Optimal leverage and strategic disclosure[*]

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Abstract

Firms seeking external financing jointly choose what securities to issue, and the extent of their disclosure commitments. The literature shows that enhanced disclosure reduces the cost of financing. This paper, in addition, analyses its effects on the composition of financing means. It considers a market where firms compete under costly-state-verification, but unlike the standard model assuming (i) that the degree of asymmetric information between firms and outside investors is variable, and (ii) that firms can affect it by committing to a disclosure policy, possibly incurring a cost. Two central predictions emerge.

On the positive side, disclosure and leverage are negatively correlated. Efficient equity financing requires a certain amount of disclosure, whereas debt does not; it is based on the threat of bankruptcy. Therefore, more transparent firms issue cheaper stocks and face a higher opportunity cost of leveraged financing. The prediction is shown to be consistent with the behavior of US corporations since the 1980s.

On the normative side, disclosure externalities lead to under-disclosure and excessive leverage relative to the constrained best. Mandatory disclosures can be Pareto improving, when feasible. Otherwise, the mapping I derive from greater equity financing to voluntary higher transparency suggests that the regulator should tighten the capital requirements. According to the model, capital standards are especially useful when (i) firms performances are highly correlated, and (ii) disclosure requirements can be dodged to a large extent. Both conditions seem to apply to large financial firms.

Key words: leverage, costly-state-verification, disclosure, asymmetric information, capital requirements, financial regulation

JEL classification: D82, G21, G32, G38

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1 Introduction

Firms seeking external financing face a multidimensional choice problem. On the one hand, they need to decide what securities to issue; whether to borrow or to issue stocks, for example. On the other hand, they choose the extent of their disclosure commitments; for instance, whether to go public or to keep private. The existing evidence suggests that greater disclosures tend to reduce the firm's *cost of financing*, as the theory predicts, dampening the degree of asymmetric information in the market.[1] However, the effect of disclosure on the *composition of financing means* has been largely overlooked by previous research. This paper aims to fill the gap, by modeling explicitly the inter-linkage between disclosure and security design under asymmetric information. Two central predictions emerge from the analysis.

On the positive side, *disclosure and leverage are negatively correlated.* Enhanced disclosure leads to the possibility of issuing cheaper equity, increasing the opportunity cost of leveraged financing. Some firm-level evidence that supports this prediction is found analyzing the behavior of US corporates since the 1980s. Incidentally, one could also note that the results are consistent with the early development of modern stock markets, in the 19th century, that has been driven to a large extent by: (i) improvements in the information environment (e.g., the telegraph), and (ii) the growing financing needs of relatively more transparent industries such as the infrastructure sector (railways and canals, especially).[2]

On the normative side, externalities in disclosure across firms lead to *insufficient voluntary disclosures* and *excessive leverage* relative to the constrained best. The inefficiency gets reduced if regulators can credibly mandate truthful disclosures, but this is often not the case.[3] Modeling explicitly the inter-linkage between disclosure and leverage suggests an alternative policy: setting capital requirements. Higher capital requirements encourage firms to be more transparent, in an effort to reduce the otherwise prohibitive costs of equity financing, and are especially useful when (i) profits are highly correlated across firms, and (ii) mandatory disclosures can be dodged. Both conditions seem to apply especially to financial firms, which – consistently with the model's predictions – are both highly leveraged and opaque.[4]

[1] See especially Admati and Pfleiderer (2000) on the theory side, and Botosan (1997), Leuz and Verrecchia (2000), Bushee and Leuz (2005), Bailey et al. (2006) on the empirics.

[2] A prominent example is the London Stock Exchange (LSE). Prior to the 1840s, the LSE was essentially a market for government debt. But after the telegraph became operational (in the early 1850s), stock trading took off and by the 1870s the LSE was set to become the largest market for stocks of its time. Railways and infrastructure companies dominated the market, accounting for more than 75% of its capitalization (Grossman (2002)). Bordo et al. (1999) first implicated asymmetric information in the story, but without a formal model and not discussing why debt was not used instead of stocks.

[3] Two examples are particularly telling. First, Sloan (2007) documents that a typical RMBS (Residential Mortgage Backed Security) sold prior to 2008 had a disclosure prospectus of more than 300 pages. Though it complied with regulation, the prospectus hardly made such security transparent. Second, to show that banks balance sheet are a black box even for experienced investors, Partnoy and Eisinger (2013) quote Paul Singer (founder of Elliott Associates) writing to his partners that "There is no major financial institution today whose financial statements provide a meaningful clue [about its risks]".

[4] In the US, the *median* leverage ratio for financial firms after the 1980s ranges between 0.88 and 0.93

More specifically, I consider a financial market where firms seek financing from a competitive pool of investors under costly-state-verification (CSV). Firms and investors are symmetrically informed at the contracting stage, but acquire different information about the realized output ex post. Previous CSV models assumed an extreme type of hidden information: the entrepreneurs learn the output perfectly ex post; the investors learn nothing, but can verify the output reported by the entrepreneur at a cost.[5] This paper relaxes the assumption, supposing that the investors learn the realized output with some probability $\pi \in [0, 1]$, and know nothing otherwise.[6] Disclosure is privately costly and it affects the precision of the information revealed to investors. In addition, the private disclosure of a firm might convey information about its competitors.[7]

Optimal securities. The optimal capital structure is a mixture of debt and equity, and the amount of assets backed by debt (i.e., the *leverage* ratio) is monotonically decreasing in the probability that the investors are informed, denoted by π, which captures the degree of asymmetric information in the market. If $\pi = 0$, we have full leverage as in Gale and Hellwig (1985). The intuition is as follows: (i) the financier must verify low messages to prevent cheating by the entrepreneur when output is higher; (ii) whenever there is verification, the optimal repayment equals the full realized output (this resembles bankruptcy, in which debt holders are senior claimants); finally, (iii) whenever there is no verification, the repayment is incentive compatible if and only if it equals a fixed constant (the face value of debt), regardless of the realized output.[8]

Now consider $\pi > 0$. Property (iii) no longer holds: the highest incentive compatible repayment strictly increases with the output, because firms with higher output ex post have more to lose if caught cheating by the financiers (something that happens with probability $\pi > 0$). Moreover, it is always optimal to increase the repayments outside bankruptcy in order to minimize the ex ante need for costly verification. Therefore, the optimal contract has an equity component. Pure debt does not work because upon default the firm gets nothing, whereas if output is high it retains a needlessly large fraction of it. In other words, debt imposes an inefficient subsidy across states of nature ex post. Eventually, when π is high enough, there is no need for verification on-the-equilibrium path and the optimal contract is pure equity.[9]

(Source: author's calculation on Compustat data).

[5]The results of a CSV model rely on the minimization of expected bankruptcy costs. Recent evidence that these are substantial can be found in Molina (2005) and in Almeida and Philippon (2007).

[6]The model generalizes Townsend (1979) and Gale and Hellwig (1985), who restrict attention to $\pi = 0$. More general signal structures give rise to quite complex optimal contracts, but which maintain similar qualitative properties as those derived here. I refer the interested reader to Trigilia (2015).

[7]Recent work of Badertscher et al. (2013), Shroff et al. (2013) and Durnev and Mangen (2009) identifies the presence of substantial information externalities across firms. See also the earlier literature on *industrial districts*, such as Pyke et al. (1990).

[8]More precisely, Townsend (1979) and Gale and Hellwig (1985) show that debt is the optimal contract among those that feature commitment to deterministic audits. The result does not hold if one allows for random audits (Border and Sobel (1987) and Mookherjee and Png (1989)) or lack of commitment (Gale and Hellwig (1989)). Krasa and Villamil (2000) argue that debt is optimal if *both* lack of commitment and random audits are assumed, see also Krasa and Villamil (2003).

[9]Only in the limit, when $\pi = 1$, hidden information vanishes and Modigliani and Miller (1958) holds (i.e., the security design problem becomes irrelevant).

Importantly, whenever there is verification on-the-equilibrium path the optimal capital structure is unique, for every π. Otherwise, though there may be multiple optimal securities, they are ex ante identical to issuing no debt, and selling a fraction $s\pi$ of shares, for some $s \in (0, 1)$ that is pinned down by the zero profit condition of the investors. As a result, the feasible strategies of a firm can be reduced to selecting the extent of its disclosure commitments, as this immediately maps into an optimal capital structure.

Optimal disclosure. The optimal amount of disclosure can be derived as a solution to the following trade-off: on the one hand, higher disclosure comes at a higher cost;[10] on the other hand, it decreases the degree of asymmetric information ex post, enabling the firm to issue cheaper equity – i.e., lower its leverage – and hence to reduce the expected bankruptcy costs. Each firm chooses its disclosure and capital structure as a solution to the aforementioned trade-off, best responding to its competitors who move simultaneously.

The disclosure game is potentially discontinuous, because the optimal leverage ratio might jump discretely for a marginal increase in disclosure, and it is not necessarily quasi-concave. Therefore, a Nash equilibrium is not guaranteed to exist in general. However, I present sufficient conditions for continuity and quasi-concavity, and show that the restrictions needed are relatively mild.[11] Under such restrictions, the set of Pure Strategy Nash Equilibria (PSNE) of the game is non-empty, and can be fully characterized.

Comparative statics and the evidence. Cæteris paribus, the model yields two main positive predictions, for which supporting empirical evidence on US data is found.

First, *leverage is monotonically decreasing in the degree of transparency*. The prediction is novel, to my knowledge, and indeed its empirical validity has not been much investigated.[12] This paper takes a step toward filling this gap, by introducing a measure of transparency in an otherwise standard capital structure regression. In particular, I merge COMPUSTAT with IBES analysts' forecast and CRSP prices.[13] I add to the standard variables considered in Frank and Goyal (2009) various market measures of *transparency*, such as the *coefficient of variation of analysts' Earnings Per Share (EPS) forecasts*. The intuition behind this measure of transparency is that disagreement among analysts should decrease with the amount of public information about the firm (i.e., its transparency),

[10]This is a central hypothesis of Admati and Pfleiderer (2000) and much of the subsequent disclosure literature. For evidence of the significant (direct and indirect) costs of disclosure see Bushee and Leuz (2005), Leuz et al. (2008), Iliev (2010), Ellis et al. (2012) and Alexander et al. (2013) and Dambra et al. (2015).

[11]They require that the distribution of output satisfies two properties: (i) an increase in the interest rate at the optimal leverage ratio increases the expected profits of the investors (i.e., it more than compensates for the expected increase in verification costs); and (ii) the density function is continuously differentiable, and the first derivative is bounded below by some constant $z < 0$.

[12]A notable exception is Aggarwal and Kyaw (2009), who compare leverage and transparency across 14 EU countries and find a negative correlation. However, it seems that we still lack firm level evidence.

[13]COMPUSTAT contains both balance sheet and cash flow (annual) information or the universe of US public firms. IBES (acronym for 'Institutional Brokers' Estimate System') contains analysts' estimates of earnings per share for several US corporations. Finally, CRSP (acronym for 'Centre for Research in Security Prices') offers equity prices used to calculate market-based equity measures.

and hence the variance of forecasts is likely to reflect – at least be correlated to – the degree of asymmetric information between firm's insiders and analysts.[14]

The regression analysis reveals that: (i) *there exists a strong, statistically significant negative correlation between leverage and transparency*; (ii) *the correlation is robust* to the inclusion of both standard control variables, and time-firm fixed effects. As a result, even if one restricts attention to variation within firm across time in leverage and transparency, the two remain reliably negatively correlated.

Second, consistently with the existing empirical evidence, *leverage is monotonically decreasing in profitability.*[15] The intuition is that more profitable firms need to issue less shares (for a given price-per-share) to finance any given investment. Therefore, they have an easier chance of being able to issue incentive-compatible equity. The result is of interest from a theory perspective, as it reconciles the theory of optimal capital structure based on bankruptcy costs with the evidence.[16] The negative relationship between leverage and profitability is further confirmed in my regression analysis.

Mandatory capital and disclosure requirements. Comparing the PSNE to the Socially Efficient (SE) disclosure levels, I show that *whenever information is correlated across firms the private provision of information is excessively low, and hence leverage is excessively high.* Firms under-disclose because they free ride on the information disclosed by their competitors, and they end up collectively stuck in a Pareto suboptimal equilibrium. The public good nature of information leads to the possibility of Pareto improving government interventions in financial markets.

A government that seeks to restore social optimality should consider two instruments. First, it could mandate a certain degree of disclosure. To the extent that this is feasible, and firms cannot dodge the disclosure requirements, then mandatory disclosures restore optimality. Indeed, we observe a wide range of disclosure requirements in every developed economy (Leuz (2010)).

However, as Ben-Shahar and Schneider (2010) document, disclosure regulation is not effective in many instances. In particular, 'mandating transparency through disclosure' proves harder (i) the more complex the underlying firm, and (ii) the greater the opportunity cost of disclosure. As it is often argued (e.g., Partnoy and Eisinger (2013)), these conditions hold especially for large financial firms. So, are there indirect regulatory tools that could promote endogenously greater transparency of financial institutions?

The model I present suggests that capital requirements are a suitable instrument to

[14]The idea of measuring transparency in this way is not new – see for instance Thomas (2002), Tong (2007), Chang et al. (2007). Many other factors, such as herding or contrarianism – as well as personal opinions – enter the forecast process. Such factors are discussed in greater depth in Bernhardt et al. (2006). I implicitly assume that these additional sources of disagreement are orthogonal to leverage. Bhat et al. (2006) show that analysts' forecasts error and dispersion are strongly positively correlated with the country-level transparency measures of Bushman et al. (2004).

[15]The negative correlation between leverage and profitability has been documented in several previous studies, such as Frank and Goyal (2009), Welch (2011) and Graham and Leary (2011).

