Persuading Large Investors

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Introduction

- Regulators/Policy makers
  - care about the health of the financial system as a whole, so may want to **save even insolvent systemic institutions** in times of crisis,
  - would ideally **elicit private investment** to participate in any bail-ins/outs, to avoid using taxpayer money,
  - one way in which they can **coordinate such investment is by the public disclosure of stress tests**, which shape agents' learning about the health of systemic financial institutions.
- Private investors
  - are usually **large financial institutions** themselves, like other banks, pension funds, etc,
  - ideally would **like to co-invest** in side with others to avoid too concentrated of an exposure, so they have a coordination motive,
  - have their **own information** on the state of other institutions, through research/analysts and financial networks they are part of,
  - **care about own shareholders**, so they'd rather avoid investing in 'bad' (insolvent) vs 'good' (illiquid) institutions; hence their interests are conflicted to that of the regulator(s).

Research Questions and Results Preview

- What are the features of the optimal stress test?
  $\rightarrow$ *An experiment with two realizations. Can dispel strategic uncertainty but maintains fundamental uncertainty.*

- **The interplay between public and private information:** Does the regulator provide more informative tests to better informed investors?
  $\rightarrow$ *Yes, as long as investors remain responsive to public news.*

- Are investors better-off observing the regulator's test?
  $\rightarrow$ *Investors' welfare improvement from more precise signals may stem from their impact on the public signal.*

Related Literature

- **Information Design**
  - **Single receiver:** Brocas and Carrillo (2007), Rayo and Segal (2010), Kamenica and Gentzkow (2011), Alonso and Camara (2016a).
  - **Multiple receivers:** Alonso and Camara (2016b), Barhi and Guo (2016), Mathevet, Perego, Taneva (2016), Bergemann and Morris (2017).
  - **Informed receiver:** Kolotilin (2017), Kolotilin et al. (2017), Bergemann and Morris (2016).
- **Stress Testing (Financial Regulation):** Goldstein and Leitner (2015), Bouvard et al. (2015), Goldstein and Huang (2016).
- **Endogenous Public Info in Global Games:** Angeletos et al. (2007), Edmond (2013), Inostroza and Pavan (2023).

Model

- Financial Regulator (Sender).
- Two investors (Receivers), $i = 1, 2$.
- Investor i can: Invest ($a_i = 1$), or Not Invest ($a_i = 0$).
- State $\omega \in \Omega = \{+1, -1\}$, 'good' or 'bad' bank; prior belief $\Pr[\omega = +1] = \mu_0$.
- Investors' payoff: $v_i(a_i, a_j, \omega) = a_i(\omega + \gamma a_j)$, $\gamma \in (-1, 1)$, where γ captures the importance of coordination.
- Strategic complementarity for $\gamma > 0$, substitutability for $\gamma < 0$.

Investors private signals

Each investor privately observes x_i.

- This talk, focus on the symmetric, conditionally independent case. Let

$$\Pr[x_i \leq x|\omega = +1] = F(x),$$
$$\Pr[x_i \leq x|\omega = -1] = G(x),$$

  with continuous pdfs $f(x)$ and $g(x)$ in [0,1].

- MLRP: In intersection of supports of f and g, i.e., likelihood ratio

$$\lambda(x) = \frac{f(x)}{g(x)},$$

  strictly increasing in x.

Public stress test

- Regulator: Preferences over joint-investment

$$u_R^{ex-post} = a_i a_j \left[\eta \mathbb{I}(\omega = -1) + \mathbb{I}(\omega = 1)\right], \eta \in [-1, 1],$$

  where a_i is the action (invest, not invest) of investor i; η measures the strength of the conflict of interest.

- Regulator designs an "experiment" π (stress test).
  - A realization space S, and
  - A family of likelihood functions, $\pi(s|\omega)_\Omega$.
  - Experiment π is "commonly understood."
  - Public Persuasion: realization s commonly observed by investors.
    - Common posterior.

