Managerial Entrenchment, Stakeholders, and Capital Structure

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Abstract

We study the effects of combining managerial entrenchment (Harris and Raviv 1990) with liquidation-averse stakeholders (Titman 1984). When a firm's debt is below (above) its liquidation value, small debt increases have a high (low) marginal cost for the stakeholders: if they lead to insolvency, then the firm must be worth less (more) as a going concern than as the sum of its assets – so it will (not) be liquidated. Because of this declining marginal cost of debt, a firm's value is a nonconcave function of its debt level and thus has multiple local maxima. Consequently, small shocks can cause large jumps in a firm's optimal debt level even in the absence of issuance costs.

J.E.L. Codes: G32, G33, G34.

Keywords: Managerial Entrenchment, Stakeholders, Capital Structure, Debt, Leveraged Buyouts, Swaps.

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1 Introduction

We study a simple model of optimal capital structure that yields a decreasing marginal cost of debt. As a result, the firm's value is a nonconcave function of its debt level. Hence small changes in a firm's characteristics or environment can cause large changes in its optimal debt level, which may help explain leveraged buyouts (LBOs) and swaps of debt for equity and vice-versa. The high marginal cost of debt at low levels may also help explain the puzzle of zero-debt firms (Strebulaev and Yang [89]). Importantly, the results are obtained without a fixed cost of debt issuance.

The model combines ingredients from Harris and Raviv [47] and Titman [91]. As in Harris and Raviv [47], a firm has an entrenched manager who will liquidate the firm only if she is forced to do so.[1] As in Titman [91], liquidation harms the firm's stakeholders: its customers, suppliers, and workers.[2,3] Hence the risk of liquidation can discourage them from investing in their relationship with the firm.[4] We assume for simplicity that the stakeholders are not harmed by a reorganization bankruptcy.[5]

A rough intuition for our result runs as follows. By assumption, an increase in debt harms the stakeholders only if it raises the chance that the firm will be liquidated. This, in

[1] The idea that debt shifts control rights away from corporate insiders in bad states appears also in Aghion and Bolton [1] and Hart and Moore [48]. More generally, the notion that debt helps align the incentives of managers and firm owners is due to Jensen and Meckling [57].

[2] Titman's model assumes the firm is run by a value-maximizing founder rather than an entrenched manager.

[3] Empirical evidence for Titman's hypothesis appears in Titman and Wessels [92].

[4] Empirical evidence comes from Graham *et al* [43], who find that the filing of a reorganization bankruptcy raises the employee quit rate by 10-17%, and Babina [7], who finds that unexpected industry shocks raise a worker's likelihood of leaving a more levered firm by about 25%. Similarly, Brown and Matsa [15] find that distressed firms attract fewer job applicants than nondistressed firms. Andrade and Kaplan [4, p. 1475] find that about a third of distressed firms report trouble retaining key customers and suppliers. Hortaçsu *et al* [56] find that the used cars of distressed automakers fetch lower prices at auction, particularly for cars that have more time left on their warranties. In J.D. Power's 2009 Avoider Study, 18% of new car buyers who avoided a particular vehicle model cited concerns about the model's future as a reason (Hortaçsu *et al* [56]).

[5] Andrade and Kaplan [4] find that financial distress *per se* imposes negligible costs on firms that are not also affected by negative economic shocks.

turn, holds only so long as the face value of the debt is less than the firm's liquidation value.[6] At higher debt levels, additional debt leads merely to reorganization which - by assumption - does not harm the stakeholders. Thus, the marginal cost of additional debt - its negative effect on the stakeholders' incentive to do business with the firm - falls discretely when the face value of debt reaches the firms' liquidation value. This leads to a nonconcave objective function.

For instance, suppose a firm's liquidation value is $1 million while its going-concern value takes a random value between zero and $2 million. The firm chooses how much debt to issue before the going-concern value is realized. Also assume, as is standard, that insolvency occurs whenever the firm's going-concern value is less than the face value of its debt. In particular, with zero debt the firm will never be insolvent so the entrenched manager will never liquidate. Now suppose the firm issues exactly $1 million in debt. Insolvency implies that the firm's going concern value must be less than $1 million. In this case, insolvency leads to liquidation. Hence the first $1 million in debt imposes costs on the stakeholders. Now suppose the firm further raises its debt from $1 million to $2 million. This causes additional insolvencies when the firm's going-concern value lies between $1 million and $2 million. But at these going-concern values, liquidation is not optimal: the second $1 million in debt imposes no costs on the stakeholders.

One can see also that the marginal cost of additional debt is positive (zero) at debt levels below (above) the firm's liquidation value. Hence the slope of the firm's value function rises discretely at this point. This nonconcavity must give rise to multiple local optima. Accordingly, a small change in parameters can lead to a large jump in the optimal debt level.

Above we stated that debt deters the participation of stakeholders who fear liquidation. But we did not explain why this is costly to the firm. To fill this gap, we assume that a higher participation rate benefits the firm by raising its going-concern value. Since this lowers liquidation risk, there can be multiple self-fulfilling prophecies: if the participation rate is expected to be high (low), the firm is less (more) likely to be liquidated, so stakeholders have a stronger (weaker) incentive to participate. To select a unique equilibrium, we use

[6] In each case, "only if" means "if and only if".

techniques from the global games literature (Carlsson and van Damme [18]).[7]

Our model makes several predictions that are supported in the empirical literature. We find that if a firm's stakeholders have more to lose in a reorganization bankruptcy, a firm will choose lower debt in order to maintain their loyalty. Indeed, Shivdasani and Stefanescu [86] find that firms with defined-benefit pension plans tend to have lower debt. We also find that entrenched management commits a firm to liquidate less often, thus eliciting more participation from stakeholders. Indeed, Cen, Dasgupta, and Sen [20] and Johnson, Karpoff, and Yi [58] find that antitakeover provisions can enhance firm value by strengthening stakeholder relationships. The model also implies that firms with entrenched management will tend to choose lower debt levels, as found empirically by Berger, Ofek, and Yermack [11] Garvey and Hanka [39], and Lundstrum [66]. Finally, a firm's liquidation value has an ambiguous effect on its optimal debt level in our model. The empirical literature is also ambiguous: Gilson [40] finds no significant effect, while Alderson and Betker [2] find a negative effect.

In our model, a stakeholder's incentive to invest is stronger if the firm is expected to survive which, in turn, is more likely if other stakeholders invest. This can give rise to multiple self-fulfilling prophecies. In order to obtain a unique prediction, we rely on the theory of global games. Such games were first studied by Carlsson and van Damme [18] in the context of 2-player, 2-action games with two pure Nash equilibria. They showed that if, instead of the game's payoffs being common knowledge, each player receives a slightly noisy signal of these payoffs, there is a unique equilibrium. This result has been generalized to multiple players and actions, and to more general information and payoff structures (e.g., Frankel, Morris and Pauzner [36], Morris and Shin [71, 75]). Similar findings are obtained in dynamic games with frictions and shocks under common knowledge of payoffs (Burdzy, Frankel, and Pauzner [17]; Frankel and Pauzner [37]).[8]

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[7] In our setting, this approach consists of letting the payoff from not investing be stochastic and unknown. There are dominance regions: when this payoff is sufficiently low (high), it is strictly dominant (not) to invest. Each small stakeholder gets an independent private signal of this parameter. In the limit as the signal errors shrink to zero, a unique equilibrium emerges in which the stakeholders invest whenever the parameter lies below a common threshold. For a survey and key intuitions, see Morris and Shin [71].

[8] For limitations on the uniqueness result, see Angeletos, Hellwig, and Pavan [5], Angeletos and Werning [6], Chassang [24], Hellwig, Mukherji, and Tsyvinski [53], and Morris and Shin [72].

In a global game, as the fundamental crosses a given threshold, aggregate behavior changes abruptly. This property makes global games useful for studying aggregate fluctuations and crises. Applications include bank runs and international contagion (Goldstein and Pauzner [42, 41]), currency crises, debt pricing, and market crashes (Morris and Shin [70, 73, 72]), search-driven business cycles (Burdzy and Frankel [16]), investment cycles (Chamley [22], Oyama [81]), neighborhood tipping (Frankel and Pauzner [38]), merger waves (Toxvaerd [93]), and recurring crises (Frankel [34]).