[16]Indeed, the static trade-off theory would suggest the exact opposite should hold (see, for instance, Kraus and Litzenberger (1973)). The interpretation of bankruptcy costs as the costs of verification is discussed in Gale and Hellwig (1985) and Tirole (2010).

this end. Through the lens of the model, even taking into account the costs of disclosure, firms who face stringent capital requirements are encouraged to disclose better information to the market in an effort to reduce the costs of equity financing.[17] Although the argument is simple and plausible, it is strikingly absent from the current debate on capital standards, which I believe should not be as separated from that on information requirements as it is at present.[18]

Consider the recent discussion around capital standards that is ongoing in the US. The Federal Reserve justifies its regulation as follows:

> The primary function of capital is to *support the bank's operations*, *act as a cushion to absorb unanticipated losses and declines in asset values* that could otherwise cause a bank to fail, and *provide protection to uninsured depositors and debt holders* in the event of liquidation. [emphasis not in the original]
>
> FED Supervisory Policy and Guidance Topics, as of 14.09.2015

The FED's statement highlights three objectives. The first is to 'support the bank's operations', a relatively vague proposition which is absent from much of the political and academic debate on the matter. The second objective is coherent with the position of many prominent economists, who emphasize the importance of requiring a sufficient 'loss absorbing' capital buffer, and is at the center stage of both the public and the academic debate.[19] However, it offers a natural counterargument to finance lobbyists and skeptics of regulation. Despite the virtue of capital buffers ex-post, in crises times, they counter argue that stringent requirements tend to curb investment during booms, making it more expensive for firms to obtain external financing. So, from an ex ante perspective they are not necessarily desirable.[20] Finally, the third argument surprised me at first sight, and can be considered as another subsidy to debt instruments relative to alternatives, in

[17]Of course, the argument relies on the presumption that the government shares with the market a knowledge of individual firms covariates. Otherwise, the Pareto gains or losses in setting capital requirements depend on the average effect on firms, as in Admati and Pfleiderer (2000). Though supposing that governments are well informed is empirically implausible in many instances, observe that at present Basel III does distinguish firms that are too-big-to-fail, and imposes a capital surcharge on them.

[18]The complementaries across different regulations are a generally under-researched and important area for future work, as emphasized in Leuz and Wysocki (2008). This is but one instance of the more general phœnomenon.

[19]See especially the Squam Lake Report (French et al. (2010)); recent influential books by Kotlikoff (2010), Sinn (2012), Admati and Hellwig (2014) and Stiglitz et al. (2015); academic papers such as Admati et al. (2013), Chamley et al. (2012) and Miles et al. (2013). The general discontent among academics (and a few politicians) with the outcome of Basel III, that sets capital requirements to less than 5%, shifted much of the debate at the national level.

[20]For instance, the former CEO of Deutsche Bank Josef Ackermann claimed that capital requirements 'would restrict bank's ability to provide loans to the rest of the economy', which 'reduces growth and has a negative effect for all'. The CEO of JP Morgan, Jamie Dimon, argued that capital requirements would 'greatly diminish growth', and a similar position has been expressed by the former CEO of Citigroup Vikram Pandit, as well as by the lobbying group *Institute for International Finance* (see Admati and Hellwig (2014), pagg. 97, 232 (18) and 274 (60)). A few papers estimated the growth loss coming from capital requirements in a DSGE framework to be substantial, but crucially under the *exogenous assumption* that equity is more costly for banks to issue (see for instance Van den Heuvel (2008)).

much the same spirit as the tax deduction of interest payments.[21]

This paper wishes to shift spotlight toward the first goal, offering an argument that substantiates how capital requirements might 'support the bank's operations'. The mechanism I suggest starts with a coordination failure in information provision across banks, aggravated by (i) systemic risk and correlation of assets portfolios, and (ii) the easiness to dodge mandatory disclosures. The under-provision of information not only leads to opacity of financial intermediaries, evidently, but it also promotes an excessive reliance on debt instruments to get funding. Capital requirements force corporations to be more transparent, in order to obtain more favorable costs of equity financing, and this is unambiguously beneficial ex ante because it lowers the expected costs of distress, and the reduction in this dead-weight loss more than compensates the increase in disclosure costs.

Related Literature. The paper wishes to contribute to the existing literature mainly pointing at the link between security design and disclosure.

On the security design side, it builds on Townsend (1979) and Gale and Hellwig (1985) CSV framework. The idea that outside information leads to the optimality of issuing some equity in a CSV model dates back to Chang (1999), who considers a firm with two technologies: one subject to CSV and one observable and verifiable (for which Modigliani and Miller (1958) holds). Although my interpretation in terms of signals is different, and in general it yields different conclusions from those in Chang (see Trigilia (2015)), the intuition is similar: the presence of *some* reliable information ex post leads to optimal contracts that cross debt from the right.

As such, the rationale for equity in the model I present is distinct from other stories that involve either risk-aversion and transaction costs (Cheung (1968)), costly-state-falsisification (Lacker and Weinberg (1989) and Ellingsen and Kristiansen (2011)), double-sided moral hazard (Bhattacharyya and Lafontaine (1995)), control rights and infinite investment horizon (Fluck (1998)) or the combination of ambiguity and ex ante moral hazard (Carroll (2015) and Antic (2014)).[22]

On the disclosure side, the model builds on two literatures. First, as Fishman and Hagerty (1989, 1990) and Admati and Pfleiderer (2000) I suppose that disclosure is privately costly and it leads to an externality due to its public good nature.[23] Second, as

[21] An often mentioned force pushing firms toward increasing their leverage is the tax deductibility of interest payments, but not of dividends. Observe, though, that such factor cannot account for the vast cross-sectional variation in leverage across firms in the US. It is therefore overlooked here. On the contradiction between capital requirements and tax advantages of debt, see especially De Mooij (2012) and Fleischer (2013). Both scholars promote the abolition of any tax advantage of debt.

[22] Explanations for optimal equity based on control rights face increasing difficulties in accounting for the empirical evidence that many corporations are adopting a two-tiered equity structure, whereby investors are offered non-voting stocks (e.g., Google and Facebook). On this point, see also Zingales (2000). In contrast, explanations based on cash-flow rights used to require that the investors play an active role. Only recently, with Carroll (2015) and this paper, equity has been found optimal in models with relatively passive investors.

[23] Namely, the disclosure made by one firm affects the optimal disclosure of its competitors, and this consideration feeds back into the initial optimal disclosure decision. In such a scenario, the private provision of information is likely to be socially inefficient, although as Fishman and Hagerty show inefficient

Rayo and Segal (2010) I consider disclosure policies that are chosen before the realization of uncertainty, and cannot be modified ex post. This prevents a source of potential time inconsistencies, and makes the analysis different from models of Bayesian Persuasion such as Kamenica and Gentzkow (2011). I intend to consider ex post disclosure policies in future work.[24]

As Leuz (2010) discusses at length, the presence of information externalities is a major justification for the existence of mandatory disclosure requirements in practice. This paper wishes to contribute by highlighting that a similar argument leads naturally to capital requirements as well.[25]

2 Setup

There are two dates $t \in \{0, 1\}$, $N \geq 1$ identical *firms* and a large number of competitive *investors*. Both firms and investors are risk-neutral and maximize date one consumption.

Each firm is endowed with no initial wealth, and has access to an investment technology at $t = 0$ that requires a fixed input $K > 0$ and generates stochastic output $\tilde{x}$ at $t = 1$. I assume that $\tilde{x} \in X \equiv [0, \bar{x}]$, and denote by $F(x)$ the cumulative distribution of $\tilde{x}$, and by $f(x)$ its density. For simplicity let $f(x) > 0$ for all x and suppose it is continuous. To make the problem interesting, Assumption 1 guarantees that the project has positive net present value (NPV) under full information.

Assumption 1. $K < \mathbb{E}_f[\tilde{x}]$. **(Positive NPV)**

In this paper, I overlook the presence of agency problems within the firm, and I refer to the owner/manager of each firm as the *entrepreneur*. I intend to explore the issue in future research.

The representative investor is endowed with large initial wealth and can either lend it to some firm, or invest it in a risk-less bond with interest factor normalized to unity.

Investment occurs under *symmetric* information. Hidden information comes ex post, when the state of the project is privately observed by the entrepreneur. The investors observe the state with some probability $\pi \in [0, 1]$, which I will discuss in depth later on. If the investors do not observe the state, they still have the option of verifying it at a fixed cost $\mu \geq 0$. The entrepreneur can affect π at $t = 0$ by committing to a disclosure policy – e.g., hiring an independent and trustworthy auditor or going public.

The timing of the game is as follows:

does not necessarily mean too low.

[24]Additional recent papers on disclosure include Guttman et al. (2014) and Ben-Porath et al. (2014). Alvarez and Barlevy (2014) also emphasize externalities in information provision, though focusing more on contagion.

[25]The argument for capital requirement presented in this paper differs markedly from the general equilibrium arguments based on pecuniary externalities (such as Korinek and Simsek (2014) and Geanakoplos and Kubler (2015)). It also differs from arguments based on excessive risk taking and 'collective moral hazard' (see Farhi and Tirole (2012) and Admati and Hellwig (2014))

t=0 The entrepreneurs offer a contract (take-it-or-leave-it) to the investors. If the investors accept, K is invested;[26]

t=1 Nature determines the realised state $x \in X$. Then, in sequence:

1. Each entrepreneur privately observes x and sends a public message $m \in M$ about it (e.g., a balance sheet statement);
2. Investors observe x with probability π, and observe nothing otherwise;
3. If the investors did not observe the state, they can verify it at a cost μ;
4. Transfers occur and the game ends.

I now describe the feasible portfolio of securities and disclosure policies.

2.1 Securities

For a given set of public messages M, the aggregate payout from firm i to its investors can decomposed in three parts:

(i) The *repayment* function $s_i(m) : M \to \mathbb{R}$ specifies the payout when investors are *uninformed* about the state;

(ii) The *claw-back* function $z_i(m, x) : M \times X \to \mathbb{R}$ specifies the payout when investors are *informed* about the state;

(iii) The *verification* function $\sigma_i(m) : M \to [0, 1]$ specifies the probability that the state is verified for every message, when the investors are uninformed otherwise.

I impose two restrictions on admissible securities: (i) limited liability; (ii) deterministic verification. Limited liability implies that repayments and claw-backs cannot be negative, and their upper bound depends on the verifiable output. Namely, if the investors are informed the upper bound is the realized output x, otherwise it is the message m. It is a standard assumption and it guarantees the existence of an optimal contract.[27]

Deterministic verification is commonly assumed in CSV models, but it is a restrictive assumption. Indeed, Border and Sobel (1987) and Mookherjee and Png (1989) show that the optimal random contract is not debt. I make the assumption for two reasons: (i) the optimal random contracts still exhibit the key features of interest here;[28] and (ii) they cannot be fully characterized, because local incentive compatibility does not suffice for global (see Border and Sobel (1987)). Formally:

Assumption 2. *A portfolio of securities is* feasible *only if,* $\forall m, x$*:*

$$\begin{aligned} &\text{Payments satisfy limited liability:} && s_i(m) \in [0, m],\ z_i(m, x) \in [0, x] \\ &\text{Verification is deterministic:} && \sigma_i(m) \in \{0, 1\} \end{aligned}$$

[26] Investment is assumed to be an observable and verifiable action.

[27] What is important is that the verifiable output lies in a compact set for every state x. One could therefore easily accommodate the equivalent of a finite non-pecuniary penalty.

[28] Namely, lower messages are generally associated with higher verification, higher states are not verified and repay a flat rate (in the absence of signals).

2.2 Disclosure policies

The disclosure policy of firm i consists in the choice of a binary signal, which reveals with probability $p_i \in [0,1]$ the state of nature ex-post to the investors public at a cost $c(p_i)$.

In the absence of correlation across firms, the probability that the investors observe x for a given firm – denoted by π_i – equals p_i. In contrast, when there is more than one firm and output is correlated across firms, we may have $p_i < \pi_i$. Observing other firms' output might be informative about firm i's realized output as well.

I assume that the correlation between firm i and firm j is captured by a parameter $q_{i,j} \in [0,1]$, so that the probability that the signal sent by firm j is informative about firm i is $q_{i,j}p_j$.[29] In aggregate, the probability of having at least an informative signal out of N independent but *not* identically distributed Bernoulli trials is described by the inverse cdf of a *Poisson Binomial* distribution evaluated at zero successes, and it reads:

$$\pi_{\text{i}}(\text{p}_{\text{i}}, \text{p}_{\text{-i}}, \text{q}_{\text{-i}}) = 1 - (1-p_i)\prod\nolimits_{j\neq i}(1-q_{i,j}p_j) \tag{1}$$

The formula captures a positive externality coming from each firm's disclosure policy, because $\partial\,\pi_{\text{i}}(\text{p}_{\text{i}}, \text{p}_{\text{-i}}, \text{q}_{\text{-i}})\,/\partial p_j \geq 0$ and $\partial\,\pi_{\text{i}}(\text{p}_{\text{i}}, \text{p}_{\text{-i}}, \text{q}_{\text{-i}})\,/\partial q_{i,j} \geq 0$. However, one could envision the presence of negative externalities as well. For instance, in a model where the feasible aggregate media coverage is limited, the disclosures made by other firms may end up limiting the attention that firm i can attract, hence reducing the information that the investors can acquire about its output. The analysis of such scenarios, which may give rise to strategic complementarities across firms, is left for future research.

2.3 Equilibrium concept and preliminary lemmas

Before stating the equilibrium concept and the contracting problem, it is important to acknowledge that in the environment I described the revelation principle holds:

Lemma 1. *Without loss of generality, we can restrict attention to direct revelation mechanisms.*[30]

As a result, from now onwards let $M = X$ and focus on truthful implementation. A *type* of firm refers to the *state* x of the project that the entrepreneurs observe before sending their public messages. The driving force in deriving the optimal portfolio of securities for a firm is the continuum $[0, \overline{x}]$ of incentive compatibility constraints for each ex-post type x, which I now describe.