Timing

- Regulator's problem: choose π^* that maximizes expected $u_R^{ex-post}$.
- Timing:
  - Regulator selects and publicly announces π.
  - State ω and outcome of π realized.
  - Signals x_i, $i = 1, 2$, realized and privately observed by investors.
  - Investors simultaneously choose to Invest or Not Invest.
  - Payoffs are realized.
- Equilibrium selection: Perfect Bayesian Equilibrium
  - If multiplicity, focus on Regulator(Sender)-preferred PBE.
- *Preliminary result:* For $\eta \leq 0$ (no conflict) a fully informative result is optimal; focus on $\eta > 0$.

Investors' behavior

- Public test: interim common posterior μ.
- Pick investor i and suppose $a_j = 1$ iff $x_j \geq k_j$.
- Investor i's payoff for posterior $q(x_i) = \Pr[\omega = +1|x_i, \mu]$ is

$$v_i(k_j, x; \mu) \equiv \mathbb{E}[\omega|x_i = x] + \gamma\mathbb{E}[a_j|x_i = x]$$
$$= \left(1 + \gamma\overline{F}(k_j|x)\right)\Pr[\omega = 1|x_i = x] - \left(1 - \gamma\overline{G}(k_j|x)\right)\Pr[\omega = -1|x_i = x].$$

- Best response: invest if $x_i \geq k_i$ with $v_i(k_j, k_i; \mu) = 0$.
- We focus on symmetric threshold strategies $k_i = k_j = k$; define

$$\widetilde{R}(k) \equiv \overbrace{\lambda(k)}^{\text{Likelihood}} \underbrace{\frac{1 + \gamma\overline{F}(k|k)}{1 - \gamma\overline{G}(k|k)}}_{\text{Coordination}}.$$

Then the equlibrium condition is $(1 - \mu)/\mu = \widetilde{R}(k)$.

Continuation Equilibrium $\gamma > 0$

We focus on case of strategic complementarities: $\gamma > 0$. Define

$$R(k) \equiv \max_{0 \le k' \le k} \widetilde{R}(k'),$$

with $R^{-1}(y) = \min\left\{k : y = \widetilde{R}(k)\right\}$.

Lemma

(Under some regularity conditions) For $\mu \in \left(0, \frac{1}{1+R(0)}\right)$, the equilibrium investment threshold is

$$k(\mu) = \begin{cases} R^{-1}\left((1-\mu)/\mu\right), & \text{if } \frac{1}{1+R(1)} \le \mu \le \frac{1}{1+R(0)}, \\ 1, & \text{if } \mu \le \frac{1}{1+R(1)}. \end{cases}$$

If $\mu > 1/\left(1 + \min_{k \in (0,1)} \widetilde{R}(k)\right)$, then $k(\mu) = 0$.

So we choose the continuation $k(\mu)$ with highest joint investment; (preliminary result) $\exists\ \overline{\gamma}$ so that threshold is unique for $\gamma \in (0, \overline{\gamma})$.

Optimal Test: Convafication Approach

Kamenica-Gentzkow: binary state $\rightarrow$ there $\exists$ an optimal test with two realizations depending where the common prior μ is.

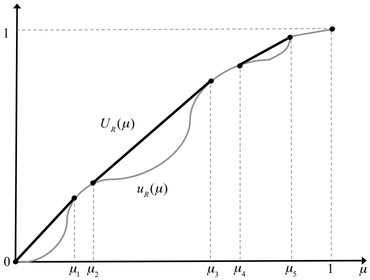


Figure: Regulator's indirect utility u_R and associated concave closure U_R, defined via the cutoffs $\{\mu_1, \ldots, \mu_5\}$.

Lemma

Suppose investors' signals are imperfect then for $\eta > 0$ a fully informative test is never optimal.

Two special tests: "Critical-Fault" and "Coordinated-Investment" Tests

These tests (under certain conditions for existence) dispel *strategic uncertainty* but maintain *fundamental uncertainty*.