In our model, the benefit of debt is to shield income from taxation as in Modigliani and Miller [69]. Other possible benefits of debt include completing markets (Allen and Gale [3], Stiglitz [87]), limiting rent extraction (Bronars and Deere [14])[9], signalling firm quality (Ross [85]), and minimizing informational asymmetries (Myers and Majluf [77])[10].

2 The Model

The model consists of a single firm, a manager, a unit measure of agents (the "stakeholders"), and a continuum of deep-pocketed investors.[11] All participants are risk-neutral and fully rational. The firm first announces a debt level D. The debt is then sold to the investors for the price $P(D)$, to be determined below. Each agent then decides whether or not to invest in a relationship with the firm. Each agent who does not invest gets a common outside option payoff θ.

The firm then either survives or is liquidated, according to a criterion to be described below. If the firm survives, each agent who invested gets the constant payoff $b > 0$ and the firm receives revenue $r\ell$ where $r > 0$ is a constant and $\ell \in [0, 1]$ is the *participation rate*: the proportion of agents who invested. We refer to $r\ell$ as the firm's *going-concern value*. If instead the firm is liquidated, each agent who invested gets zero (a normalization) while the

[9] See also Sengupta [27] and Perotti and Spear [82].

[10] See also DeMarzo and Duffie [28], DeMarzo, Frankel, and Jin [29], Leland and Pyle [65], and Nachman and Noe [78].

[11] The assumption of a continuum of small stakeholders is made for tractability. The results are qualitatively the same with a finite number (two or more) of stakeholders.

firm's revenue is just the (fixed) salvage value $A > 0$ of its assets.

This general framework embraces two different cases.

1. The agent is a a customer, supplier, or worker, who chooses whether or not to do business with the firm. If she does so and the firm survives, this interaction yields a surplus $s > 0$. The firm and agent then bargain over the division of this surplus. Letting $\eta \in (0, 1)$ denote the agent's relative bargaining power, her payoff from this interaction is $b = \eta s$ while the firm's revenue is $r = (1 - \eta) s$.[12]

2. While not trading directly with the firm, the agent chooses whether or not to make an investment whose return depends on the firm's survival. She might be a small store owner who chooses whether or not to locate near the firm. The firm, in turn, benefits from nearby stores as they help it recruit workers. Or the agent might be a software developer who chooses whether or not to write apps for the firm's platform. The firm, in turn, benefits from a wider selection of apps as it helps attracts users.

The liquidation decision occurs in the following way. After the firm chooses a debt level, it turns over day-to-day decisions to its manager, who remains in charge as long as the firm is solvent. The manager gets a benefit $B > 0$ if the firm operates and zero if it is liquidated.[13] Hence, she will not voluntarily liquidate the firm, which leaves us with two cases.

1. If the firm is solvent ($r\ell \geq D$), the manager pays the bondholders the face value D of their debt. The firm's payout is $(1 - \tau)(r\ell - D)$ where $\tau \in (0, 1)$ is the corporate income tax rate. We assume that the maximum such payout to the firm is not less

[12] These bargaining payoffs coincide with the Nash [79] and Kalai-Smorodinsky [61] cooperative bargaining solutions in the case of equal bargaining power: when $\eta = 1/2$. For general η, it can also be obtained as the equilibrium of the following noncooperative game. One party is chosen at random to make a take-it-or-leave-it offer to the other. The agent's chance of being selected is η. Clearly, the winner will ask for the whole pie: s (respectively, $(1 - \eta) s$) if the offerer is the agent (respectively, the firm). This yields expected payoffs of ηs for the agent and $(1 - \eta) s$ for the firm.

[13] While B is positive, we ignore it for purposes of social welfare. (Intuitively, society does not seem to value the sinecures of wealthy managers.) This approach would have to be revisited in a setting with scarce managerial talent, as firms that offer lower rents would have to pay their managers more.

than the firm's liquidation value:[14]

$$(1-\tau)\,r \geq A. \tag{1}$$

2. If the firm is insolvent ($r\ell < D$), the bondholders take over and maximize the firm's ex-post value. There thus are two cases.

   (a) If the going-concern value $r\ell$ exceeds the liquidation value A, the firm is not liquidated. The bondholders get $r\ell$ and the firm gets zero.

   (b) If the liquidation value A exceeds the going-concern value $r\ell$, the bondholders liquidate. If $A \geq D$, the bondholders get D and the firm gets $A - D$.[15] If $A < D$, the bondholders get A and the firm gets zero.

A concise summary of the payoffs is as follows. If the participation rate ℓ is not less than the *survival threshold*

$$\ell_D = \min\{A, D\}/r, \tag{2}$$

then the firm is not liquidated, an agent who invested gets $b - \theta$, the bondholders are paid $\min\{r\ell, D\}$, and the firm gets $(1-\tau)\max\{r\ell - D, 0\}$. If instead ℓ is less than ℓ_D, the firm is liquidated, an agent who invested gets $-\theta$, the bondholders are paid $\min\{A, D\}$, and the firm gets $\max\{A - D, 0\}$. As the investors are perfectly patient and competitive, they bid their offer $P(D)$ for the bonds up to the expectation of their above payout. The firm, in turn, chooses a face value D of its debt that maximizes its ex-ante value, which is just the sum of the initial payment $P(D)$ for the bonds and the expectation of its above payout.[16]

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[14] When D is small but positive, the firm gets $A - D$ if no agents invest and $\theta(r - D)$ if all invest. With small enough D, the first payoff is the higher if (1) fails. Hence, without condition (1) a founder with positive but low debt ($D \approx 0$) would have a perverse incentive to encourage discourage the agents from investing so as to force the manager to liquidate.

[15] Liquidation is assumed to have no tax implications. While we do not specify the purchase price of the firm's assets, they would typically be sold at a loss because of obsolescence, wear, customization, fire-sale effects, and so on. Moreover, the tax deduction for such a loss would typically be limited to the firm's operating income which, by assumption, is zero.

[16] As the investors are individually infinitesimal and lack a public randomizing device, by the law of

Throughout we will assume that the parameters b, r, A, and τ are common knowledge. As for the outside option payoff θ, we consider two cases. In the first, it is also common knowledge and there are multiple equilibria. In the second, each agent gets a noisy private signal of θ. A unique prediction emerges in the limit as the noise becomes small.[17]

2.1 Case 1: Common Knowledge of Payoffs

In the common-knowledge case there are multiple equilibria, as follows.

Claim 1 *Assume the outside-option payoff θ is common knowledge.*

1. *If debt $D = 0$, then there is a unique equilibrium: the agents invest for all $\theta > b$ and do not invest for any $\theta < b$.*

2. *If $D > 0$, there are three cases.*

   (a) *If $\theta < 0$, there is a unique equilibrium, in which all agents invest.*

   (b) *If $\theta > b$, there is a unique equilibrium, in which no agents invest.*

   (c) *If θ lies in $[0, b]$, both all-invest and none-invest are equilibria.*

Proof. If $D = 0$, then the firm is never insolvent so it will never be liquidated. Hence, an agent who invests gets b for sure. It follows that (not) investing is strictly dominant for $\theta < (>)\, b$ as claimed. If $D > 0$, the result follows from the following argument. Suppose all agents invest. Since the firm's going concern value r exceeds its liquidation value A by (1), the firm will not be liquidated.[18] An agent who invests thus gets b. So this is an equilibrium if and only if b exceeds the outside option payoff θ. If instead no agents invest, the firm's going concern value is zero. Since $D > 0$ and $A > 0$, the creditors take over the

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large numbers the price P_D that they pay is uniquely determined by the firm's debt D and the investors' equilibrium strategies. Hence the firm can predict P_D for each debt level D.

[17] This second approach is due to Carlsson and van Damme [18].

[18] This does not depend on the firm being solvent: if it is insolvent, it will be reorganized rather than liquidated as $r > A$.

firm and liquidate it. An agent who invests thus gets zero. So this is an equilibrium if and only if the outside option payoff θ is positive. ■

For any positive debt level D, there are multiple equilibria if the outside option payoff θ lies between zero and b. Hence it is not possible to predict the effects of changes in D. Without such predictions, we cannot study the firm's optimal debt level D and how this optimum it varies with other parameters. The common-knowledge case is thus not very useful except as a baseline.

