

SHOULD WE REGULATE FINANCIAL INFORMATION?

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Abstract

Regulations that require asset issuers to disclose payoff-relevant information to potential buyers sound like obvious measures to increase investor welfare. But in many cases, such regulations harm investors. In an equilibrium model, asset returns compensate investors for risk. By making payoffs less uncertain, disclosure reduces risk and therefore reduces return. As high-risk, high-return investments disappear, investor welfare falls. Of course, information is still valuable to each individual investor. But acquiring information is like a prisoners' dilemma. Each investor is better off with the information, but collectively investors are better off if they remain uninformed. The two cases in which providing information improves investors' welfare are 1) where there would otherwise be severe asymmetric information, and 2) where the information induces firms to take on riskier investments. Using a model of information markets, the paper explores when such outcomes are likely to arise. When financial markets with information allocate the real capital stock more efficiently, disclosure improves efficiency, but more efficient firms do not offer investors higher returns. Investors only benefit when disclosure induces firms to take on riskier investments. Since the efficiency gains are fully captured by asset issuers, who can choose to disclose without disclosure being mandatory, the efficiency argument is not a logical rationale for regulation.

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Regulations that require asset issuers to disclose payoff-relevant information to potential buyers sound like obvious measures to increase investor welfare. This paper builds a new model with an equilibrium asset market, an information market and a real production sector to investigate whether such information regulations improve investor welfare. We find that in many cases, requiring information disclosure harms investors. The reason is that asset returns compensate investors for risk. By making payoffs less uncertain, disclosure reduces risk and therefore reduces return. As high-risk, high-return investments disappear, investor welfare falls. Of course, information is still valuable to each individual investor. But acquiring information is like a prisoners' dilemma. Each investor is better off with the information, but collectively investors are better off if they remain uninformed. The only cases in which providing information improves investors' welfare are ones where there would otherwise be information asymmetry, or where disclosing information induces firms to undertake riskier investments. The paper explores when such outcomes are likely to arise.

Many recent financial reforms have sought to increase the transparency of financial products by requiring the seller to disclose additional information.¹ Proponents of these reforms argue that giving buyers more information about the expected costs and benefits of a financial product increases their welfare, and allows the financial market to allocate capital more efficiently. Opponents point out that disclosure is costly for firms and that an active market for financial information and consulting services exists to provide this information in cases where it is efficient. We show why neither argument is correct. Although the free-market efficiency argument is intuitively appealing, our model highlights the free-rider problems, spillovers to real investment, and other externalities that make information market outcomes inefficient. Similarly, we show that while information can improve the allocation of capital, that does not translate into a rationale for mandatory disclosure.

Because many of these regulations pertain to new assets being sold, we analyze a menu auction setting where a firm is endowed with its shares and sells them to a continuum of investors at a market-clearing price. While prices in this auction resemble those in a standard noisy rational expectations model, the distribution of welfare gains does not. On top of this foundation, we build a new framework with an information market, whose outcomes affect the asset market, and the real economy, all in an analytically tractable way. In our model, information can be produced at a cost.

¹For example, Title X, section 1032 of the Dodd-Frank act of 2010 requires that features of consumer financial products, such as credit cards or insurance, are clearly disclosed to the consumer. Title IV, section 404 requires that hedge funds must disclose their leverage, types of assets held, trading practices, etc. Title IX, section 942 requires that the issuers of asset-backed securities disclose asset composition and risk-retention of originators. Title XIV, section 1419 requires that mortgage lenders disclose fees, total interest, and maximum payments. Title IV of the Sarbanes-Oxley act of 2002 increased the amount of financial information that publicly traded corporations are required to disclose.

This cost can be borne by the issuer of a security, who discloses the information, free of charge, to all potential investors, or by independent analysts who can produce the information and sell it to each investor. After observing issuer or analyst reports, rational investors choose how much to pay for the security. After all shares are sold at a market-clearing price, the payoff of the security is realized and agents get utility payoffs. The policy we evaluate in the model is a mandatory disclosure regulation, which requires asset issuers to provide the information at their own cost.

Section 2 begins by considering the welfare effects of an exogenous change in the amount of symmetric information investors observe. Information affects asset prices in two ways: First, a surprisingly positive report will push the price of the asset up, while a surprisingly negative report will reduce the price. In expectation, reports are neutral and this effect washes out. The second effect is that information makes the asset's payoff less uncertain. In doing so, it makes the asset less risky. Lowering risk lowers the equilibrium return and systematically raises the asset's price. For welfare, this means that information reduces the asset's risk, but also implies lower return. With exponential utility and normally distributed payoffs, the return effect always dominates. One potential objection to these results is that they come from a model with exponential utility and normally-distributed payoffs. Section 3.3 shows that this effect persists when the utility function has wealth effects on risk aversion. In fact, section 3.4 explains why it arises in a broad class of asset pricing models where more payoff variance typically increases the return per unit of risk. Finally, section 5 uses numerical analysis to show that the same effects arise when asset payoffs are binary. The conclusion is that requiring firms to disclose information that no investors would otherwise know makes investors worse off.

There are some circumstances in which mandatory disclosure can improve investor welfare. Since mandatory disclosure shifts information costs from investors to asset issuers, one might think that disclosure would be most valuable to investors when this cost is large. Ironically, investors only benefit from disclosure when the cost of information is low. If the information cost is high, few investors will buy the reports and there is little information asymmetry. With little asymmetry, the effect of disclosure is similar to the previous case where information is symmetric and more information reduces investor welfare. But when the analyst reports are cheap, many investors buy them. Any remaining uninformed investors face severe asymmetric information, which reduces risk-sharing. Disclosure can remedy this distortion. For which assets is asymmetric information likely? Section 3.2 shows that information asymmetry arises and therefore regulation may be beneficial not for assets with the most or least uncertain payoffs, but for the ones in between, where asymmetric information is likely to arise. A similar argument reveals that disclosure is also most beneficial

when analyst report precision is not very high or very low.

These results help us understand the value of information in a well-understood modeling environment. They provide a useful starting point for exploring optimal regulation in a world where the financial market has external effects on real investment. Section 4.2 explores two spillovers from financial information to the real economy and how they interact with the welfare effects of information regulation.

One often-cited reason to regulate financial information provision is that better information in financial markets facilitates efficient real investments. Therefore, in the first model, an issuer can choose how much real capital to invest in his firm at time 1. His payoff depends on the price the asset sells for in the time-2 financial market. If financial asset prices are very sensitive to changes in the value of the capital stock (they are informationally efficient), then the issuer is incentivized to invest the optimal amount.

Our results show that requiring more information disclosure improves the efficiency of capital allocation and maximizes output. But, surprisingly, considering the positive spillovers from financial information to the real economy does not overturn our result that more precise information hurts *investor* welfare. The reason is that all the efficiency gains accrue to the issuer. Investor returns are compensation for bearing risk. A project that is known by all to be more valuable will command a higher price. In equilibrium, it will have the same return as an equally risky, but lower-payoff project. If improving efficiency does not affect the risk of the project, then promoting efficient real investment may be a laudable goal, but it does not interact in any way with investor protection.

In the second model, information disclosure encourages the firm to invest more, which makes the firm payoff more risky. In this setting, more symmetric information can increase investor welfare, but only if it induces the firm to choose a more risky level of investment. Ironically, while mandatory disclosure is intended to reduce investor risk, it may be beneficial mainly in cases where it induces firms to compensate by increasing risk.

Ultimately, the desirability of mandatory disclosure depends on parameter values, which makes the optimal policy a quantitative question. Of course, quantifying a model based on sale of information is not an easy task. But one context where information is quantifiable is credit ratings. Section 5 uses data on ratings, prices, and performance of corporate bonds issued between 2004 and 2005 to estimate the model parameters and uses those estimates to compare the costs and benefits of ratings. The resulting numerical predictions tell us that rating costs are low, compared to the benefit of information, for the typical security. The costs are sufficiently low that without regulation, issuers would cease to buy ratings and all investors would buy analyst reports for themselves.

Thus, requiring disclosure has no effect on the amount of information available about the average security. It would simply replace analyst markets with issuer disclosures. Shifting information costs from investors to issuers benefits investors, but does not improve efficiency. It is a pure transfer.

Markets for information, and the question of whether to mandate information provision, matter beyond just the finance industry. For instance, buying consumer goods or services with uncertain benefits is similar to investing in a risky asset. While financial information helps to allocate real productive capital, consumer goods information encourages high-value goods to be supplied and low-value goods to be withdrawn. In both cases, mandatory information improves allocative efficiency. But this efficiency gain may not benefit consumers because, in equilibrium, the price of goods with less-uncertain quality is higher. One contribution of this paper is to assess regulation of financial market disclosure laws. But a second contribution is a framework that can be used to think through and to quantify these competing equilibrium effects in a broad array of markets.

Related literature Our paper is closely related to a recent economics literature on the welfare consequences of information disclosure. In Amador and Weill (2012, 2010) and Kondor (2011), providing financial information can be welfare-reducing. But they do not model an information market and do not consider the same equilibrium effects as we do. Similarly, Gozalo Llosa and Venkateswaran (2012) consider the efficiency of information acquisition decisions in a coordination game, but not in an equilibrium asset market. Gorton and Ordonez (2012) allow investors to acquire information that helps them distinguish firms with good collateral from those without. This type of information is specific to collateralized lending and is distinct from the information about asset payoffs that we consider.

Hirshleifer (1971) also argues that information acquisition is welfare-reducing because investors pay for it and it does not create any social value. Our results go beyond Hirshleifer's effect by showing that investor welfare falls even when the investors do not pay for the information, even when it does not distort investor risk-sharing, and even in an economy where informed asset trade results in more output. Our welfare analysis differs also because of the auction setting. Because our firm is endowed with its own shares, higher asset prices result in transfers from the investors to the firm.

Our work also contributes to the literature that connects the real and financial sides of the economy. Most of these linkages work through the supply of credit to individuals or firms. In contrast, our model captures the idea that asset markets govern incentives: Market prices that aggregate more investor information provide better incentives for firms to invest in a more efficient

manner. Like our model, Goldstein, Ozdenoren, and Yuan (2011), Ozdenoren and Yuan (2008) Albagli, Hellwig, and Tsyvinski (2009) and Angeletos, Lorenzoni, and Pavan (2010) all propose mechanisms that capture an information externality. The information spillover is that asset prices aggregate information that firm managers can use to guide their real investment decisions. When financial investors can affect real investment, this creates complementarities in demand among investors and the potential for multiple equilibria. This effect is not possible in our model because real investment takes place first. More importantly, the type of information spillover our model describes is distinct. An important part of our contribution is a simple, tractable way to capture the idea that improving investors' access to information incentivizes firms to allocate capital efficiently.

Literatures in finance and accounting consider how disclosures remedy managers' incentive problems in principal-agent settings. But to examine market externalities and evaluate the merits of free-market efficiency claims requires a model with many agents interacting in a market. More closely related is work on costly information acquisition, such as Grossman and Stiglitz (1980), Verrecchia (1982), Peress (2010), and Fishman and Parker (2011). But we extend this work by considering the trade-offs between issuer- and investor-purchased information and connecting the asset market to the real economy. If the issuer does not provide the signal, investors themselves can choose to purchase the information from an information market. We model the market for information in a richer way than most of the previous literature by considering the non-rival nature of information and solving for its endogenous market price (as in Wiederholt (2011)). This allows us to consider whether, in the absence of disclosure regulation, either issuer-provided or investor-purchased information markets will fill in the void. Furthermore, the model connects financial information choices to real investment choices, output and welfare.

Finally, this work is also related to a microeconomics literature on welfare and information disclosure (e.g. Shavell (1994), Diamond (1985) and Jovanovic (1982)). Our model differs because it features a continuum of investors in a market that has an equilibrium price. Our results come primarily from equilibrium effects.

1 Model

Asset issuer A risk-neutral issuer sells a risky asset whose whose payoff is $y \sim N(\bar{y}, \frac{1}{h_y})$. Before knowing y , the issuer must decide whether to produce a report about the asset's quality. The report is a number θ which is a noisy, unbiased signal about the risky asset's payoff: $\theta = y + \eta$, where $\eta \sim N(0, \frac{1}{h_\theta})$. Producing this report has a cost χ . Denote the sale price of the asset by p ,

the decision to produce a report by $D = 1$ and the decision not to do so by $D = 0$. The issuer's objective function is:

$$E(p|D) - \chi D \quad (1)$$

A policy of mandated disclosure consists of mandating that the issuer choose $D = 1$.