- **Critical Fault:** For $\mu \in (0, \underline{\mu})$ posteriors are (either of) the end points, where

$$\underline{\mu} \in \arg\max_{\mu} u_R(\mu)/\mu.$$

- **Coordinated Investment:** For $\mu \in (\overline{\mu}, \mu_{CI})$ posteriors are (either of) the end points, where $\mu_{CI} = 1/(1 + R(0))$ and:

$$\overline{\mu} \in \arg\min_{\mu}(u_R(\mu) - u_R(\mu_{CI}))/(\mu - \mu_{CI}).$$

Interplay between Investors' Expertise and Optimal Tests

- Focus on Critical Fault $(0, \underline{\mu}(\alpha))$ tests.
- Consider family of Blackwell ordered signals indexed by $\alpha \in (0,1)$.
- Optimal CF-test satisfies $\underline{\mu}(\alpha) = (1 + R(k^*(\alpha), \alpha))^{-1}$ for $k^*(\alpha)$ from:

$$\underbrace{-2f(k,\alpha)\overline{F}(k,\alpha) - 2\eta g(k,\alpha)\overline{G}(k,\alpha)R(k,\alpha)}_{\text{the gain from increasing average joint investment by lowering investors' threshold}} + \underbrace{\eta\overline{G}^2(k,\alpha)\frac{\partial R(k,\alpha)}{\partial k}}_{\text{the cost of under-weighting joint investment when the state is } \omega=-1} = 0,$$

- Moreover, must account for investors' response to public news $k(\mu, \alpha)$.

Local Crowding In and Crowding Out

Proposition

Let $k(\mu, \alpha)$ be the equilibrium threshold. A marginal increase in investors' expertise crowds in the regulator's test iff

$$\frac{dk^*(\alpha)}{d\alpha} \leq \left.\frac{\partial k(\mu, \alpha)}{\partial \alpha}\right|_{\mu=\underline{\mu}(\alpha)}.$$

- Local crowding-in obtains whenever investors' respond to public news more aggressively than the regulator's revised optimal threshold.

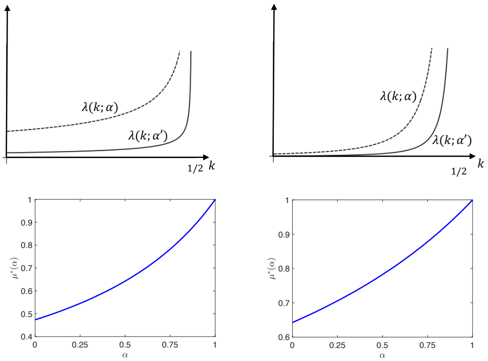
Example 1: Conclusive Good News Signals

Fix a decreasing (in k) $m(k,\alpha) \geq 0$ in $[0, 1/2]$ with $\int_0^{1/2} m(t,\alpha)dt = 1$.

$$X_+(\alpha) : \left[f(k;\alpha) = \begin{cases} 2(1-\alpha), & k < 1/2, \\ 2\alpha, & k \geq 1/2. \end{cases}, g(k) = \begin{cases} m(k,\alpha), & k < 1/2, \\ 0, & k \geq 1/2. \end{cases} \right].$$

In other words, each investor learns that $\omega = +1$ upon observing $k \geq 1/2$.

$$m(k,\alpha) = \sqrt{k - 1/2} \quad m(k,\alpha) = (k - 1/2)^2$$



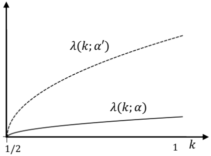
Example 2: Conclusive Bad News Signals

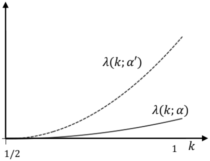
Fix an increasing (in k) $h(k,\alpha) \geq 0$ in $[1/2, 1]$ with $\int_{1/2}^{1} h(t,\alpha)dt = 1$.