The expected payout from the firm to the investors when the realized state is x and the message is x' is denoted by:

$$r_i(x', x) \equiv [\pi_i + (1-\pi_i)\sigma_i(x')]z_i(x', x) + (1-\pi_i)(1-\sigma_i(x'))s_i(x')$$

[29] Evidently, it must be that $q_{i,i} = 1$ for every i. Observe that q is not a statistical correlation coefficient, it just captures the presence of spillovers in information provision. Hence, it being positive is without loss of generality.

[30] The validity of the revelation principle follows from the exact same logic as in Gale and Hellwig (1985); the proof is omitted.

where recall that π_i is a function of p_i, p_{-i} and q_{-i}: $\pi_{\mathrm{i}}(\mathrm{p_i}, \mathrm{p_{\text{-}i}}, \mathrm{q_{\text{-}i}})$. To understand the above expression, observe that:

1. The payout equals $z_i(x', x)$ whenever: (i) there is verification, which happens with probability $(1-\pi_i)\sigma_i(x')$; and (ii) whenever the investor is informed, which happens with probability π_i;
2. The payout is equal to $s_i(x')$ otherwise – i.e., when the signal is uninformative and no verification takes place. The probability of this event is equal to $(1-\pi_i)(1-\sigma_i(x'))$.

To simplify the notation, let $r_i(x, x) \equiv r_i(x)$.

As a consequence of Lemma 1, incentive compatibility requires that, for every x, at the optimal contract the expected payoff for the entrepreneur under truthful reporting (i.e. $x - r(x)$) is greater than the expected payoff by pretending to be any other type $x' \neq x$, i.e.:

$$x - r_i(x) \geq x - r_i(x, x'), \qquad \forall (x, x') \in X^2 \tag{2}$$

It is useful to refer to the incentive compatibility constraint when (i) the true state is x and (ii) the message sent is x', as $IC(x', x)$.

Any contract that implements investment must also satisfy the participation constraint (PC) for the investor, which by Lemma 1 reads:

$$\int_X \big[r_i(x) - (1-\pi_i)\sigma_i(x)\mu\big] dF(x) \geq K \tag{3}$$

I restrict attention to pure strategy Nash equilibria, defined as follows:

Definition 1. *A Pure Strategy Nash Equilibrium (PSNE) of the game consists in a set of strategies $\{s_i^*, z_i^*, \sigma_i^*, p_i^*\}$ for all firms $i = 1, ..., N$ such that, for each firm i and for a given vector p_{-i}^*, both the portfolio of securities issued and the disclosure policy are optimal:*

$$\begin{aligned} \{s_i^*, z_i^*, \sigma_i^*, p_i^*\} \in \arg\max & \int_X [x - r_i(x)] dF(x) - c(p_i) \\ \text{s.t. } & LL;\ \ DV;\ \ IC(x, x')\ \forall x, x';\ \ \text{PC.} \end{aligned} \tag{4}$$

It is easy to see that PC must be binding at any optimal contract. This is because whenever a contract $\{s, z, \sigma\}$ is feasible and incentive compatible, so is a contract $\{s', z', \sigma'\}$ such that (i) $\sigma' = \sigma$, (ii) $s' = \alpha s$, and (iii) $z' = \alpha z$ for some $\alpha \in [0, 1)$. By substitution, the contracting problem can be rewritten as:

$$\begin{aligned} \{s_i^*, z_i^*, \sigma_i^*, p_i^*\} \in \arg\max & \int_X [x - (1-\pi_i)\sigma_i(x)\mu] dF(x) - c(p_i) - K \\ \text{s.t. } & LL;\ \ DV;\ \ IC(x, x')\ \forall x, x' \end{aligned} \tag{5}$$

The latter formulation highlights that the objective function is simply to minimize the expected dead-weight costs of verification and disclosure. Two intuitive lemmas hold irrespective of p_i, and prove useful in characterizing the optimal contracts.

The first lemma deals with off-equilibrium claw-back provisions, and shows that we can restrict attention to contracts that impose the harshest feasible claw-backs after cheating by the entrepreneur has been verified. Namely, optimal contracts are such that verification takes place when $m < y$, which proves that the entrepreneur is cheating with certainty, and $z(m, x) = x$ whenever $m \neq x$.

Lemma 2. *We can restrict attention to contracts such that:*

(i) All assets are seized upon verified cheating: $z^*(m, x) = x$ *whenever* $m \neq x$*;*

(ii) Messages revealed to be false are verified.

Proof. See the Appendix. □

Observe that we have one degree of freedom in setting $s^*(m)$ whenever $\sigma_i(m) = 1$. As a consequence of Lemma 2, I let $s^*(m) = z^*(m, x) = x$ in such events.

The second Lemma shows that we can restrict attention to securities such that *both* the aggregate payout and the repayment function are weakly increasing on X. The intuition is that having a non-monotonic optimal contract implies that incentive compatibility is not binding in some states, and one can always construct a monotonic contract that replicates the same ex ante allocation satisfying all constraints.

Lemma 3. *We can restrict attention to monotonic securities such that (i)* $r(x) \geq r(x')$*, and (ii)* $s(x) \geq s(x')$ *whenever* $x > x'$*.*

Proof. See the Appendix. □

I now proceed to the characterization of optimal contracts.

3 Privately Optimal Leverage and Disclosure

The results are presented according to the following road-map. In section 3.1 I characterize the optimal portfolio of securities issued for a given π_i. In particular, I show that it is a mixture of debt and equity, with leverage decreasing monotonically with π_i. Moreover, π_i is a sufficient statistic to fully characterize the optimal leverage ratio.

Next, in section 3.2, I characterize the set of Pure Strategy Nash Equilibria (PSNE) of the disclosure game, where the strategy set of each firm simply consists in choosing a $p_i \in [0, 1]$. Despite the simple structure of optimal contracts in the model, the game is generally discontinuous and not quasi-concave. I introduce two mild restrictions on the distribution of output $f(\cdot)$, and show that they are sufficient to obtain a well-behaved – i.e., continuous and quasi-concave – game, with a unique PSNE. Comparative static results are presented and discussed at the end of the analysis.

3.1 Optimal securities for a given disclosure policy

For this section, take p_i as given for every i, and focus on the optimal associated portfolio of securities. The analysis is of independent interest because it generalizes Gale and

Hellwig (1985) – who restricted attention to the case of $\pi_i = 0$ for all i – and it highlights the key driving forces behind optimal securities in a CSV model with signals. For easiness of notation, in this section I omit the subscript i and any reference to the disclosure cost $c(\cdot)$.

To set a benchmark, consider the case of either $\pi = 1$ or $\mu = 0$. The participation constraint for investors in both cases reads $\int_X r(x)dF(x) \geq K$, and $IC(x, x')$ becomes $r(x) \leq x$. It follows that:

Remark 1. *When either $\pi = 1$ or $\mu = 0$, Modigliani and Miller (1958) holds, and every feasible security that makes PC binding is optimal.*

Proof. Immediate from the above reasoning. □

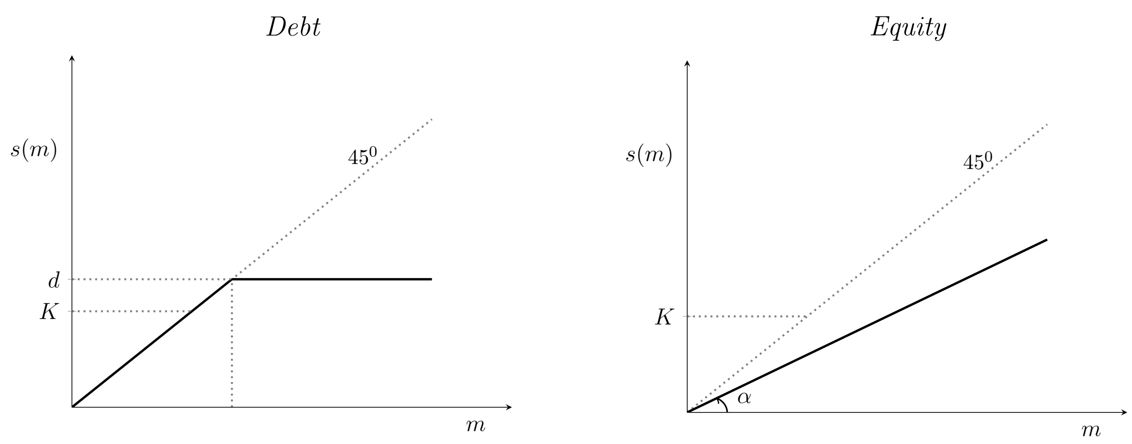
From now onwards, I restrict attention to $\pi < 1$ and $\mu > 0$. Define the two securities that will be part of any optimal contract as follows:

Definition 2. *A security is* debt *if and only if $s(m) = \min\{m, d\}$ for some $d \in X$.*

Definition 3. *A security is* equity *if and only if $s(m) = \alpha m$ for $\alpha \in [0, 1]$.*

The two securities are depicted in Figure 1. It is important to stress that because investment is risky, any feasible debt contract that implements investment must be such that $d > K$, as depicted in the left panel of the Figure. The following proposition characterizes the optimal contract.

Figure 1: The Relevant Securities



Proposition 1. *If $\mathbb{E}_f[\pi\tilde{x}] \geq K$ equity is optimal and debt is suboptimal. If $\mathbb{E}_f[\pi\tilde{x}] < K$ the uniquely optimal contract is a mixture of debt and equity.*

Proof. See the Appendix. □

The result follows from establishing three properties of optimal contracts:

Property 1: when the signal is not informative it is optimal to verify only a convex set of low messages that includes message zero. This is because verifying higher messages imposes a cost and no gains in terms of increasing the feasible and incentive compatible payout from the firm to the investors. Define the following sets: $V \equiv \{m|\sigma(m) = 1\}$, and $NV \equiv \{m|\sigma(m) = 0\}$. Because X is bounded, there must exist $x_{NV} \equiv \inf_{x\in NV}\{x\}$ and $x_V \equiv \sup_{x\in V}\{x\}$. The first property implies that at the optimal contract $x_{NV} > x_V$.

Property 2: whenever $x_{NV} > 0$, the optimal repayment function for every $x \in NV$ is given by:

$$s^*(x) = (1 - \pi_i)x_{NV} + \pi_i x$$

The expression follows from two considerations. First, $r^*(x_{NV}) = x_{NV}$ by monotonicity (i.e., Lemma 3) and the fact that all states $x < x_{NV}$ are verified and hence cannot be profitable deviations by Lemma 2. Second, it is optimal to extract the highest incentive compatible repayment in the no-verification region to push x_{NV} to the minimum possible level that satisfies PC with equality. Under the given $s^*(x) = (1-\pi_i)x_{NV} + \pi_i x$, incentive compatibility binds for every $x \in NV$ and hence it is optimal.

Otherwise, if $x_{NV} = 0$, there exist multiple optimal repayment functions. They only need to be such that the slope is less than or equal to π_i for every state in the no-verification region. Therefore, a pure equity contract with $\alpha \leq \pi_i$ is optimal.

Property 3: for every $x \in V$, $z^*(x, x) = s^*(x) = x$. That is, investors are senior claimants in verification states (that are the model equivalent of bankruptcy). This holds because bankrupt firms have no feasible deviation such that they can repay less (in expectation) than their realized output. As a result, minimization of bankruptcy costs requires them to payout all their output.

Figure 2, Panel (a), depicts the firm's payout at the optimal mixture of debt and equity. Panel (b) sketches the characterization of the optimal contract as a function of both transparency (measured by π) and profitability (measured as the ratio $K/\mathbb{E}_f[\tilde{x}]$). Moving from the bottom-right corner – high profitability, high transparency – toward the top-left corner – low profitability, low transparency – the amount of debt in the optimal contract is increasing. The gray area denotes the parameter region where the first-best (no verification on-the-equilibrium path) can be implemented and firms have zero leverage at the optimal contract. In the upper-left triangle, instead, the solution is second-best and the amount of debt in the contract is increasing in $K/\mathbb{E}_f[\tilde{x}]$ and decreasing in π.

The comparative static results behind the graph will be formally stated and proved in Corollary 3. First, observe that Proposition 1 implies that pure debt is optimal if and only if $\pi_i = 0$.

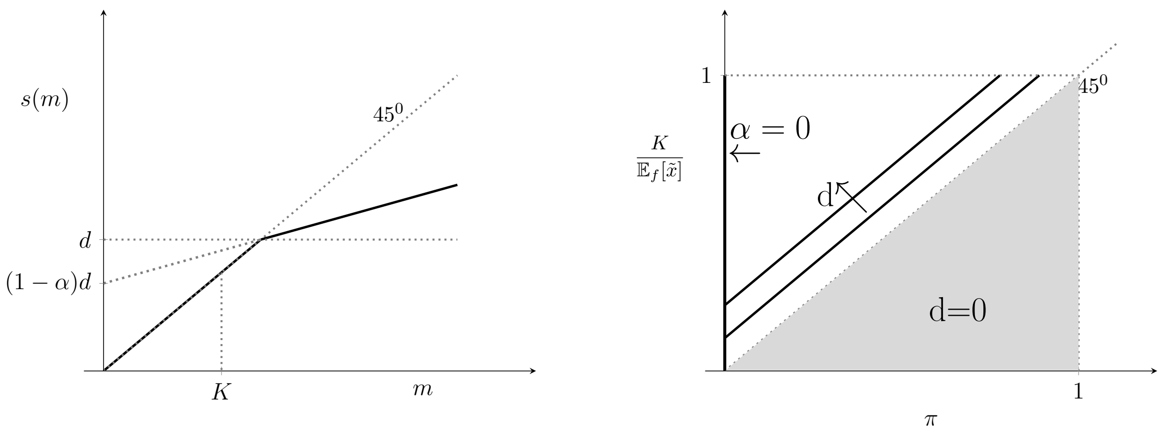
Corollary 1. *Pure debt is optimal if and only if $\pi = 0$.*

Proof. Immediate from Proposition 1, since whenever $x_{NV} > 0$ we must have $\alpha = \pi$. □

Notice that both Proposition 1 and Corollary 1 identify the shape of the optimal contract that implement investment, however they offer no guarantee that investment

Figure 2: Optimal contract

(a) Debt and Equity, Aggregate Payout *(b) Sketch of the Characterization*



would take place. I turn to the question of whether investment occurs or not next.