Investors and financial markets There is a continuum of ex-ante identical investors with measure Q . They have CARA expected utility² with coefficient of risk aversion ρ :

$$EU = E[-e^{-\rho W}], \quad (2)$$

where W is their realized wealth. They have an initial endowment of wealth w_0 . Investors can purchase fractional shares of the risky asset. They can also store their initial endowment with zero net return. If the issuer has not provided a report on the asset quality, it may instead be possible for individual investors to purchase an equivalent report from an independent analyst at a price c . Each investor i individually chooses whether to purchase such a report ($d_i = 1$) or not ($d_i = 0$). The investor's realized wealth is therefore

$$W = w_0 + q_i(y - p) - d_i c. \quad (3)$$

where q_i is the share of the project the investor buys.

The price p is determined in an auction. Each investor submits a bidding function $b_i(q)$ that specifies the maximum amount that he is willing to pay for a fraction q of the risky asset as a function of his information. These bid functions determine the aggregate demand. The auctioneer specifies a market-clearing price p that equates aggregate demand and supply, and each trader pays this price for each unit purchased (a Walrasian auction).³

Asset supply noise There is a set of agents who are subject to random shocks that force them to buy or sell the asset, at any current price. The demand of this group of agents is normally distributed with mean zero: $\xi \sim N(0, \frac{1}{h_x})$. Let x denote the net supply of the asset, after accounting for the

²Since the model has a single asset, any risk is systematic and will be priced as such. More generally, since asset returns are correlated, the return has a systematic component, which justifies modeling investors in any given asset as risk-averse.

³As shown by Reny and Perry (2006), this formulation of the financial market is equivalent to proposing a Walrasian rational-expectations equilibrium. In particular, this is equivalent to assuming that investors take the market-clearing price as given and the price is part of their information set.

noise trader demand: $x \equiv 1 - \xi$. Thus, $x \sim N(1, \frac{1}{h_x})$. This noise ensures that the price investors condition on is not perfectly informative about information that others may know.

Information markets If the issuer does not produce information about the asset, the same signal θ can be discovered by independent analyst, at the same cost χ .⁴ Once this fixed cost is incurred, the information can be distributed at zero marginal cost. Analysts sell their services to individual investors at a price c . For now, we assume that the information is protected by intellectual property law and reselling it is forbidden. We revisit this assumption in the concluding remarks.

The analyst market is perfectly contestable, so that analysts earn zero profits.⁵ This implies that, if a measure λ of investors chooses to purchase the analyst report, the price of the report must be $c = \frac{\chi}{\lambda}$.

The fact that information markets are competitive is crucial. The exact market structure is not. Veldkamp (2006) analyzes a Cournot and a monopolistic competition market as well. All three markets produce information prices that decrease in demand.

Order of Events

1. The issuer decides whether or not he will pay to disclose information. (He does not know y , θ or η yet.)
2. (a) If the issuer discloses, all investors observe θ .
(b) If the issuer does not disclose, the analyst decides whether to find out θ and sets the price c . Investors then simultaneously decide whether or not to buy the analyst's report. Those who do observe θ .
3. Investors submit menus of prices and quantities of assets they are willing to purchase at each price $b_i(q)$.
4. Asset auction takes place. The auctioneer sets a market-clearing price.
5. y is realized and all payoffs are received.

⁴One might think that the cost would be higher for the independent analyst, especially if the issuer does not cooperate, but as we will see below the issuer has every incentive to make the collection of information as easy as possible.

⁵One way to ensure that the market is contestable is to force agents to choose prices in a first stage and choose entry in a second stage.

Equilibrium An equilibrium is a disclosure decision D by the issuer, a demand d_i by each investor for analyst reports, a decision by the analyst about whether to produce a report and a price c for the report, bidding functions $b_i(q)$ for each possible information set and an asset price $p(\theta, D, \{d_i\}, \xi)$ such that: issuers choose disclosure D to maximize (1); investors choose d_i and bidding functions to maximize (2) subject to (3); analysts make zero profits, and the asset market clears: $\int_0^Q q_i di = x$.

2 Equilibrium

We start by analyzing the properties of the second-period financial market equilibrium, for given information choices.

Equilibrium prices With CARA utility and Normal asset payoffs, investor i 's first order condition for portfolio choice is:

$$q_i = \frac{E_i(y) - p}{\rho \text{Var}_i(y)} \quad (4)$$

The bidding function is just the inverse of (4), i.e. $b_i(q) = E_i(y) - q\rho \text{Var}_i(y)$. The subscript i denotes the fact that the calculation is made under investor i 's information set. For investors who have observed the report θ , Bayes' law says that

$$E_\theta(y) = \frac{\bar{y}h_y + \theta h_\theta}{h_y + h_\theta} \quad (5)$$

$$\text{Var}_\theta(y) = \frac{1}{h_y + h_\theta}. \quad (6)$$

For investors who have not observed the analyst report, the market-clearing auction price of the risky asset partially reveals the analyst report that others (if any) have observed. Since the price depends on asset demand and demand depends on information in the price, there is a fixed point problem. We solve by guessing a linear price rule

$$p = \alpha + \beta\xi + \gamma(\theta - \bar{y}), \quad (7)$$

and solving for the coefficients α , β and γ . The following price coefficients are derived in appendix

A.1:

$$\alpha = \bar{y} - \frac{\rho}{\lambda(h_y + h_\theta) + (Q - \lambda)(h_y + h_p)} \quad (8)$$

$$\beta = \frac{\rho}{\lambda h_\theta} \frac{\lambda h_\theta + (Q - \lambda) h_p}{\lambda(h_y + h_\theta) + (Q - \lambda)(h_y + h_p)} \quad (9)$$

$$\gamma = \frac{\lambda h_\theta + (Q - \lambda) h_p}{\lambda(h_y + h_\theta) + (Q - \lambda)(h_y + h_p)} \quad (10)$$

where h_p is the informativeness of the price and satisfies

$$h_p = \frac{\lambda^2 h_\theta^2 h_x}{\lambda^2 h_\theta h_x + \rho^2}. \quad (11)$$

and λ is the measure of investors who observe the signal θ .

The average price is α , and it consists of the ex-ante expected payoff \bar{y} less a term that accounts for investors' risk aversion ρ and the amount of information they have, which depends on the precision of the information, the informativeness of prices and how many investors buy the report. The sensitivity of the price to information (the report or disclosure) is given by γ . γ takes values between 0 and 1, and is greater when information is very precise relative to the prior and a large fraction of investors buy them. The sensitivity of the price to noise in demand is given by β . Prices will tend to be relatively sensitive to demand noise when investors are risk averse, when few have bought the analysts' report or when the report is not very informative.

For the case where the issuer discloses the information (either by choice or due to the mandate), formulas (8) - (11) still apply, setting $\lambda = Q$. For the case where no one buys the analyst report, the formulas apply taking the limit as $\lambda \rightarrow 0$.

Information choice when the issuer does not disclose In case the issuer does not provide the report, investors will simultaneously choose whether to buy it from the analyst. Since they are ex-ante identical, they will only make different choices when those choices yield identical expected utility. Appendix A.2 shows that the equilibrium measure of informed investors is

$$\lambda = \frac{\rho}{\sqrt{h_x h_\theta}} \sqrt{\frac{h_\theta}{(h_y + h_\theta)(1 - \exp(-2\rho c))}} - 1 \quad (12)$$

By equation (11), higher values of λ make prices more informative, which diminishes the value of the signal, and vice versa, which means there is at most one value of λ that makes investors

indifferent. If equation (12) produces a number that is not between 0 and Q , then there is a corner solution. If the right hand side of (12) is an imaginary number, this means that utility is always higher for uninformed investors and therefore the corner solution is $\lambda = 0$. If the right hand side of (12) is greater than Q , then the corner solution is $\lambda = Q$ and all investors become informed.

Equation (12) implies that demand for the analyst report is decreasing in the price c , decreasing in the precision of the prior h_y and increasing in the variability of noise trader demand $\frac{1}{h_x}$, which makes prices less informative. The effect of analyst report precision h_θ is ambiguous. On the one hand, more precise information is more valuable; on the other, it induces informed traders to take larger positions in the asset, which makes equilibrium prices more informative as well.

Equilibrium implies that, if the issuer does not disclose, either the analyst does not produce the signal or (12) and the zero-profit condition holds:

$$c = \frac{\chi}{\lambda}. \quad (13)$$

Voluntary disclosure by the issuer In those cases where, absent regulation, the issuer would voluntarily provide a report then disclosure mandates would be irrelevant. The issuer will voluntarily choose $D = 1$ only when the increase in expected prices from doing so outweighs the cost χ . Let p_1 be the price of an asset when the issuer chooses $D = 1$ and p_0 be the price of the asset if $D = 0$ and information provision is determined by whatever is the outcome in the market for analyst reports. Then, the issuer will disclose when $E[p_1] - \chi > E[p_0]$.

Proposition 1 (*Disclosure by issuer*)

1. If

$$\frac{\rho}{Q} \frac{h_\theta}{h_y (h_\theta + h_y)} > \chi, \quad (14)$$

then either the issuer will disclose, or at least *some* investors will buy a report

2. If condition (14) does not hold, the issuer will not disclose.

When the issuer considers whether or not to disclose, he takes into account the equilibrium measure of investors that will buy the analyst report if he doesn't provide it (λ). In case disclosing results in more information (which will be the case unless $\lambda = Q$), equation (8) implies that this raises his expected revenue from selling the asset. The reason is that, by providing investors with information, the issuer reduces the risk they have to bear, which increases average prices. Of course, it is always possible that the disclosure results in bad news that reduces the asset's price.

But on average, the news is neither good nor bad. It's average effect is simply its effect of reducing uncertainty. The issuer trades off this expected gain against the cost χ of disclosure.

Condition (14) says that the gains from providing information outweigh the cost, assuming that if the issuer does not disclose, the investors will not buy analyst reports. If the condition holds, then either the issuer expects a sufficient number of investors to buy information on their own, or he will disclose. If the condition doesn't hold, then the issuer prefers not to disclose in any circumstance, even if he expects all investors to remain uninformed.

Proposition 1 implies that issuers will certainly not disclose (and therefore mandatory disclosure regulation will matter) if: (1) the precision h_θ is too low; or (2) the cost χ is too high; or (3) investors are sufficiently risk tolerant (low ρ) or numerous (high Q) that the discount from bearing risk is small; or (4) the precision of investors' prior is high enough that the additional information from the disclosure makes little difference

3 Welfare Effects of Information Regulation

Maximizing a weighted sum of utilities is the most commonly used social welfare criterion. In this setting, the objective this produces depends on how one weights the issuer (a single entity) versus the investors (a continuum of agents). The question of how one models the noise traders then also comes into play. Since we have no guidance on how to weight these various constituencies, we simply examine their utilities separately. In each case, we ask how they would be affected by a policy that mandated $D = 1$.

3.1 Who benefits from information regulation?

Issuer A simple revealed preference argument establishes that the asset issuer is always weakly better off without the disclosure mandate. Without the mandate, the asset issuer can always choose $D = 1$, with identical effects as if he were forced to do so. But with the mandate, he cannot choose $D = 0$, which could be the preferred option for some parameter values.

Investors We start by comparing a hypothetical market where investors have no access to any information (in the notation above, $\lambda = 0$) to one where there is mandatory disclosure.

Proposition 2 (*Investors prefer information market collapse*) *Investors have higher ex-ante expected utility when no information is provided than when disclosure is mandatory.*

Investors benefit from access to a high-risk, high-return asset. They are indifferent between holding the last, marginal share of a risky asset, but earn a utility benefit from holding all the inframarginal shares. When firms disclose, it is as if the asset is replaced by a lower-risk, lower return asset. Investors earn less of a utility benefit from holding this asset at the new, higher equilibrium price.

To see why investors prefer high return and high risk, note that in the CARA-Normal framework, conditional expected utility satisfies

$$E_i[U] \propto -\exp\left\{\frac{-1}{2}\frac{(E_i(y) - p)^2}{Var_i(y)}\right\}. \quad (15)$$

(See Appendix A.2 for derivation.) Roughly speaking, expected returns enter quadratically in investors' utility because the direct effect is compounded by them taking larger positions. The fact that variance enters (linearly) in the denominator of the fraction tells us that each investor individually would prefer more information. But when all investors acquire more information, the expected return falls. Using equation (8) for the special cases of $\lambda = 0$ or $\lambda = Q$, the unconditional expected return per unit of the asset is proportional to the conditional variance: $E[y] - p = \rho Var_i(y)$. Overall, the effect of higher variance on utility through higher expected returns dominates the direct risk effect and expected utility is increasing in the conditional variance of the asset payoff. Acquiring information is like a prisoner's dilemma. Each investor wants to observe more information. But investors would like to collectively commit to observe less.

