

Deposit Clustering

Ruslan Sverchkov

Chaojun Wang*

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Abstract

Depositors in the 2023 bank runs belonged to close-knit communities. We show that clustering of information within each community fuels runs. We let depositors within a community observe nearly identical signals about their bank in an otherwise standard global game of bank runs. Each depositor believes that fewer others would run given a higher fundamental. Information clustering shrinks this negative covariance between the fundamental and the proportion of runners from each depositor's perspective, making depositors more inclined to run—and more so where they cluster into fewer communities. Yet, clustering is privately optimal. Our model implies that geographic ring-fencing exacerbates run risk while branching mitigates it, and further rationalizes ambiguity in regulators' disclosures.

Keywords: Global game, bank runs, regional bank, social network, funding concentration

*Ruslan Sverchkov (ruslan.sverchkov@wbs.ac.uk) is at Warwick Business School, University of Warwick. Chaojun Wang (wangchj@wharton.upenn.edu) is at the Wharton School, University of Pennsylvania.

1 Introduction

Depositors at the banks that suffered runs in 2023 belonged to close-knit communities, which exposed them to clustered information sources. Silicon Valley Bank’s (SVB) depositors in technology leaned heavily on their venture capitalists for first-hand financial information, the Signature Bank’s depositors on firms in law, real estate, and also in cryptocurrency, and the Silvergate Bank’s on cryptocurrency firms. During the Panic of 1930, small rural banks were hit especially hard; their depositors—predominantly local agricultural workers—relied on local newspapers, word of mouth, and farmers’ markets for information. Does information clustering fuel bank runs?

We model information clustering in an otherwise standard global game of bank runs. A bank’s depositors are partitioned into several communities. Signals are *clustered* within a community, in that depositors in a community observe nearly identical signals about the bank’s fundamental. We show that clustering makes depositors strictly more inclined to run, and more so as depositors cluster into fewer, larger communities. Despite fueling costly runs, clustering is privately optimal.

Underlying our results is a *negative covariance* between the fundamental and the proportion of runners from a depositor’s perspective, in that she believes fewer other depositors would run conditional on a higher fundamental. Clustering into fewer communities gradually shrinks this negative covariance. As depositors in a community observe and act on virtually the same signal, that signal screens off the true fundamental from inferring the proportion of them who run: Their consensus reality obscures the underlying truth for forecasting their behavior. Given fewer communities, a depositor’s signal screens off the fundamental from the proportion of runners in her increasingly larger community.

The negative covariance results in fewer others running when the fundamental is higher, which is precisely the state of the world where each runner inflicts greater damage to the bank’s payoff and thus also to another depositor’s willingness to stay. By gradually attenuating of this negative covariance, clustering therefore monotonically lowers the depositor’s expected willing to stay.

Our results imply that geographic ring-fencing strengthens information clustering and

exacerbates runs, while bank branching information clustering across depositors and mitigates runs. Beyond banking, ambiguity in regulators' disclosures amplifies the covariance between the fundamental and the strategic states for market participants who face strategic complementarity, steering them toward the socially efficient action.

1.1 Bank Runs with Information Clustering

We partition a continuum of depositors at a bank into K equal-sized communities. Each depositor observes a signal about the bank's fundamental θ , subject to an error common to all depositors in her community and an infinitesimal idiosyncratic noise specific to that depositor. The remaining setup is an otherwise standard global game of bank runs.¹ Upon observing her signal, every depositor may choose to run or stay. A depositor has a stronger incentive to run if a larger proportion n of others do so (strategic complementarity) or if the fundamental θ is lower (state monotonicity). We assume a general payoff function, only requiring the strategic complementarity to strengthen with the fundamental.

1.2 Clustering Induces More Runs

A unique equilibrium exists, in which every depositor runs whenever her signal is below an equilibrium threshold θ_K^* . The community error and the idiosyncratic noise together generate strategic uncertainty, which global games require for equilibrium uniqueness. Specifically, the marginal depositor, whose signal is at the threshold θ_K^* , is uncertain about the proportion of runners in other communities because she does not know how their community errors compare to her own. She is also uncertain about the proportion of others running in her own community because she does not know how their idiosyncratic noises compare to her own. The model nests a standard global game with no clustering as the limiting case of infinitely many communities, in that $\lim_{K \rightarrow \infty} \theta_K^* = \theta_\infty^*$, where θ_∞^* is the equilibrium threshold of the standard global game. As the depositors cluster into fewer communities, the threshold θ_K^* strictly increases: Depositors become more inclined to run.

¹Diamond and Dybvig (1983) pioneered the literature on bank runs. Carlsson and Van Damme (1993) originated global games as an equilibrium selection theory. Morris and Shin (1998) started the applied literature, introducing global games to currency attack. Goldstein and Pauzner (2005); Rochet and Vives (2004) applied them to bank runs.

Clustering induces more runs by decorrelating fundamental θ and the proportion n of runners for the marginal depositor without affecting her perception about either of them.² Consider two extreme cases—the standard case of no clustering ($K = \infty$) and maximum clustering, where all depositors cluster into a single community ($K = 1$)—both from the marginal depositor’s perspective. With no clustering, θ and n move in lockstep in opposite directions: A higher fundamental implies that fewer others will observe a signal below threshold θ_∞^* and run. With maximum clustering, all depositors act on virtually the same signal, that signal alone is a sufficient statistic—and the true fundamental contains no incremental information—for the marginal depositor to infer others’ actions and thus n . With no clustering, the perfect negative covariance between θ and n results in the smallest proportion n of runners when fundamental θ is the highest, which is precisely in the state of the world where each runner inflicts the most damage to the bank’s payoff and thus also to the depositor’s willingness to stay. Maximum clustering eliminates this negative covariance, reducing the depositor’s willingness to stay relative to no clustering. Between these two extreme cases, clustering of depositors into one fewer community increasingly decorrelates θ and n for the marginal depositor, because her signal screens off θ from the proportion of runners in her own, now larger, community. **Figure 1** illustrates how clustering decorrelates θ and n for the marginal depositor.

Through depositors’ greater propensity to run, clustering raises the social cost of runs in *all* fundamental states, and strictly so *ex ante*. Despite so, clustering is privately optimal, in that it is weakly dominant for a depositor to observe her community signal even if every depositor could choose to observe an idiosyncratic signal instead. The community signal dominates the idiosyncratic signal by almost certainly revealing the action of other depositors choosing to observe virtually the same community signal.

²We will show that the marginal depositor’s belief about n is always $\text{Uniform}(0, 1)$ for any number $K \in [1, \infty]$ of communities, extending the classic Laplacian property. A depositor’s posterior belief about θ given any signal does not depend on K either.