2.2 Case 2: Global Game Version

In order to obtain a unique equilibrium, we use techniques from global games (Carlsson and van Damme [18]). The outside option payoff θ is now random and unobserved. For brevity, we sometimes refer to θ as the *state*. Each agent sees a slightly noisy private signal of θ before she chooses whether or not to invest. There are *dominance regions*: before seeing their signals, the agents cannot rule out the possibility that θ exceeds the maximum payoff b from investing (which would make it strictly dominant not to invest) or that θ is not less than zero (which would make investing strictly dominant). As the signal noise shrinks to zero, these dominance regions spark a contagion argument that uniquely pins down the agents' behavior for every possible state θ.

Formally, the state θ is now drawn from a bounded, continuous density ϕ and distribution function Φ. The interior of the support of ϕ is a connected interval $(\underline{c}, \overline{c})$ where $\underline{c}$ may be $-\infty$ and $\overline{c}$ may be ∞. This interval contains the region $[0, b]$ where the complete-information game has multiple equilibria:

$$[0, b] \subset (\underline{c}, \overline{c})\,. \tag{3}$$

Each player i observes a private signal x_i, which equals the sum of the state θ and a random error $\sigma\varepsilon_i$, where $\sigma > 0$ is a scale factor and the random variable ε_i is drawn from a common atomless density f and support contained in the interval $\left[-\frac{1}{2}, \frac{1}{2}\right]$. The state θ and the signal errors $(\varepsilon_i)_{i\in[0,1]}$ are mutually independent.

With this noise structure we obtain a unique prediction in the limit as the noise shrinks to zero ($\sigma \to 0$): all (none) of the agents invest when the outside-option payoff θ is less (greater) than the *investment threshold*

$$\theta_D = b\left[1 - \ell_D\right], \tag{4}$$

where ℓ_D is the participation threshold defined in (2).

Claim 2 *Fix debt $D \geq 0$. For any $\varepsilon > 0$ there is a $\delta > 0$ such that for any noise scale factor σ in the interval $(0, \delta)$, in any strategy profile that survives iterated deletion of strictly dominated strategies, each agent invests if her signal is less than $\theta_D - \varepsilon$ and does not invest if her signal exceeds $\theta_D + \varepsilon$.*

Proof. Appendix. ■

Intuitively, by (3), there are *dominance regions*: the outside option θ may be negative, whence investing is strictly dominant, or exceed b, whence *not* investing is strictly dominant. While these regions can be arbitrarily small, they spark a contagion argument that determines agents' behavior at virtually every state θ.[19] In particular, in the limit as the signal errors shrink to zero, the agents invest if and only if the state lies below the threshold at which an agent is indifferent if she believes that no particular realization of ℓ is more likely than any other: that $\ell \sim U[0,1]$. Following the literature, we will refer to these as *Laplacian beliefs*.[20]

What is the limiting investment threshold? An agent who invests gets b (resp., zero) if the participation rate ℓ exceeds (is less than) the survival threshold ℓ_D defined in (2).

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[19] The argument runs roughly as follows. Assume debt D is less than r so that the firm survives even if a few agents do not invest. Fix a signal noise scale factor σ below $|\underline{c}|/2$, so an agent with the lowest possible signal $x_i = \underline{c} - \sigma/2$ knows that θ is negative and thus that investing is strictly dominant. Let $\underline{x}$ be the highest signal for which it is strictly dominant to invest: an agent will invest even if the firm is expected to fail for sure. Now suppose an agent i gets a signal $x_i = \underline{x}$. She cannot rule out the possibility that the state θ is as low as $\underline{x} - \sigma/2$. And for states θ this low, nearly every other agent j will get a signal x_j below $\overline{x}$, leading him to invest for sure: since $D < r$, the firm will survive. Realizing this, agent i strictly prefers to invest at all signals below some higher threshold $\overline{x}'$. We then use this information to show that agents will invest at signals below an even higher threshold, and so on. The same reasoning can be used to construct a declining sequence of thresholds, above which agents do not invest. Finally, one shows that as the signal errors shrink, the two sequences converge to the same point.

[20] An intuition appears in Morris and Shin [71, pp. 61-63]. The result was originally derived by Kim [59] in a game with a finite number of agents. The prediction finds experimental support, even in settings when payoffs are common knowledge (Heinemann, Nagel, and Ockenfels [52]).

Hence, her expected payoff from investing under Laplacian beliefs is $\int_{\ell=\ell_D}^{1} b d\ell = \theta_D$. Thus, in the limit as the signal errors shrink, the agents invest if and only if their outside option payoff θ is less than the *investment threshold* θ_D.

For any debt level D, we now compute the expected final payouts to the firm and bondholders, as well as the firm's value function. We show first that we can disregard debt levels D are above the maximum going-concern value r.[21] We then compute expected final payouts (5) and (6), and sum them to obtain the firm's value function (7). Finally, we write the value function in the form of the maximum of two simpler functions in (8). This latter form turns out to be very useful in understanding the model's empirical implications.

Claim 3 *1. The firm will choose nonzero debt D.*

2. Any debt $D \geq r$ is payoff-equivalent to $D = r$.

3. For any debt $0 < D \leq r$, the price of debt (which equals the expected payout to bondholders) is

$$P(D) = \min\{A, D\}[1 - \Phi(\theta_D)] + D * \Phi(\theta_D), \tag{5}$$

the firm's expected profit after debt repayment and taxes is

$$\Pi(D) = [A - \min\{A, D\}][1 - \Phi(\theta_D)] + (1 - \tau)(r - D)\Phi(\theta_D), \tag{6}$$

and the firm's value function - the sum of $P(D)$ and $\Pi(D)$ - is

$$V(D) = A + [(1 - \tau)r + \tau D - A]\Phi(\theta_D) \tag{7}$$

or, equivalently,

$$V(D) = \max\{V_1(D), V_2(D)\} \tag{8}$$

[21] Suppose $D = r$ and the firm contemplates switching to some $D > r$. If $\ell < 1$ this has no effect since, in both cases, the firm is insolvent so the bondholders will take over. If $\ell = 1$, the increase in D makes the fiirm insolvent: the bondholders take over. But they will make the same choice as the manager - which is not to liquidate - as the going-concern value of the firm r exceeds the liquidation value A. Hence, the takeover by creditors has no effect on anyone's payoff. We thus may assume w.l.o.g. that $D \leq r$.

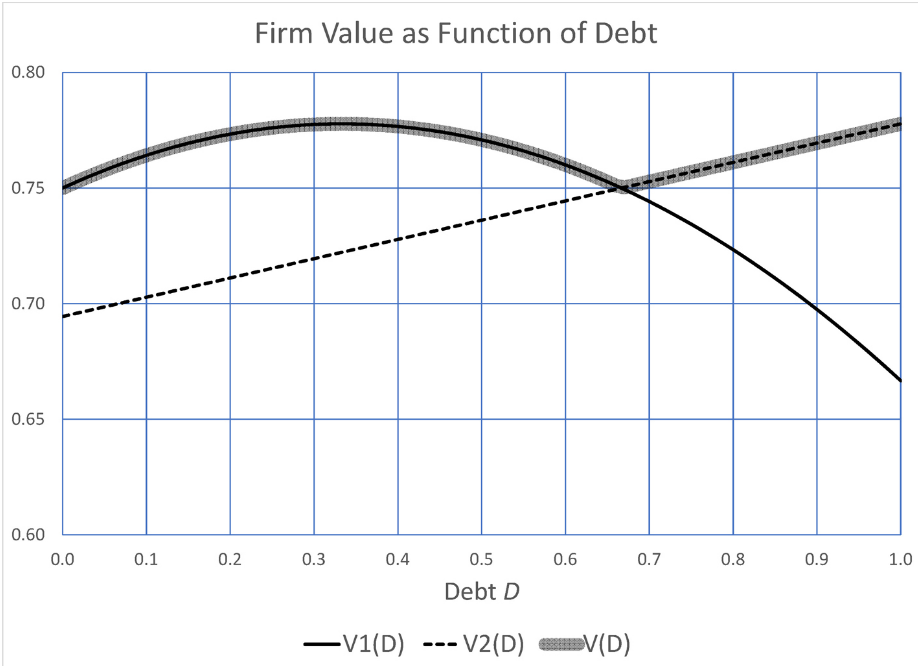

Figure 1: Simulation of global-games version for $b = r = 1$, $A = 2/3$, $\tau = 1/4$, and $\Phi(z) = z$.

where

$$V_1(D) = A + [(1-\tau)r + \tau D - A]\,\Phi(b(1 - D/r))$$

and

$$V_2(D) = A + [(1-\tau)r + \tau D - A]\,\Phi(b(1 - A/r))$$

A simple example is computed in Figure 1 for parameters $b = r = 1$, $A = 2/3$, $\tau = 1/4$, and $\Phi(z) = z$.[22] Function V_1 is the concave solid black curve and V_2 is the upwards sloping dashed line. Their upper envelope - the firm's value function V - is shown as the thick grey curve. It has equally high local maxima at debt values of 1/3 and 1, where the latter equals the maximum firm value since $r = 1$. By altering which local maximum is higher, a small change in parameters can lead to large changes in the chosen debt level.