Proposition 2 implies that if the choice were between mandating and prohibiting disclosure (or the distribution of any analysis), investors would collectively benefit from a prohibition. However, this does not immediately imply that disclosure mandates make them worse off. Investors may prefer mandatory disclosure when the alternative is asymmetric information. If issuers will not disclose and only some investors are willing to buy the analyst report at the equilibrium information price, then there will be asymmetric information, with some investors knowing θ and others not. The informed and uninformed investors will hold different quantities of risky and riskless assets. But since all investors are identical ex-ante, holding different portfolios entails sharing risk inefficiently. Inefficient risk sharing reduces investor welfare. If this welfare effect is strong enough, investors prefer that a mandatory disclosure statute restore information symmetry.

Proposition 3 (*Investors prefer mandatory disclosure to asymmetric information*) *If in equilibrium $D = 0$ and λ is sufficiently high, then investors have higher expected utility when disclosure is mandatory.*

If the equilibrium is such that most investors will choose to buy the signal from the independent analyst, any given investor faces a choice between being less informed than most other traders or paying for the information. In the limit, if everyone else is informed ($\lambda = Q$), an investor who pays for the information will have the same utility as in the mandatory disclosure case minus the cost of the report. In an equilibrium with λ close to Q , each investor will be indifferent between bearing the cost of information or suffering from asymmetric information and would prefer mandatory disclosure, which shifts the cost of the report onto the issuer.

Noise traders Finally, there is the issue of how (whether) to include noise traders in the welfare calculation. One possible interpretation of noise traders is that they are merely a modeling convenience to capture the idea of imperfection in the information aggregation process and thus one can safely ignore them in the welfare calculation. Another is to assume that noise traders are either trading for liquidity reasons or are making mistakes. Their welfare is still affected by the profits or losses they make from trading in this market. The aggregate profits they make are given by

$$\pi = (y - p)\xi$$

and, using (7), expected profits are given by

$$\mathbb{E}\pi = -\frac{\beta}{h_x} \tag{16}$$

where β , given by equation (9), is the sensitivity of the asset price to noise trader demand. Noise traders are hurt by the fact that when they trade they move the price against themselves.

Proposition 4 (*Noise traders benefit from mandates*) *The expected profits of noise traders are maximized when disclosure is mandatory.*

When all investors are informed, the asset is less risky for them, which makes their demand more elastic and thus more able to absorb noise with little change in price. Furthermore, the fact that investors are informed means they don't infer anything from prices, so noise traders do not adversely affect investors' estimates of the value of the asset. For this reason, noise traders are always better off when $\lambda = Q$, which the mandate brings about.

3.2 For Which Assets Might Regulation Help Investors?

The results above show that mandatory disclosure regulation can be beneficial for investors when, absent a mandate, there would be asymmetric information. Next, we analyze under what conditions this situation is likely to arise. We consider two features of an asset: the cost of producing information about that asset and the precision of the information produced.

Proposition 5 (*Investors prefer mandatory disclosure when information is cheap.*)
There exists a cutoff χ^ such that for $\chi < \chi^*$, investor welfare is higher with mandatory disclosure.*

One might think that it is when information is very expensive that investors would prefer for asset issuers to pay for it and provide it to them for free. Instead, when information is expensive, investors know that few among them will buy analyst reports, so there will be few informed investors to drive up asset prices and excess returns will be available. Instead, when information is cheap, most investors will buy it. Anticipating this, the issuer will choose not to provide the report. In this scenario, investors would prefer that disclosure be provided for free.

Proposition 6 (*Investors do not buy low-precision reports*) *If*

$$\frac{h_\theta}{h_y} < \exp\left(\frac{2\rho\chi}{Q}\right) - 1 \quad (17)$$

investors will not buy an analyst report

Proposition 6 implies that an investor-based information market will not exist if: (1) the information content of the analyst report h_θ is small relative to the precision of the prior h_y , since this makes information less valuable; or (2) either the fixed cost of information discovery χ is high or the investor base Q is small (which makes the price c that the analyst needs to charge high, or (3) investors are very risk averse, which makes them take small positions in the asset and therefore profit little from better information.

Proposition 7 (*Investors do not buy high-precision reports*) *Investors will not buy an analyst report if h_θ is sufficiently high.*

Proposition 7 reveals a subtlety about the market for analyst reports. If the reports contain very precise information, informed investors will take large positions, which makes prices highly informative. With a fixed price c for the analyst report, this would imply that as precision increases,

only a vanishing measure of investors choose to become informed, as is the case in the model of Grossman and Stiglitz (1980). However, because the analyst must cover the fixed cost χ , low demand means it must raise prices. For sufficiently high precision, there is simply no price at which this market is viable.

Propositions 6 and 7 jointly imply that an investor-led market for analyst reports can only function if the information is of some intermediate level of precision. Therefore it is only for these intermediate levels of precision where the asymmetric information situation might arise. In either precision extreme, the independent analyst market is not viable so investors do not have to worry about being less informed than others.

3.3 Welfare with Heterogeneous Investors and Wealth Effects

One of the shortcomings of working with the CARA specification for preferences is that it assumes away wealth effects in investment decisions and, by extension, in information choice decisions. A simple way to allow for wealth effects while keeping the simplicity of the CARA-Normal framework is to allow for different investors to have different (constant) absolute risk aversion coefficients. One could in principle then link back the level of absolute risk aversion to each investor's wealth by postulating a relationship between wealth and absolute risk aversion. Makarov and Schornick (2010) follow this approach. This extension makes it possible to ask whether different disclosure regulations might have different impact on investors of different wealth levels.

Formally, assume that there is a function ρ_i that specifies the absolute risk aversion coefficient of investor i and assume without loss of generality that this function is increasing. The issuer and investors play the same game as in section 1. Equating supply and demand reveals that the equilibrium price will be linear, as in (7), with coefficients

$$\begin{aligned}\alpha &= \bar{y} - \frac{1}{(h_y + h_\theta)\psi_L + (h_y + h_p)\psi_H} \\ \beta &= \frac{1}{\psi_L h_\theta} \frac{\psi_L h_\theta + \psi_H h_p}{(h_y + h_\theta)\psi_L + (h_y + h_p)\psi_H} \\ \gamma &= \frac{\psi_L h_\theta + \psi_H h_p}{(h_y + h_\theta)\psi_L + (h_y + h_p)\psi_H},\end{aligned}$$

where $\psi_L \equiv \int_0^{i^*} 1/\rho_i di$ is the average risk tolerance of informed agents, $\psi_H \equiv \int_{i^*}^Q 1/\rho_i di$ is the average risk tolerance of uninformed agents, and i^* is the investor who is indifferent between

buying and not buying the signal, who satisfies the indifference condition

$$\rho_{i^*} = \frac{1}{2c} \log \left(\frac{h_y + h_\theta}{h_y + h_p} \right).$$

Finally, the equilibrium asset price is a signal about firm value, with precision

$$h_p = \frac{\psi_L^2 h_\theta^2 h_x}{\psi_L^2 h_\theta h_x + 1}.$$

Investors with lower absolute risk aversion (implicitly, wealthier investors) take larger positions in the risk asset and therefore have a higher willingness to pay for a given piece of information. In equilibrium, there is a cutoff investor i^* such that investors with lower risk aversion than i^* buy the analyst report and those with higher risk aversion choose to remain uninformed. In principle, this could mean that some investors benefit from mandatory disclosure rules while other are hurt by them. Nevertheless, the results below show that the main welfare results for the homogeneous-investor case carry over to this more general case.

Proposition 8 (*Investor welfare with heterogeneity*)

1. *All investors have higher expected utility with no information than with mandatory disclosure.*
2. *If in equilibrium $D = 0$ and i^* is sufficiently high, all investors have higher expected utility with mandatory disclosure.*
3. *There exists a cutoff χ^* such that all investors have higher expected utility with mandatory disclosure if $\chi < \chi^*$.*

Part 1 of Proposition 8 generalizes Proposition 2 for the case with heterogeneous risk aversion; part 2 generalizes Proposition 3 and part 3 generalizes Proposition 5.

Together, these results show that none of the main welfare results are depend on the assumption of homogeneous investors and/or the absence of wealth effects. All investors, irrespective of their risk aversion, benefit when the lack of information gives them access to a higher risk, higher return asset. Also, all investors benefit from mandatory disclosure when it is the only way to avoid a choice between paying a cost or being at an informational disadvantage. This case is still likely to arise when the cost of producing information is relatively small.

3.4 A General Revealed Preference Argument

The symmetric information result that disclosure reduces investor welfare (proposition 2) extends far beyond the CARA-normal framework analyzed here. To see why it arises in many commonly-used asset pricing models, consider the following revealed preference argument. If all investors learn the disclosed information, then the asset market after disclosure is identical to an asset market with no disclosure, but with a less risky asset. Bayes' law dictates that the new asset payoff variance would be $V^L \equiv (h_y + h_\theta)^{-1}$, instead of $V^H = h_y^{-1}$.⁶ Then, the question becomes, do investors achieve higher expected utility with a high or a low variance asset?

Let the expected return per share on the high-risk asset be ER^H and on the low risk asset be ER^L . Recall that the risk-free return here is 0.⁷ Suppose that the Sharpe ratio of the high-risk and low-risk assets is the same: $ER^L/\sqrt{V^L} = ER^H/\sqrt{V^H}$. Then (assuming that the correlation of this payoff risk with the stochastic discount factor is not altered), for any portfolio of low-risk assets, the investor could achieve the exact same risk and return by holding a smaller amount of the high-risk asset. If risk and return of the low-risk asset are each half as much as the high-risk asset, then 1/2 a share of the high-risk is equivalent to 1 share of the low risk asset. So, the investor cannot be worse off with the low-risk asset because any optimal low-risk portfolio chosen can be replicated in the high-risk environment. Similarly, if $ER^L/\sqrt{V^L} < ER^H/\sqrt{V^H}$, then any low-risk portfolio can be replicated with high risk asset, except with strictly higher expected returns (or strictly lower risk). As before, if the low-risk portfolio is replicable (with free disposal of wealth) in the high-risk environment, the investor must be weakly better off with the high-risk asset.

This revealed preference reasoning tells us that the only circumstance in which an investor might benefit from disclosure in a symmetric-information environment, is if the Sharpe ratio of the asset rises when payoff uncertainty falls: $ER^L/\sqrt{V^L} > ER^H/\sqrt{V^H}$. Although it is not impossible, this is typically the case. To see why, consider the Hansen-Jagannathan bound. It tells us that the maximum possible Sharpe ratio achievable by any stochastic discount factor m that prices an asset is $std(m)/E(m)$. If the risk to the asset payoff is not correlated with m , then this is not priced risk. If it is correlated with m , then all else equal, a less volatile asset payoff means a lower $std(m)$, which lowers the maximum Sharpe ratio. So for any asset pricing model whose stochastic discount factor is sufficiently close to the one that achieves the Hansen-Jagannathan bound, lower payoff

⁶Of course, information will also change the conditional mean of the asset payoff. But when information is symmetric, any change in the expected value of the asset should show up as a correspondingly higher price. Therefore, it doesn't affect the asset return and doesn't affect investor welfare.

⁷If the risk-free return is positive, we can simply interpret ER as an expected return in excess of the risk-free rate.

risk after disclosure reduces the Sharpe ratio and results in a risk-return choice that would have been achievable with the high-risk asset. Since reducing risk creates an investment possibility set that is a subset of what was available with the high-risk asset, it must not increase utility.

4 Financial Information and Real Economic Efficiency

By studying the asset market in isolation, we have seen why investors prefer no information, to full information, to severe asymmetric information. But one would suspect that these results could change dramatically if financial information had spillovers into the real economy.

We consider two types of spillovers. The first is that more information creates better incentives for entrepreneurs to invest a socially optimal amount. Information regulation here has social value, but does not benefit investors, except when the alternative is asymmetric information, just as before. The second spillover is that disclosure reduces the cost of capital and induces entrepreneurs to take more risk. Ironically, more symmetric information given to all investors can only increase investor welfare when it encourages firms to take more risk.