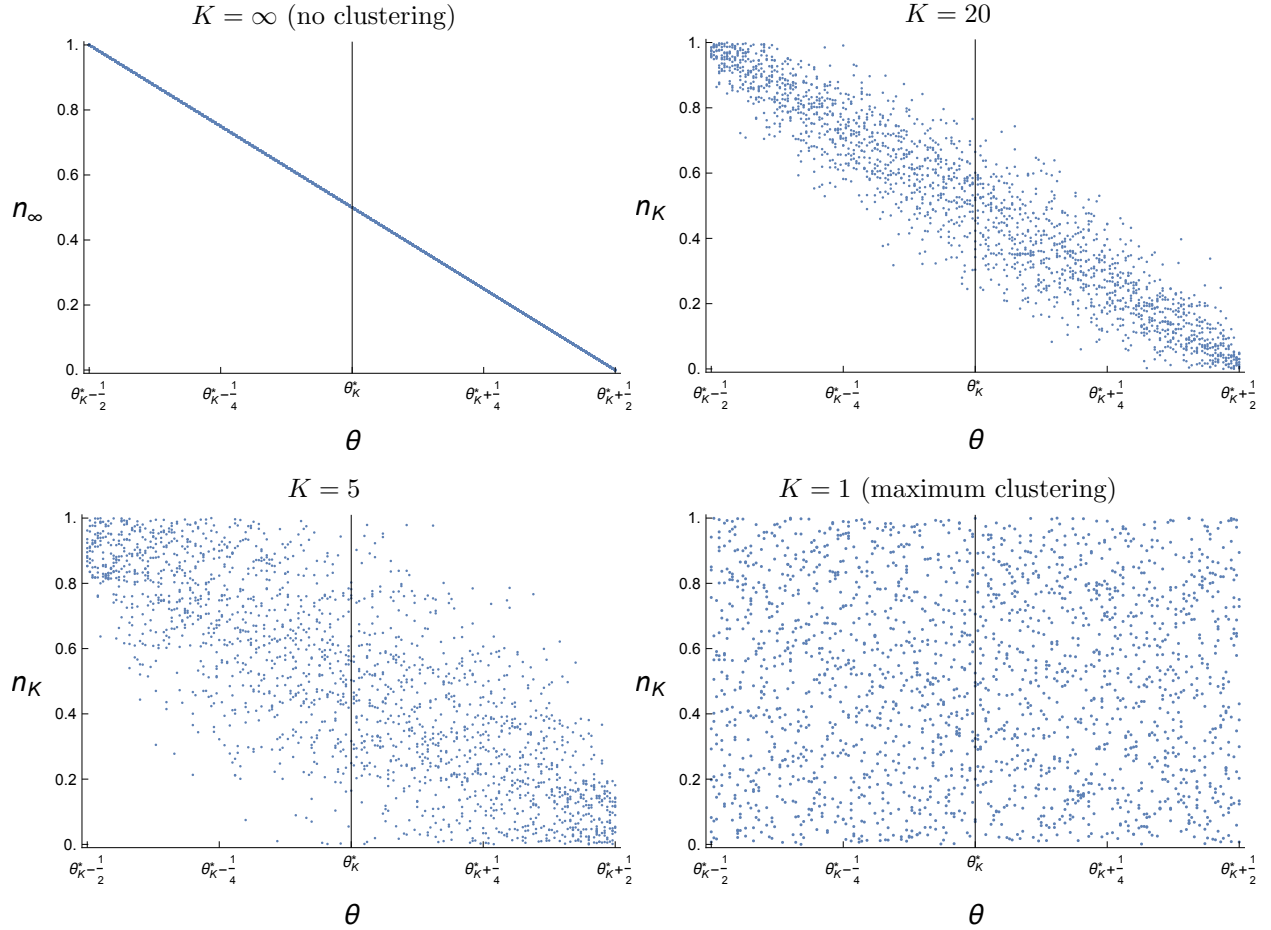


Figure 1. An empirical distribution of (θ, n_K) from the marginal depositor's perspective, where $\sigma = 1$, and $\varepsilon \sim \text{Uniform}(-\frac{1}{2}, \frac{1}{2})$.

1.3 Normative Implications

Our results imply that geographic ring-fencing exacerbates the risk of bank runs, whereas inter-state branching mitigates it. Geographic ring-fencing segregates the balance sheets of the bank’s various national subsidiaries. This segregation increases the risk of runs as each national subsidiary has a more clustered depositor base than the conglomerate bank as a whole, even if all national subsidiaries perfectly hedge their idiosyncratic asset risks in financial markets through synthetic risk transfers using credit derivatives or loan sales using securitization. Inter-state branching diversifies a bank’s depositor base, which reduces information clustering across depositors and reduces the risk of runs.

1.4 Ambiguous Disclosure

Beyond bank runs, a different application of our model rationalizes ambiguity in regulators’ disclosure. Starting with our model’s canonical version of no clustering, $K = \infty$, we introduce a planner who chooses and commits *ex-ante* to a level of ambiguity in disclosing fundamental θ . We map the ambiguity level to the signals’ noise level, in that a more ambiguous disclosure leads to greater idiosyncratic interpretation errors across agents. The model implies that some level of ambiguity is optimal. Ambiguity has two countervailing effects on an agent’s incentive to take the efficient action: It augments the agent’s fundamental uncertainty, and amplifies the covariance between the fundamental and the strategic states from the agent’s perspective. A positive level of ambiguity optimally trades off agents’ aversion to fundamental uncertainty against their desire for the covariance, and induces the lowest threshold for them to take the efficient action. This result also extends to any number $K > 1$ of communities.

1.5 Contributions

In summary, (i) we uncover an inherent covariance between the fundamental and the strategic states from each agent’s perspective in coordination games. This covariance is a general property of all coordination games, yet never exploited in existing papers. This covariance steers the agent’s choice toward an action that is consistent with a better funda-

mental under general payoff functions. *(ii)* We propose common information as a mechanism that shrinks this covariance. This mechanism fundamentally differs from the classic concept of diversification and other mechanisms. *(iii)* We introduce a framework for studying common information in global games. The framework organically separates the commonality and the accuracy of information. *(iv)* In this framework, our mechanism generates a unique and clean result: Common information steers agents' choices to an action that is consistent with a lower fundamental. This result answers a basic question: What information structure induces fewer agents to choose an inefficient action (running on a bunk, underinvesting in a project, not rolling over a debt, attacking a currency, etc.)?

The rest of the paper proceeds as follows. [Section 2](#) builds a model of information clustering upon the classic global game of bank runs. [Section 3](#) shows how clustering induces more runs by decorrelating the fundamental and the mass of runners from the marginal depositor's perspective. [Section 4](#) presents normative implications. [Section 6](#) delineates our contributions.

2 Bank Runs with Information Clustering

We model information clustering in an otherwise standard global game of bank runs. [Section 2.1](#) presents the model and [Section 2.2](#) explains our modeling assumptions.

2.1 Clustering in a Global Game

Our model's only departure from a standard global game is its signal structure. A bank's unit mass of depositors, each indexed by $i \in [0, 1]$ and holding one unit of demand deposit, are partitioned into K equal-sized communities. Each depositor i in community $k = 1, \dots, K$ observes a private signal about the bank's fundamental θ ,

$$x_{K,i} = \theta + \sigma\varepsilon_k + \delta\nu_i,$$

where $\sigma\varepsilon_k$ is a common error that all depositors in community k are exposed to and $\delta\nu_i$ is an idiosyncratic noise of depositor i . Fundamental θ follows a uniform distribution $\mathbb{U}(\underline{\theta}, \bar{\theta})$. The

community error ε_k has a cumulative distribution function (CDF) $F(\varepsilon)$. The idiosyncratic noises ν_i has a CDF $G(\nu)$. Both CDFs F and G are continuous and have support $[-\frac{1}{2}, \frac{1}{2}]$. All random variables $(\theta, (\varepsilon_k)_{k=1,\dots,K}, (\nu_i)_{i \in [0,1]})$ are appropriately independent so that the exact law of large numbers and Fubini's theorem hold.³ We fix the magnitude $\sigma > 0$ of the community bias and consider a vanishingly small idiosyncratic noise, $\delta \rightarrow 0$.

What remains is a standard global game. Upon observing her signal, each depositor may choose to *run* or *stay*. Her willingness to stay $v(\theta, n)$ (the payoff differential between staying and running) is strictly increasing in θ (state monotonicity), weakly decreasing in the proportion n of runners (strategic complementarity), and for any $n_1 < n_2$,

$$v(\theta, n_1) - v(\theta, n_2) \text{ is weakly increasing and not constant in } \theta. \quad (1)$$

Assumption 1. The range $[\underline{\theta}, \bar{\theta}]$ of fundamentals is sufficiently wide so there exist $\theta_L \geq \underline{\theta} + \sigma$ and $\theta_U \leq \bar{\theta} - \sigma$ such that $v(\theta_L, 0) < 0$ and $v(\theta_U, 1) > 0$.

Runs are socially costly, incurring a deadweight cost $c(\theta, n)$ that is increasing and weakly convex in the proportion n of runners.

2.2 Discussion

Information clustering. A community is a social network with common professional, residential, or cultural traits.⁴ The community error $\sigma \varepsilon_k$ captures the fact that depositors in a community receive common information about their bank's fundamental from clustered sources or overlapping social connections. Such information also encompasses exogenous communication to the depositors that explicitly allows them to coordinate their run decisions. For example, many venture capitalists advised their clients to withdraw their deposits from SVB in the early hours of its bank run. Information clustering assumes that each depositor

³“Appropriately independent” means essentially pairwise independent—for a continuum of random variables—defined in [Duffie and Sun \(2007\)](#).

