information acquisition in an interior equilibrium. We hence have the same properties as in the baseline model. For $o \leq \underline{o}$ we have full information acquisition ($a^* = o - l$). Between $\underline{o}$ and $\bar{o}$, there is an interior degree of information acquisition which is declining in opacity. For opacity larger than $\bar{o}$, no information is acquired.

C.1 | Decreasing marginal costs

In a similar fashion, the case where marginal costs are decreasing could be analyzed. In that case, interior amounts of information acquisition will never materialize in equilibrium: Either all information is acquired or none, similar to the case where learning is about loss states (see Appendix B). The outcome in terms of information acquisition is then also similar: Sufficiently high opacity deters information acquisition as it still limits the value of a given unit of information, while there is a threshold opacity level such that information is fully acquired if opacity falls below the threshold.

APPENDIX D: ADVERSE SELECTION COSTS

Modify the baseline model by assuming that the utility of the impatient investor is

$$U^I = C_0^I + qC_1^I, \quad \text{with } q \geq 1. \tag{D1}$$

This modification does not affect trading with the market: an impatient investor will always sell while the patient investor sells only when she knows the asset is worthless. Consider next the investor's incentives to acquire information. Similar to equation (4), utility is now

$$u(a, \tilde{a}) = o\left(\left((1-\pi)q + \pi\frac{a}{o}\right)p(\tilde{a}, o) + \pi\frac{o-a}{o}\frac{l}{o-a}\right) - k_I \cdot a. \tag{D2}$$

The derivative with respect to a is $\pi p(\tilde{a}, o) - k_I$—the same as in the baseline model (equation (5)). The incentives to acquire information are hence unchanged and Proposition 1 still applies. The reason is that information acquisition benefits only the investor if she turns out to be patient, thus the fact that q may be larger than one does not matter.

The expression for welfare is now as follows. Whenever the investor is impatient and sells to the market, there is an additional welfare gain of $(q-1)p(a^*(o), o)$ compared to the baseline model. We thus have for welfare that

$$W(o, a^*(o)) = w^I + w^M + l + \pi(q-1)p(a^*(o), o) - k_O \cdot (1-o) - k_I \cdot a^*(o). \tag{D3}$$

Opacity now has a new effect, arising because it can affect the price p through a change in information acquisition. Because p is declining in information acquisition (equation (2)), opacity-induced increases in information acquisition now have two effects. First, they directly lead to costs k_I. Second, they reduce the gains for the impatient investor by lowering the price at which she can sell to the market (when $q > 1$, these losses are not completely offset by gains for the market).

Optimal opacity is determined analogous to the baseline model. For $1 \leq \bar{o}$, full opacity maximizes welfare. For $1 > \bar{o}$, one needs to compare welfare under full and no opacity (because of the dependence on p, welfare is now non-linear in the region $[l, \bar{o}]$, but this does not affect the optimal decision). Full opacity is optimal if and only if $W(1, a^*(1)) > W(l, 0)$, which is when $\pi(q-1)p(a^*(1), 1) - k_I \cdot a^*(1) > \pi(q-1)p(0, o) - k_O \cdot (1-l)$. Otherwise full transparency should be chosen.