4.1 Production Model 1: Information Improves Real Efficiency

To see how real economic spillovers change the results, we build on the previous model by adding an initial period where an issuer builds up his firm, prior to its IPO. Suppose that instead of having an exogenous payoff y , the dividend from the asset depends on the issuer's investment according to

$$y = f(k) + u \tag{18}$$

where $k \geq 0$ is real capital investment and f is a concave function with $f'(0) > 1$ and $u \sim N(0, \frac{1}{h_y})$. The issuer chooses D first, and then k to maximize:

$$\mathbb{E}(p|k, D) - k - CD \tag{19}$$

The choice of k is not observable by investors. The game progresses as follows. First, the issuer chooses D and k . Then the game progresses as in section 1. Finally, y is realized and payoffs are received. Since the decision D is observable but k is not, it is necessary to specify both what investment $k(D)$ the issuer would choose for each disclosure decision D (including off-equilibrium) and what are investors' beliefs about k depending on D , which we denote by $k^*(D)$. Note that the issuer chooses his disclosure first, so that there is no signalling value to the choice of D and no

strategic disclosure. The realistic counterpart to this assumption is that firms have long-standing disclosure policies. They disclose at regular intervals and rarely change that policy, even if they would prefer not to disclose bad news. This leads to the following equilibrium definition.

Equilibrium An equilibrium consists of a disclosure decision D and then an investment decision $k(D)$ by the issuer; a demand d_i by each investor for analyst reports, a decision by the analyst about whether to produce a report and a price c for the report, bidding functions $b_i(q)$ for each possible information set and an asset price $p(\theta, D, \{d_i\}, \xi)$ such that: issuers choose disclosure D to maximize (19) and, taking D as given, choose $k(D)$ to maximize (19); investors choose d_i and bidding functions to maximize (2) subject to (3); analysts make zero profits; the asset market clears: $\int_0^Q q_i d_i = x$, and investors' belief about investment is correct: $k^*(D) = k(D)$.

Real investment decision Replacing the equilibrium price into the issuer's objective function in (19) and noting that $\theta = f(k) + u + \eta$, the issuer solves

$$\max_k E[\alpha + \beta\xi + \gamma(f(k) + u + \eta - f(k^*(D)))] - k$$

Note that, because investment is unobserved, the issuer cannot affect beliefs about $k^*(D)$ through the investment decision. The reason for the issuer to undertake investment is to affect the analyst report and therefore to indirectly affect the selling price.

The first order condition for investment is

$$f'(k) = \frac{1}{\gamma} \tag{20}$$

The value of γ depends on whether the issuer has disclosed and, if he has not, on how many investors have purchased analyst reports. Since by equation (10), $\gamma < 1$, investment always falls below its first-best level, which is defined by $f'(k) = 1$. Furthermore, since γ is increasing in λ , investment will be higher when more investors are informed. Therefore whenever the equilibrium value of λ in an investor-driven market is less than Q , investment will be higher under disclosure. Note further that if no information is provided for investors, then $\gamma = 0$ and therefore $k = 0$.⁸

Information is socially valuable in this model because when investors are informed, they bid more for firms that have invested more. Since the owners of the high-investment firms gain more

⁸The result that $k = 0$ without disclosure is obviously unrealistic. To remedying this problem simply requires adding a free public signal about y . Section 6 works out a model with a free public signal. It does not undermine our effect.

from selling higher-priced shares, this gives issuers an incentive to invest. The inefficiency here comes from the fact that investment is unobserved. Providing investors with noisy signals about the firm's value helps to remedy this friction. Thus it promotes a level of investment that is closer to the efficient level.

Issuer disclosure decision The addition of a production economy makes it more advantageous for the issuer to disclose information, which makes asymmetric information problems less likely. Let p_1 be the price of an asset when investment $k^*(1)$ is undertaken and all investors observe the analysts' report. Let p_0 be the price of the asset when investment $k^*(0)$ is undertaken and there is an active market for analyst reports. Then, the issuer will disclose iff expected payoffs net of the information cost χ exceed expected payoffs without information: $E[p_1] - k^*(1) - \chi > E[p_0] - k^*(0)$.

Proposition 9 (*Disclosure by issuer with production*)

1. If

$$f(k^*(1)) - k^*(1) - f(0) + \frac{\rho}{Q} \frac{h_\theta}{h_y (h_\theta + h_y)} > \chi, \quad (21)$$

then either the issuer will disclose, or at least *some* investors will buy a report

2. If condition (21) does not hold, the issuer will not disclose.

As before, providing investors with information reduces the risk they have to bear, which increases average prices. The new effect is the additional term $f(k^*(1)) - k^*(1) - f(0)$ which reflects the investment efficiency gains from disclosure. Hence the set of parameters for which the issuer will choose to disclose voluntarily ($D = 1$), making regulation irrelevant, is larger than in the economy with no production. Although policy makers cite efficiency gains as a rationale for mandatory disclosure laws, ironically, adding real efficiency gains weakens the case for disclosure as an investor protection measure.

4.2 Welfare in Production Model 1

Effect on output One possible objective a government might have is to simply maximize the production of real goods. This is obviously a simplification, but it makes for a good starting point. The relevant question becomes: Which disclosure policies maximize output $f(k)$?

The primary friction in the model is that investors' imperfect information about capital investment decisions of the firm reduces the issuer's return to investing in capital. In other words, if

investors don't know that the issuer invested more, he won't be compensated for that investment when he sells his firm. Efficiency requires that the marginal return to investment be equal to its unit marginal cost: $f'(k) = 1$. Therefore if we somehow manage to ensure that the private return to a marginal unit of investment is equal to its social return, $\frac{\partial \mathbb{E}(p|k)}{k} = f'(k)$, then investment will be efficient. With imperfect information, the left side is typically smaller than the right because prices can only respond to changes in k to the extent that investors know k . The following analysis shows that mandatory information provision to financial markets helps to remedy this friction because it makes p more responsive to k .

Since the production function is concave, a higher $f(k)$ corresponds to a lower marginal product of capital $f'(k)$. The issuer's first-order condition tells him to set $f'(k) = 1/\gamma$. The pricing coefficient γ (equation 10) is increasing in the measure of informed investors λ because $h_\theta \geq h_p$, i.e. prices cannot reveal more information than what is contained in the signals they are revealing.

If disclosure is mandated by the government, $\lambda = Q$, this maximizes γ , minimizes $f'(k)$ and thus maximizes $f(k)$ over all feasible values ($\lambda \in [0, Q]$). Thus, mandating disclosure provides the maximum possible information, which maximizes output of real economic goods. Since information facilitates the efficient allocation of capital, mandatory information disclosure maximizes gross output.

Effect on output net of costs One obvious objection to the analysis in the previous subsection is that it does not take into account the cost of information production. Another possible objective is to maximize $f(k) - k - \delta\chi$, where $\delta = 1$ if any agent (issuer or investor) discovers information and $\delta = 0$ otherwise.

If equilibrium is such that $D = 0$ but $\lambda \in (0, Q]$, then it is immediate that mandatory disclosure maximizes net output, since the cost will be paid regardless and $\lambda = Q$ will bring investment closest to efficient levels. If equilibrium is such that $D = 1$, then mandatory disclosure is irrelevant. Finally, if equilibrium is such that the information is not produced at all, then in equilibrium $k = 0$ and mandatory disclosure maximizes net output whenever $f(k^*(1)) - k^*(1) - \chi > f(0)$. Substituting in k from the first-order condition in this inequality yields

$$f\left((f')^{-1}\left(1 + \frac{h_y}{h_\theta}\right)\right) - (f')^{-1}\left(1 + \frac{h_y}{h_\theta}\right) - \chi > f(0)$$

We know that $f'(k^*(1)) > 1$, so that anything that increases $k^*(1)$ also increases $f'(k^*(1)) - k^*(1)$ and therefore makes the inequality more likely to hold. A higher ratio of the signal precision to

prior precision (h_θ/h_y) makes $k^*(1)$ higher, making it more likely that the high-information level of capital is the one that maximizes output net of investment and information costs.

Investor welfare Next, we show that the same two investor welfare results from the model without production still hold in the model with production.

Proposition 10 (*Investor welfare in the economy with production*) *Propositions 2-7 hold in the production economy.*

What the production economy changes is that now disclosure raises the expected value of the asset. But recall that investors benefit from access to a high-risk, high-return asset. They do not benefit from high-expected-value assets because these assets have a high price to compensate for their high value. Return is offered for bearing risk, not for buying valuable assets. This can be seen from equation (8), which shows that increases in \bar{y} translate one-for-one into increases in the price, and therefore have no effect on expected returns or on investor welfare. In other words, any efficiency gains from improved incentives to invest are captured 100% by the issuer of the asset. Therefore all the results regarding how mandatory disclosure affects investor welfare carry through directly.

Of course, this is a stylized model. One could certainly build a model where the presence of the production economy affected investor welfare. But the key to building such a model would be that the production economy must change the risk investors bear. Expected increases in efficiency result in more valuable assets, and higher prices for those assets. When the payoff and the price increases together, the return on the asset doesn't change. In an equilibrium model with a constant price of risk, anything that doesn't change risk doesn't change returns.

4.3 Production Model 2: Information Increases Firm Risk

The key feature of the production model that prevented disclosure from having an effect on investor welfare was that the entrepreneur's investment choice only shifted the mean of the firm value and did not affect its variance. If information disclosure causes entrepreneur's to choose a riskier production technology, then we can reverse the previous result. While investor welfare may improve, ironically, it is because the *disclosure results in investors holding assets with more uncertain* payoffs. This is the opposite of the usual justification for disclosure mandates.

To show how disclosure can affect investor risk-taking, we alter the production function so that the stochastic shock is multiplicative, rather than additive. Suppose the dividend from the asset

depends on the issuer's investment according to

$$y = f(k) * (1 + u) \quad (22)$$

where $k \geq 0$ is real capital investment and f is a concave function with $f'(0) > 1$ and $u \sim N(0, \frac{1}{h_y})$. As before, the issuer chooses D first, and then k to maximize $\mathbb{E}(p|k, D) - k - CD$. The definition of equilibrium is identical to the previous case.

The expected payoff of the asset is the same function of equilibrium investment as before: $E[y] = f(k^*)$. But now, the variance of payoffs is no longer a fixed parameter: $Var[y] = f(k)^2/h_y$. The different payoff variance changes the price formula because h_y must be replaced everywhere by $h_y/f(k^*)^2$. Note that the actual level of capital investment cannot affect the price of the asset because this investment is not observed by those who purchase the asset. Instead, what affects the asset price is beliefs about k . Since this is a noisy rational expectations model, those beliefs about k correspond to the optimal k^* . But the fact that the entrepreneur cannot affect beliefs about the riskiness of the asset is important because in his optimization problem, this entrepreneur still takes the price coefficients α , β and γ as given. Thus, the first order condition for capital investment is the same as before (20), albeit with a different equilibrium level of γ .

Recall that time-2 investor expected utility is proportional to $(E[y] - p)^2/Var[y]$. The asset pricing formula (7) tells us that if $\lambda = Q$, then $E[y|p] - p = \rho Var[y|\theta]/Q$. Therefore, time-2 expected utility is proportional to $(\rho x/Q)^2 Var[y|\theta]$. By Bayes' law, we know that $Var[y|\theta] = f(k^*)^2(h_y+h_\theta)^{-1}$. Thus, expected utility is clearly increasing in firm production $f(k)$, but decreasing in signal precision h_θ .

What this tells us is that, if agents start with symmetric information, then requiring a firm to disclose has a direct effect and an indirect effect. The direct effect is to reduce investor utility by increasing h_θ and decreasing the expected asset return. The indirect affect increases utility by inducing the firm to increase production. The net effect depends on how sensitive production is to investor information, which in turn depends on the shape pf the production function. Define the inverse of the marginal product function as $g(x) : x \rightarrow g : f'(g) = x$. Then disclosure increases welfare iff $2f(k^*)^{-3}f'(k^*)g'(1 + h_y/h_\theta)(h_y/h_\theta)^2 < -1$. As long as firm production is sufficiently sensitive to disclosure, then the positive welfare benefits of more production can outweigh the negative effects of lower returns identified in the previous cases and disclosure can help improve investor welfare

5 Extension to Non-Normal Payoffs and Application to Corporate Bonds

Assuming that the asset's payoff is normally distributed is admittedly restrictive, as there are settings where this is likely to be a poor approximation to reality. In this section we examine numerically whether our main results extend to a case where payoffs instead follow a binary distribution, as in Breon-Drish (2012). We then calibrate the model parameters using data from corporate bonds markets and credit ratings.