⁴In the old days, communities were largely shaped by geographic proximity due to limited communication technology. Today, users cluster in private groups or echo chambers through messaging applications or online platforms ([Cookson, Engelberg, and Mullins, 2023](#); [Cookson, Lu, Mullins, and Niessner, 2024b](#)). Empirically, [Kelly and Ó Gráda \(2000\)](#) identify a depositor community as then-recent Irish immigrants coming from the same county of origin in Ireland, [Iyer and Puri \(2012\)](#) as depositors sharing the same introducer when opening their bank accounts or the same neighborhood of residence in India.

is still free to make her own run decision upon receiving such information. It excludes the case where a venture capitalist makes the run decisions *on behalf* of her clients.⁵

We restrict attention to communities of equal size to avoid any effect coming from heterogeneous run thresholds. It is known that such heterogeneity in global games reduces runs by inducing a beneficial negative assortative matching between equilibrium run thresholds and the perceived proportion of others running: A marginal depositor who has a higher run threshold—and who thus is more vulnerable to runs—perceives fewer runners (Dai, Luo, and Yang, 2024; Goldstein, Kopytov, Shen, and Xiang, 2024). With equal-sized communities, we make sure that our results are not driven by heterogeneous run thresholds, as our depositors are homogeneous and thus will *all* have an identical run threshold. Instead, we vary the number K of communities to show how clustering into fewer communities induces more runs. When varying K , we also keep all other parameters constant to avoid contaminating effects. For example, we fix the magnitude σ of each signal’s error. Appendix B shows that this choice—rather than fixing the aggregate information of all signals—prevents the mechanical effect of a depositor’s fundamental uncertainty on her run behavior.

Idiosyncratic noise. We assume a vanishingly small idiosyncratic noise $\delta\nu_i$ to avoid equilibrium multiplicity, similar to how the standard noisy observations technology of global games ensures equilibrium uniqueness as in Morris and Shin (2003). Without $\delta\nu_i$, multiple equilibria would arise for example with $K = 1$ community, because all depositors would observe precisely the same signal. One can interpret the idiosyncratic noise as an individual depositor’s cognitive noise in perceiving $\theta + \sigma\varepsilon_k$ (Frydman and Nunnari, 2024).

Depositor’s willingness to stay. The strategic complementarity and state monotonicity are standard in global games (Frankel, Morris, and Pauzner, 2003). The additional property (1) that the strategic complementarity strengthens with the fundamental maps to the fact that each additional runner inflicts greater damage to the bank’s payoff and thus also to another depositor’s willingness to stay when the bank could otherwise generate a higher

⁵In our equilibrium, depositors in a community will endogenously make identical run choices almost surely, aligned with the finding of Kelly and Ó Gráda (2000); Iyer and Puri (2012).

payoff.⁶ A class of such willingness to stay is $v(\theta, n) = \sum_h R_h(\theta)u_h(n) - 1$, where $R_h(\theta)$ is the expected return of the bank's asset h , $u_h(n)$ is the amount of funds invested in h after fulfilling the early withdrawals by a given proportion n of runners, and 1 is a depositor's initial deposit that she receives back if she runs. Such a $v(\theta, n)$ can accommodate: *i*) a downward jump at certain n to capture the forced liquidation of an indivisible asset when the proportion n of runners crosses above a critical value; *ii*) a kink at certain n to reflect the switch into the liquidation of a different type of asset, as an asset with a greater liquidation cost would make $v(\theta, n)$ decline faster in n ; or *iii*) a flat range in n where no costly liquidation occurs.

Common distributional and parametric assumptions in global games. Global games often focus on the limit where noises vanish. Our community error stays away from the limit, $\sigma > 0$, so that a depositor is uncertain about fundamental θ , allowing us to exploit the covariance between θ and n from a depositor's perspective. Doing so requires us to assume a uniform prior on θ , which global games with non-vanishing noises need for equilibrium uniqueness (Morris and Shin, 2003).⁷ **Assumption 1** is standard and necessary for equilibrium uniqueness.⁸

Social cost of runs. Runs cause harm beyond the bank, its depositors, and other immediate stakeholders. The social cost $c(\theta, n)$ of runs arises from (a) forced liquidations of the bank's investments to outside investors, who are less efficient than the bank in managing the investments (Shleifer and Vishny, 1992; Kiyotaki and Moore, 1997), or who need to raise costly capital in a frictional financial market;⁹ and (b) the loss of the bank's franchise value (Drechsler et al., 2023). The social cost is needed only for our **Proposition 4**.

⁶Here, the bank's payoff may include its probability of project success (Diamond and Dybvig, 1983; Goldstein and Pauzner, 2005), deposit franchise value (Drechsler, Savov, Schnabl, and Wang, 2023), lending-relationship values (Chang, Cheng, and Hong, 2023), etc.

⁷Otherwise, the posterior $\frac{1}{\sigma}f(\frac{x_i - \theta}{\sigma})$ of θ depends on its prior's parameters, on which additional conditions are needed for uniqueness.

⁸Under **Assumption 1**, it is a dominant strategy for depositor i to run upon observing a low signal $x_i \leq \theta_L - \frac{\sigma}{2}$, and to stay if $x_i \geq \theta_H + \frac{\sigma}{2}$. In the intermediate region $x_i \in (\theta_L - \frac{\sigma}{2}, \theta_U + \frac{\sigma}{2})$, **Assumption 1** ensures that the depositor's posterior about θ is sufficiently far away from and not truncated by its upper and lower boundaries, $\underline{\theta}$ and $\bar{\theta}$.

⁹Frictions include information asymmetry (Myers and Majluf, 1984) or agency costs (Jensen and Meckling, 1976).

3 Clustering Induces More Runs

This section establishes our equilibrium results and delineates their driving mechanism. (i) The model's unique equilibrium is a switching equilibrium, where depositors run upon observing a signal below a run threshold ([Proposition 1](#)). (ii) Our model nests a standard global game of bank runs without information clustering ([Proposition 2](#)). (iii) Information clustering raises the equilibrium run threshold, and more so as depositors cluster into fewer, larger communities ([Theorem 1](#)). Clustering fuels runs by decorrelating the fundamental and the run proportion for the marginal depositor. (iv) The social cost of runs rises with a higher degree of clustering in *all* fundamental states of the world, and strictly so *ex-ante* ([Proposition 4](#)). (v) Despite so, clustering is privately optimal: It is weakly dominant for a depositor to observe her community signal even if every depositor could choose to observe an idiosyncratic signal instead ([Proposition 5](#)).

3.1 Equilibrium

Proposition 1 (Unique equilibrium). *A unique equilibrium surviving iterative strict dominance exists. In equilibrium, every depositor i runs if and only if her signal is below a threshold, $x_{K,i} < \theta_K^*$, where θ_K^* solves the indifference condition*

$$\mathbb{E}[v(\theta, n_K) \mid x_{K,i} = \theta_K^*] = 0, \quad (2)$$

and $n_K = \int_{i \in [0,1]} \mathbb{1}(x_{K,i} < \theta_K^*) di$ is the proportion of depositors observing a signal below θ_K^* .

The indifference condition (2) says that the marginal depositor, whose signal is at the threshold θ_K^* , is indifferent between staying and running. We introduce the idiosyncratic noise ν_i to avoid equilibrium multiplicity. Without ν_i , all depositors in a community would observe an identical signal $\theta + \sigma\varepsilon_k$ and may choose any arbitrary action simply based on the self-fulfilling belief that others within the same community are choosing that action. The indeterminacy of a depositor's belief about the proportion of runners in her own community may lead to multiple equilibria. Adding an idiosyncratic noise ν_i to $\theta + \sigma\varepsilon_k$ pins down which within-community belief will prevail in equilibrium, similar to how global games resolve the

indeterminacy of beliefs by adding a private noise to the fundamental (Morris and Shin, 2003). **Proposition 1** holds for communities of arbitrary sizes and any willingness to stay v satisfying the usual state monotonicity and strategic complementarity (more precisely, any $v(\theta, n)$ that strictly increases with θ and weakly decreases with n). All proofs are in **Appendix A**.