In equation (8) the firm's value function is written as the maximum of two simpler functions, V_1 and V_2, which can be understood as follows.

[22] The global games result requires the support of ϕ to be of the form $[-\varepsilon, 1+\varepsilon]$ for fixed $\varepsilon > 0$. Hence, the simulation depicts the limit as first σ and then ε goes to zero. It will be approximately correct for fixed, small $\varepsilon > 0$.

1. V_1 is the firm's value function if the agent loses her benefit b following *any* insolvency.[23] The functions coincide when debt D is less than the liquidation value A since, in this case, insolvency implies liquidation. But they differ if debt D exceeds the liquidation value A since going-concern values $r\ell$ in (A, D) now deprive an agent of her benefit b while they did not before. Hence, an agent's payoff from investing falls under Laplacian beliefs, leading her to invest for a smaller range of outside options θ. This makes the firm less likely to survive: V_1 is less than V for $D > A$.

2. V_2 is the firm's value function without an entrenched manager.[24] In this case, the firm will liquidate when doing so is ex-post optimal: when its going-concern value $r\ell$ is less than its liquidation value A. The value functions coincide when debt D exceeds the liquidation value A since, in this case, if liquidation is ex-post optimal then the firm must also be insolvent. But they differ if debt D is less than A since going-concern values $r\ell$ in (D, A) now lead to liquidation while they did not before. Hence, an agent's payoff from investing falls under Laplacian beliefs, leading her to invest for a smaller range of outside options θ. This makes the firm less likely to survive: V_2 is less than V for $D < A$.

Comparing V to V_1 we see that if the stakeholders expect to lose their benefit b also when the firm is reorganized, the firm value falls. But this occurs *only* if the firm's debt D exceeds its liquidation value A, whence there is a nonempty interval (A, D) of going-concern values $r\ell$ that trigger reorganization. In this case, the fear of losing b under reorganization will lead the agents *not* to participate for a wider range of outside-option payoffs θ. Benefits that are vulnerable under reorganization include pension plans and retirement health plans. The model thus implies that the existence of such a plan raises the cost of issuing debt in

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[23] In this case, an agent's expected payoff from investing under Laplacian beliefs is $\int_{\ell=D/r}^{1} bd\ell = b\,[1 - D/r]$. Hence, the agents (do not) invest when the state θ is less (greater) than the modified investment threshold $b\,[1 - D/r]$. The probability of firm survival is thus $\Phi\,(b\,[1 - D/r])$, which, when substituted for $\Phi\,(\theta_D)$ in (7), yields the value function V_1.

[24] In this case, the firm will be liquidated whenever $r\ell < A$. Hence, an agent's expected payoff from investing under Laplacian beliefs is $\int_{\ell=A/r}^{1} bd\ell = b\,[1 - A/r]$. Thus, the agents (do not) invest when the state θ is less (greater) than the modified investment threshold $b\,[1 - A/r]$. The probability of firm survival is thus $\Phi\,(b\,[1 - A/r])$, which, when substituted for $\Phi\,(\theta_D)$ in (7), yields the value function V_2.

excess of a firm's liquidation value. Consistent with this, Shivdasani and Stefanescu [86] find that firms with defined-benefit pension plans have lower debt in cross section.[25]

Comparing V to V_2, we see that hiring an entrenched manager raises a firm's value. But this occurs *only* if the firm's debt D is less than its liquidation value A, whence there is a nonempty range (D, A) of going-concern values $r\ell$ at which liquidation is ex-post optimal $(r\ell < A)$ but the firm is solvent $(r\ell > A)$ so the entrenched manager - who never liquidates - retains control. In this case, the lower risk of liquidation under the entrenched manager entices the agents to participate for a wider range of outside-option payoffs θ. Consistent with this, Cen, Dasgupta, and Sen [20] and Johnson, Karpoff, and Yi [58] find that antitakeover provisions are adopted by firms that have important relationships with stakeholders, and enhance the value of these firms. The fact that V exceeds V_2 when $D < A$ also implies that firms with entrenched management will tend to choose lower debt levels, as found empirically by Berger, Ofek, and Yermack [11], Garvey and Hanka [39], and Lundstrum [66].

A Proofs

We first prove a general uniqueness result that implies Claim 2 and might be useful in other settings.[26] Consider the following game, which we refer to as Φ_σ. There is a unit measure of agents $i \in [0, 1]$. Each agent i sees a private signal $x_i = \theta + \sigma\varepsilon_i$ of an exogenous random state θ, where $\sigma > 0$ is a scale factor. The noise terms ε_i (which are independent of each other and of θ) are identically distributed with continuous density f, cumulative distribution function F, and connected support contained in $[-1/2, 1/2]$. The state θ has distribution Φ, with continuous and bounded density ϕ and connected support S.

On their signals, the agents simultaneously choose actions from the set $\{0, 1\}$, where 1 is interpreted as "invest" and 0 as "not invest". Let the $\ell \in [0, 1]$ denote the proportion

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[25] They argue that this is because the pension plans are a debtlike liability; our model suggests another reason.

[26] This result is a generalization of Theorem 2 in Frankel [35, p. 126]. That result obtains dominance regions by assuming that the support of the state θ is the whole real line. The new result permits finite support as long as it is connected and has contains dominance regions. Finite support is appealing since, in our base model, arbitrarily large outside-option payoffs mght be ruled out. For instance, it is hard to see how an agent's income from her outside option could exceed the world's Gross Domestic Product.

of agents who take action 1. We will refer to ℓ as the *investment rate*. Agent i's realized payoff is denoted $u(a_i, \ell, \theta)$. Let $r_\theta^\ell = u(1, \ell, \theta) - u(0, \ell, \theta)$ denote the *relative payoff* of investing vs. not investing. We assume r_θ^ℓ is bounded on compact sets.

We assume the following properties of the agents' payoffs. The first property is strategic complementarities in investment:

AM. Action Monotonicity. There is a constant $k_1 \in (0, \infty)$ such that for any state θ and investment rates $\ell' > \ell$, $0 \leq r_\theta^{\ell'} - r_\theta^\ell \leq k_1$.

Under this property, the relative payoff function r_θ^ℓ may be locally constant in the investment rate ℓ, and may also jump upwards at certain "threshold" investment rates. In our model, for instance, investors care whether the firm survives which, in turn, occurs only if enough agents invest.

In some applications (including ours), the following property will hold: for any given investment rate ℓ, an increase in the state θ lowers an agent's incentive to invest in the firm at a finite rate that is bounded away from zero.

SM. State Monotonicity. There are constants $0 < k_2 < k_3 < \infty$ such that for any investment rate ℓ and states $\theta' > \theta$, $\frac{r_{\theta'}^\ell - r_\theta^\ell}{\theta' - \theta} \in (-k_3, -k_2)$.

We do not rely on SM, but rather on two weaker properties that it implies. Let

$$R_\theta = \int_{\ell=0}^{1} r_\theta^\ell d\ell \tag{9}$$

denote the mean relative payoff over all investment rates ℓ. The first property is that the mean relative payoff function R is decreasing in the state θ at a rate that is bounded away from zero.