The model has the same assumptions as before, with the following three changes:

1. The asset's payoff y has a binary, rather than a normal distribution. It takes the values 0 or 1. The unconditional probability of each outcome is governed by the parameter $\bar{y} \equiv \Pr[y = 1]$.
2. The costly signal θ is informative about a variable θ_0 , which is in turn informative about the asset's payoff. The distribution of y conditional on θ_0 is $\Pr(y = 1|\theta_0) = \frac{e^{\theta_0}}{1+e^{\theta_0}}$.⁹ The unconditional probability of $y = 1$ is \bar{y} . The signal θ is a noisy observation of θ_0 :

$$\theta = \theta_0 + \eta$$

where $\eta \sim N\left(0, \frac{1}{h_\theta}\right)$.

3. Investors can observe an additional, public signal $\omega = \theta_0 + \nu$ where $\nu \sim N\left(0, \frac{1}{h_\nu}\right)$, at no cost. This additional signal allows the model to explain the high information content of bond prices. In a model where the only exogenous source of information is the costly signals, the equilibrium price cannot be more informative than the signal itself. The fact that true bond prices are more informative than credit ratings tells us that they must contain additional information, beyond what is in credit ratings (the costly signal). Therefore, adding public signals to the model allows us to compare the data and model in a meaningful way.

⁹This conditional probability results from a θ_0 whose unconditional distribution is "tilted Normal": $f(\theta_0) = (1 + e^{\theta_0}) (1 - \bar{y}) \phi\left(h_0^{1/2} \left(\theta_0 - \log\left(\frac{\bar{y}}{1-\bar{y}}\right) - \frac{1}{2h_0}\right)\right)$, where $\phi(\cdot)$ is a standard normal probability density function and h_0 is a parameter. See Breon-Drish (2012) for details.

5.1 Equilibrium with binary payoffs

Each investor i chooses a quantity of risky assets q to maximize expected utility:

$$\max_q - \left[e^{-\rho[q(1-p)-c]} \Pr(y = 1|\mathcal{I}_i) + e^{-\rho[q(0-p)-c]} \Pr(y = 0|\mathcal{I}_i) \right]$$

where \mathcal{I}_i denotes i 's information set. The first-order condition is

$$q_i(\mathcal{I}_i) = \frac{1}{\rho} \left[\log \left(\frac{\Pr(y = 1|\mathcal{I}_i)}{\Pr(y = 0|\mathcal{I}_i)} \right) - \log \left(\frac{p}{1-p} \right) \right] \quad (23)$$

Applying Bayes' Rule, the log ratio of informed investors' posteriors about y are given by

$$\log \left(\frac{\Pr(y = 1|\theta, \omega)}{\Pr(y = 0|\theta, \omega)} \right) = \kappa_\theta^I \theta + \kappa_\omega^I \omega + (1 - \kappa_\theta^I - \kappa_\omega^I) \log \left(\frac{\bar{y}}{1 - \bar{y}} \right) \quad (24)$$

where $\kappa_\theta^I \equiv \frac{h_\theta}{h_\theta + h_0 + h_\omega}$ and $\kappa_\omega^I \equiv \frac{h_\omega}{h_\theta + h_0 + h_\omega}$.

Since all informed investors have the same information set and all uninformed investors have the same information set, risky asset demand (q_i) takes on only two possible values. For informed investors, let $q_i = q^I(\theta, \omega, p)$ and for uninformed investors, let $q_i = q^U(\omega, p)$. If a measure λ of investors are informed, the market clearing condition is

$$\lambda q^I(\theta, \omega, p) + (Q - \lambda) q^U(\omega, p) = 1 - \xi \quad (25)$$

Replacing (24) and (23) in (25) tell us that a known function of price θ_U is a noisy signal about θ that takes the following form: $\theta_U = \theta + \rho/(\lambda \kappa_\theta^U) \xi$, where ξ is the normally-distributed asset supply shock, $\kappa_\theta^U = j/(j + h_0 + h_\omega)$, and where $j^{-1} = h_\theta^{-1} + h_x^{-1} \rho(1 + h_\theta^{-1} h_0)/\lambda$.

Applying Bayes' Rule, the log ratio of uninformed investors' posteriors is

$$\log \left(\frac{\Pr(y = 1|p, \omega)}{\Pr(y = 0|p, \omega)} \right) = \kappa_\theta^U \theta_U + \kappa_\omega^U + (1 - \kappa_\theta^U - \kappa_\omega^U) \log \left(\frac{\bar{y}}{1 - \bar{y}} \right) \quad (26)$$

where $\kappa_\omega^U = h_\omega/(j + h_0 + h_\omega)$. Substituting (24) and (26) into (23) to get q^U and q^I and then substituting those in the market clearing condition (25) reveals the following expression for the equilibrium price:

$$p = \frac{\exp A + B\theta + C\omega + D\xi}{1 + \exp A + B\theta + C\omega + D\xi} \quad (27)$$

The coefficients A , B , C and D are defined in the appendix.

After substituting this price back into the objective function, the next step is to compute the expected utility achieved by informed and uninformed investors for each realization of θ , ω and ξ , and then integrate over the distribution of all three random variables to compute ex-ante utility. There is no closed form solution because expected utility depends on asset demands, which contain terms like $p/(1-p)$, where p is a random variable at time 1. Computing expectations of ratios of such random variables is not tractable. However, it is possible to compute expected utility numerically. Then, we solve for a λ that equates utilities of informed and uninformed investors when setting the cost of ratings c to satisfy the zero-profit condition $c = \chi/\lambda$, if such a λ exists, or by setting $\lambda = 0$ or $\lambda = Q$ if it does not.

5.2 Calibration for corporate bonds and credit ratings

For numerical analysis, focusing on corporate bonds and credit ratings has advantages. There is a clear sense of what the information in credit ratings is and there exist measures of how much it costs to produce. Furthermore, current regulation on credit ratings is somewhat akin to a mandatory disclosure system, in that many types of investors can only invest in rated assets and therefore issuers must pay for a rating if they wish to sell their securities to these investors. Finally, the assumption of a binary distribution for payoffs is arguably a plausible representation of the payoff profile of bonds, with $y = 0$ representing default. Of course, the recovery rate on bonds that default is not zero, so the mapping is not perfect.

Data description Our data comes from Datastream and includes all corporate bonds issued in 2004 and 2005, with maturities of not more than 30 years, whose prices are tracked by Datastream. In total, this amounts to 770 different bonds. The bond ratings are the Standard and Poor's rating at the time of issuance. For each bond, we know its face value, the price \tilde{p}_0 at the time when it was issued, the rating at the time of issue and the market price \tilde{p}_1 one year later.

Since bonds are heterogeneous in their contract terms (e.g. coupon rate), we normalize them in the following way. Let z be the present value of all the promised payments of a bond (coupons plus face value at redemption) discounted at the risk-free rate. We express all values per unit of z , letting $p_0 \equiv \tilde{p}_0/z$ and $p_1 \equiv \tilde{p}_1/z$. Furthermore, we adjust p_1 for changes in the risk-free rate, which would affect bond prices for reasons that are outside our model.

Calibration targets We assume that the data has been generated by the model under the current regime of issuer-provided ratings, which implies $\lambda = Q$. For each bond, we assume that the observed

p_0 arises from equation (27). We then assume that in the interval between the observation of p_0 and the observation of p_1 , the value of θ_0 has been revealed and there are no more noise-traders, so that

$$\log\left(\frac{p_1}{1-p_1}\right) = \theta_0 - \frac{\rho}{Q} \quad (28)$$

We need to find values for the following parameters: \bar{y} , h_0 , h_θ , h_ω , h_x and $\frac{\rho}{Q}$ (ρ and Q are not separately identified). We choose these values to match the following empirical moments.

1. Average bond payoffs. The first parameter to set is \bar{y} . Ideally, this could be done by tracking all the bonds to maturity or default and set \bar{y} to match observed default rates. Unfortunately, data limitations prevent this. Instead, we rely on findings by Giesecke, Longstaff, Schaefer, and Strebulaev (2011) who report that on average bond yields can be decomposed roughly equally between a default probability and a risk premium. Denoting the average bond yield by \bar{r} , this implies $1 - \bar{y} = \bar{r}/2$. Since for any bond the yield is simply $p_0 = 1/(1+r)$, we set the value of \bar{y} to

$$\bar{y} = 1 - \frac{1}{2}E\left[\frac{1-p_0}{p_0}\right]$$

2. Mean and variance of p_1 . By equation (28), the model says that p_1 depends on θ_0 and on $\frac{\rho}{Q}$. Using that \bar{y} is already established from the previous step, we choose values of $\frac{\rho}{Q}$ and h_0 such that the mean and variance of p_1 implied by the model match the ones we find in the data. $\frac{\rho}{Q}$ affects only the mean but h_0 affects both the mean and the variance, so these two parameters need to be set jointly.
3. Informativeness of ratings. In the model, θ is a noisy signal of θ_0 , which then translates directly into p_1 through equation (28). Therefore the covariance between θ and p_0 (or, equivalently, the R^2 of a regression of p_1 on θ) depends on the precision of the signal, h_θ . We set h_θ to a value such that the R^2 implied by the model matches that of a regression of p_1 on dummies for each possible ratings level.
4. Variance and informativeness of prices at issuance. By equation (27), prices are sensitive to both the θ signal (credit ratings) and the ω public signal, as well as to noise traders ξ . Both signals are informative about θ_0 so they should correlate with p_1 , while noise traders introduce pure noise. Therefore the informativeness of p_0 about p_1 depends on the total noise-to-signal ratio, while the variance of p_0 depends on the variances of both signals and noise. We set

Parameter	Value	Target
\bar{y}	0.95	default probability $\frac{1}{2}$ of yields
h_0	1.34	mean (0.89) and variance (0.0078) of p_1
$\frac{\rho}{Q}$	0.88	
h_θ	1.65	informativeness of ratings ($R^2 = 0.47$)
h_w	1.41	informativeness ($R^2 = 0.56$) and variance (0.0068) of p_0
h_x	8.25	
χ	2.97×10^{-4}	Treacy and Carey (2000)

values of h_w and h_x such that the R^2 of a regression of p_1 on p_0 and the variance of p_0 implied by the model match those we find in the data.

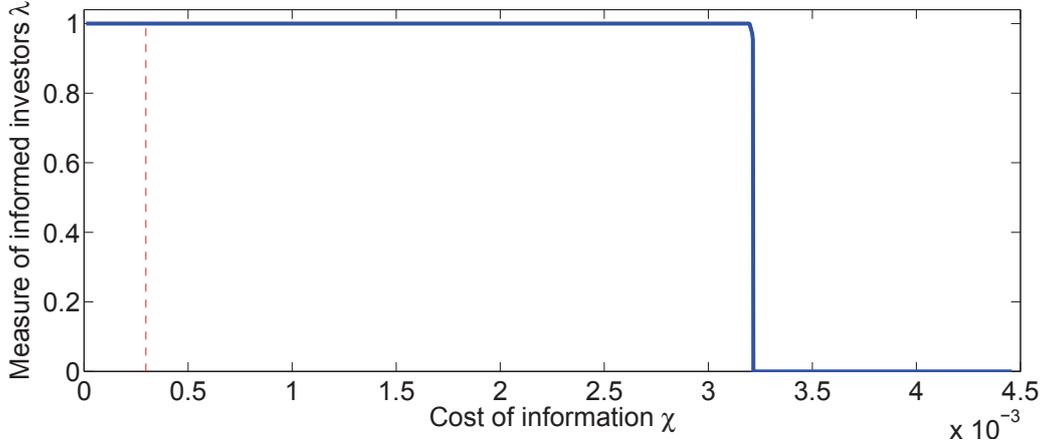
5. Cost of ratings. The one other parameter we need to calibrate is the fixed cost of information discovery. Treacy and Carey (2000) report that the average cost of rating an asset is 0.0325% of the value of the issue, so we set χ equal to 0.0325% times the average p_0 of 0.91.

Table 1 summarizes our parameter estimates. It reveals that the precisions of prior beliefs h_0 , public information h_w and credit ratings h_θ are roughly equal.

Numerical results Figure 1 shows the measure of investors λ that choose to become informed as a function of the cost of producing information χ , assuming the issuer has chosen not to obtain and disclose ratings voluntarily. For low values of χ , all investors choose to become informed. According to our estimates, this would be the case for any $\chi < 3.19 \times 10^{-3}$, so even if the cost of ratings were 10 times higher than our estimate, the model still predicts that all investors would choose to buy ratings if the issuer does not disclose them. Knowing this, the optimal strategy for the asset issuer is not to obtain a rating, since investors will buy it anyway. Thus, with or without mandatory disclosure, all investors are informed. A disclosure mandate simply transfers the amount of the ratings fee c from investors to issuers. These findings suggest that policies of mandatory disclosure policies benefit investors, at the expense of asset issuers. But they also tell us that these measures are not likely to affect market information or liquidity.