As a benchmark, we consider the limiting case of $K = \infty$ communities, each comprising only one depositor. In this case, the community noise ε_k effectively becomes idiosyncratic and our model then intuitively approximates a standard global game without clustering, where each depositor i observes signal

$$x_i = \theta + \sigma \varepsilon_i, \quad \varepsilon_i \stackrel{\text{iid}}{\sim} F.$$

(The other noise $\delta \nu_i$ is vanishingly small and can be removed without affecting the signal structure.) This canonical global game has a unique equilibrium, whose run threshold θ_∞^* satisfies

$$\mathbb{E}[v(\theta, n_\infty) \mid x_i = \theta_\infty^*] = 0,$$

where $n_\infty = \int_{i \in [0,1]} \mathbb{1}(x_i < \theta_\infty^*) di$. The next result formalizes this intuitive approximation.

Proposition 2 (Benchmark of no clustering). *As the number of communities goes to infinity, $K \rightarrow \infty$, the equilibrium run threshold converges to the one without information clustering, $\theta_K^* \rightarrow \theta_\infty^*$.*

Proposition 2 shows that our setup nests the standard global game without clustering as the limiting case of infinitely many small communities, $K \rightarrow \infty$.¹⁰ This result allows us to study the effect of information clustering on the equilibrium run threshold θ_K^* by changing the number K of communities, starting from $K = \infty$ (no clustering) to smaller K (greater clustering).

¹⁰**Proposition 2** holds for any payoff v satisfying strategic complementarity and state monotonicity.

3.2 Clustering Makes Depositors More Inclined to Run

Our main result establishes that information clustering makes depositors more inclined to run, and more so as depositors cluster into fewer communities.

Theorem 1 (Main result). *The equilibrium run threshold θ_K^* strictly and monotonically increases as the number K of communities decreases.*

We explain **Theorem 1** in three steps. (A) Information clustering does not affect the marginal depositor’s belief about either fundamental θ or the proportion n_K of runners. (B) Instead, clustering impacts her joint belief in (θ, n_K) by decorrelating the two. (C) The decorrelation lowers the depositor’s expected willingness to stay and raises her run threshold.

(A) The marginal depositor is uncertain about both fundamental θ and the proportion n_K of runners. Clustering does not affect the depositor’s posterior belief about fundamental θ , which is always $\frac{1}{\sigma}f\left(\frac{x-\theta}{\sigma}\right)$ for a given signal realization x , regardless of the degree of clustering, $K \in [1, \infty]$. The next results shows that her belief about n_K (strategic belief) is always uniform regardless of K . We let $\mathcal{D}$ denote “distribution.”

Proposition 3 (Strategic belief is Laplacian). *The marginal depositor’s belief about the proportion n_K of runners is uniform, $\mathcal{D}(n_K \mid x_{K,i} = \theta_K^*) = \mathbb{U}(0, 1)$.*

Proposition 3 generalizes the Laplacian property to clustered signals, and holds for any payoff v satisfying strategic complementarity and state monotonicity. With a uniform prior on θ and an infinitesimally small idiosyncratic noise, $\delta \ll 1$, each signal $x_{K,i} = \theta + \sigma\varepsilon_k + \delta\nu_i$ is uninformative about its community error ε_k and idiosyncratic noise ν_i , thus also about its rank $r_{K,i} = \int_{j \in [0,1]} \mathbb{1}(x_{K,j} < x_{K,i}) dj$ among all signals. Hence, the average of the threshold types’ strategic beliefs coincides with the average rank distribution of all signals and therefore is uniform on $[0, 1]$ (Laplacian).¹¹ These strategic beliefs are symmetric and therefore must all be Laplacian.

(B) Instead, clustering impacts the marginal depositor’s joint belief in (θ, n_K) by decorrelating the two. To see how, we first compare the case of no clustering, $K = \infty$, to the other

¹¹Precisely, $\int_{i \in [0,1]} \mathbb{P}(n_K \leq n \mid x_{K,i} = \theta_K^*) di = \int_{i \in [0,1]} \mathbb{P}(r_{K,i} \leq n \mid x_{K,i} = \theta_K^*) di = \int_{i \in [0,1]} \mathbb{P}(r_{K,i} \leq n) di = \mathbb{E} \int_{i \in [0,1]} \mathbb{1}(r_{K,i} \leq n) di = \mathbb{E} n = n$. One can show that the average strategic belief is Laplacian for communities of any sizes, which extends the belief constraint in [Sákovics and Steiner \(2012\)](#) to arbitrarily clustered signals.

extreme case of maximum clustering where all depositors belong to the same community, $K = 1$.

In the standard case of no clustering ($K = \infty$), θ and n_K have the perfect Spearman rank correlation of -1 , in that know one is equivalent to knowing the other, and a higher θ is equivalent to a smaller n_∞ . Precisely, given fundamental θ , the exact law of large number implies that n_∞ —the proportion of depositors observing a signal less than the threshold signal θ_∞^* —is deterministic and equal to $F\left(\frac{\theta_\infty^* - \theta}{\sigma}\right)$. Here, fundamental θ is a sufficient statistic for knowing n_K ,

$$\mathcal{D}(n_K | x_{K,i}, \theta) = \mathcal{D}(n_K | \theta) \quad \text{when } K = \infty.$$

In the other extreme case of maximum clustering ($K = 1$), all depositors act on virtually the same signal, that signal screens off the true fundamental θ from the proportion n_K of them who run:

$$\mathcal{D}(n_K | x_{K,i}, \theta) = \mathcal{D}(n_K | x_{K,i}) \quad \text{when } K = 1.$$

More precisely, each signal $x_{K,i}$ is the sum of $\theta + \sigma\varepsilon_k$ and an idiosyncratic noise $\delta\nu_i$. Thus, $\theta + \sigma\varepsilon_k$ is a sufficient statistic for signals $(x_{K,i})_{i \in [0,1]}$, about which the true fundamental θ contains no incremental information,

$$\mathcal{D}\left((x_{K,i})_{i \in [0,1]} | \theta + \sigma\varepsilon_k, \theta\right) = \mathcal{D}\left((x_{K,i})_{i \in [0,1]} | \theta + \sigma\varepsilon_k\right) \quad \text{when } K = 1.$$

Upon an almost perfect observation of $\theta + \sigma\varepsilon_k$, with only an infinitesimally small error $\delta\nu_i$, depositor i cannot extract any additional information from the true fundamental θ for learning the proportion n_K of those signals that fall below certain threshold.

(C) The complete decorrelation between θ and n_K from the perspective of the marginal depositor lowers her expected willingness to stay and raises her run threshold. For illustration only, we set $v(\theta, n) = R(\theta)u(n) - 1$. If the opposite were true, $\theta_1^* \leq \theta_\infty^*$, the marginal depositor

with maximum clustering would strictly prefer to run,

$$\begin{aligned}
0 &= \mathbb{E}[v(\theta, n_\infty) \mid x_i = \theta_\infty^*] \\
&> \mathbb{E}[R(\theta) \mid x_i = \theta_\infty^*] \mathbb{E}[u(n_\infty) \mid x_i = \theta_\infty^*] - 1 \\
&\geq \mathbb{E}[R(\theta) \mid x_{1,i} = \theta_1^*] \mathbb{E}[u(n_1) \mid x_{1,i} = \theta_1^*] - 1 \quad (\text{if } \theta_1^* \leq \theta_\infty^*) \\
&= \mathbb{E}[v(\theta, n_1) \mid x_{1,i} = \theta_1^*].
\end{aligned}$$

The first inequality follows because with no clustering, the perfect negative covariance between θ and n_∞ results in the smallest proportion n_∞ of runners when fundamental θ is the highest, which is precisely the state of the world where each runner inflicts the most damage to the bank's payoff and thus also to the depositor's willingness to stay. Therefore, the depositor's expected willingness to stay is higher than if the fundamental θ and the proportion n_∞ of runners were independent for her.¹²

Between these two extreme cases, the equilibrium run threshold θ_K^* monotonically increases with the number K of communities. An intermediate degree of clustering partially decorrelates n_K from θ for the marginal depositor, and increasingly so with fewer communities. To see how, we write the proportion n_K of depositors running as the simple average of the proportion $n_{K,\ell}$ of those running in each of the K communities,

$$n_K = \frac{1}{K} \sum_{\ell=1}^K n_{K,\ell},$$

The marginal depositor's signal screens off fundamental θ from the proportion $n_{K,k}$ of runners in her own community,

$$\mathcal{D}(n_{K,k} \mid x_{K,i}, \theta) = \mathcal{D}(n_{K,k} \mid x_{K,i}),$$

because all within-community depositors act upon virtually the same signal. With fewer communities, the within-community proportion $n_{K,k}$ carries a larger weight $1/K$ in the overall proportion n_K , and the marginal depositor's signal increasingly screens off θ from n_K .