The expected profits of the investors at a given mixture of debt and equity are denoted by $R(x_{NV}) \equiv \mathbb{E}_f[r(x) - (1-\pi)\sigma(x)\mu] - K$, or:

$$R(x_{NV}) = \int_0^{x_{NV}} [x-(1-\pi)\mu]dF(x) + \int_{x_{NV}}^{\overline{x}} \pi x dF(x) + (1-F(x_{NV}))(1-\pi)x_{NV} - K \quad (6)$$

$R(x_{NV})$ takes values on a compact subset of the real line, and the continuity of $f(\cdot)$ implies that it is continuous in x. As a result, there must exist (at least one) threshold x^* that maximizes $R(x_{NV})$. If there is more than one, pick the smallest. Formally

$$x^* \equiv \min\left\{x_{NV} \,\middle|\, x_{NV} \in \arg\max\, R(x_{NV})\right\} \quad (7)$$

We obtain the following characterization of the financing constraint coming from hidden information:

Corollary 2. *Investment takes place only if $R(x^*) \geq 0$.*

Proof. It follows from the above reasoning. □

In turn, the equilibrium face value of debt d^* is given by:

$$d^* = \min\left\{x_{NV} \,\middle|\, R(x_{NV}) = 0\right\} \quad (8)$$

Although the expected profits of the investors do not necessarily increase with the interest rate in a CSV model (due to the presence of verification costs), it must be that $R(d^*)$ is weakly increasing in its argument. Namely, that the expected *equilibrium* profits of the investors increase at the margin with the interest rate.

Lemma 4. *$R(d^*)$ is weakly increasing in d^*.*

Proof. See the Appendix. □

Because of Lemma 4, the effect of transparency (π), profitability (lower K for a given $\mathbb{E}_f[\tilde{x}]$) and verification costs (μ) on leverage (d^*) are monotonic and can be easily derived.

Corollary 3. *Cæteris paribus, leverage (d^*) is monotonically increasing in profitability and decreasing in transparency. It also increases with the verification cost.*

Proof. See the Appendix. □

The effect of transparency and profitability on optimal leverage ratios is depicted in Figure 2, panel (b). More transparent firms can finance with equity projects of relatively lower profitability. As the converse, firms that are more opaque need to have highly profitable investment opportunities to issue equity, it is otherwise optimal for them to borrow (to some degree).

To provide some more intuition, I conclude the section solving an example.

Example. Suppose that $\tilde{x}$ is distributed uniformly and $X = [0, 10]$. If the verification cost is given by $\mu = 1$ and $K = 4$, the optimal leverage ratio (i.e. debt over total assets) is depicted in Figure 3, panel (a). Zero-leverage firms are such that $\pi > 4/5$, else some amount of debt will be issued, monotonically decreasing in transparency.

Consider now $\pi \leq 4/5$. The PC reads:

$$\int_0^d [x - (1-\pi)]dx + \int_d^{10} [\pi x + (1-\pi)d]dx = 40$$

which can be rewritten as: $0.5(1-\pi)d^2 - 9(1-\pi)d + 40 - 50\pi = 0$. Of the two roots, it is easy to check that we should always pick the negative one. Therefore, we get:

$$d^* = 9 - \frac{\sqrt{-19\pi^2 + 18\pi + 1}}{1-\pi}$$

Moreover, the derivative of the expression with respect to π reads:

$$\frac{\partial d^*}{\partial \pi} = \frac{-10}{(1-\pi)\sqrt{-19\pi^2 + 18\pi + 1}} < 0$$

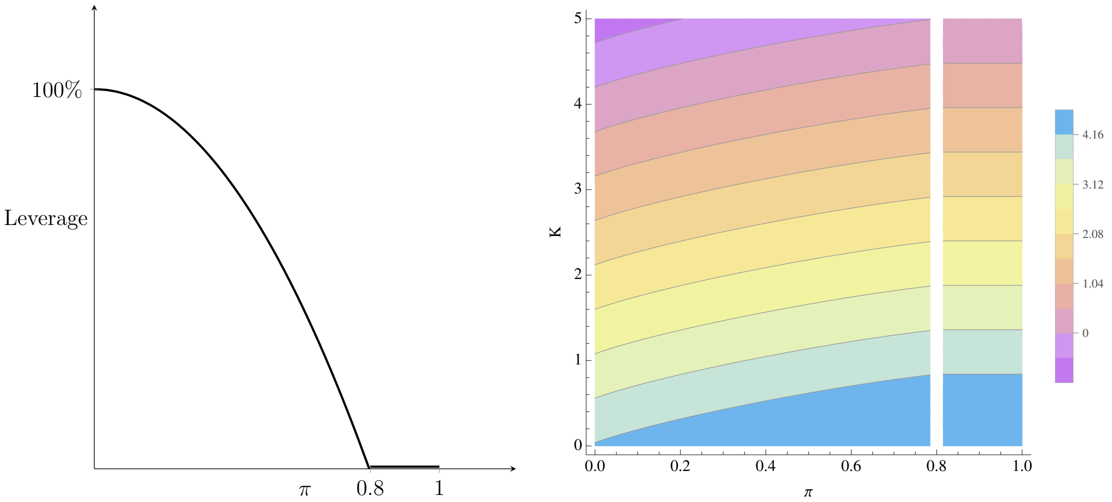
Panel (b) plots the firm's profits as a function of both π and K. In the purple region at the top-left corner, investment does not take place (in fact, firm's profits show to be negative in this region). Otherwise, investment takes place and profits are decreasing in K and increasing in π. In particular, profits are strictly increasing in transparency when some debt is issued (i.e., $\pi < 0.8$), and constant otherwise.

3.2 Optimal disclosure policies

The previous section offered a characterization of the optimal contract as a function of π_i. The optimal contract is unique whenever verification takes place on-the-equilibrium path,

Figure 3: Optimal Contract in the Example

(a) Leverage and Transparency *(b) Firm profits (gross of disclosure costs)*



and it can be implemented by pure equity otherwise. In this section, we take advantage of this characterisation to derive the equilibria of the disclosure game.

To set a benchmark, consider what happens when disclosure is costless. From PC, it is obvious that the entrepreneur only gains from increasing p_i, as it prevents any need for ex post verification. Therefore, full disclosure is expected:

Remark 2. *If disclosure is costless (i.e., if $c(p_i) = 0$, $\forall p_i$ and $\forall i$), optimal contracts are such that $p_i^* = p_j^* = 1$ for all i, j and Modigliani and Miller (1958) holds.*

Proof. Immediate from the above reasoning and Remark 1. □

A more interesting and realistic scenario occurs when disclosure is costly – e.g., the fee charged by an independent audit firm. Increasing the degree of disclosure on the one hand raises the disclosure cost $c(p_i)$, on the other it lowers the costs of financing by enabling the entrepreneur to issue more (cheaper) equity, hence decreasing the face value of debt and the expected dead-weight verification costs.

Observe that (8) allows us to express d_i^* as a function of p_i through its dependence on $\pi_i(p_i, p_{-i}, q_{-i})$, for any given strategy of the other $N-1$ firms. Moreover, we can disregard every p_i such that $p_i > K/\mathbb{E}_f[\tilde{x}]$ (regardless of strategy of the opponents), because it is dominated by $p_i = K/\mathbb{E}_f[\tilde{x}]$. To rule out uninteresting corner solution, suppose that the cost function satisfies the following Inada conditions:

Assumption 3. *The cost function $c(\cdot)$ is strictly increasing ($c' > 0$), strictly convex ($c'' > 0$) and it satisfies the following Inada conditions: $c(0) = c'(0) = 0$ and $c'(1) \to +\infty$.*

Because the optimal capital structure can be fully described by π_i, Program (5) can be rewritten as follows:

$$p_i^* \in \underset{p_i \in [0, K/\mathbb{E}_f[\tilde{x}]]}{\arg\max} \quad V(p_i, p_{-i}) \equiv \mathbb{E}_f[\tilde{x}] - (1 - \pi_{\text{i}}(\text{p}_{\text{i}}, \text{p}_{\text{-i}}, \text{q}_{\text{-i}}))F(d^*(\pi_{\text{i}}(\text{p}_{\text{i}}, \text{p}_{\text{-i}}, \text{q}_{\text{-i}})))\mu - c(p_i) - K \tag{9}$$

The objective function $V(p_i, p_{-i})$ need not be differentiable with respect to p_i, because $d^*(\pi_{\text{i}}(\text{p}_{\text{i}}, \text{p}_{\text{-i}}, \text{q}_{\text{-i}}))$ may jump as p_i changes infinitesimally. This phœnomenon happens when the payout to investors does not increase with the face value of debt – that is, when $(1 - F(d^*)) = f(d^*)\mu$[31] – and such discontinuities are problematic for the existence of a solution to the program. However, if the set of points such that the equality holds is empty, then $d^*(\pi_{\text{i}}(\text{p}_{\text{i}}, \text{p}_{\text{-i}}, \text{q}_{\text{-i}}))$ is differentiable and so is $V(p_i, p_{-i})$.

Define the following threshold, which corresponds to the equilibrium face value of debt of a standard CSV model with $\pi_i = 0$:

$$\bar{d} \equiv \min \left\{ x \in X \;\middle|\; \int_0^x [x - \mu] dF(x) + (1 - F(d))d = K] \right\}$$

A sufficient condition for differentiability of $d^*(\pi_{\text{i}}(\text{p}_{\text{i}}, \text{p}_{\text{-i}}, \text{q}_{\text{-i}}))$ is the following:

Lemma 5. *The objective function $V(p_i, p_{-i})$ is differentiable if the hazard rate $h(x)$ is uniformly bounded so that:*

$$h(x) \equiv \frac{f(x)}{(1 - F(x))} < \frac{1}{\mu}, \quad \forall x \leq \bar{d} \tag{10}$$

Proof. See the Appendix. □

The condition has a natural economic interpretation. It guarantees that the gains to the investors coming by an increase in the face value of debt (e.g., a marginally higher interest rate) more than compensate the losses due to verification. The bound becomes tighter when the verification cost μ increases, and/or profitability falls.

If (10) holds, Program (9) is guaranteed to have at least one solution by the theorem of the maximum. Moreover, totally differentiating (8) with respect to x_{NV} and p_i, and evaluating at $x_{NV} = d_i^*$ yields:

$$\frac{\mathrm{d}\, d_i^*}{\mathrm{d}\, p_i} = \frac{\mathrm{d}\, d_i^*}{\mathrm{d}\, \pi_i} \cdot \frac{\mathrm{d}\, \pi_i}{\mathrm{d}\, p_i} = -\frac{\mathrm{d}\, \pi_i}{\mathrm{d}\, p_i} \cdot \frac{\mu F(d_i^*) + \int_{d_i^*}^{\bar{x}} [x - d_i^*] dF(x)}{(1 - \pi_i)\big[1 - F(d_i^*) - \mu f(d_i^*)\big]} < 0 \tag{11}$$

where the inequality follows from three observations: (i) π_i is strictly increasing in p_i; (ii) $\mu F(d_i^*) + \int_{d_i^*}^{\bar{x}} [x - d_i^*] dF(x) > 0$ for every $d_i^* \in X$; and finally (iii) $(1 - \pi_i)\big[1 - F(d_i^*) - \mu f(d_i^*)\big] > 0$ by inequality (10) and Assumption 1.[32]

[31] Recall that by Lemma 4 it can never be the case that $(1 - F(d^*)) < f(d^*)\mu$.

[32] Assumption 1 implies that $K/\mathbb{E}_f[\tilde{x}] < 1$, so it is never the case that $(1 - \pi_i) = 0$, irrespective of q.

As a result, the first derivative of the objective function $V(p_i, p_{-i})$ reads:

$$\frac{\partial V(p_i, p_{-i})}{\partial p_i} = \mu \frac{\partial \pi_i}{\partial p_i} \underbrace{\left[F(d_i^*) + f(d_i^*) \cdot \frac{\mu F(d_i^*) + \int_{d_i^*}^{\bar{x}} [x - d_i^*] dF(x)}{1 - F(d_i^*) - \mu f(d_i^*)} \right]}_{\equiv \gamma > 0} - c'(p_i) \tag{12}$$

Equation (12) formalizes the trade-off that underpins the choice of an optimal disclosure policy: on the one hand, greater disclosure comes at a higher marginal cost c' (due to the strict convexity of the cost functional), on the other it pushes leverage down – enabling the firm to issue a larger fraction of incentive compatible equity – at a gain proportional to $\gamma > 0$.