MSM. Mean State Monotonicity. There is a constant $k_2 \in (0, \infty)$ such that, for any states $\theta' > \theta$, $\frac{R_{\theta'} - R_\theta}{\theta' - \theta} < -k_2$.

Second, if r_θ^ℓ ever increases in the state θ, it does so in a bounded way:

OSL. One-Sided Lipschitz Continuity. There is a constant $k_4 \in (0, \infty)$ such that for any investment rate ℓ and states $\theta' > \theta$, $r^{\ell}_{\theta'} - r^{\ell}_{\theta} < k_4 (\theta' - \theta)$.

Claim 4 *SM implies MSM and OSL.*

Proof. Trivial. ■

Now define

$$\theta_R = \sup \{\theta : R_\theta \geq 0\} = \inf \{\theta : R_\theta \leq 0\} \tag{10}$$

denote the boundary between states at which the mean relative payoff R_θ is positive and negative.[27] Also define the constants

$$\underline{\theta} = \inf \left\{\theta : r^0_\theta \leq 0\right\} \text{ and } \overline{\theta} = \sup \left\{\theta : r^1_\theta \geq 0\right\}. \tag{11}$$

Any state at which an agent does not have a strictly dominant action must lie in the interval $[\underline{\theta}, \overline{\theta}]$:

Claim 5 *Assume AM and MSM. Then $-\infty < \underline{\theta} \leq \overline{\theta} < \infty$ and, at any state $\theta < \underline{\theta}$ (resp., $\theta > \overline{\theta}$), it is strictly dominant (not) to invest.*

Proof. First, $\theta' \stackrel{d}{=} \inf \{\theta : R_\theta \leq k_1\}$ and $\theta'' \stackrel{d}{=} \sup \{\theta : R_\theta \geq -k_1\}$ are finite by MSM. If $\theta < \underline{\theta}$ then $r^0_\theta > 0$ whence, by AM, $r^1_\theta > 0$, so $\theta < \overline{\theta}$; accordingly, $\underline{\theta} \leq \overline{\theta}$. Moreover, for all ℓ, $r^\ell_\theta \in [R_\theta - k_1, R_\theta + k_1]$ by AM and thus $r^0_\theta \geq R_\theta - k_1 > 0$ for all $\theta < \theta'$ and $r^1_\theta \leq R_\theta + k_1 < 0$ for all $\theta > \theta''$. It follows that $\left(\underline{\theta}, \overline{\theta}\right) \subset (\theta', \theta'')$, whence $\underline{\theta}$ and $\overline{\theta}$ are finite as claimed. Finally, at any state θ below $\underline{\theta}$ (resp., above $\overline{\theta}$), it is strictly dominant (not) to invest since, by AM, $r^\ell_\theta > 0$ (resp., $r^\ell_\theta < 0$) for any investment rate ℓ. ■

For our iterative argument to work, each action must have a positive probability of being strictly dominant. This is ensured by the following property. Since the support S of the state is connected and the density ϕ of the state is atomless, the interior of S must be a nonempty interval $(\underline{c}, \overline{c})$, where $\underline{c}$ may be $-\infty$ and $\overline{c}$ may be $+\infty$. It is strictly dominant

[27] The sup and inf are equal by MSM, which we will assume R satisfies.

(not) to invest when the state lies in the interval $(\underline{c}, \underline{\theta})$ (resp., $(\overline{\theta}, \overline{c})$). DR states that these "dominance regions" are nonempty:

DR. Dominance Regions. The intervals $(\underline{c}, \underline{\theta})$ and $(\overline{\theta}, \overline{c})$ are nonempty.

Henceforth, let

$$k_5 = \min\left\{\underline{\theta} - \underline{c}, \overline{\theta} - \overline{c}\right\} > 0 \tag{12}$$

denote the measure of the smaller of the two dominance regions.

Our general uniqueness result is as follows.

Theorem 1 (Agent Subgame) *Assume AM, MSM, OSL, and DR. Then for any $\varepsilon > 0$ there is a $\delta > 0$ such that for any noise scale factor σ in the interval $(0, \delta)$, in any strategy profile of the above game Φ_σ that survives iterated deletion of strictly dominated strategies, each agent invests if her signal is less than $\theta_R - \varepsilon$ and does not invest if her signal exceeds $\theta_R + \varepsilon$, where θ_R is defined in (10).*

Before proving Theorem 1, we use it to prove Claim 2:

Proof of Claim 2. In our base model, an agent who invests gets b if $\ell \geq \ell_D$ and zero otherwise. An agent who does not invest gets θ for sure. Hence the relative payoff function in the base model is

$$r_\theta^\ell = \begin{cases} b - \theta & \text{if } \ \ell \geq \ell_D \\ -\theta & \text{if } \ \ell < \ell_D \end{cases} \tag{13}$$

We next verify AM, SM, and DR holds for any $D \geq 0$.

1. For any state θ and investment rates $\ell' > \ell$, equals either zero or b. Hence AM holds with $k_1 = b$.

2. For any investment rate ℓ and states $\theta' > \theta$, $\frac{r_{\theta'}^\ell - r_\theta^\ell}{\theta' - \theta} = -1$. Hence SM holds with $k_2 = k_3 = 1$.

3. As the support of θ is connected, its interior must be an interval of the form $(\underline{c}, \overline{c})$ where either endpoint (or both) may be infinite. As the density ϕ of θ is continuous, it is atomless. Hence, since $\Pr(\theta > b)$ and $\Pr(\theta < 0)$ are both positive, $\underline{c} < 0$ and $\overline{c} > b$. There are now two cases.

(a) If $D = 0$ then, by (13), r_θ^0 and r_θ^1 each equals $b - \theta$ whence, by (11), $\underline{\theta} = \overline{\theta} = b$.

(b) If $D > 0$ then, since $A > 0$, r_θ^0 equals $-\theta$ and r_θ^1 equals $b - \theta$ whence, by (11), $\underline{\theta} = 0$ and $\overline{\theta} = b$.

Hence, $(\underline{c}, \underline{\theta})$ and $\left(\overline{\theta}, \overline{c}\right)$ are nonempty for all $D \geq 0$: DR holds.

By Claim 5, the four properties AM, MSM, OSL, and DR hold in the base model. Moreover, by (9) and (13), $R_\theta = \int_{\ell=0}^{1} r_\theta^\ell d\ell = \theta_D - \theta$ whence, by (10), $\theta_R = \theta_D$. Hence, by Theorem 1, for any $\varepsilon > 0$ there is a $\delta > 0$ such that for any noise scale factor σ in the interval $(0, \delta)$, in any strategy profile of the base model that survives iterated deletion of strictly dominated strategies, each agent invests if her signal is less than $\theta_D - \varepsilon$ and does not invest if her signal exceeds $\theta_D + \varepsilon$ as claimed. Q.E.D.$_{\text{Claim 2}}$

We now prove Theorem 1

Proof of Theorem 1. Suppose an agent i sees the signal x and believes that each other agent j will use the investment threshold k. Under this belief, the law of large numbers implies that the proportion ℓ of agents who invest at a given state θ will be $\Pr\left(\theta + \sigma\varepsilon_j < k | \theta\right) = F\left(\frac{k-\theta}{\sigma}\right)$. Hence, agent i's expected relative payoff $\pi_\sigma(x, k)$ from investing equals[28]

$$\pi_\sigma(x, k) \stackrel{d}{=} \int_{\theta=x-\sigma/2}^{x+\sigma/2} \omega_\sigma(\theta|x)\, r_\theta^{F\left(\frac{k-\theta}{\sigma}\right)} d\theta \tag{14}$$

where, by Bayes's Rule,

$$\omega_\sigma(\theta|x) = \frac{\frac{1}{\sigma} f\left(\frac{x-\theta}{\sigma}\right) \phi(\theta)}{\int_{t=x-\sigma/2}^{x+\sigma/2} \frac{1}{\sigma} f\left(\frac{x-t}{\sigma}\right) \phi(t)\, dt} \tag{15}$$

is the agent's posterior density of the state θ given her signal x.

By definition, the support S of the state θ is a closed subset of $\Re$ and its interior $(\underline{c}, \overline{c})$ is open. For any c in $\Re$, let S_c denote the result of widening this open interval by c on each end: $S_c = (\underline{c} - c, \overline{c} + c)$. In particular, S_0 equals the original interval $(\underline{c}, \overline{c})$.