Figure 1 jointly simulates (θ, n_K) according to the marginal depositor's belief and illustrates

¹²The second inequality follows because $R_h(\theta)$ is weakly increasing for all h and the strategic belief remains Laplacian with any number K of communities.

how clustering gradually decorrelates the two.

A higher degree of clustering shrinks the negative covariance between θ and n_K and thus lowers the marginal depositor's expected willingness $\mathbb{E}[v(\theta, n_K) | x_{K,i} = \theta_K^*]$ to stay as a function of θ_K^* . Illustrating with $v(\theta, n) = R(\theta)u(n) - 1$,

$$\begin{aligned} & \mathbb{E}[R(\theta)u(n_K) | x_{K,i} = \theta_K^*] \\ = & \underbrace{\text{Cov}[R(\theta), u(n_K) | x_{K,i} = \theta_K^*]}_{\text{declines with clustering}} + \underbrace{\mathbb{E}[R(\theta) | x_{K,i} = \theta_K^*] \mathbb{E}[u(n_K) | x_{K,i} = \theta_K^*]}_{\text{unaffected by clustering (Proposition 3)}}. \end{aligned}$$

Through depositors' greater propensity to run, clustering raises the social cost of runs in *all* fundamental states of the world, and strictly so *ex ante*.

Proposition 4 (Social cost of runs). *As the number K of communities decreases, (i) the expected cost $\mathbb{E}[c(\theta, n_K) | \theta]$ of runs conditional on any given fundamental θ weakly increases, and (ii) the ex-ante cost $\mathbb{E}[c(\theta, n_K)]$ strictly increases.*

Clustering monotonically raises the equilibrium run threshold θ_K^* (Theorem 1), thereby increasing—given any fundamental θ —each depositor's probability $\mathbb{P}(x_{K,i} < \theta_K^* | \theta)$ of running and the expected mass $\mathbb{E}(n_K | \theta)$ of runners. Clustering also leads to a more volatile $n_K = \sum_{\ell=1}^K n_{K,\ell} / K$ given any θ , because depositors in each community either all run or all stay, $n_{K,\ell} = 0$ or 1 almost surely. Together, clustering results in a higher expected cost $\mathbb{E}[c(\theta, n_K) | \theta]$ of runs in any fundamental state θ of the world.

How large is the impact of clustering? In a numerical example, moving from $K = 2$ to $K = 1$ community is equivalent to a downward shift of 4.17% in the bank's return in terms of raising the *ex-ante* cost of runs (Appendix C).

3.3 Clustering is Privately Optimal

This section shows that clustering is privately optimal despite being socially inefficient.

Depositors are partitioned into K communities. To our global game, we add a period 0 where every depositor simultaneously chooses between observing in period 1 either $x_{K,i}$

defined in [Section 2.1](#) or an idiosyncratic signal

$$\tilde{x}_{K,i} = \theta + \sigma \tilde{\varepsilon}_i + \delta \nu_i,$$

where $\tilde{\varepsilon}_i \sim F$ and all random variables $(\theta, (\varepsilon_k)_{k=1,\dots,K}, (\tilde{\varepsilon}_i)_{i \in [0,1]}, (\nu_i)_{i \in [0,1]})$ are appropriately independent. All depositors' choices become common knowledge at the end of period 0. In period 1, each depositor chooses to run or stay upon observing a realization of her chosen signal, with a willingness to stay $v(\theta, n)$.

The next result shows that it is weakly dominant for every depositor to choose her $x_{K,i}$.

Proposition 5. *The extended game has a unique equilibrium surviving iterative weak dominance. On the equilibrium path, every depositor chooses to observe her $x_{K,i}$, and runs if and only if $x_{K,i} < \theta_K^*$.*

[Proposition 5](#) holds for communities of any arbitrary sizes and any v satisfying the usual strategic complementarity and state monotonicity. To model clustering as an endogenous outcome, the extended game gives every depositor the alternative choice of an idiosyncratic signal $\tilde{x}_{K,i}$ that is equally informative about the fundamental as $x_{K,i}$. Choosing $x_{K,i}$ is to cluster with all others in her community who choose their $x_{K,j}$, while choosing idiosyncratic signal $\tilde{x}_{K,i}$ is to not cluster with anyone else. If no depositor chooses to cluster, a standard global game with no clustering follows. If all depositors choose to cluster, signals are clustered in K communities. Between these two extreme outcomes, signals could be clustered in arbitrary proportions $\mu_1, \dots, \mu_K$, with the remainder unclustered. [Proposition 5](#) shows that it is optimal for every depositor to cluster regardless of others' choices.

Signal $x_{K,i}$ dominates idiosyncratic signal $\tilde{x}_{K,i}$ because $x_{K,i}$ is more payoff relevant and allows a depositor to make a more informed run decision. Specifically, $x_{K,i}$ almost surely reveals the run decision of all others in her community who choose to cluster (as long as $x_{K,i}$ is not at the threshold θ_K^*). In contrast, $\tilde{x}_{K,i}$ contains no information about anyone's run decision conditional on fundamental θ .

4 Normative Implications

Our results imply that geographic ring-fencing strengthens clustering and exacerbate runs even if , while bank branching reduces information clustering across depositors and mitigates runs.

4.1 Ring-fencing

Geographic ring-fencing segregates the balance sheets of a large bank’s various national subsidiaries.¹³ Academic work and policy discussions exploit the premise that different subsidiaries’ assets have significantly heterogeneous risk exposure and geographic ring-fencing impedes asset diversification and risk sharing across subsidiaries. However, the presence of a highly integrated and efficient financial market can mitigate or even eliminate this heterogeneity, because the national subsidiaries—especially of a large conglomerate bank—may hedge the local risks of their loan portfolios through synthetic risk transfers using credit derivatives or loan sales using securitization. Our mechanism does not rely on heterogeneous risk exposure across subsidiaries’ assets, and a frictionless financial market cannot remove information clustering across individual depositors. Even if the subsidiaries’ assets perfectly hedge away their local risks and therefore are exposed to a common risk factor, ring-fencing undermines bank stability by raising the risk of runs as each national subsidiary has a more clustered depositor base than the conglomerate bank as a whole.

Our model incorporates geographic ring-fencing as follows. Initially, a bank operates K_1 and K_2 branches in two countries, respectively. Each branch has a unit mass of depositors, each holding one unit of demand deposit.¹⁴ The bank and its depositors are characterized by our model with parameters $(\theta, \bar{\theta}, \sigma, \delta, v, K_1 + K_2)$, where a community maps to a branch where depositors receive common information about the bank’s fundamental. Ring-fencing by both

¹³Examples of geographic ring-fencing rules include the Intermediate Holding Company rule for foreign bank in the U.S. and U.K. Ring-fencing Regime. The incentive for host country regulators to ring-fence is to ensure the maximum amount of funds remain in the host country to ensure local depositors, creditors, and other stakeholders are paid first. Ring-fencing is different from China Walls implemented between key affiliates within a bank conglomerate. China walls are internal *information* barriers (Lee, Nathan, and Wang, 2024), whereas ring-fencing imposes no such barrier.

¹⁴Aguirregabiria, Clark, and Wang (2016) find that the dispersion of deposit sizes across branches remained low throughout their sample period of 1976–2006.

countries segregates the balance sheets of the two national subsidiaries. Both subsidiaries have the same fundamental θ , which represents the state of their identical asset portfolios after their local risks are hedged away in financial markets. Therefore, ring-fencing entails neither loss in asset diversification nor risk sharing between the two subsidiaries, and each subsidiary m is described by the same parameters $(\underline{\theta}, \bar{\theta}, \sigma, \delta, v, K_m)$ except the number it operates K_m branches. [Corollary 1](#) shows that ring-fencing exacerbates runs in any state of the world.