The second derivatives with respect to p_j for $j = 1, ...N$ is a relatively long collection of terms, and therefore I leave its derivation and explanation to the Appendix (at the beginning of the proof of Lemma 6). It suffices to mention here that most of the terms can be signed to be negative, suggesting that the problem has a certain degree of concavity built in, and coming from the participation constraint for the investors (the zero profit condition). Indeed, a lower bound on the derivative of the density function is sufficient for $V(p_i, p_{-i})$ to be strictly concave, as the next lemma shows:

Lemma 6. *A sufficient condition for $V(p_i, p_{-i})$ to be strictly concave is the following:*

$$f'(x) > -\frac{1}{h(x)^{-1} - \mu}, \quad \forall x \in [0, \bar{d}] \tag{13}$$

Proof. See the Appendix. □

The condition in Lemma 6 is not very restrictive if (10) holds, as $h(x)^{-1} > \mu$ and the lower bound is negative. Moreover, alike (10), it is a straightforward property to check. From now onwards, I assume that both restrictions on the distribution of output hold, so that the disclosure game is well behaved:

Assumption 4. *Both (10) and (13) hold. Hence, $V(p_i, p_{-i})$ is $\mathbb{C}^2$ and strictly concave.*

Define *strict sub-modularity* and *aggregativity* of a game as follows:

Definition 4. *A game is* strictly sub-modular *if $\partial V(p_i, p_{-i})/\partial p_i \partial p_{j \neq i} < 0$ for every i and for every $j \neq i$.*

Definition 5. *A game is* aggregative *if there exists a continuous and additively separable function $g : [0, 1]^{N-1} \to [0, 1]$ (the aggregator) and functions $\bar{V} : [0, 1]^2 \to \mathbb{R}$ (the reduced payoff functions) such that for each player i:*[33]

$$V(p_i, p_{-i}) = \bar{V}(p_i, g(p_{-i})), \ \forall \, \mathbf{p} \in [0, 1]^N$$

From these definitions, and from Assumption 4, it follows that:

[33] Both definitions are the analog of those in Acemoglu and Jensen (2013), for instance, for the case of one-dimensional strategy sets.

Lemma 7. *The disclosure game is aggregative and strictly sub-modular.*

Proof. See the Appendix. □

The aforementioned properties guarantee both the existence of a PSNE, and the presence of monotone comparative statics with respect to the correlation parameter q.

Proposition 2. *The set of Pure Strategy Nash Equilibrium (PSNE) is non-empty, and each firm $i = 1, ...N$ chooses a disclosure policy p_i^* such that:*

1. *If $V_1(K/\mathbb{E}_f[\tilde{x}], \mathbf{p}^*_{-\mathbf{i}}) > 0$, $p_i^* = K/\mathbb{E}_f[\tilde{x}]$;*
2. *Otherwise $V_1(p_i^*, \mathbf{p}^*_{-\mathbf{i}}) = 0$ and $p_i^* \in [0, K/\mathbb{E}_f[\tilde{x}])$.*[34]

Moreover, the smallest and the largest equilibria, denoted by $Q_*(q)$ and $Q^*(q)$ respectively, are such that: $Q_* : [0,1]^{\frac{N(N-1)}{2}} \to \mathbb{R}$ is lower semi-continuous and $Q^* : [0,1]^{\frac{N(N-1)}{2}} \to \mathbb{R}$ is upper semi-continuous.

Proof. See the Appendix. □

Existence of a PSNE follows from three properties of the game: (i) the convexity and compactness of the strategy set $[0, 1]$, for all i; (ii) the continuity of $V(p_i, p_{-i})$ in all arguments; and (iii) the quasi-concavity of $V(p_i, p_{-i})$ in p_i. Aggregativity and sub-modularity also imply that monotone comparative statics with respect to the correlation vector q_{-i} can be derived:[35]

Corollary 4. *Cæteris paribus, the equilibrium disclosure p_i^* decreases with $q_{i,j}$, for every i, j. The equilibrium leverage might decrease or increase with $q_{i,j}$.*

Proof. See the Appendix. □

Summing up, the equilibrium disclosure policies are a function of the correlation vector q, and the higher the correlation the lower the disclosure of each firm, because the larger the gains from free riding on the information produced by competitors. It remains to consider the efficiency properties of the private disclosure and leverage policies, which is the subject of the next section.

4 Socially Optimal Leverage and Disclosure

The set of Socially Efficient (SE) disclosure policies can be simply defined as the set of disclosure vectors of length N that maximize the aggregate surplus:

$$SE \equiv \left\{ p^e \in [0,1]^N \;\middle|\; p^e \in \arg\max_{p \in [0,1]^N} \sum_{i=1}^{N} V(p_i, p_{-i}) \right\}$$

The set SE is non-empty, and can be characterized as follows:

[34]As standard, V_1 denotes the derivative of V with respect to the first argument.

[35]See Acemoglu and Jensen (2013) for general results, of which my results are a special case.

Proposition 3. *There exists a non-empty set of Socially Efficient (SE) disclosure policy vectors such that* $p^e > p^*$, *where* p^* *belong to the largest Nash equilibrium* $Q^*(q)$. *In addition,* $p^e >> p^*$ *whenever* $q_{-i} > 0$.

Proof. See the Appendix. □

Proposition 3 shows that the presence of disclosure spillovers across firms leads to an inefficiently low private provision of information, and consequently inefficiently high leverage ratios. A social planner could increase the aggregate welfare by promoting higher disclosure and lower borrowing. How could the result be achieved?

A first policy would focus on mandatory disclosures, and mandate that firms disclose according to the vector p^e. However, there may be limits in the efficacy of mandatory requirements, especially when dealing with firms that are naturally opaque (such as banks or insurance companies).

In fact, opaque sectors such as the financial industry are regulated according to different principles. In particular, they tend to be subject to mandatory *capital requirements* – that is, a certain amount of their assets must be backed by equity claims. At present, Basel III confirms capital requirements in the range of 4% of the risk weighted assets for banks.[36] This paper shows that mandatory capital requirements may well be welfare increasing, and can be an alternative to disclosure regulation in those instances where reaching effective disclosures may prove daunting. The result is summarized in the following proposition.

Proposition 4. *When* $q_{-i} > 0$ *for some* i, *the SE can be implemented as a PSNE either mandating a certain amount of disclosure* p_i^e, *or mandating capital requirements of size* l_i^e.

Proof. The case for mandatory disclosure is straightforward: simply solve for the SE, and set p_i^e equal to the disclosure at the unique SE.

If disclosure cannot be mandated effectively, consider the leverage at the SE: it would be $\alpha_i^e = p_i^e$ by Proposition 1. Then, compute the corresponding $d(p_i^e)$, and set:

$$l_i^e \equiv \frac{d(p_i^e)}{d(p_i^e)(1-p_i^e) + p_i^e \mathbb{E}_f[\tilde{x}]}$$

Note that: $l_i^e = 0$ if $d(p_i^e) = 0$, and $l_i^e = 1$ if $d(p_i^e) = \bar{d}$ (which implies that $\alpha_i^e = 0$). □

An important remark on the implementation of socially efficient outcomes concerns the assumption that the regulator knows the degree of connectedness of individual firms. Although we implicitly assumed that the market knows such information, and price it correctly, it could be that a regulator does not know it. In such a scenario, it cannot rely on firms disclosing truthfully their *systemic risk*: all firms have strong incentives to

[36] However, many policy makers and academics called for substantially higher requirements. For instance, Calomiris called for 10%, Admati and Hellwig 20-30%, and Kotlikoff 100%.

under-report so they can avoid the regulatory requirements. Similar problems arise in most models of disclosure under externalities, such as Admati and Pfleiderer (2000).[37]

Though this limitation is likely to be relevant in practice, observe that current US regulation is implicitly following the approach sketched here, when it imposes additional capital requirement to the *too-big-too-fail* institutions. Effectively, the regulator is using a measure of the *size* of firms to capture their potential interconnectedness, and requires better capitalization precisely when the model I presented suggests it to be necessary. Better measures are currently studied by academics and policy makers.

I conclude the section by returning to our example, and solving for the privately and socially optimal disclosure policies.

Example (cont'd). Recall from the previous analysis that:

$$d^* = \begin{cases} 9 - \dfrac{\sqrt{-19\pi_i^2 + 18\pi_i + 1}}{1 - \pi_i} & \text{if } \pi \le 4/5 \\ 0 & \text{otherwise} \end{cases}$$

The function is continuous, and inequality (10) holds because: (i) $\bar{d} = 8$; and (ii) the hazard rate reads: $1/(10 - x)$, which is strictly less than $1/\mu = 1$ for every $x \in [0, 9]$. Moreover, $f' = 0$ implies that (13) holds.

Suppose that $N = 2$, $\pi_i = p_i + q(1 - p_i)p_{j \neq i}$ for both firms, and $c = |1 - 0.8(0.8 - p_i)^{-1}|/100$. Program (5) can be written as:

$$\max_{p_i \in [0,0.8]} V(p_i, p_{-i}) = -\frac{1 - \pi_i}{10}\left[9 - \frac{\sqrt{-19\pi_i^2 + 18\pi_i + 1}}{1 - \pi_i}\right] - \frac{|1 - 0.8(0.8 - p_i)^{-1}|}{100} + 1 \quad (14)$$

It is easy to check that $\partial^2 V(p_i, p_{-i})/\partial p_i^2 < 0$ and $\partial^2 V(p_i, p_{-i})/\partial p_i \partial p_{-i} < 0$. As a result, there exists a unique interior maximum, fully characterized by the first order condition: $\partial V(p_i^*, p_{-i})/\partial p_i = 0$.

In contrast, exploiting symmetry, the socially optimal disclosure can be derived as the solution of a planner's problem, who maximizes aggregate welfare with $p_i = p_{-i} = p$:

$$\max_{p \in [0,0.8]} W(p) \equiv \frac{p + q(1-p)p - 1}{5}\left[9 - \frac{\sqrt{-19(p + q(1-p)p)^2 + 18(p + q(1-p)p) + 1}}{1 - p - q(1-p)p}\right] \quad (15)$$

$$- \frac{|1 - 0.8(0.8 - p_i)^{-1}|}{50} + 2 \quad (16)$$

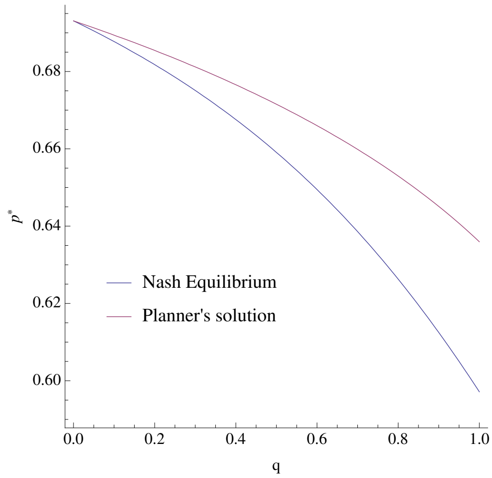
Again, it is easy to check that the planner's objective function is strictly concave in p. Hence, the socially optimal disclosure level satisfies: $\partial W(p^*)/\partial p = 0$.

The SNE and the planner's solution are plotted in Figure 4. As expected, in the

[37] I overlook them here not because they are unimportant, but because their consequences are obvious: the regulation trades off a distortion due to 'pooling' with the benefits of enhanced disclosure and lower leverage. The final result depends on parameter values.

absence of externalities (i.e., when $q = 0$) the private and social optimum coincide. However, for every $q > 0$ the SNE displays an inefficiently low level of disclosure, relative to the social optimum. Moreover, the divergence between private and social optimum increases with the externality parameter q.[38] From Proposition 1, it follows that leverage is inefficiently high whenever $q > 0$, and the inefficiency is increasing in q.

Figure 4: Privately and Socially optimal disclosure policies



5 Empirical analysis

In order to check whether the predictions of the model appear consistent with the empirical evidence, I first build a firm-level panel of the universe of US public firms, then I construct various measures of transparency and leverage (as well as other standard controls), and finally I run a series of regressions.

To construct my data, I combine two sources: (i) the CRSP/COMPUSTAT merged dataset; and (ii) the IBES analysts' forecast dataset. To do so, I follow the path described below.

I first collect the raw CRSP/Compustat merged dataset, which contains balance sheet information about the universe of US public corporations, as well as the prices of their securities for the period 1979-2014. From the original file, I drop the observations that satisfy at least one of the following requirements: (i) total assets (AT) are missing or negative; (ii) the firm is not US based (i.e. FIC≠USA); (iii) total liabilities (LT) are missing or negative; (iv) total liabilities exceed total assets (LT>AT); (v) either the equity price (PRCC) or the market capitalization (CSHO) are missing.

Then I collect the detail IBES dataset (adjusted for stock splits), which contains individual analysts' forecasts for US corporates EPS (Earnings per share). For any given firm-year pair, I generate the following summary statistics: (i) NUMEST – the number of

[38] This is an instance of the monotone comparative static derived in Acemoglu and Jensen (2013) for more general (though still aggregative) sub-modular games.

analysts' estimates of expected EPS; and (ii) CV – the coefficient of variation of analysts' forecasts (i.e. their standard deviation normalized by the mean). I drop those firm-date pairs for which there are less than five analysts' forecast, and I collapse the data at the firm-year level.[39]

The procedure ends with 32,361 matched firm-year pairs such that (i) both Compustat and IBES data is successfully merged, and (ii) more than five forecasts are available.

Table 1: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
LT/AT	0.56	0.24	0	1	32361
CV forecasts	0.07	0.15	0	7.92	32361
Estimates	13.12	8.19	5	59	32361
Total Assets	7.29	1.87	-0.03	14.7	32361
Profitability	0.01	0.18	-5.88	4.1	32361
Book-to-Market	0.59	0.56	0	21.26	32361
Intangibles	0.13	0.18	0	0.92	28949
Industry Leverage	0.57	0.18	0.17	0.94	32361

The descriptive statistics for the variables of interest are reported in Table 1. The definition I adopt of leverage includes both financial and non-financial liabilities (as suggested in Welch (2011)), and it is easily computed as the ratio of total liabilities (LT) over total assets (AT).[40] The Book-to-Market ratio is computed as the book value of a share (PRCCF) multiplied times the total number of outstanding shares (CSHO), and then divided by the market value of equity (MEQ). Intangibles consists in the fraction of intangible assets, defined as INTAN/AT. Finally, Total Assets are reported as the natural logarithm of AT, hence the negative minimum numbers which obtain for AT $\in (0, 1)$.