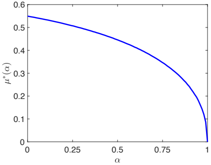
$$X_{-}(\alpha) : \left[f(k) = \begin{cases} h(k,\alpha), & k \geq 1/2, \\ 0, & k < 1/2. \end{cases}, g(k;\alpha) = \begin{cases} 2(1-\alpha), & k \geq 1/2, \\ 2\alpha, & k < 1/2. \end{cases} \right].$$

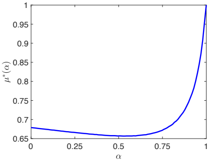
In other words, each investor learns that $\omega = -1$ upon observing $k \leq 1/2$.

$$h(k,\alpha) = \sqrt{1/2 - k} \qquad h(k,\alpha) = (1/2 - k)^2$$









Asymptotic Crowding In and Crowding Out

Let

$$\tau(k,\alpha) \equiv -\frac{\partial \ln \widetilde{R}(k,\alpha)/\partial k}{\partial \ln \overline{G}(k,\alpha)/\partial k} = \frac{(\partial \widetilde{R}(k;\alpha)/\partial k)/\widetilde{R}(k;\alpha)}{g(k;\alpha)/\overline{G}(k;\alpha)},$$

which is the ratio of the cost to the benefit (of investing) in the bad state.

Proposition

Suppose that for some $\alpha' < 1$, f and g are continuously differentiable and $\tau(k,\alpha)$ is uniformly bounded, in $(k,\alpha) \in [0,1] \times [\alpha', 1)$. For each $\alpha \geq \alpha'$, consider a selection $k_s(\mu,\alpha)$ of investment equilibria with associated $R_s(k,\alpha)$, so that $R_s(k,\alpha) = \widetilde{R}(k,\alpha)$ for each $k \in \{k : k = k_s(\mu,\alpha), \mu \in (0,1)\}$. Then, for every $\mu_0 \in (0,1)$ the regulator's test perfectly reveals the state as $\alpha \to 1$.

- Private and public information act as complements when investors are very well informed, as long as they remain responsive to the stress test—as ensured by boundness of τ.

Back to Example 1: Conclusive Good News

Corrolary

Suppose that investors' signals provide conclusive good news $X_+(\alpha)$ *and there is a constant* M *so that* $|\partial m(k,\alpha)/\partial k| \leq M/(1/2-k)$, $k \in [0,1/2]$. *Then, for any* $\mu_0 \in (0,1)$ *the regulator's test becomes perfectly informative as* $\alpha \to 1$.

Back to Example 2: Conclusive Bad News

Corrolary

(Under some regularity conditions) For $X_-(\alpha)$ we have:

(i) *If* $\max_{1/2 \leq k \leq 1} \partial h(k,\alpha)/\partial k \leq M$ *and* $h(1/2,\alpha) \geq \varepsilon > 0$ *for* $\alpha \in [0,1]$, *then the regulator's test fully reveals the state as* $\alpha \to 1$.

(ii) *Suppose that* $h(1/2,\alpha) = 0$ *and that* $\lim_{\alpha \to 1} \partial_+ h(1/2,\alpha)/\partial k = \overline{h}'$. *Define*

$$\underline{\mu}_h = \frac{1}{1 + \eta(1+\gamma)^2 \overline{h}'/8}. \quad (1)$$

Then, the regulator's optimal test converges to $\left\{0, \underline{\mu}_h\right\}$ *if* $\mu_0 \in \left(0, \underline{\mu}_h\right)$ *and is completely uninformative if* $\mu_0 \geq \underline{\mu}_h$. *In particular, we have investors' asymptotic crowding-in of the public test iff* $\partial_+ h(1/2,\alpha)/\partial k$ *tends to* 0, *while we have asymptotic crowding-out of the public test iff* $\partial_+ h(1/2,\alpha)/\partial k$ *becomes unbounded, as* $\alpha \to 1$.

Conclusions

- Regulators use public stress tests to elicit investment for both "good" and "bad" banks form private investors who are large, would want to invest only in good banks, and have a coordination motive.
- Optimal public tests can dispel strategic uncertainty and coordinate investments and maintain fundamental uncertainty; but perfect coordination is non-generic.
- Private and public information complement each other, leading to crowding-in when investors heed public news. For example, (asymptotic) crowding-in always obtains if investors' signals are discrete or in the case of Conclusive News Signals.
- **Main empirical prediction:** In settings where large investors are well-informed and responsive to public news, regulators will release more informative stress tests, as indicated by the market's reaction.