Corollary 1. *Conditional on any fundamental θ , the total mass of runners on the two ring-fenced subsidiaries first-order stochastically dominates that on the consolidated bank with no ring-fencing, with the dominance being strict for $\theta \in (\theta_K^* - \frac{\sigma}{2}, \max\{\theta_{K_1}^*, \theta_{K_2}^*\} + \frac{\sigma}{2})$.*¹⁵

Ring-fencing make depositors more inclined to run because each national subsidiary has a higher degree of information clustering across depositors ([Theorem 1](#)).

4.2 Bank Branching

The U.S. banking system has historically been highly fragmented, with a large number of small, local banks. It has also faced numerous bank runs over the years. Reviewing banking panics during pre-Federal Reserve episodes, [Calomiris and Gorton \(1991\)](#) argue that local banking exacerbates bank fragility. Further supporting their concern are the approximately 5,000 failures of primarily unit banks during the Great Depression, as well as the more than 2,900 failures of mostly small thrifts during the savings-and-loan crisis (1980-1995). Additionally, international evidence suggests that countries with extensive bank branching experience significantly fewer bank panics ([Grossman, 1994](#)).

The key factor preventing the geographic expansion of U.S. banks were long-standing restrictions on interstate branching. The restrictions ended with the passage of the Riegle-Neal Interstate Banking and Branching Efficiency Act in 1994. The Act triggered a wave of bank consolidation and the emergence of major national banks. Despite the consolidation,

¹⁵We follow the common definition of the first-order stochastic dominance, that X stochastically dominates Y if $\mathbb{P}(Y \leq x) \leq \mathbb{P}(X \leq x)$ for all $x \in \mathbb{R}$ ([Mas-Colell, Whinston, and Green, 1995](#), p. 195 and [Shaked and Shanthikumar, 2007](#), p. 3). If the inequality holds strictly for all x , we say that the dominance is strict.

a significant number of community banks continue to operate locally (Aguirregabiria et al., 2016). Whether local banking harms bank stability remains a relevant question today.

The existing theoretical literature focus on how branching affects bank fragility through the bank’s asset risk. However, the direction of this effect is ambiguous. Branching helps diversify a bank’s idiosyncratic loan risk, while increasing systemic risk (Wagner, 2010). Both predictions find empirical support through the staggered interstate deregulation, which provides an exogenous source of variation for branch expansion.¹⁶

Our results contribute a funding-side mechanism through which branching enhances stability. Our model incorporates branching in the same way as it incorporates ring-fencing, except that the two “national subsidiaries” become two banks in two different states that are allowed to merge by the Riegle-Neal Act. The assumption that the two banks have the same θ turns off any effect arising from asset diversification upon the merger. **Corollary 1** implies that the merger unambiguously reduces bank fragility by declustering depositors and making them less inclined to run in all states of the world—without any countervailing effect. Diversification of funding operates through a mechanism that is fundamentally different from diversification of assets, resulting in its unambiguous benefit. **Section 6** explains this difference.

5 Ambiguous Disclosure

The covariance between the fundamental and the strategic states is universal to coordination games. To prove its generality, we develop another application that is beyond clustering and bank runs. The application rationalizes ambiguity in regulators’ disclosures.

Regulators’ disclosures about the state of the economy are usually open to a wide range of interpretations across different audiences, despite the public’s universal aversion to uncertainty. One example is central banks’ use of “fragmented” communication channels: Individual officials often deliver their own economic assessments at various conferences and outlets, leading distinct communities of market participants to receive differing messages. Existing

¹⁶Goetz, Laeven, and Levine (2016) find that geographic bank expansion diversifies exposure to idiosyncratic local loan portfolio risk, while Chu, Deng, and Xia (2020) find that branching leads to increased systemic risk measured as the change in conditional value at risk.

literature rationalizes *coarse* disclosure, in that the disclosed information is not subject to alternative interpretations yet may be consistent with multiple states.¹⁷ Relatively few studies consider ambiguity, and they show that ambiguity *per se* harms efficiency (Morris and Shin, 2007; Goldstein, Ozdenoren, and Yuan, 2011, Proposition 9).

A comparative statics of our model implies that some level of ambiguity is optimal. Ambiguity augments an agent’s fundamental uncertainty and amplifies its covariance with her strategic uncertainty. An interior level of ambiguity optimally balances agents’ aversion to fundamental uncertainty against their desire for uncertainty covariance, and induces the lowest threshold for them to take the efficient action.

We start with our model’s canonical version of no clustering, $K = \infty$, and introduce a planner who chooses and commits *ex-ante* to a level of ambiguity in disclosing fundamental θ . We map the ambiguity level to the noise level σ , in that a more ambiguous disclosure allows for greater idiosyncratic interpretation errors across agents. An agent chooses whether to invest in the economy, and her willingness to invest is $v(\theta, n) = R(\theta)u(n) - 1$, where $u > 0$, $R > 0$, and R is concave in θ and an agent is averse to fundamental uncertainty. For tractability, we assume a quadratic R and a noise distribution F symmetric around 0. The resulting model is a classic global game, in which the planner chooses the ambiguity level σ to minimize the equilibrium threshold θ_∞^* .

We decompose an agent’s expected payoff gain from taking the efficient action into her

¹⁷Crawford and Sobel (1982) initiated the cheap-talk literature, showing that the equilibrium degree of revealed information is decreasing with the preference misalignment between the sender and the receiver. Morris and Shin (2002) show that a more accurate public signal could induce a less efficient outcome in a model of beauty contest. Kamenica and Gentzkow (2011) introduced Bayesian persuasion, allowing to determine the optimal disclosure rule that a sender can commit to. Faria-E-Castro, Martinez, and Philippon (2017) study the optimal disclosure accuracy that trades off the risks of bank runs and adverse selection in financial crises (jointly with the optimal fiscal backstop). Goldstein and Leitner (2018) examine the optimal disclosure rule in stress tests that maximizes risk sharing among banks.

aversion to fundamental uncertainty and desire for uncertainty covariance,

$$\begin{aligned}
E[v(\theta, n)|x_i = \theta_\infty^*] = & \sigma R'(\theta_\infty^*) \int_0^1 (-F^{-1}(p)) u(p) dp \\
& + \sigma^2 \frac{R''(\theta_\infty^*)}{2} \int_0^1 (F^{-1}(p))^2 u(p) dp \\
& + \underbrace{R(\theta_\infty^*) \int_0^1 u(p) dp}_{\text{unaffected by ambiguity}} - 1.
\end{aligned}$$

The first term captures the desire for uncertainty covariance. It is positive and increases with a greater level of ambiguity σ . The second term captures the aversion to fundamental uncertainty. It is negative and decreases with σ . An interior σ optimally trades off these two countervailing effects. **Proposition 6** formalizes this comparative statics and generalizes the result to any number K of communities.

Proposition 6. *If $K > 1$, the equilibrium threshold θ_K^* first strictly decreases and then strictly increases in σ . If $K = 1$, then θ_K^* strictly increases with $\sigma > 0$.*

With a finite number K of communities, depositors in a community are subject to a common interpretation error $\sigma \varepsilon_k$, where σ is the overall ambiguity level of the disclosure. Maximum clustering ($K = 1$) differs from other cases because it fully decouples the two uncertainties. There, the aversion to fundamental uncertainty dictates the entire effect of ambiguity, which is then always negative.

The left panel of **Figure 2** illustrates **Proposition 6**. The right panel illustrates the case of a linear R , which assumes away the aversion to the fundamental uncertainty. Therein, the desire for uncertainty covariance dictates the effect of ambiguity, which is then always positive.

6 Contributions

This concluding section discusses how information clustering differs from related mechanisms, and then our contributions to related literature.