For values of χ between 3.19×10^{-3} and 3.22×10^{-3} , not all investors obtain ratings but a market for ratings is still viable. Since not all investors buy the rating, the zero profit condition implies that $c > \chi$. For $\chi > 3.22 \times 10^{-3}$, no investor-pay market for ratings can exist.

Figure 1: The measure of informed investors λ falls as the cost of information χ rises. The dotted line is the calibrated information cost.



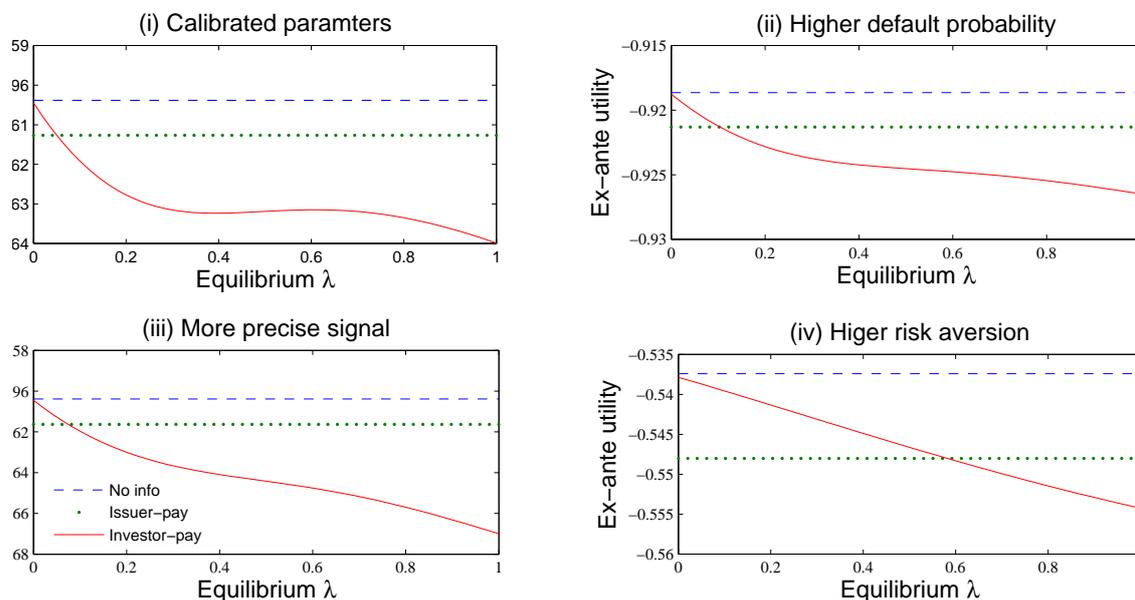
Our main results regarding investor’s welfare from the case where payoffs are Normally distributed (Proposition 2 and Proposition 3) can be verified numerically in our calibrated example. Table 2 shows investors’ ex-ante utility under three possibilities. The first is when no information production takes place (perhaps because χ is prohibitively high); the second is when information is voluntarily disclosed by the issuer; the third is when information production is possible but it has not been provided by the issuer so investors buy it themselves, as will be true in equilibrium in our calibrated example. As seen from the table, investors prefer no information to free information (Proposition 2) but, because information is cheap, a system of non-mandatory disclosure leaves them the option of either paying for information of being asymmetrically less informed than other investors, which yields even lower utility (Proposition 3).

Table 2: Welfare Comparison. Investors’ Ex-Ante Utility

No information	Issuer-Provided	Investor-Purchased
-0.9606	-0.9615	-0.9617

Numerical exploration reveals that this welfare ranking still holds for other values of the parameters. Figure 2 shows the comparison of ex-ante utility in different regimes for different parameter values. Panel (i) shown the comparison for our estimated parameter values; panel (ii) shows an economy with three times the default rate of the baseline ($\bar{y} = 0.84$); panel (iii) shows an economy with signals that are three times as informative ($h_\theta = 5.17$) as our baseline and panel (iv) shows an economy with a risk aversion coefficient three times as high ($\frac{\rho}{Q} = 2.65$) as our baseline. In all cases the pattern is the same. No information is better for investors than issuer-provided information,

Figure 2: Welfare comparison for alternative parameter values. No information (dashed line) is always most preferred. Mandatory disclosure (dotted line) improves welfare when many investors choose to become informed (λ is high).



but issuer provided information is better than an investor-pay market if the investor-pay market would result in high λ .

6 Conclusions

The paper investigated the welfare consequences of mandatory financial disclosures. It characterizes the types of assets for which a free market for information will provide reports to investors. Information could be produced and disclosed by an issuer who wants to make his project less risky and therefore more valuable to investors, so that it fetches a higher price at auction. Alternatively, analyst reports could be purchased by investors who want to know how much of the risky asset to buy.

When the private market provides information to most investors, mandatory disclosure will have little effect on most assets' prices or on welfare. But in some instances, that private market does not provide information. In these cases, issuers are always better off without the disclosure mandate. Surprisingly, investors are often better off without the mandate as well. Investors' welfare is maximized when no information about the asset payoff is available to anyone.

There are some limitations to interpreting these welfare results. This model included only two salient potential benefits of financial information: facilitating the allocation of productive capital and preventing the inefficient risk-sharing that comes with asymmetrically informed investors. These benefits must be weighed against the cost of information discovery and the loss of investors surplus when an asset becomes less risky. But there are other possible benefits of disclosure, such as the ability to limit risk-taking by banks or portfolio managers or the ability to assess the risk of large pools of assets. There are also other possible problems with disclosures such as manipulation of reports, the possibility that firm disclosures crowd out some richer more nuanced sources of information, or outright fraud. None of these are incorporated in the model. Yet, the ability of disclosures to ameliorate asymmetric information problems and to improve the efficiency of asset prices are certainly two of the most widely-acknowledged benefits.

A maintained assumption in the model is that, unlike partial revelation through prices, direct leakage of information, for instance by investors who bought the analyst report sharing it with those who have not, can be effectively prevented by intellectual property laws. However, this might be hard to enforce due to technologies that make it easy to disseminate information. If information leakage cannot be prevented, analysts might not be able to sell enough copies of the information at a high enough price to pay for the fixed cost of information discovery. This would render the investor-pay market infeasible through a far more direct channel than the model examines.

The degree to which information leakage is an insurmountable concern is a matter of debate. For the case of credit ratings, ratings agencies did mainly follow an investor-pay model until around the mid-twentieth century, and historical accounts differ on the relative roles played by regulation and technological progress (in particular, photocopying machines) in driving the shift towards an issuer-pay market (White, 2010). For other types of information such as equity analysis, the issue is even less clear. Analysts can try to take measures to prevent easy retransmission of information, such as delivering their reports in non-recorded oral communications, but whether these attempts are successful remains an open question.

If the threat of information leakage undermines the investor pay market, asset issuers would still prefer no regulation because then they can choose to disclose or not. Investors' opposition to a disclosure mandate would now be unambiguous: Unregulated information markets would never result in asymmetric information. Therefore, if the mandate has any effect at all, it is to prevent there being no information available. But investors prefer this outcome because more information reduces the expected return on the assets they buy.

References

- ALBAGLI, E., C. HELLWIG, AND A. TSYVINSKI (2009): “Information Aggregation and Investment Decisions,” Yale Working Paper.
- AMADOR, M., AND P.-O. WEILL (2010): “Learning from Prices: Public Communication and Welfare,” *Journal of Political Economy*, 118, 866–907.
- (2012): “Learning from Private and Public Observation of Others’ Actions,” *Journal of Economic Theory*, forthcoming.
- ANGELETOS, G.-M., G. LORENZONI, AND A. PAVAN (2010): “Beauty Contests and Irrational Exuberance: A Neoclassical Approach,” MIT Working Paper.
- BREON-DRISH, B. (2012): “On Existence and Uniqueness of Equilibrium in Noisy Rational Expectations Economies,” *Stanford University Working Paper*.
- DIAMOND, D. (1985): “Optimal Release of Information by Firms,” *Journal of Finance*, 40(4), 1071–1094.
- FISHMAN, M., AND J. PARKER (2011): “Valuation, Adverse Selection and Market Collapses,” Kellogg working paper.
- GIESECKE, K., F. A. LONGSTAFF, S. SCHAEFER, AND I. STREBULAEV (2011): “Corporate bond default risk: A 150-year perspective,” *Journal of Financial Economics*, 102(2), 233–250.
- GOLDSTEIN, I., E. OZDENOREN, AND K. YUAN (2011): “Trading Frenzies and Their Impact on Real Investment,” Wharton working paper.
- GORTON, G., AND G. ORDONEZ (2012): “Collateral Crises,” Yale Working Paper.
- GOZALO LLOSA, L., AND V. VENKATESWARAN (2012): “Efficiency under Endogenous Information Choice,” Penn State University working paper.
- GROSSMAN, S., AND J. STIGLITZ (1980): “On the Impossibility of Informationally Efficient Markets,” *American Economic Review*, 70(3), 393–408.
- HIRSHLEIFER, D. (1971): “The private and social value of information and the reward of inventive activity,” *American Economic Review*, 61, 561–574.
- JOVANOVIC, B. (1982): “Truthful Disclosure of Information,” *Bell Journal of Economics*, 13, 36–44.
- KONDOR, P. (2011): “The more we know on the fundamental, the less we agree on the price,” *The Review of Economic Studies*, forthcoming.
- MAKAROV, D., AND A. V. SCHORNICK (2010): “A note on wealth effect under CARA utility,” *Finance Research Letters*, 7(3), 170–177.
- OZDENOREN, E., AND K. YUAN (2008): “Feedback Effects and Asset Prices,” *Journal of Finance*, 63(4), 1939–1975.

- PERESS, J. (2010): “The Tradeoff between Risk Sharing and Information Production in Financial Markets,” *Journal of Economic Theory*, 145(1), 124–155.
- RENY, P., AND M. PERRY (2006): “Toward a Strategic Foundation of Rational Expectations Equilibrium,” *Econometrica*, 74 (5), 1231–1269.
- SHAVELL, S. (1994): “Acquisition and Disclosure of Information Prior to Sale,” *Rand Journal of Economics*, 25, 20–36.
- TREACY, W. F., AND M. CAREY (2000): “Credit risk rating systems at large US banks,” *Journal of Banking & Finance*, 24(1-2), 167 – 201.
- VELDKAMP, L. (2006): “Media Frenzies in Markets for Financial Information,” *American Economic Review*, 96(3), 577–601.
- VERRECCHIA, R. (1982): “Information Acquisition in a Noisy Rational Expectations Economy,” *Econometrica*, 50(6), 1415–1430.
- WHITE, L. (2010): “Markets: The Credit Rating Agencies,” *Journal of Economic Perspectives*, 24(2), 211–226.
- WIEDERHOLT, M. (2011): “Markets for Information and the Allocation of Capital across Countries,” Northwestern working paper.

A Mathematical Appendix

A.1 Financial market equilibrium

Beginning with the market clearing condition $\lambda q^I + (Q - \lambda) q^U = x$ we use the formulas for q^I and q^U and to solve for p :

$$\begin{aligned} Qf(k^*(D))h_y + \lambda[\theta h_\theta - p(h_y + h_\theta)] + (Q - \lambda) \left[\left(f(k^*(D)) + \frac{p - \alpha}{\gamma} \right) h_p - p(h_y + h_p) \right] &= \rho x \\ Qf(k^*(D))h_y + (Q - \lambda) \left[f(k^*(D)) - \frac{\alpha}{\gamma} \right] h_p + \lambda\theta h_\theta - p \left[\lambda(h_y + h_\theta) + (Q - \lambda)(h_y + h_p) - (Q - \lambda) \frac{h_p}{\gamma} \right] &= \rho x \\ p = \frac{Qf(k^*(D))h_y + (Q - \lambda) \left[f(k^*(D)) - \frac{\alpha}{\gamma} \right] h_p + \lambda\theta h_\theta - \rho x}{\lambda(h_y + h_\theta) + (Q - \lambda)(h_y + h_p) - (Q - \lambda) \frac{h_p}{\gamma}} & \end{aligned} \quad (29)$$

which has a linear form as conjectured. Equating coefficients:

$$\begin{aligned} \alpha &= \frac{f(k^*(D))[\lambda(h_y + h_\theta) + (Q - \lambda)(h_y + h_p)] - (Q - \lambda) \frac{\alpha}{\gamma} h_p - \rho}{\lambda(h_y + h_\theta) + (Q - \lambda)(h_y + h_p) - (Q - \lambda) \frac{h_p}{\gamma}} \\ \beta &= \frac{\rho}{\lambda(h_y + h_\theta) + (Q - \lambda)(h_y + h_p) - (Q - \lambda) \frac{h_p}{\gamma}} \\ \gamma &= \frac{\lambda h_\theta}{\lambda(h_y + h_\theta) + (Q - \lambda)(h_y + h_p) - (Q - \lambda) \frac{h_p}{\gamma}} \end{aligned} \quad (30)$$

Computing price informativeness yields

$$h_p = \frac{1}{\frac{1}{h_\theta} + \left(\frac{\beta}{\gamma} \right)^2 \frac{1}{h_x}}. \quad (31)$$

Substituting in expressions for β and γ yields (11) and replacing h_p in (30) yields (8)-(10).