[28] The posterior density $w_\sigma(\theta|x)$ is defined by (15) as long as the denominator in (15) is positive: when x lies in the interior $(-\sigma/2, 1 + \sigma/2)$ of the set of possible signals. If instead x equals the lowest (highest) possible signal $-\sigma/2$ (resp., $1 + \sigma/2$), then the posterior is then a Dirac delta function with all of its weight on the lowest state $\theta = 0$ (resp., the highest state $\theta = 1$).

Lemma 1 *1. For any $c' > c$, $S_c \subseteq S_{c'}$.*

2. Fix constants $c, c_0, c_1 \in \Re$ such that $c_0 \leq c_1$. Then $[c_0, c_1]$ is a subset of S_c if and only if, for any $\Delta \in \Re$, $[c_0 + \Delta, c_1 - \Delta]$ is a subset of $S_{c-\Delta}$.

Proof. Part 1. Trivial.

Part 2. If: let $\Delta = 0$. Only if: assume $[c_0, c_1]$ is a subset of $S_c = (\underline{c} - c, \overline{c} + c)$. Since $[c_0, c_1]$ is nonempty it must be that $c_0 > \underline{c} - c$ and $c_1 < \overline{c} + c$. Hence, for any $\Delta \in \Re$, $c_0 + \Delta > \underline{c} - c + \Delta$ and $c_1 - \Delta < \overline{c} + c - \Delta$. There are two cases. First, if $c_0 + \Delta > c_1 - \Delta$ then $[c_0 + \Delta, c_1 - \Delta]$ is empty and so is a subset of any set. Second, if $c_0 + \Delta \leq c_1 - \Delta$ then, collecting inequalities,

$$\underline{c} - c + \Delta < c_0 + \Delta \leq c_1 - \Delta < \overline{c} + c - \Delta,$$

whence $S_{c-\Delta}$ contains $[c_0 + \Delta, c_1 - \Delta]$ as claimed. ■

Lemma 2 *Fix $\sigma > 0$.*

1. For any θ in $\Re$, $\omega_\sigma(\theta|x)$ is well-defined if and only if x lies in $S_{\sigma/2}$.

2. $\omega_\sigma(\theta|x)$ is continuous in $(x, \theta) \in S_{-\sigma/2} \times \Re$.

Proof. Part 1. Since both f and ϕ are atomless, the denominator in (15) is nonzero if and only if x lies in $S_{\sigma/2}$. Part 2. Fix an $(x, \theta) \in S_{-\sigma/2} \times \Re$ and constant $\varepsilon > 0$. It suffices to find a $\delta > 0$ such that for any $(x', \theta') \in S_{-\sigma/2} \times \Re$ satisfying $\max\{|x' - x|, |\theta' - \theta|\} < \delta$, we have $|\omega_\sigma(\theta'|x') - \omega_\sigma(\theta|x)| \leq \varepsilon$. By assumption, ϕ has a finite upper bound $\overline{\phi}$. Let $\vee$ and $\wedge$ denote the pairwise maximum and minimum, respectively. Since ϕ is continuous and positive on the open set $(\underline{c}, \overline{c})$, it attains a positive minimum $\underline{\phi}$ on the compact subset $I = [(x \wedge x') - \sigma/2, (x \vee x') + \sigma/2]$ of $(\underline{c}, \overline{c})$. For $x'' \in \{x, x'\}$, $\frac{1}{\sigma}\int_{t \in I} f\left(\frac{x''-t}{\sigma}\right) dt = \int_{\varepsilon_i=-1/2}^{1/2} f(\varepsilon_i)\, d\varepsilon_i = 1$. Since, moreover, $\phi(t) \in \left[\underline{\phi}, \overline{\phi}\right]$ for all t in I, it follows that $\int_{t \in I} f\left(\frac{x''-t}{\sigma}\right) \phi(t)\, dt \in \left[\sigma\underline{\phi}, \sigma\overline{\phi}\right]$. As f is continuous, it is uniformly continuous on any compact set by the Heine-Cantor theorem. Moreover, ϕ is continuous. Hence, for any $\varepsilon' > 0$ there exists a $\delta' > 0$ (which can depend on the initial choice of θ) such that (a) if

$z, z' \in I$ and $|z' - z| \leq \delta'$ then $|f(z') - f(z)| \leq \varepsilon'$ and (b) for any θ' in $(\theta - \delta', \theta + \delta')$, we have $|\phi(\theta') - \phi(\theta)| < \varepsilon'$. In particular, let $\varepsilon' = \varepsilon\sigma\underline{\phi}^2 \left[\left(\overline{\phi} + \overline{f}\right)\underline{\phi} + 2\overline{f\phi}^2\right]^{-1} > 0$ where $\overline{f} = \max_{z\in[-1/2,1/2]} f(z)$, let δ' be the corresponding constant, and let $\delta = \min\{\delta', (\delta'\sigma)/2, \sigma\}$. Now choose any $(x', \theta') \in S_{-\sigma/2} \times \Re$ satisfying $\max\{|x' - x|, |\theta' - \theta|\} < \delta$. By construction, the distances $|\theta' - \theta|$, $\left|\frac{x'-\theta'}{\sigma} - \frac{x-\theta}{\sigma}\right|$, and $\left|\frac{x'-t}{\sigma} - \frac{x-t}{\sigma}\right|$ (for all t) are all less than δ' and, moreover, $|I| \leq 2\sigma$ whence $|\phi(\theta') - \phi(\theta)|$ and $\left|f\left(\frac{x'-\theta'}{\sigma}\right) - f\left(\frac{x-\theta}{\sigma}\right)\right|$ are less than ε' and

$$\int_{t\in I} \left| f\left(\frac{x-t}{\sigma}\right) - f\left(\frac{x'-t}{\sigma}\right)\right| \phi(t)\, dt < 2\sigma\varepsilon'\overline{\phi}.$$

Hence, cancelling the $1/\sigma$ terms in (15) and using the triangle inequality,

$$\begin{aligned}
|\omega_\sigma(\theta'|x') - \omega_\sigma(\theta|x)| &= \left| \frac{f\left(\frac{x'-\theta'}{\sigma}\right)\phi(\theta')}{\int_{t\in I} f\left(\frac{x'-t}{\sigma}\right)\phi(t)\, dt} - \frac{f\left(\frac{x-\theta}{\sigma}\right)\phi(\theta)}{\int_{t\in I} f\left(\frac{x-t}{\sigma}\right)\phi(t)\, dt} \right| \\
&\leq \left[\begin{array}{c} \phi(\theta)\left|f\left(\frac{x'-\theta'}{\sigma}\right) - f\left(\frac{x-\theta}{\sigma}\right)\right| \\ +f\left(\frac{x'-\theta'}{\sigma}\right)|\phi(\theta') - \phi(\theta)| \end{array}\right] \left[\int_{t\in I} f\left(\frac{x-t}{\sigma}\right)\phi(t)\, dt\right]^{-1} \\
&\quad + \frac{f\left(\frac{x'-\theta'}{\sigma}\right)\phi(\theta')\int_{t\in I}\left|f\left(\frac{x-t}{\sigma}\right) - f\left(\frac{x'-t}{\sigma}\right)\right|\phi(t)\, dt}{\left[\int_{t\in I} f\left(\frac{x'-t}{\sigma}\right)\phi(t)\, dt\right]\left[\int_{t\in I} f\left(\frac{x-t}{\sigma}\right)\phi(t)\, dt\right]} \\
&\leq \frac{\overline{\phi}\varepsilon' + \overline{f}\varepsilon'}{\sigma\underline{\phi}} + \overline{f\phi}\frac{2\sigma\varepsilon'\overline{\phi}}{\left[\sigma\underline{\phi}\right]^2}
\end{aligned}$$

which equals ε as claimed. ■

Lemma 3 *Assume AM. 1. For all $x \in S_{-\sigma/2}$, $\pi_\sigma(x, k)$ is nondecreasing in $k \in \Re$. 2. $\pi_\sigma(x, k)$ is continuous in $(x, k) \in S_{-\sigma/2} \times \Re$.*