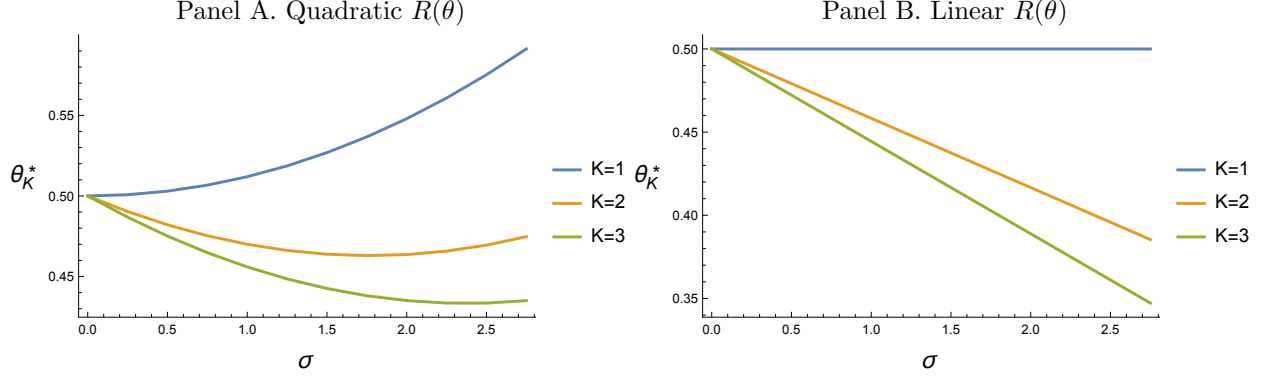


Figure 2. The equilibrium threshold θ_K^* as a function of the ambiguity level σ . In the graph, $\varepsilon_k \sim \text{Uniform}(-\frac{1}{2}, \frac{1}{2})$, $v(\theta, n) = R(\theta) \left(1 - \frac{n}{B+1}\right) - 1$ with $B = 0.5$, $R(\theta) = 1 + \theta$ (right panel), and $R(\theta) = 0.5625 + 2\theta - 0.25\theta^2$ (left panel). These parameters are chosen so that θ^* at $\sigma = 0$ is the same in both panels.

6.1 Related Mechanisms

We find that the lack of funding diversification raises run risk through depositors receiving clustered information. In general, that a lack of diversification increases risk is well known. One might wonder if information clustering repackages a known mechanism of diversification. Below, we discuss whether asset diversification or other mechanisms can generate our main result: The downside risk rises while the upside risk falls—ubiquitously so in any relevant state of the world and unambiguously so with no countervailing effect.

Asset diversification

Asset diversification reduces portfolio return risk by canceling out the idiosyncratic risk across assets. Lack of asset diversification cannot generate our main result: (a) Lack of asset diversification increases both the downside and the upside risks of the portfolio return, raising the second moment—the volatility—of the return. Both risks move in lockstep because diversification is a statistical property that cannot change an individual asset’s return, and thus cannot change the first moment—the expectation—of the portfolio return. (b) While diversification benefits a portfolio manager by smoothing her utility across future states of the world, she may choose to forgo diversification if she possesses superior information about which future state is more likely to occur. (c) Although diversification reduces the

volatility of a portfolio return, it raises the systemic risk of returns across portfolios.¹⁸ The net benefit depends on how a social preference weighs the two types of risks. In contrast to diversification, information clustering (a') raises the *first* moment of the mass of runners (b') in all relevant fundamental states, and (c') has no countervailing effect—all because each depositor *strategically* becomes more inclined to run.

Sectoral liquidity shocks

Depositors may experience exogenous liquidity shocks that force them to withdraw early, and these shocks are more likely to be correlated among depositors from the same sector or location. In theory, exogenous and sectoral liquidity shocks function like undiversifiable risk in asset returns, and thus have similar effects on the bank as the lack of asset diversification. In practice, capital regulations require banks to hold sufficient short-term assets to meet early withdrawals caused by such exogenous liquidity shocks at any given time.

Deposit concentration

Information clustering differs from the concentration of deposits among a few large depositors. Corsetti, Dasgupta, Morris, and Shin (2004) show that the presence of a large trader facilitates coordination and makes all small traders more inclined to attack a currency. If applied to bank runs, their mechanism would imply that the presence of a large depositor mitigates runs—rather than fueling runs—because a successful coordination means to stay in the bank-run application but to attack in the currency-attack one.

6.2 Related literature

We make four contributions to the literature. (i) We uncover an inherent covariance between the fundamental and the strategic states in coordination games. This covariance is a general property of all coordination games, yet never exploited in existing papers. This covariance steers the agent’s choice upward, to an action that is consistent with a higher fundamental, under general payoff functions. (ii) We propose common information as a mechanism that shrinks this covariance. (iii) We introduce a framework for studying common

¹⁸Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015) illustrate how diversification raises systemic risk in credit networks, and Goldstein et al. (2024) do so in a bank run setting.

information in global games. The framework ensures equilibrium uniqueness and organically separates the commonality and the accuracy of information. *(iv)* In this framework, our mechanism generates a unique and clean result: Common information steers agents' choices toward an action that is consistent with a lower fundamental. This result answers a basic question: What information structure induces fewer agents to choose an inefficient action (running on a bunk, underinvesting in a project, not rolling over a debt, attacking a currency, etc.)?

We discuss these contributions' relevance to three strands of literature.

Public information in games with strategic complementarity or substitutability

The literature closest to our paper examines the effect of public information in games with strategic complementarity or substitutability, such as beauty contests, investment spillovers, and business cycles (Angeletos and Pavan, 2007, provide a unifying analysis; other examples include Morris and Shin, 2002; Vives, 1990; Angeletos and Pavan, 2004; Hellwig, 2005; Morris and Shin, 2007; Woodford, 2003; Myatt and Wallace, 2014). In these papers, every agent receives a public signal and an equally precise private signal about the fundamental. Angeletos and Pavan (2007) show that agents' forecast errors about the fundamental are symmetrically correlated, and refer to the correlation as information commonality. A higher precision of public signal raises the commonality of agents' information, akin to how clustering raises the scope of the common information in our model. *(i)* Constrained by tractability, this literature is limited to quadratic payoffs. In such a payoff function, the interaction term between the fundamental and the actions of other agents does not depend and thus has no bearing on the agent's own action choice. As a result, the restrictive assumption of quadratic payoffs suppresses the role of the inherent covariance between the two. *(ii)* Further, our mechanism that common information shrinks this covariance cannot exist in this literature. *(iii)* The precision of the public information also affects the accuracy of agents' information, resulting in a mixed net effect. In our framework, varying the number K of communities changes the commonality but not the accuracy, leading to a clean result. In addition, K has a clear applied interpretation as how widely information is clustered across agents. *(iv)* Angeletos and Pavan (2007) and Myatt and Wallace (2014) show that a change in commonality (for

given accuracy) affects only the second moment of agents' equilibrium actions, similar to how it raises the volatility of the proportion n_K of runners in our model. In our model, commonality also steers every agent's equilibrium action strictly downward conditional on any relevant fundamental. This effect on the first moment is absent in the literature, where a change in commonality has no impact on the expectation of an agent's equilibrium action (Angeletos and Pavan, 2007, p.1136, $\mathbb{E}k = \mathbb{E}K = \mathbb{E}\kappa$; conditional on the fundamental, $\mathbb{E}(k|\theta) = \kappa(\theta)$; Myatt and Wallace, 2014, Proposition 1, $\mathbb{E}(p_\ell|\theta) = \theta$). Our result shows that a suboptimal information structure not only can make agents' actions more dispersed or volatile, it can also induce *more* agents to choose an inefficient action.

Endogenous information acquisition in quadratic-payoff coordination games

Another strand of literature considers endogenous information acquisition in quadratic-payoff coordination games (Hellwig and Veldkamp, 2009; Myatt and Wallace, 2012, and their follow-up papers). To this literature, (i), (ii), and (iv) remain to be our contributions. Contribution (iii) is not applicable, as this literature is not concerned with the effect of common information. Rather, it studies how agents endogenously cluster in their information choices, giving rise to common information. Replacing (iii) is (iii') our **Proposition 5**, which extends their main result to global games and general payoffs.