I now proceed to the regression analysis. I follow the procedure of gradually introducing independent variables, to check how the sensitivity and significance of the coefficients of interest evolve. The general linear regression that I estimate takes the following form (where i indexes firms and t years):

$$\text{Leverage}_{i,t} = \alpha + \beta X_{i,t-1} + \gamma_i + \gamma_t + \epsilon_{i,t}$$

where the matrix $X_{i,t}$ includes various covariates of a firm-date pair, among which the main regressor of interest (i.e. CV – the coefficient of variation of analysts' forecasts).

The regression results are reported in Table 2. I first regress leverage on CV, a constant and the time dummies (column (1)). Then, in column (2) I add the set of controls that

[39]In the empirical Appendix, I conduct robustness exercises where I let the cutoff run from 1 to 4, and show the results are unchanged. Moreover, I consider alternatives to CV such as the median absolute deviation from the mean (both normalized and not). Again, the results do not change.

[40]Other definitions I consider in the Appendix are: (i) LT/AM, where AM stands for market value of assets; (ii) DT/AT, where DT = DLC + DLTT refers to the aggregate financial liabilities (debt); and finally (iii) DT/AM. Overall, the qualitative results are not very sensitive to the leverage measure chosen, although they are more statistically significant when book values are considered rather than market values.

Table 2: Regression table

	(1) LT/AT	(2) LT/AT	(3) LT/AT	(4) LT/AT	(5) LT/AT	(6) LT/AT
L.CV forecasts	0.0983***	0.0427**	0.0432***	0.0217*	0.0342**	0.0354**
	(5.11)	(2.90)	(4.18)	(2.53)	(2.99)	(2.72)
L.Total Assets		0.0589***		0.00934	0.00596	0.00539
		(31.28)		(1.73)	(1.06)	(0.82)
L.Profitability		-0.193***		-0.170***	-0.160***	-0.216***
		(-6.28)		(-7.96)	(-7.33)	(-7.79)
L.Book-to-Market		-0.000492		0.00132	-0.00218	-0.0143**
		(-0.10)		(0.33)	(-0.50)	(-2.75)
L.Intangibles		-0.000937		0.0260	0.0303	0.00306
		(-0.05)		(1.06)	(1.19)	(0.10)
L.Industry Leverage		0.466***		0.146**	0.135*	0.123
		(22.09)		(2.67)	(2.27)	(1.77)
Constant	0.544***	-0.111***	0.592***	0.424***	0.420***	0.504***
	(49.22)	(-8.19)	(133.26)	(7.55)	(7.42)	(6.49)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	Yes	Yes	Yes	Yes
Exclude Finance	No	No	No	No	Yes	No
10 forecasts or more	No	No	No	No	No	Yes
Observations	26337	23499	26337	23499	19121	13395
Adjusted R^2	0.010	0.479	0.847	0.846	0.778	0.856

t statistics in parentheses. $^{*}\ p < 0.05$, $^{**}\ p < 0.01$, $^{***}\ p < 0.001$

Sources: Compustat merged with CRSP (annual), IBES (detail, adjusted for stock splits).

Notes: all independent variables are lagged by one year. Standard errors are clustered at the firm level.

the previous papers (e.g. Frank and Goyal (2009)) identified as reliable predictors of the leverage of a firm. In column (3) I regress leverage on CV, a constant, the time dummies and firms fixed effects. Column (4) adds the controls to the fixed-effect regression of column (3). Next, I present two robustness checks: in column (5) I restrict attention to non-financial firms; in column (6) I increase the cutoff on the number of forecasts to ten. In both cases, the coefficient of interest remains significant, and it even marginally increases in magnitude relative to that of column (4).[41]

Importantly, the sign of most other controls is consistent with previous studies. Profitability is strongly negatively correlated with leverage. Average industry leverage is strongly positively correlated with leverage. Total assets (i.e., size) is positively correlated with leverage, though the correlation vanishes after the inclusion of firms fixed effects. Both the Book-to-Market ratio and the fraction of intangible assets are not robustly signed. Finally, the inclusion of firms fixed effects explains about 50% of the observed variation in leverage, consistently with other studies such as Lemmon et al. (2008).

Overall, the results support the predictions of the model I propose, although a validation of the my hypotheses with statistical causality is left for future research.

6 Conclusions

This paper analyses the effect of disclosure on the composition of financing means for firms. In a novel costly-state-verification setting with variable and endogenous degrees of asymmetric information between firms and investors, the paper highlights that disclosure and leverage should be negative correlated. Higher disclosure leads to the possibility of issuing cheaper incentive-compatible stocks, hence increasing the opportunity of leveraged financing and its bankruptcy costs.

I find this prediction consistent with the empirical evidence for US public firms after the 1980s, to the extent that effective transparency is correlated to the dispersion in analysts' EPS forecasts. Of course, the dispersion in analysts forecasts appears a noisy proxy of transparency, and one needs to confirm that the results are robust across various alternative measures in future work. Nevertheless, the validity of the correlation derived in the paper hinges on the observing that most factors that influence the dispersion of forecasts, such as herding or contrarianism, and not linked unambiguously to leverage ratios by any existing theory.

The presence of disclosure externalities across firms yields insufficient voluntary disclosure and excessive leverage, relative to the constrained best. Therefore, it brings about the question of regulation. If regulators can effectively mandate truthful disclosures, then social efficiency can be restored. However, the explicit treatment of the inter-linkage between disclosure and financing policies suggests an additional tool that regulators should explore when truthful disclosures prove hard to implement: capital requirements. By

[41] In the Appendix, I run additional robustness exercises and show that the results are qualitatively similar throughout various specifications.

setting higher capital requirements, regulators promote endogenously enhanced transparency and can restore social efficiency.

The argument for mandatory capital standards I put forward relies on two pillars: (i) firms' output should be sufficiently correlated (e.g., in the presence of high systemic risk); and (ii) mandatory disclosures are hard to translate into greater transparency, because they can be dodged to a large extent. Both conditions plausibly apply to financial firms, and indeed they are the subject of regulatory capital requirements.

Moreover, the argument is immune from the most common critique of the existing, alternative, story based on the absorbing of losses in crises (e.g., Admati and Hellwig (2014)). Banking lobbyists commonly counter argue that, although ex-post desirable in crises times, capital requirement are ex-ante detrimental to credit extension and would dampen growth during boom times, because they increase the cost of funding for banks. Indeed, if this was not the case we would observe already much higher equity financing in the financial industry. The model I present is immune from this critique, because capital requirements are efficient ex ante, and solve a coordination failure in information provisions across firms.

As always with regulation, the devil lies in the details. Moreover, important aspects such as agency problems within firms and on the government side have been ignored here, for the sake of simplicity. Any regulatory effort must confront such issues convincingly in order to be credible. All this paper wishes to achieve is to raise awareness that the debates around capital requirements and mandatory disclosures for financial firms should be more closely connected both in the policy and in the academic arenas.

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A Proofs

Lemma 2

Proof. **Claim (i).** Suppose there exists an optimal contract $\{s, z, \sigma, p\}$ such that:

$$\{x \,|\, z(m, x) < x, \quad \text{for some } \; m \neq x\} \neq \emptyset$$

Consider replacing it with another contract $\{s', z', \sigma', p'\}$ such that $\sigma = \sigma'$, $s = s'$, $p = p'$ and:

$$z'(m, x) = \begin{cases} x & \text{if } m \neq x \\ z(m, x) & \text{otherwise} \end{cases}$$

Clearly, the new contract is feasible because when $\sigma = 1$ the maximum feasible claw-back equals x. To see that it is incentive compatible, observe that because $\{s, z, \sigma, p\}$ is optimal, we know that $r(x) \leq r(x, x')$ for every pair x, x'. We also know that (i) $r(x) = r'(x)$ for every x, and (ii) $r(x, x') \leq r'(x, x')$ for every x, x' by construction. Hence, $\{s', z', \sigma', p'\}$ is incentive compatible. The participation constraint remains binding because $\mathbb{E}_f[r'(x)] = \mathbb{E}_f[r(x)]$, and the dead-weight loss due to verification and disclosure do not change. Therefore, the entrepreneur is indifferent between $\{s, z, \sigma, p\}$ and $\{s', z', \sigma', p'\}$, proving our claim.

Claim (ii). It mirrors the proof of claim (i): start with an optimal $\{s, z, \sigma, p\}$ that does not satisfy the property (i.e., $\sigma(m) = 0$ for some $m < y$). For all such cases, replace σ with $\sigma' = 1$. Otherwise, set $\sigma = \sigma'$, $z = z'$ and $s = s'$ and $p = p'$ Because the change occurs only off-equilibrium path, the participation constraint remains unchanged. Furthermore, incentive compatibility and feasibility are trivially satisfied, proving the claim. □

Lemma 3

Proof. **Claim (i).** First, we know that when $\pi = 0$ the optimal contract is debt, and it is monotonic (Gale and Hellwig (1985)). Therefore, we can restrict attention to $\pi > 0$ and consider an optimal contract $\{s, z, \sigma, p\}$. Suppose that under $\{s, z, \sigma, p\}$ there exists a set $A \subset X$ and an $\hat{x}$ such that $A \equiv \{x > \hat{x} | r(\hat{x}) > r(x)\}$. Evidently, the contract is not monotonic. Without loss of generality, suppose there only exists one such $\hat{x}$ (if there was more than one, the same reasoning could be iterated).

Consider another contract $\{s', z', \sigma', p'\}$ such that $\sigma = \sigma'$, $p = p'$, $s'(x) \in [s(x), x]$, $z'(x, x) \in [z(x, x), x]$ and:

$$r'(x) = \begin{cases} r(x) & \text{if } x \notin A \\ r(\hat{x}) & \text{otherwise} \end{cases}$$

The new contract is feasible because $r(\hat{x}) \leq \hat{x} < x$ for every $x \in A$. To show that it is also incentive compatible, I partition the state according to whether they belong to A or not.

First, consider $x \notin A$. By construction (i) $r'(x) = r(x)$, and (ii) $r'(x', x) \geq r(x', x)$ for every x'. Hence, because $\{s, z, \sigma, p\}$ was incentive compatible, incentive compatibility holds also under $\{s', z', \sigma', p'\}$.

Second, consider $x \in A$. From the way I constructed r', I know that $r'(x') = r(x')$. First, $IC(\hat{x}, x')$ under the old contract reads:

$$\hat{x} - r(\hat{x}) \geq (1 - \pi)(1 - \sigma(x'))[\hat{x} - s(x')] \Rightarrow \hat{x} \geq \frac{r(\hat{x}) - (1 - \pi)(1 - \sigma(x'))s(x')}{\pi + (1 - \pi)\sigma(x')}$$

The ratio is well defined because $\pi > 0$. Under the new contract, by construction we have: $\sigma'(x') = \sigma(x')$;

$s'(x') = s(x')$ and $r'(\hat{x}) = r(\hat{x})$, so we can write:

$$\hat{x} \geq \frac{r(\hat{x}) - (1-\pi)(1-\sigma(x'))s(x')}{\pi + (1-\pi)\sigma(x')} = \frac{r'(\hat{x}) - (1-\pi)(1-\sigma'(x'))s'(x')}{\pi + (1-\pi)\sigma'(x')}$$

Observe that $IC(x, x'')$ under the new (prime) contract reads:

$$x \geq \frac{r'(x) - (1-\pi)(1-\sigma'(x'))s'(x')}{\pi + (1-\pi)\sigma(x')} = \frac{r'(\hat{x}) - (1-\pi)(1-\sigma'(x'))s'(x')}{\pi + (1-\pi)\sigma'(x')}$$

where the last equality holds by construction of the new contract $\{s', z', \sigma', p'\}$ – i.e., the fact that, for every $x \in A$, $r'(x) = r(\hat{x})$. Since $x > \hat{x}$ the prime contract is incentive compatible as well.

Now consider the participation constraint. Regardless of the measure of the set A, at the prime contract the investors make strictly positive profits. Define a third contract $\{s'', z'', \sigma'', p''\}$ such that $p'' = p' = p$, $\sigma'' = \sigma' = \sigma$, $z'' = \alpha z'$ and $s'' = \alpha s'$ for some $\alpha \in [0,1]$ such that: $\mathbb{E}_f[r''(x) - (1-\pi)\sigma''(x)\mu] = \mathbb{E}_f[\alpha r'(x) - (1-\pi)\sigma''(x)\mu] = K$ We know that such an α exists because: (i) when $\alpha = 1$ we have $\mathbb{E}_f[\alpha r'(x) - (1-\pi)\sigma''(x)\mu] \geq K$; (ii) when $\alpha = 0$ we have $\mathbb{E}_f[-(1-\pi)\sigma''(x)\mu] < 0$; and (iii) the left hand side of the equation is continuous in α. The new (double-prime) contract is feasible because $\alpha \in (0,1)$, and it is trivially incentive compatible. Because the dead-weight loss does not change and the investors make zero profits, the firm must be indifferent between $\{s, z, \sigma, p\}$ and $\{s'', z'', \sigma'', p''\}$, proving the claim.

Claim (ii) Consider an optimal contract $\{s, z, \sigma, p\}$ that satisfies Claim (i). Suppose there exists an interval $A \subset X$, such that $s(x) < s(\hat{x})$ for every $x \in A$ and some $\hat{x} < \inf\{x | x \in A\}$. The repayment function is not monotonic. Introduce another contract $\{s', z', \sigma', p'\}$ such that: $p = p'$, $\sigma = \sigma'$, $r = r'$ but:

$$s'(m) = \begin{cases} s(m) & \text{if } m \notin A \\ s(\hat{x}) & \text{otherwise} \end{cases}$$

Of course, for all $x \in A$ the fact that $r = r'$ and the shape of s' imply that:

$$z'(x,x) = z(x,x) - \frac{(1-\pi)}{\pi}[s(\hat{x}) - s(x)] < z(x,x)$$

The new repayment function is monotonic. To see that the prime contract is feasible, notice that (i) the original contract was feasible; (ii) $s(\hat{x}) \leq \hat{x} < x$ and (iii) by the monotonicity of r we have:

$$r(x) \geq r(\hat{x}) \geq (1-\pi)s(\hat{x}) \;\; \Rightarrow \;\; z'(x,x) = z(x,x) - \frac{(1-\pi)}{\pi}[s(\hat{x}) - s(x)] \geq 0, \;\; \forall x \in A$$

To show it is also incentive compatible, partition the incentive constraints in the following categories:

First, consider $x \notin A$. All incentive constraints hold because $\{s, z, \sigma, p\}$ was incentive compatible and: (i) $s(x) = s'(x)$ for all $x' \notin A$; (ii) $s(x) < s(\hat{x}) = s'(x')$ for all $x' \in A$.