Proof. Part 1. Fix $x \in S_{-\sigma/2}$ and let $k' > k$. By part 1 of Lemma 2, the denominator of (15) is positive. Hence, by (14) and (15),

$$\pi_\sigma(x, k') - \pi_\sigma(x, k) = \frac{\int_{\theta=x-\sigma/2}^{x+\sigma/2} f\left(\frac{x-\theta}{\sigma}\right)\left[r_\theta^{F\left(\frac{k'-\theta}{\sigma}\right)} - r_\theta^{F\left(\frac{k-\theta}{\sigma}\right)}\right] d\Phi(\theta)}{\int_{\theta=x-\sigma/2}^{x+\sigma/2} f\left(\frac{x-\theta}{\sigma}\right) d\Phi(\theta)},$$

whence $\pi_\sigma(x, k') \geq \pi_\sigma(x, k)$ by AM: $\pi_\sigma(x, k)$ is nondecreasing in k. Part 2. Fix $(x, k) \in$

$S_{-\sigma/2} \times \Re$. We will show that for any $\varepsilon \in (0, \sigma]$, there is a $\delta \in (0, \sigma/2]$ such that for any $(x', k') \in S_{-\sigma/2} \times \Re$ satisfying $\max\{|x' - x|, |k' - k|\} < \delta$, we have $|\pi_\sigma(x', k') - \pi_\sigma(x, k)| < \varepsilon$. Let Δ denote $k' - k$. Doing the change of variables $\theta' = \theta - \Delta$ (whence $k' - \theta = k - \theta'$) and then renaming θ' to θ, we have $\pi_\sigma(x', k') = \int_{\theta=x'-\Delta-\sigma/2}^{x'-\Delta+\sigma/2} \omega_\sigma(\theta + \Delta|x') \, r_\theta^{F\left(\frac{k-\theta}{\sigma}\right)} d\theta$. Since, by construction,

$$|(x' - \Delta) - x| \leq |x' - x| + |\Delta| < 2\delta \leq \sigma,$$

the Cauchy-Schwarz inequality implies

$$\begin{aligned} |\pi_\sigma(x', k') - \pi_\sigma(x, k)| &= \left| \int_{\theta=x-3\sigma/2}^{x+3\sigma/2} \left[\omega_\sigma(\theta + \Delta|x') - \omega_\sigma(\theta|x)\right] r_\theta^{1-F\left(\frac{k-\theta}{\sigma}\right)} d\theta \right| \\ &\leq \sqrt{\int_{\theta=x-3\sigma/2}^{x+3\sigma/2} \left[\omega_\sigma(\theta + \Delta|x') - \omega_\sigma(\theta|x)\right]^2 d\theta} \sqrt{\int_{\theta=x-3\sigma/2}^{x+3\sigma/2} \left[r_\theta^{F\left(\frac{k-\theta}{\sigma}\right)}\right]^2 d\theta}. \end{aligned} \tag{16}$$

The second square root is no greater than $\overline{r}\sqrt{3\sigma}$ where $\overline{r} > 0$ is the (finite by assumption) maximum of $\left|r_\theta^\ell\right|$ over pairs (θ, ℓ) in the compact set $[x - 3\sigma/2, x + 3\sigma/2] \times [0, 1]$. By Lemma 2, ω_σ is continuous on $S_{-\sigma/2} \times \Re$. Let $c > 0$ be small enough that $[x - c, x + c]$ is a subset of $S_{-\sigma/2}$. Then $\Sigma = [x - c, x + c] \times [x - 2\sigma, x + 2\sigma]$ is a compact subset of $S_{-\sigma/2} \times \Re$ whence, by the Heine-Cantor theorem, ω_σ is absolutely continuous on Σ. Accordingly, there is a $\delta \in (0, \max\{c, \sigma/2\}]$ such that for any $(x', \Delta) \in [x - \delta, x + \delta] \times [-\delta, \delta]$, we have $|\omega_\sigma(\theta + \Delta|x') - \omega_\sigma(\theta|x)| < \varepsilon (3\sigma\overline{r})^{-1}$ uniformly in $\theta \in [x - 3\sigma/2, x + 3\sigma/2]$ whence the first square root in (16) is less than $\varepsilon (3\sigma\overline{r})^{-1} \sqrt{3\sigma}$. Hence, $|\pi_\sigma(x', k) - \pi_\sigma(x, k)| \leq \varepsilon$ as claimed.

■

The positive constant k_5 is defined in (12).

Lemma 4 *Fix some $\sigma \in (0, k_5)$. The set $S_{\sigma/2} = (\underline{c} - \sigma/2, \overline{c} + \sigma/2)$ of signals x for which, by Lemma 2, $\omega_\sigma(\cdot|x)$ and thus $\pi_\sigma(x|\cdot)$ are well-defined is the union of three nonempty subintervals. (a) A high interval $\left[\overline{\theta} + \sigma/2, \overline{c} + \sigma/2\right)$. For any x in this interval and any k, $\pi_\sigma(x|k)$ is negative. (b) An intermediate interval $\left[\underline{\theta} - \sigma/2, \overline{\theta} + \sigma/2\right]$, which is contained in $S_{-\sigma/2}$. For all x in this interval, $\pi_\sigma(x|k)$ satisfies the properties of Lemma 3. (c) A low interval $(\underline{c} - \sigma/2, \underline{\theta} - \sigma/2]$. For any x in this interval and any k, $\pi_\sigma(x|k)$ is positive.*

Proof. Intervals (a) and (c) are nonempty by DR and, for x in these intervals, $\pi_\sigma(x|k)$ has the claimed sign by (11) and (14). The interval (b) is nonempty since $\sigma > 0$. It is contained in $S_{-\sigma/2}$ by DR and since $\sigma < k_5$, whence $\pi_\sigma(x|k)$ satisfies the properties of Lemma 3 for x in the interval. ■

For any k in $\Re$, define $\overline{\beta}(k) = \sup\{x : \pi_\sigma(x,k) \geq 0\}$ and $\underline{\beta}(k) = \inf\{x : \pi_\sigma(x,k) \leq 0\}$. By Lemma 4, $\overline{\beta}(k) \leq \overline{\theta} + \sigma/2$ and $\underline{\beta}(k) \geq \underline{\theta} - \sigma/2$. Lemma 3 then implies that each is also nondecreasing in k. By construction, $\pi_\sigma(x,k) < 0$ for all $x > \overline{\beta}(k)$, and $\pi_\sigma(x,k) > 0$ for all $x < \underline{\beta}(k)$. Hence, by AM, if all others are known (not) to invest when their signals are less (greater) than k, then it is optimal for a given agent (not) to invest when her signal is less than $\underline{\beta}(k)$ (greater than $\overline{\beta}(k)$).

Let $\underline{k}_0 = \underline{\theta} - \sigma/2$ and, for $n = 1, 2, ...,$ let $\underline{k}_n = \underline{\beta}\left(\underline{k}_{n-1}\right)$. For any signal x below $\underline{k}_0$ it is strictly dominant to invest so, in particular, $\pi_\sigma(x, \underline{k}_0) > 0$, whence $\underline{\beta}(\underline{k}_0) \geq \underline{k}_0$. Since $\underline{\beta}(k)$ is, moreover, nondecreasing in k, the sequence $(\underline{k}_n)_{n=0}^\infty$ is nondecreasing by induction. It is bounded above by $\overline{\theta} + \sigma/2$, so it converges to a limit $\underline{k}$ by the monotone convergence theorem, and all agents invest if their signals are below $\underline{k}$. By part 2 of Lemma 3, $\pi_\sigma\left(\underline{k}_n, \underline{k}_{n-1}\right) = 0$ for all n and $\lim_{n\to\infty} \pi_\sigma\left(\underline{k}_n, \underline{k}_{n-1}\right) = \pi_\sigma(\underline{k}, \underline{k})$; thus, $\pi_\sigma(\underline{k}, \underline{k}) = 0$. We can construct an analogous sequence $\overline{k}_0 = \overline{\theta} + \sigma/2$ and, for $n = 1, 2, ...,$ $\overline{k}_n = \overline{\beta}\left(\overline{k}_{n-1}\right)$, which converges to a limit $\overline{k}$ such that no agents invest if their signals exceed $\overline{k}$ (whence $\overline{k} \geq \underline{k}$) and $\pi_\sigma\left(\overline{k}, \overline{k}\right) = 0$.