A.2 Equilibrium measure of informed investors

Recall the utility function:

$$EU = -E[\exp\{-\rho W\}]$$

where

$$W_i = (w_0 - cd) + q_i [y - p]$$

where c is the price of the rating and $d = 1$ if the investor bought it and zero otherwise.

Because of the CARA-Normal structure, expected utility conditional on an information set for investor i is

$$EU_i = -\exp\left\{-\rho \left[E_i(W_i) - \frac{\rho}{2} \text{Var}_i(W_i) \right]\right\} \quad (32)$$

Use that $q_i = \frac{E_i(y) - p}{\rho \text{Var}_i(y)}$ so that

$$W_i = w_0 - cd + \frac{E_i(y) - p}{\rho \text{Var}_i(y)} [y - p]$$

and therefore

$$E_i(W_i) = (w_0 - cd) + \frac{[E_i(y) - p]^2}{\rho \text{Var}_i(y)} \quad (33)$$

and

$$\text{Var}_i(W_i) = \frac{[E_i(y) - p]^2}{\rho^2 \text{Var}_i(y)} \quad (34)$$

Replacing (33) and (34) in (32):

$$EU_i = -\exp(-\rho(w_0 - cd)) \exp\left\{-\frac{1}{2} \frac{[E_i(y) - p]^2}{\text{Var}_i(y)}\right\} \quad (35)$$

Denote an informed investore by the subscript I and an uninformed investor by the subscript U . The information set of an informed investor includes θ and p . Let

$$\Sigma_I \equiv \text{Var} [E_I (y) - p] \quad (36)$$

$$Z_I \equiv \frac{E_I (y) - p}{\sqrt{\Sigma_I}} \quad (37)$$

Replacing (36) and (37) into (35):

$$EU_I = -\exp(-\rho(w_0 - c)) \exp\left\{-\frac{\Sigma_I}{2\text{Var}_I(y)} Z_I^2\right\} \quad (38)$$

Conditional on p , Z_I follows a Normal distribution with mean $A_I = \frac{E(y|p) - p}{\sqrt{\Sigma_I}}$ and standard deviation 1. Using that, by the law of total variance

$$\text{Var}(y|p) = \Sigma_I + \text{Var}_I(y)$$

and the MGF of a noncentral χ^2 distribution to take conditional expectations of (38), we conclude that

$$E[U_I|p] = -\exp(-\rho(w_0 - c)) \sqrt{\frac{\text{Var}_I(y)}{\text{Var}(y|p)}} \exp\left(-\frac{(E(y|p) - p)^2}{2\text{Var}(y|p)}\right) \quad (39)$$

For the uninformed investor, equation (35) directly implies

$$E[U_U|p] = -\exp(-\rho w_0) \exp\left(-\frac{(E(y|p) - p)^2}{2\text{Var}(y|p)}\right) \quad (40)$$

To compare the the conditional expected utilities of informed and uninformed investors, use (39) and (40) and note that $\text{Var}_I(y) = \text{Var}(y|\theta, p) = \text{Var}(y|\theta)$ to conclude that

$$E[V_I|p] - E[V_U|p] = \left[\exp(\rho c) \sqrt{\frac{\text{Var}(y|\theta)}{\text{Var}(y|p)}} - 1 \right] E[V_U|p]$$

Taking expectations over p , ex-ante indifference requires:

$$\exp(\rho c) \sqrt{\frac{\text{Var}(y|\theta)}{\text{Var}(y|p)}} = 1 \quad (41)$$

Using

$$\text{Var}(y|\theta) = \frac{1}{h_y + h_\theta} \quad (42)$$

$$\text{Var}(y|p) = \frac{1}{h_y + h_p} \quad (43)$$

and equation (11) to solve for λ yields equation (12).

A.3 Proof of proposition 1

1. Suppose to the contrary that the issuer does not provide information, and investors do not buy it either. Expected profits for the issuer will be:

$$\Pi^0 = \bar{y} - \frac{\rho}{Qh_y}$$

If instead the issuer paid the cost of disclosure, expected profits would be:

$$\Pi^1 = \bar{y} - \frac{\rho}{Q(h_\theta + h_y)} - \chi$$

Rearranging the inequality $\Pi^1 - \Pi^0 > 0$ yields condition (14). If the condition holds, it contradicts the assumption that the issuer does not provide information.

2. If condition (14) does not hold, then $\Pi^1 \leq \Pi^0$, so an issuer will not disclose if he expects investors not to buy the report either. But the average price, which is equal to α , satisfies

$$\frac{\partial \alpha}{\partial \lambda} = \frac{h_\theta - h_p + (Q - \lambda) \frac{\partial h_p}{\partial \lambda}}{(Qh_u + \lambda h_\theta + (Q - \lambda)h_p)^2} \rho > 0$$

because $\frac{\partial h_p}{\partial \lambda} > 0$ and $h_\theta > h_p$. Therefore if the issuer expects some positive λ the profits from not disclosing are even higher than if he expects $\lambda = 0$. This implies that the issuer will not provide a rating regardless of what he expects investors to do.

A.4 Welfare of investors - proof of propositions 2, 3 and 5

Expected utility conditional on an information set is given by (35). Let

$$\begin{aligned} A_i &\equiv E[E_i(y) - p] \\ \Sigma_i &\equiv \text{Var}[E_i(y) - p] \\ Z_i &\equiv \frac{E_i(y) - p}{\sqrt{\Sigma_i}} \end{aligned}$$

Ex-ante, $Z_i \sim N\left(\frac{A_i}{\sqrt{\Sigma_i}}, 1\right)$.

Rewrite (35) as

$$EU_i = -\exp(-\rho(w_0 - cd)) \exp\left\{-\frac{1}{2} \frac{1}{\text{Var}_i(y)} \Sigma_i Z_i^2\right\}$$

Using the formula for the moment-generating function of a chi-square distribution, the ex-ante expected utility is

$$EU = E(EU_i) = -\exp(-\rho(w_0 - cd)) \frac{\exp\left\{-\frac{1}{2} \frac{A_i^2}{\text{Var}_i(y)} \frac{1}{\Sigma_i}\right\}}{\sqrt{1 + \frac{1}{\text{Var}_i(y)} \Sigma_i}}$$

or, re-normalizing:

$$V_i \equiv -2 \log \left[\frac{-EU}{\exp(-\rho w_0)} \right] = \frac{A_i^2}{\text{Var}_i(y) + \Sigma_i} + \log(\text{Var}_i(y) + \Sigma_i) - \log(\text{Var}_i(y)) - 2\rho cd \quad (44)$$

1. In case the issuer supplies the rating, then, using (8) - (11):

$$\begin{aligned} E_I(y) - p &= \frac{\rho x}{Q(h_y + h_\theta)} \\ \text{Var}_I(y) &= \frac{1}{h_y + h_\theta} \end{aligned}$$

Therefore

$$\Sigma_I = \left[\frac{\rho}{Q(h_y + h_\theta)} \right]^2 \frac{1}{h_x} \quad (45)$$

$$A_I = \frac{1}{Q} \frac{\rho}{h_y + h_\theta} \quad (46)$$

2. In case the issuer does not supply the rating and $\lambda \in (0, Q)$, there are two expected utilities to consider, that of the informed agent and that of the uninformed. But in an interior equilibrium, the two must be equal. So, it suffices to look only at the expected utility of the uninformed agent. Using (8) - (11):

$$\begin{aligned} EU(y) - p &= \frac{h_y \bar{y} + h_p \left(\bar{y} - \frac{\alpha - p}{\gamma} \right)}{h_y + h_p} - p \\ &= \bar{y} - \alpha + \left(\frac{h_p}{h_y + h_p} - \gamma \right) (\theta - \bar{y}) + \left(\frac{h_p}{h_y + h_p} - \gamma \right) \frac{\beta}{\gamma} \xi \\ \text{Var}_U(y) &= \frac{1}{h_y + h_p} \end{aligned}$$

so

$$A_U = \frac{\rho}{(h_y + h_\theta)\lambda + (h_y + h_p)(Q - \lambda)} \quad (47)$$

$$\Sigma_U = \left[\left(\frac{\rho}{\lambda h_\theta} \right)^2 \frac{1}{h_x} + \left(\frac{1}{h_y} + \frac{1}{h_\theta} \right) \right] \left[\frac{h_p}{h_y + h_p} - \frac{\lambda h_\theta + (Q - \lambda) h_p}{\lambda (h_y + h_\theta) + (Q - \lambda) (h_y + h_p)} \right]^2 \quad (48)$$

3. In case the issuer does not supply the rating but in equilibrium $\lambda = 0$, utility can be found by setting $h_\theta = 0$ in (45) and (46):

$$\Sigma_0 = \left[\frac{\rho}{Q h_y} \right]^2 \frac{1}{h_x} \quad (49)$$

$$A_0 = \frac{1}{Q} \frac{\rho}{h_y} \quad (50)$$

4. Finally, for the case where the issuer does not provide a rating but in equilibrium $\lambda = Q$, utility for each is as in the issuer-provided rating, subtracting the fixed cost $c = \frac{\chi}{Q}$, so that

$$V_Q = V_I - 2\rho \frac{\chi}{Q}$$

Replacing (49), (50), (45) and (46) respectively into (44)

$$V_0 - V_I = \rho^2 h_x \left[\frac{1}{Q^2 h_y h_x + \rho^2} - \frac{1}{Q^2 (h_y + h_\theta) h_x + \rho^2} \right] + \log \left(\frac{1 + \frac{1}{h_y} \left(\frac{\rho}{Q} \right)^2 \frac{1}{h_x}}{1 + \frac{1}{h_y + h_\theta} \left(\frac{\rho}{Q} \right)^2 \frac{1}{h_x}} \right) > 0$$

that is positive because $h_\theta > 0$. This proves Proposition 2.

Now we prove Proposition 3. First, from (47) and (46), it follows that $\lim_{\lambda \rightarrow Q} A_U = A_I$. Second, we use (48), (45) and (11) to establish the following two claims.