Second, consider $x \in A$ If message $x' \neq x$ is such that $\sigma'(x') = 1$ incentive compatibility trivially holds. Moreover, if x is such that $\sigma'(x) = 1$ incentive compatibility holds because $s'(x)$ is irrelevant (i.e., $r(x) = z(x,x)$). Finally, if x, x' are such that $\sigma'(x) = 0 = \sigma'(x)$, we have:

$$\pi z'(x,x) + (1-\pi)s'(x) \leq \pi x + (1-\pi)s'(x')$$

If $x' \in A$, then $s'(x) = s'(x') = s(\hat{x})$ by construction and since $z'(x,x) \leq x$ by limited liability incentive compatibility holds. If $x' \notin A$ and $x' > x$, incentive compatibility follows from $s'(x') = s(x') \geq s(\hat{x}) = s'(x)$, by definition of the set A.t Finally, if $x' \notin A$ and $x' < x$, incentive compatibility follows from $r = r'$ and $s'(x') = s(x')$. So, the prime contract is incentive compatible.

In conclusion, observe that: (i) because $\sigma = \sigma'$ the dead-weight verification cost does not change; and (ii) because $r = r'$ the investors revenues do not change. As a result, the two contracts are equivalent from the firm's perspective and because $\{s, z, \sigma, p\}$ is optimal, so is $\{s', z', \sigma', p'\}$. □

`Proposition 1`

Proof. **Case 1:** $\mathbb{E}_f[\pi\tilde{x}] \geq K$**.** The contract with minimum possible verification on-the-equilibrium path is such that $\sigma(m) = 0$ for every m. Because of Lemmas 2-3, when $\sigma(m) = 0$ for every m there is at most one binding incentive constraint for each type $x \in X$, $IC(x, 0)$: $x - r(x) \geq (1 - \pi)x$, or equivalently: $r(x) \leq \pi x$ – where I substituted $s(0) = 0$ by limited liability. In addition, evidently one can set $s(x) = r(x)$ for every x. If $\sigma(m) = 0$ for every m and incentive compatibility holds, the fraction of equity that needs to be sold is $\alpha = K/\mathbb{E}_f[\tilde{x}]$, and because $\alpha \leq \pi$ equity is optimal.[42]

Debt is suboptimal because the incentive constraint for a type $x \leq d$ reads $x \leq \pi x$, which is never satisfied because $\pi < 1$. Moreover, $d > K$ because investment is risky, and hence the set of $x < d$ is nonempty.

Case 2: $\mathbb{E}_f[\pi\tilde{x}] < K$**.** The proof proceeds in three steps:

Step 1: Any optimal contract is such that $x_V < x_{NV}$.

Proof. Divide X into intervals X_1, X_2, ..., X_n such that (i) $\min X_1 = 0$, $\max X_n = \bar{x}$, $\cup_{i=1}^n X_i = X$, and (ii) for every i, and for every pair $x, x' \in X_i^2$, $\sigma(x) = \sigma(x')$. By contradiction, suppose that at the optimal contract $\{s, z, \sigma\}$ we have $x_V > x_{NV}$. Without loss of generality, suppose that $X_1 \subseteq NV$, so that (i) $X_2 \neq \emptyset$ and $X_2 \subseteq V$, (ii) $X_3 \neq \emptyset$ and $X_3 \subset NV$, and so on. For $x \in X_3$, incentive compatibility of $\{s, z, \sigma, p\}$ requires that (i) for every $x' \in X_1$ we have $r(x) \leq \pi x + (1 - \pi)s(x')$; and (ii) for every $x'' \in X_2$ we have $r(x) \leq x$.

Consider another contract $\{s', z', \sigma'\}$ such that $s' = s$, $z' = z$, $p = p'$ and:

$$\sigma'(m, 0) = \begin{cases} \sigma(m) & \text{if } m \notin X_2 \\ 0 & \text{otherwise} \end{cases}$$

By Lemma 1 the new contract is feasible, because $\max\{m^*(x), y\} = x$ for every x. Now I prove it is incentive compatible.

If $x \in X_2$, incentive compatibility of $\{s, z, \sigma, p\}$, $s = s'$ and $z = z'$ jointly imply that $IC(x, x')$ is satisfied at the prime contract for every $x' \in X$. If $x \in X_1$, incentive compatibility follows from the monotonicity of $s(m)$ – by Lemma 3. If $x \in X_3$ we have two cases: (i) if $x' \in X_1$ or $x' \in X_i$ and $i \geq 3$ then we have $r'(x) \leq r'(x, x')$ because $r = r'$ and $\sigma'(x') = \sigma(x')$; (ii) if instead $x' \in X_2$ incentive compatibility reads: $\pi z'(x, x) + (1 - \pi)s'(x) \leq \pi x + (1 - \pi)s'(x')$. Because $x' > x''$ for every $x'' \in X_1$, and since $X_1 \subseteq V$, we also have: $\pi x + (1 - \pi)s'(x') = \pi x + (1 - \pi)s(x') \geq \pi x + (1 - \pi)s(x'') = \pi x + (1 - \pi)s'(x'')$, where the inequality follows from incentive compatibility of $\{s, z, \sigma, p\}$. Similar arguments can be used for $x \in X_i$ and $i > 3$, proving the claim. □

Step 2: For every $x \geq x_{NV}$, $z^*(x, x) = s^*(x) = (1 - \pi)x_{NV} + \pi x$.

Proof. First I show that $s(x_{NV}) = x_{NV}$. Suppose not, i.e. there exists an optimal contract $\{s, z, \sigma, p\}$ such that $x_{NV} > r(x_{NV})$ (the case of the opposite inequality is prevented by limited liability). Define the set $B \equiv \{x \in NV \,|\, r(x) < x_{NV}\}$. Design a new contract $\{s', z', \sigma', p'\}$ such that $z = z'$, $\sigma = \sigma'$, $p = p'$ and:

$$s'(m) = \begin{cases} s(m) & \text{if } x \notin A \\ x_{NV} & \text{otherwise} \end{cases}$$

Clearly, the prime contract is feasible. It is also incentive compatible because $\{s, z, \sigma, p\}$ is incentive compatible. It remains to show that from the optimality of $\{s, z, \sigma, p\}$ it follows that B is of zero measure, hence PC remains binding. By contradiction, suppose not. Define the following threshold:

$$\hat{x} \equiv \left\{ x \in X \,\middle|\, \int_0^{\hat{x}} [x - (1 - \pi)\mu] dF(x) + \int_{\hat{x}}^{\bar{x}} \min\{s'(x), x\} dF(x) = K \right\}$$

[42] In the limit, when $\mathbb{E}_f[\pi\tilde{x}] = K$, pure equity is the uniquely optimal contract.

We know that $\hat{x}$ exists and $0 < \hat{x} < x_{NV}$ because if $\hat{x} = 1$ we have:

$$\int_0^{\hat{x}} [x - (1-\pi)\mu] dF(x) + \int_{\hat{x}}^{\bar{x}} \min\{s'(x), x\} dF(x) = \int_0^{x_{NV}} [x - (1-\pi)\mu] dF(x) + \int_{x_{NV}}^{\bar{x}} s'(x) dF(x) > K$$

if, instead, $\hat{x} = 0$ we have $\int_0^{\bar{x}} \min\{s'(x), x\} dF(x) < K$, where the inequality follows from the fact that $\mathbb{E}_f[\pi\tilde{x}] < K$. Observe that a contract $\{s'', z'', \sigma'', p''\}$ such that $z'' = z' = z$, $p'' = p' = p$, $s'' = \min\{s', x\}$ and:

$$\sigma''(m) = \begin{cases} \sigma(m) & \text{if } m \notin [\hat{x}, x_{NV}] \\ 0 & \text{otherwise} \end{cases}$$

would be both feasible and incentive compatible. Moreover, it would make the participation constraint for the investors binding, strictly reducing the expected verification costs relative to $\{s, z, \sigma, p\}$.[43] As a result, $\{s, z, \sigma, p\}$ cannot be optimal, proving our claim.

That $s(x) = (1-\pi)x_{NV} + \pi x$ follows from three observations. First, incentive compatibility for $x, x' \in NV^2$ reads:

$$s(x) \leq \pi x + (1-\pi)s(x')$$

Second, because $r(x_{NV}) = x_{NV}$ and by Lemma 3 (i.e., monotonicity of $s(\cdot)$) we have: $\min\{s(m)|m \in NV\} = x_{NV}$. Third, incentive compatibility must be binding almost surely for every $x \in NV$ (that is, up to sets of zero measure). To see the latter observation must hold, simply observe that if there is a set of strictly positive measure where incentive compatibility does not hold at any candidate optimal contract, one can repeat the argument given for the previous claim (i.e., $r(x_{NV}) = x_{NV}$) and show that the candidate contract cannot be optimal. □

Step 3: For every x such that $\sigma(x) = 1$, we have $z^*(x, x) = s^*(x) = x$.

Proof. The proof is identical to that of Step 2. It consists in showing that if a contract is such that $z^*(x, x) < x$ for a set of states of strictly positive measure, such contract cannot be optimal because the dead-weight verification costs can be reduced moving to $z^*(x, x) = x$ for every $x \in V$ with another feasible, incentive compatible contract that makes PC binding. □

Summing up, steps 1-3 imply that the optimal contract is a mixture of debt and equity with $\alpha^* = \pi$ and $d^* = \min\{x_{NV}|\text{ PC binds}\}$. □

Lemma 4

Proof. First notice that the repayment to investors when $x^* = 0$ is equal to $\mathbb{E}_f[\pi\tilde{x}]$, and it must be strictly less than K when $x^* > 0$ by Proposition 1. Suppose that – by contradiction – the derivative at x^* of the objective function in (7) is strictly negative, i.e.: $(1 - F(x^*)) < f(x^*)\mu$. Because the function is continuous, and it starts at a positive value below strictly below K, then whenever the derivative is negative it must be that there exists an $x' < x^*$ such that the repayment to investors equals K. But this contradicts the definition of x^*, proving our claim. □

Corollary 3

Proof. Consider profitability first. We have two cases: $d = 0$ and $d > 0$. If $d = 0$, it means that $K/\mathbb{E}_f[\tilde{x}] = \alpha \leq \pi$. If $K' < K$ I have $K'/\mathbb{E}_f[\tilde{x}] = \alpha' < K/\mathbb{E}_f[\tilde{x}] = \alpha \leq \pi$ and $d' = d = 0$. Now consider the case of $d > 0$. At any optimal contract that sustains investment where $d > 0$, (2) holds with equality at $x^* = d$. We can rewrite (2) at the optimum as:

$$[\mathbb{E}_f[\tilde{x}] - K] - (1-\pi)\mu F(x^*) - \int_{x^*}^{\bar{x}} (1-\pi) x dF(x) + (1 - F(x^*))(1-\pi)x^* = 0$$

[43] Strictly because we supposed that B had a strictly positive measure.

Suppose that K increases for a given $\mathbb{E}_f[\tilde{x}]$. By Lemma 4 I know that $(1 - F(x^*)) \geq f(x^*)\mu$. If the inequality is strict, totally differentiating the expression with respect to K and x^* I get:

$$-dK + dx^*(1-\pi)\big[1 - F(x^*) - f(x^*)\mu\big] = 0$$

and $dx^*/dK > 0$ implies that either d increases as profitability falls, or at the new K there is no investment. If, instead, $(1 - F(x^*)) = f(x^*)\mu$, then d must jump to the right and again either there exists a higher d that satisfies PC, or there is no investment.

As for transparency, suppose it decreases to $\pi' < \pi$. If $\pi' \geq K/\mathbb{E}_f[\tilde{x}]$, then $d' = d = 0$. If $\pi' < K/\mathbb{E}_f[\tilde{x}] \leq \pi$, then either at π' there is no investment or it must be that $d' > d = 0$. Finally, if $\pi' < \pi < K/\mathbb{E}_f[\tilde{x}]$, I must have that again either at π' there is no investment or $d' > d$ because the derivative of (2) with respect to π is equal to $\mu F(x^*) + \int_{x^*}^{\overline{x}}[x - x^*]f(x)dx > 0$.

Finally, that x^* increases with μ is immediate from inspection. □

Lemma 5

Proof. First, recall that by Lemma 3 the equilibrium face value of debt is monotonically decreasing with p_i. Therefore, we must have $d^* \leq \bar{d}$.