Let k_σ denote either $\underline{k}$ or $\overline{k}$. Substituting $\ell = F\left(\frac{k_\sigma - \theta}{\sigma}\right)$,

$$0 = \pi_\sigma(k_\sigma, k_\sigma) = \int_{\ell=0}^{1} \alpha(\ell, k_\sigma, \sigma)\, r^\ell_{k_\sigma - \sigma F^{-1}(\ell)} d\ell$$

where $\alpha(\ell, k_\sigma, \sigma) = \frac{\phi\left(k_\sigma - \sigma F^{-1}(\ell)\right)}{\int_{\ell=0}^{1} \phi(k_\sigma - \sigma F^{-1}(\ell)) d\ell}$. To finish the proof, it suffices to show that for all $\varepsilon > 0$, there is a $\delta > 0$ such that for all $\sigma \in (0, \delta)$, $k_\sigma \in (\theta_R - \varepsilon, \theta_R + \varepsilon)$. Suppose otherwise: there is an $\varepsilon > 0$ such that for all $\delta > 0$, there is some $\sigma \in (0, \delta)$ for which $k_\sigma \notin (\theta_R - \varepsilon, \theta_R + \varepsilon)$. For $n = 1, 2, ...,$ let $\delta_n = 1/n$ and let $\sigma_n \in (0, \delta_n)$ be such that $k_{\sigma_n} \notin (\theta_R - \varepsilon, \theta_R + \varepsilon)$. By taking subsequences if needed, we may assume that either $k_{\sigma_n} \leq \theta_R - \varepsilon$ for all n or $k_{\sigma_n} \geq \theta_R + \varepsilon$ for all n; w.l.o.g. assume the former. Let σ now denote σ_m for some $m \geq \lceil 1/\varepsilon \rceil$ that will be specified later. As $\sigma < \varepsilon$, we have $k_\sigma + \sigma/2 < \theta_R - \varepsilon/2$. Now, by MSM and (10) we have $R_\theta > 0$ for all $\theta < \theta_R$ and thus, again by MSM, $\int_{\ell=0}^{1} r^{\ell}_{k_\sigma+\sigma/2} d\ell = R_{k_\sigma+\sigma/2} > R_{\theta_R-\varepsilon/2} \geq k_2\varepsilon/2 = \pi_\sigma(k_\sigma, k_\sigma) + k_2\varepsilon/2$. Thus, $\frac{k_2\varepsilon}{2} \leq \int_{\ell=0}^{1} r^{\ell}_{k_\sigma+\sigma/2} d\ell - \pi_\sigma(k_\sigma, k_\sigma) = A + B$ where $A = \int_{\ell=0}^{1} r^{\ell}_{k_\sigma+\sigma/2} [1 - \alpha(\ell, k_\sigma, \sigma)]\, d\ell$ and $B = \int_{\ell=0}^{1} \alpha(\ell, k_\sigma, \sigma) \left[r^{\ell}_{k_\sigma+\sigma/2} - r^{\ell}_{k_\sigma-\sigma F^{-1}(\ell)} \right] d\ell$. B is a weighted average of terms $r^{\ell}_{k_\sigma+\sigma/2} - r^{\ell}_{k_\sigma-\sigma F^{-1}(\ell)}$ each of which, by OSL, is at most $k_4\sigma$; hence, $B \leq k_4\sigma$. Thus, $\frac{k_2\varepsilon}{2} - k_4\sigma$ is at most A which cannot exceed $|A|$ which, by the Cauchy-Schwarz inequality, is at most CD where $C = \sqrt{\int_{\ell=0}^{1} \left[r^{\ell}_{k_\sigma+\sigma/2} \right]^2 d\ell}$ and $D = \sqrt{\int_{\ell=0}^{1} [1 - \alpha(\ell, k_\sigma, \sigma)]^2 d\ell}$. As r is bounded on compact sets and $k_\sigma \in [\underline{\theta}, \overline{\theta}]$, C cannot exceed the maximum $\overline{r}$ of $|r^{\ell}_{\theta}|$ over pairs (θ, ℓ) in the compact set $I \times [0,1]$ where $I = [\underline{\theta} - \sigma/2, \overline{\theta} + \sigma/2]$. As for D, the compact set I is contained in $S_{-\sigma/2}$ - a subset of $(\underline{c}, \overline{c})$ - by Lemma 4. Hence, $\phi(\theta)$ is bounded below by some $\underline{\phi} > 0$ on I. And since ϕ is continuous, it is uniformly continuous on any compact set by the Heine-Cantor theorem. Hence, for any $\varepsilon' > 0$ there exists a $\delta' > 0$ such that if $|\theta' - \theta''| \leq \delta'$ and $\theta', \theta'' \in I$ then $|\phi(\theta') - \phi(\theta'')| \leq \varepsilon'$. Select any ε' in $\left(0, \frac{k_2\underline{\phi}\varepsilon}{4\overline{r}}\right)$ and let δ' be the corresponding constant. Finally, let the index m be large enough that $\sigma = \sigma_m \leq \min\left\{\varepsilon, \delta', \frac{k_2\varepsilon}{4k_4}\right\}$. Then since $F^{-1}(\ell) \in [-1/2, 1/2]$, by the triangle inequality,

$$D \leq \max_{\ell\in[0,1]} |1 - \alpha(\ell, k_\sigma, \sigma)| \leq \max_{\ell\in[0,1]} \frac{\int_{\ell'=0}^{1} |\phi(k_\sigma - \sigma F^{-1}(\ell')) - \phi(k_\sigma - \sigma F^{-1}(\ell))|\, d\ell'}{\int_{\ell'=0}^{1} \phi(k_\sigma - \sigma F^{-1}(\ell'))\, d\ell'} \leq \frac{\varepsilon'}{\underline{\phi}}$$

Thus, $\frac{k_2\varepsilon}{4} < \frac{k_2\varepsilon}{2} - k_4\sigma \leq |A| \leq CD \leq \overline{r}\frac{\varepsilon'}{\underline{\phi}} < \frac{k_2\varepsilon}{4}$, a contradiction. Q.E.D.$_{\text{Theorem 1}}$

Proof of Claim 3. We first compute the realized payoffs for each outside option θ:

A. If $\theta > \theta_D$, no agents invest. The agents get their outside option payoff θ. As for the firm and bondholders, there are two cases.

   (a) If $D = 0$, the firm continues as a (valueless) going concern. Firm and stockholders get nothing while the manager receives the rent $B > 0$.

   (b) If $D > 0$, the firm is liquidated yielding A. The bondholders get $\min\{A, D\}$ and the firm receives the residual $\Pi = A - \min\{A, D\}$.[29] The manager gets nothing.

[29] See n. 15, p. 7.

B. If $\theta < \theta_D$, all agents invest. Since $r > A$, the firm will not be liquidated even if it is insolvent. The bondholders get $\min\{r, D\}$. The residual is $\Pi = r - \min\{r, D\}$ which is then taxed at the rate τ; the firm receives the remainder, $(1-\tau)\,\Pi$. The manager gets the rent B.

All of the payoffs, as well as the threshold ℓ_D, are constant over all $D \geq r$. Hence, without loss of generality, we can restrict to $D \leq r$, whence each occurence of $\min\{r, D\}$ above is replaced by D. The firm's value is thus

$$V(D) = A1_{D>0}\left[1 - \Phi(\theta_D)\right] + \left[D + (1-\tau)(r - D)\right]\Phi(\theta_D)\,. \tag{17}$$

But by (4), θ_D is continuous in D and $\theta_0 = b$. Thus, the firm will never set $D = 0$ since, by (17), an infinitesimal increase in D raises its value by $A\left[1 - \Phi(b)\right]$ which is positive by (3). Hence the firm will choose $D > 0$ which, together with (17), implies (7). As for the payout to bondholders, it is D if $\theta > \theta_D$ and $\min\{A, D\}$ if $\theta < \theta_D$ and thus, in expectation, (5). The firm's net payout is $(1-\tau)(r - D)$ if $\theta > \theta_D$ and $A - \min\{A, D\}$ and so, in expectation, (6). Finally, if we substitute for θ_D using (2) and (4), (7) becomes (8). Q.E.D.$_{\text{Claim 3}}$

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