Claim 1 1) $\frac{\bar{\Sigma}_U}{\bar{\Sigma}_I} = \frac{h_\theta - h_p}{h_y + h_p} \frac{h_y}{h_\theta}$ and 2) $\Sigma_I - \bar{\Sigma}_U = \frac{h_p}{h_\theta} \frac{h_y + h_\theta}{h_y + h_p} \Sigma_I$

Proof. Let $\bar{\Sigma}_U \equiv \lim_{\lambda \rightarrow Q} \Sigma_U = \left[\left(\frac{\rho}{Q h_\theta} \right)^2 \frac{1}{h_x} + \left(\frac{1}{h_y} + \frac{1}{h_\theta} \right) \right] \left[\frac{h_p}{h_y + h_p} - \frac{h_\theta}{h_y + h_\theta} \right]^2$. Then

$$\begin{aligned} \frac{\bar{\Sigma}_U}{\bar{\Sigma}_I} &= \frac{\left[\left(\frac{\rho}{Q h_\theta} \right)^2 \frac{1}{h_x} + \left(\frac{1}{h_y} + \frac{1}{h_\theta} \right) \right] \left[\frac{h_p}{h_y + h_p} - \frac{h_\theta}{h_y + h_\theta} \right]^2}{\left[\frac{\rho}{Q (h_y + h_\theta)} \right]^2 \frac{1}{h_x}} \\ &= \frac{[\rho^2 h_y + Q^2 h_\theta^2 h_x + Q^2 h_\theta h_x h_y] (h_\theta - h_p)^2 h_y \frac{1}{\rho^2 h_\theta^2 (h_y + h_p)^2}}{(h_y + h_p)(\rho^2 + Q^2 h_\theta h_x) \frac{\rho^4 h_\theta^2}{(\rho^2 + Q^2 h_\theta h_x)^2}} \\ &= \frac{\rho^2 h_y}{(\rho^2 + Q^2 h_\theta h_x)(h_y + h_p)} \\ &= \frac{h_\theta - h_p}{h_y + h_p} \frac{h_y}{h_\theta} \end{aligned}$$

and

$$\begin{aligned} \Sigma_I - \bar{\Sigma}_U &= \left[1 - \frac{h_\theta - h_p}{h_y + h_p} \frac{h_y}{h_\theta} \right] \Sigma_I \\ &= \frac{h_p}{h_\theta} \frac{h_y + h_\theta}{h_y + h_p} \Sigma_I \end{aligned}$$

Claim 2 $\lim_{\lambda \rightarrow Q} \left[\frac{1}{h_y + h_p} + \Sigma_U \right] = \frac{1}{h_y + h_\theta} + \Sigma_I$

Proof. Observe that $\lim_{\lambda \rightarrow Q} h_p = \frac{Q^2 h_\theta^2 h_x}{\rho^2 + Q^2 h_\theta h_x}$. Then:

$$\begin{aligned} \lim_{\lambda \rightarrow Q} \left[\frac{1}{h_y + h_p} + \Sigma_U \right] &= \frac{1}{h_y + h_\theta} + \Sigma_I \Leftrightarrow \\ \lim_{\lambda \rightarrow Q} \frac{1}{h_y + h_p} - \frac{1}{h_y + h_\theta} &= \Sigma_I - \bar{\Sigma}_U \quad \Leftrightarrow \text{(By Claim 1)} \\ \lim_{\lambda \rightarrow Q} \frac{h_\theta - h_p}{(h_y + h_p)(h_y + h_\theta)} &= \frac{h_p}{h_\theta} \frac{h_y + h_\theta}{h_y + h_p} \Sigma_I \Leftrightarrow \\ \lim_{\lambda \rightarrow Q} \frac{h_p}{h_\theta} \left[\frac{\rho}{Q(h_y + h_\theta)} \right]^2 &= \frac{h_p}{h_\theta} \Sigma_I \quad \Leftrightarrow \\ \left[\frac{\rho}{Q(h_y + h_\theta)} \right]^2 &= \Sigma_I \end{aligned}$$

Now we establish the result:

$$\begin{aligned} V_I - \lim_{\lambda \rightarrow Q} V_U &= \left(\frac{\rho}{Q(h_y + h_\theta)} \right)^2 \left[\frac{1}{\frac{1}{h_y + h_\theta} + \Sigma_I} - \frac{1}{\frac{1}{h_y + h_p} + \Sigma_U} \right] \\ &+ \log \left(\frac{\frac{1}{h_y + h_\theta} + \Sigma_I}{\frac{1}{h_y + h_p} + \Sigma_U} \right) \\ &+ \log \left(\frac{h_y + h_\theta}{h_y + h_p} \right) \end{aligned}$$

By Claim 2, the first two terms are equal to zero, and since $h_\theta > h_p$, we have that:

$$V_I - \lim_{\lambda \rightarrow Q} V_U = \log \left(\frac{h_y + h_\theta}{h_y + h_p} \right) > 0$$

Therefore, for λ sufficiently close to Q , $V_I > V_U$.

Proposition 5 then follows from the fact that for a sufficiently small χ , the equilibrium value of λ will be Q .

A.5 Proof of proposition 4

Equation (9) and the fact that $h_p < h_\theta$ imply that β is minimized when $\lambda = Q$. The result then follows from equation (16).

A.6 Proof of proposition 6

From (12), a positive solution for λ requires

$$\frac{h_\theta}{(h_y + h_\theta)(1 - \exp(-2\rho c))} - 1 > 0 \quad (51)$$

which reduces to

$$h_\theta \exp(-2\rho c) - h_y (1 - \exp(-2\rho c)) > 0 \quad (52)$$

Since the analyst must make nonnegative profits and at most a measure Q of investors purchase the rating, this means that $c \geq \frac{\chi}{Q}$. Therefore (52) cannot hold if (17) holds.

A.7 Proof of proposition 7

Rewrite (12) as

$$\lambda = \frac{\rho}{\sqrt{h_\theta h_x}} \sqrt{\frac{\frac{h_\theta + h_y}{h_\theta} \exp(-2\rho c) - \frac{h_y}{h_\theta}}{\frac{h_\theta + h_y}{h_\theta} (1 - \exp(-2\rho c))}} \quad (53)$$

Fixing c , (53) implies $\lim_{h_\theta \rightarrow \infty} \lambda = 0$. Letting $c = \frac{\chi}{\lambda}$ does not alter this conclusion because λ is decreasing in c . Therefore, with an endogenous information price, the right side approaches zero even faster.

Even though $\lambda = 0$ in the limit, it could still be that for any finite h_θ , $\lambda > 0$. The following shows that this is not the case.

Suppose not. This means that for every h_θ (53) has a solution $\lambda \in (0, Q]$ with $c = \frac{x}{\lambda}$. Rearrange (53) and use $c = \frac{x}{\lambda}$:

$$\sqrt{h_\theta} = \frac{1}{\lambda} \frac{\rho}{\sqrt{h_x}} \sqrt{\frac{\left(1 + \frac{h_y}{h_\theta}\right) \exp(-2\rho \frac{x}{\lambda}) - \frac{h_y}{h_\theta}}{\left(1 + \frac{h_y}{h_\theta}\right) (1 - \exp(-2\rho \frac{x}{\lambda}))}}.$$

Since the previous expression holds for every h_θ , by continuity it should also hold in the limit as $h_\theta \rightarrow \infty$. On the LHS we have that $\lim_{h_\theta \rightarrow \infty} \sqrt{h_\theta} = \infty$. On the RHS, we have that:

$$\lim_{h_\theta \rightarrow \infty} \frac{1}{\lambda} \frac{\rho}{\sqrt{h_x}} \sqrt{\frac{\exp(-2\rho \frac{x}{\lambda})}{(1 - \exp(-2\rho \frac{x}{\lambda}))}} = \frac{\rho}{\sqrt{h_x}} \lim_{\lambda \rightarrow 0} \sqrt{\frac{1}{\lambda^2 \exp(2\rho \frac{x}{\lambda}) - 1}}$$

where the right hand side considers λ a function of h_θ ($\lim_{h_\theta \rightarrow \infty} \lambda(h_\theta) = 0$). Finally, L'Hopital's rule tells us that $\lim_{\lambda \rightarrow 0} \lambda^2 \exp(2\rho \frac{x}{\lambda}) = \infty$, and therefore (54) is zero in the limit.

Therefore, we have two sequences that must be equal for all finite values but are different in the limit. Since these two sequences come from continuous functions, this is a contradiction.

A.8 Proof of proposition 8

Welfare for any given investor is given by

$$V_i = 2\rho_i w_0 - 2\rho_i c d + \frac{A_i^2}{Var_i(y) + \Sigma_i} + \log\left(1 + \frac{\Sigma_i}{Var_i(y)}\right) \quad (54)$$

where

$$\begin{aligned} A_i &\equiv E[E_i(y) - p] \\ \Sigma_i &\equiv Var[E_i(y) - p] \end{aligned}$$

1. When the issuer discloses, we have

$$A_I = \frac{1}{(h_y + h_\theta)\psi} \quad (55)$$

$$\Sigma_I = \left[\frac{1}{(h_y + h_\theta)\psi}\right]^2 \frac{1}{h_x} \quad (56)$$

$$Var_I(y) = \frac{1}{h_y + h_\theta} \quad (57)$$

where

$$\psi \equiv \int_0^Q \frac{1}{\rho_i} di$$

When there is no information, we have

$$A_0 = \frac{1}{h_y \psi} \quad (58)$$

$$\Sigma_0 = \left[\frac{1}{h_y \psi}\right]^2 \frac{1}{h_x} \quad (59)$$

$$Var_0(y) = \frac{1}{h_y} \quad (60)$$

so replacing (55)-(60) into (54) and rearranging yields $V_0 > V_I$.

2. For $i^* \rightarrow Q$, the values of A_i , Σ_i and $Var_i(y)$ for an informed investor converge to (57), so for an investor who would have bought the analyst report, mandatory disclosure implies an increase in utility of $2\rho_i c$. An

investor who would not have bought the analyst report would have

$$\lim_{i^* \rightarrow Q} A_U = \frac{1}{(h_y + h_\theta) \psi} \quad (61)$$

$$\lim_{i^* \rightarrow Q} \Sigma_U = \left(\frac{h_p}{h_y + h_p} - \frac{h_\theta}{h_y + h_\theta} \right)^2 \left[\left(\frac{1}{h_\theta} + \frac{1}{h_y} \right) + \left(\frac{1}{\psi_L h_\theta} \right)^2 \frac{1}{h_x} \right] \quad (62)$$

$$\lim_{i^* \rightarrow Q} Var_U(y) = \frac{1}{h_y + h_p} \quad (63)$$

Replacing (61)-(63) into (54) and following the same steps as in the proof of Proposition 3 leads to $\lim_{i^* \rightarrow Q} V_U < V_I$.

3. This follows from the fact that for a sufficiently small χ , the equilibrium value of i^* will be Q .

A.9 Proof of proposition 10

Given that in equilibrium investors rationally expect the level of investment k^* , the only effect of the investment decision on the subsequent financial market game is to make the level of \bar{y} endogenous. Propositions 2, 3 and 5 hold because none of the terms in equation (44) depend on \bar{y} . Proposition 4 holds because β does not depend on \bar{y} . Propositions 6 and 7 hold because λ does not depend on \bar{y} .

A.10 Proof of proposition 9

The proof is identical to that of Proposition 1, except that

$$\Pi^0 = f(k^*(0)) - \frac{\rho}{Q h_y} - k^*(0) \Pi^1 = f(k^*(1)) - \frac{\rho}{Q(h_\theta + h_y)} - k^*(1) - \chi$$

A.11 Price function coefficients with binary payoffs

The coefficients in equation (27) are:

$$\begin{aligned} A &= \left[\frac{Q - \lambda}{Q} (1 - \kappa_\theta^U - \kappa_\omega^U) + \frac{\lambda}{Q} (1 - \kappa_\theta^I - \kappa_\omega^I) \right] \log \left(\frac{\bar{y}}{1 - \bar{y}} \right) - \frac{\rho}{Q} \\ B &= \frac{Q - \lambda}{Q} \kappa_\theta^U + \frac{\lambda}{Q} \kappa_\theta^I \\ C &= \frac{Q - \lambda}{Q} \kappa_\omega^U + \frac{\lambda}{Q} \kappa_\omega^I \\ D &= \left(\frac{Q - \lambda}{\lambda} \frac{\kappa_\theta^U}{\kappa_\theta^I} + 1 \right) \frac{\rho}{Q} \end{aligned}$$

B Model Calibration

Adjusting for fluctuations in the risk-free rate. We compute the spread as follows: By definition, the yield of the bond at the issue date, r_0^b satisfies

$$p_0 = \sum_{t=0}^T \frac{c_t}{(1 + r_0^b)^t}$$

where c_t is the bond's t -dated coupon (or coupon-plus-principal). The spread on the bond is

$$s_0 = r_0 - r_0^T$$

(where r_0^T is the T -maturity risk-free rate as of $t = 0$). At $t = 1$, instead of looking directly at the price of the bond, we look at a corrected price defined by

$$\tilde{p}_1 = \sum_{t=0}^T \frac{c_t}{(1 + r_0^T + s_1)^t}$$

where s_1 is the spread calculated on the basis of the $t = 1$ price. If $r_0^T = r_1^T$, the corrected price coincides with the pure price, but if risk-free interest rates have changed in the meantime, the corrected price filters out the effect.

Normalizing by the promised value. In order to account for the different contractual terms of different bonds, we normalize the price of bonds by the contractually-promised net present value y^p , defined by

$$y^p = \sum_{t=0}^T \frac{c_t}{(1 + r_0^T)^t}$$

For bonds with low probability of default (for instance, highly rated bonds), their price as a proportion of the contractually promised net present value (p/y^p) will be close to one. In our data, the average p/y^p is 0.91.