Second, observe that the derivative of (8) (conditional on $\mathbb{E}_f[\pi_i\tilde{x}] \leq K$) with respect to x_{NV} is given by $(1-\pi_i)\big[(1 - F(x_{NV})) - \mu f(x_{NV})\big]$, and it is strictly positive when (i) $h(x) < 1/\mu$ for every $x \leq \bar{d}$; and (ii) $\pi_i \leq K/\mathbb{E}_f[\tilde{x}]$

As a result, the change in d^* as p_i increases infinitesimally can be computed simply total differentiating (8) with respect to x_{NV} and p_i, and evaluating at $x_{NV} = d$. □

Lemma 6

Proof. The second derivative of $V(p_i, p_{-i})$ with respect to p_i reads:

$$\begin{aligned}\frac{\partial^2 V(p_i,p_{-i})}{\partial p_i^2} =& \underbrace{\mu\frac{\partial^2 \pi_i}{\partial p_i^2}\left[F(d_i^*) + f(d_i^*)\cdot\frac{\mu F(d_i^*) + \int_{d_i^*}^{\bar{x}}[x-d_i^*]dF(x)}{1-F(d_i^*)-\mu f(d_i^*)}\right]}_{=0 \text{ because } \partial^2\pi_i/\partial p_i^2=0} + \\ &+ \underbrace{\mu\left(\frac{\partial \pi_i}{\partial p_i}\right)^2\frac{\partial d_i^*}{\partial \pi_i}}_{\leq 0}\cdot\Bigg\{\underbrace{f(d_i^*)\cdot\frac{\mu F(d_i^*) + \int_{d_i^*}^{\bar{x}}[x-d_i^*]dF(x)}{1-F(d_i^*)-\mu f(d_i^*)}}_{>0}\underbrace{\frac{\partial f(d_i^*)}{\partial d_i^*}}_{\text{sign?}} + \\ &+ \underbrace{\frac{\mu F(d_i^*) + \int_{d_i^*}^{\bar{x}}[x-d_i^*]dF(x)}{\big[1-F(d_i^*)-\mu f(d_i^*)\big]^2}}_{>0}\left[\underbrace{\big(f(d_i^*)\big)^2}_{>0} + \underbrace{\frac{\partial f(d_i^*)}{\partial d_i^*}}_{\text{sign?}}\underbrace{\mu f(d_i^*)}_{>0}\right]\Bigg\} - \underbrace{c'(p_i)}_{>0}\end{aligned} \tag{17}$$

Though the expression looks frightening, observe that we can sign all terms *but* those that involve the derivative of the density function $f(\cdot)$. Moreover, all terms are negative, suggesting that the problem has a certain degree of concavity built in from the zero profit condition for investors.

Strict concavity requires $\partial^2 V(p_i, p_{-i})/\partial p_i^2 < 0$. From (17):

$$f'(x) > -\frac{f(x)}{1-F(x)-\mu f(x)}, \quad \forall x \in [0, \bar{d}] \quad \Rightarrow \quad \frac{\partial^2 V(p_i,p_{-i})}{\partial p_i^2} < 0$$

dividing through the fraction in the right hand side by $1 - F(x) > 0$ and applying the definition of $h(x)$ yields the result. □

Lemma 7

Proof. **Strict Concavity:** The second cross derivative of $V(p_i, p_{-i})$ with respect to $p_{j\neq i}$, for every such j, reads:

$$\frac{\partial^2 V(p_i,p_{-i})}{\partial p_i \partial p_j} = \underbrace{\mu\frac{\partial^2 \pi_i}{\partial p_i \partial p_j}\left[F(d_i^*) + f(d_i^*)\cdot\frac{\mu F(d_i^*)+\int_{d_i^*}^{\bar{x}}[x-d_i^*]dF(x)}{1-F(d_i^*)-\mu f(d_i^*)}\right]}_{<0 \text{ because } \partial^2\pi_i/\partial p_i\partial p_j<0} + \tag{18}$$
$$+\underbrace{\mu\left(\frac{\partial \pi_i}{\partial p_j}\right)^2\frac{\partial d_i^*}{\partial p_j}}_{\leq 0}\cdot\Bigg\{\underbrace{f(d_i^*)\cdot\frac{\mu F(d_i^*)+\int_{d_i^*}^{\bar{x}}[x-d_i^*]dF(x)}{1-F(d_i^*)-\mu f(d_i^*)}}_{>0}\underbrace{\frac{\partial f(d_i^*)}{\partial d_i^*}}_{\text{sign?}}+$$
$$+\underbrace{\frac{\mu F(d_i^*)+\int_{d_i^*}^{\bar{x}}[x-d_i^*]dF(x)}{\left[1-F(d_i^*)-\mu f(d_i^*)\right]^2}}_{>0}\left[\underbrace{\left(f(d_i^*)\right)^2}_{>0}+\underbrace{\frac{\partial f(d_i^*)}{\partial d_i^*}}_{\text{sign?}}\underbrace{\mu f(d_i^*)}_{>0}\right]\Bigg\}-\underbrace{c'(p_i)}_{>0}$$

The expression in curly brackets is the same that we found in (17), hence it is strictly positive under Assumption 4. As a result, the game is strictly concave.

Aggregativity: It follows immediately from the definition of $\pi_i(p_i, p_{-i}, q_{-i})$ (i.e., equation (1)). □

Proposition 2

Proof. Define the best response correspondence for firm i as follows:

$$b_i(p_{-i}) \equiv \arg\max_{p_i\in\left[0,K/\mathbb{E}_f[\tilde{x}]\right]} V(p_i,p_{-i})$$

We know $b_i(p_{-i})$ is nonempty by the theorem of the maximum because $V(p_i, p_{-i})$ is continuous and the set $[0, K/\mathbb{E}_f[\tilde{x}]]$ is compact. Moreover, $b_i(p_{-i})$ is a singleton because $V(p_i, p_{-i})$ is strictly concave. Hence, $b_i(p_{-i})$ is convex and upper semicontinuous. It follows by Kakutani fixed point theorem that a PSNE exists.

As for the properties of Q_* and Q^*, they follow from Lemma 7, which guarantees that my game is a special case of those to which Theorem 1 in Acemoglu and Jensen (2013) applies. □

Corollary 4

Proof. Observe first that the FOC can be written as:

$$\mu\frac{\partial \pi_i}{\partial p_i}\bigg|_{p_i=p^*}\cdot\left[F(d(p^*)+f(d(p^*))\cdot\frac{\mu F(d(p^*))+\int_{d(p^*)}^{\bar{x}}[x-d(p^*)]dF(x)}{1-F(d(p^*))-\mu f(d(p^*))}\right]=c'(p^*)$$

The right hand side is not a function of q_{-i}. In contrast, the left hand side is a function of q_{-i}, through its effect on π_i. Moreover, the sign of the derivative of the left hand side with respect to $q_{i,j}$ is the same as that in (18), hence it is strictly positive. Evidently, p_i^* must decrease for the equation to keep holding, proving that equilibrium disclosure decreases with $q_{i,j}$.

As a shock to q hits the aggregator, in the sense of Acemoglu and Jensen (2013), both Q_* and – more importantly – Q^* decrease with it.

Coming to leverage, from Proposition 1 we know that leverage increases with $q_{i,j}$ if and only if $\partial\pi^*/\partial q_{i,j} < 0$. However, this derivative embeds two effects: on the one hand, a higher correlation directly increases π_i^*. On the other hand, it lowers the equilibrium disclosure which in turns lowers π_i^*. The elasticities cannot be signed a priori. □

Proposition 3

Proof. Existence is immediate from continuity. Moreover, $\partial V(p_i, p_{-i})/\partial p_{j\neq i} > 0$ whenever $q_{i,j} > 0$ implies that the private disclosure is inefficiently lower than that at the SE. □

B Empirics: Robustness Checks

In this appendix, I present and discuss additional empirical exercises to confirm that the correlations presented in the paper are robust.

The first exercise pertain the cutoff in the number of analysts' forecast required for an observation to be included in the data. In the man text, I consider a cutoff of 5, but I claim this choice does not affect the results. To show that this is the case, Table 3 presents the fixed effect regression results for cutoffs ranging from 2 to 7.[44]

From now onwards, by 'Usual Controls' I shall refer to those included in the regressions of Table 3.

The second set of robustness checks, presented in Table 4, studies how the results change with different measures of analysts' forecast dispersion. Column (1) reports the benchmark estimate using the coefficient of variation (it is equivalent to column (4) of Table 2). Column (2) clarifies the importance of normalizing the standard deviation by the mean: without the normalization the significance is lost. Column (3) and (4) do the same replacing CV with MAD (the median absolute deviation from the mean forecast). Similar results attain. Finally, column (5) shows that one could also use directly the number of analysts following the firm in a given year. As expected, the number is negatively correlated with leverage, suggesting that the higher the number of analysts following a firm, the lower its subsequent leverage ratio.

The third series of robustness checks is presented in Table 5. It considers the effects on the estimates of changing the definition of leverage. In particular, column (1) presents again the estimates shown in the main text, where leverage is defined as in Welch (2011), to equal the ratio of Total Liabilities (LT) over Total Assets (AT). Column (2) replaces AT with the market value of assets (AM = MEQ + LT). The coefficient of interest is positive but looses a one degree of significance. Column (3) shows what happens when leverage is defined as the ratio of Total debt (DT) – defined as the sum of Debt in Current Liabilities (DLC) and Long Term Debt (DLTT) – over the book value of assets. The result is similar to that of column (2). Finally, column (4) shows what happens when leverage is defined as DT/AM. The coefficient looses significance altogether. Columns (5)-(7) repeat the exercise of substituting LT/AT with alternative measures of leverage for the independent variable MAD. Similar results attain.

Finally, Table 6 explores the leads and lags structure of the data. Although CV is serially correlated, the Table shows that the results are stronger when CV is assumed to precede leverage than the other way around. Of course, the results do not rule out

[44] Evidently, two is the minimum number of forecasts needed to be able to actually compute a coefficient of variation. Robustness to even higher cutoffs (in particular, ten) is presented in Table 2 in the main text.

Table 3: Robustness Check (1): different cutoffs

	(1) Cutoff 2	(2) Cutoff 3	(3) Cutoff 4	(4) Cutoff 5	(5) Cutoff 6	(6) Cutoff 7
L.CV forecasts	0.0303***	0.0238**	0.0236**	0.0215**	0.0249**	0.0240**
	(3.63)	(3.09)	(3.10)	(2.72)	(2.86)	(2.70)
L.Total Assets	0.00947*	0.0140**	0.0131**	0.0133**	0.0127*	0.0136*
	(2.20)	(3.27)	(2.91)	(2.83)	(2.51)	(2.50)
L.Profitability	-0.0476	-0.138***	-0.143***	-0.156***	-0.158***	-0.171***
	(-1.70)	(-9.43)	(-8.59)	(-8.31)	(-8.28)	(-8.16)
L.Book-to-Market	0.00528*	0.00221	0.00171	0.00147	0.00196	-0.00185
	(2.31)	(0.90)	(0.51)	(0.40)	(0.46)	(-0.34)
L.Intangibles	0.0322	0.0286	0.0279	0.0163	0.0156	0.00911
	(1.48)	(1.31)	(1.24)	(0.71)	(0.66)	(0.36)
L.Industry Leverage	0.386***	0.348***	0.340***	0.339***	0.316***	0.322***
	(8.03)	(7.32)	(6.84)	(6.53)	(5.88)	(5.82)
Constant	0.282***	0.272***	0.283***	0.285***	0.304***	0.302***
	(6.54)	(6.35)	(6.24)	(5.87)	(5.86)	(5.36)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	35263	32512	29472	26465	23686	21150
Adjusted R^2	0.842	0.845	0.846	0.845	0.848	0.848

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Sources: Compustat merged with CRSP (annual), IBES (detail, adjusted for stock splits).

Notes: all independent variables are lagged by one year. Standard errors are clustered at the firm level.

Table 4: Robustness Check (2): different independent variables

	(1) LT/AT	(2) LT/AT	(3) LT/AT	(4) LT/AT	(5) LT/AT
L.CV forecasts	0.0249**				
	(2.86)				
L.STDEV		0.0000123			
		(0.03)			
L.MAD forecasts			0.0487***		
			(3.31)		
L.MAD*MEAN				0.00103	
				(0.67)	
L.Estimates					-0.00120**
					(-3.20)
Time FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Usual Controls	Yes	Yes	Yes	Yes	Yes
Observations	23686	23686	23686	23686	23686
Adjusted R^2	0.848	0.848	0.848	0.848	0.848

t statistics in parentheses. $^{*}\ p < 0.05$, $^{**}\ p < 0.01$, $^{***}\ p < 0.001$

Sources: Compustat merged with CRSP (annual), IBES (detail, adjusted for stock splits).

Notes: all independent variables are lagged by one year.

Standard errors are clustered at the firm level.

Table 5: Robustness Check (3): different dependent variables

	(1) LT/AT	(2) LT/AM	(3) DT/AT	(4) DT/AM	(5) LT/AM	(6) DT/AT	(7) DT/AM
L.CV forecasts	0.0249**	0.0218*	0.0186**	0.0112			
	(2.86)	(2.50)	(2.67)	(1.76)			
L.MAD forecasts					0.0457**	0.0356**	0.0232
					(2.76)	(2.63)	(1.82)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Usual Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	23686	23686	23646	23646	23686	23646	23646
Adjusted R^2	0.848	0.884	0.794	0.813	0.884	0.794	0.813

t statistics in parentheses. $^{*}\ p < 0.05$, $^{**}\ p < 0.01$, $^{***}\ p < 0.001$

Sources: Compustat merged with CRSP (annual), IBES (detail, adjusted for stock splits).

Notes: all independent variables are lagged by one year. Standard errors are clustered at the firm level.

reverse causality, and a statistically causal analysis is still required in future work.

Table 6: Robustness Check (4): lags and leads

	(1) LT/AT	(2) LT/AT	(3) LT/AT	(4) LT/AT	(5) LT/AT	(6) LT/AT
L3.CV forecasts	0.0295**					
	(2.77)					
L2.CV forecasts		0.0266**				
		(3.06)				
L.CV forecasts			0.0249**			
			(2.86)			
CV forecasts				0.0650***		
				(6.84)		
F.CV forecasts					0.0176*	
					(2.06)	
F2.CV forecasts						0.00637
						(0.77)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Usual Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18597	20994	23686	23686	20568	17811
Adjusted R^2	0.860	0.855	0.848	0.849	0.855	0.858

t statistics in parentheses. $^{*}\ p < 0.05$, $^{**}\ p < 0.01$, $^{***}\ p < 0.001$

Sources: Compustat merged with CRSP (annual), IBES (detail, adjusted for stock splits).

Notes: all independent variables are lagged by one year. Standard errors are clustered at the firm level.