Global games

Unlike the above coordination games with quadratic payoffs, a global game would have multiple equilibria had there been common knowledge of its fundamental. Incorporating common information to a generic global game is challenging because such information allows agents to coordinate their choices and thus threatens equilibrium uniqueness. For example, letting any community of agents observe a semi-public signal $x_k = \theta + \sigma\varepsilon_k$ that is common within that community would result into a model similar to ours. However, such a model may have multiple equilibria.¹⁹ Within the range of parameters where equilibrium is unique, “[t]he comparative statics of the precision of public information reveal complex effects that arises from the interplay between better fundamentals information and shifts in strategic

¹⁹Morris and Shin (2003, 2004); Hellwig (2002); Metz (2002); Dahleh, Tahbaz-Salehi, Tsitsiklis, and Zoumpoulis (2016) derive conditions for equilibrium uniqueness and multiplicity in the presence of common information.

uncertainty.” (Morris and Shin, 2002). In a global game of regime change with endogenous acquisition of private information, Ahnert and Kakhbod (2017) obtains a unique switching equilibrium under certain parametric conditions, and show that the precision of a public signal (for a given realization of the public signal) shrinks the range of failure if the realization is high and expands the failure range if the realization is low (Ahnert and Kakhbod, 2017, Proposition 4). Still, “the effect of improving the quality of public information ex ante on the probability of a financial crisis ex post is ambiguous.” (Ahnert and Kakhbod, 2017, p.2149).²⁰

An exception that overcomes these challenges is Goldstein et al. (2011), which obtains a unique linear symmetric threshold equilibrium and generates a clean set of results on the effect of information commonality in a model of currency attack. Goldstein et al. (2011) show that the information commonality raises the volatilities of agents’ equilibrium actions. Here, we derive a clear distinction of our main result: The expected size of the currency attack remains constant with the information commonality in Goldstein et al. (2011), whereas the expected proportion of runners strictly increases with the commonality in our model. In Goldstein et al. (2011), each speculator observes two signals about some fundamental θ : an idiosyncratic one $s_i = \theta + \sigma_s \varepsilon_i$ and another one $s_{pi} = \theta + \sigma_p \varepsilon_p + \sigma_h \eta_i$ that shares some common noise component ε_p . The precision of the correlated signal is $1/(\sigma_p^2 + \sigma_h^2)$, and the commonality between the correlated signals of any two speculators is $\sigma_p^2/(\sigma_p^2 + \sigma_h^2)$. Each speculator chooses whether to attack a currency. The central bank observes the size A of the attack and a signal s_b about θ , and decides whether to maintain its currency peg whose net value is θ . In equilibrium, $\mathbb{E} A$ depends on the precisions $1/\sigma_s^2$ and $1/(\sigma_p^2 + \sigma_h^2)$ but not on the commonality $\sigma_p^2/(\sigma_p^2 + \sigma_h^2)$ of the signals.²¹ Relative to Goldstein et al. (2011), our model reveals a new effect of common information: (iv) The commonality impacts not only

²⁰The main result of Ahnert and Kakhbod (2017) is that endogenous acquisition of private information amplifies the impact of the *realization* (not the precision) of the public signal.

²¹Using the expression of T given in Goldstein et al. (2011, p.269, Definition 1),

$$\begin{aligned} \mathbb{E} A &= \mathbb{E} \Phi(T) = \mathbb{E} \int_{-\infty}^{\infty} \left(\int_{-\infty}^{\infty} g(\theta + \sigma_s \varepsilon, \theta + \sigma_p \varepsilon_p + \sigma_h \eta) \varphi(\eta) d\eta \right) \varphi(\varepsilon) d\varepsilon \\ &= \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \left(\int_{-\infty}^{\infty} g(\theta + \sigma_s \varepsilon, \theta + \sigma_p \varepsilon_p + \sigma_h \eta) \varphi(\eta) d\eta \right) \varphi(\varepsilon) d\varepsilon \varphi(\varepsilon_p) d\varepsilon_p \\ &= \int_{-\infty}^{\infty} \left(\int_{-\infty}^{\infty} g\left(\theta + \sigma_s \varepsilon, \theta + \sqrt{\sigma_p^2 + \sigma_h^2} \varepsilon_{ph}\right) \varphi(\eta) d\eta \right) \varphi(\varepsilon_{ph}) d\varepsilon_{ph}. \end{aligned}$$

the second moment but also the first moment of every agent’s equilibrium action by steering the action strictly downward conditional on any relevant fundamental.

Bank runs

Our paper contributes to the theoretical literature motivated by the 2023 Regional Bank Crisis. [Drechsler et al. \(2023\)](#); [Haddad, Hartman-Glaser, and Muir \(2023\)](#) study the impact of rising interest rates on deposit franchise value and bank runs. [Jiang, Matvos, Piskorski, and Seru \(2024\)](#) show how mark-to-market asset losses and large shares of uninsured deposits could lead to a “solvency run.” [Chang et al. \(2023\)](#) propose a model where banks better at risk taking attract more uninsured depositors. Our model can accommodate these channels by mapping the fundamental to the bank’s deposit franchise value, mark-to-market asset value, and lending relationship values, respectively.

Our results are also relevant to the empirical literature on the role of public signals in triggering the 2023 bank runs. [Cookson, Fox, Gil-Bazo, Imbet, and Schiller \(2024a\)](#); [Cipriani, Eisenbach, and Kovner \(2024\)](#) show that banks with higher social media attention or publicly traded stock are associated with a higher likelihood of stress and experience significantly higher deposit outflows.²² Our theory shows that greater information commonality across depositors makes them more inclined to run, which explains these empirical findings.

The same property holds in a model variant in [Goldstein et al. \(2011, Appendix B\)](#).

²²[Cipriani et al. \(2024\)](#) also show that the concentration of uninsured depositors predicts a bank run even after controlling for the fraction of uninsured deposits in the total bank funding. [Koont, Santos, and Zingales \(2024\)](#); [Benmelech, Yang, and Zator \(2023\)](#) show that digital banking can increase the speed of deposit outflows during a run.

Appendices

A Proofs

[omitted]

B Constant Fundamental Uncertainty σ

This appendix shows that our main result is *exclusively* driven by the negative covariance between fundamental θ and the proportion n_K of runners.

We keep each depositor's fundamental uncertainty σ constant while varying the number K of communities. One concern is that fewer communities mechanically leads to less aggregate information $(x_{k,i})_{k=1,\dots,K}$ about fundamental θ . We show that (1) if we were to keep constant the aggregate uncertainty (instead of the individual uncertainty) about θ , then the equilibrium run threshold would increase even faster with fewer communities, due to the negative covariance (Corollary 2). (2) the aggregate uncertainty about θ is irrelevant for the run threshold (Proposition 7 Part (i)), (3) the individual fundamental uncertainty σ matters for run threshold θ_K^* , and thus should be kept constant as K varies (Proposition 7 Part (ii)).

To show (1), we turn off any effect of uncertainties (individual or aggregate) about fundamental θ by assuming that $v(\theta, n) = \sum_h R_h(\theta)u_h(n)$, where all $R_h(\theta)$ are linear in θ . With linear R_h , neither uncertainty about θ *per se* is relevant for the expected willingness to stay, because depositors are neutral to the uncertainty. Our model allows for such a v and all our results holds in this special case. In particular, with fixed individual fundamental uncertainty σ , θ_K^* increases with fewer communities (Theorem 1). If we were to keep constant the aggregate uncertainty about θ , we would need to let the individual fundamental uncertainty σ_K increase in K . Corollary 2 shows that the equilibrium run threshold would increase even faster with fewer communities.

Corollary 2. *If the willingness to stay is $v(\theta, n) = \sum_h R_h(\theta)u_h(n)$ where $R_h(\theta)$ is linear for all h , and the expected community error is 0, $\mathbb{E}\varepsilon_k = 0$, and each depositor's fundamental uncertainty decreases when the number of communities declines from $K+1$ to K , $\sigma_{K+1} > \sigma_K$, then equilibrium threshold increases by more than if σ_{K+1} had stayed constant,*

$$\theta_K^*(\sigma_K) - \theta_{K+1}^*(\sigma_{K+1}) > \theta_K^*(\sigma_{K+1}) - \theta_{K+1}^*(\sigma_{K+1}).$$

Proof. Corollary 2 follows from Theorem 1 and Lemma 1. □

Lemma 1. *If $v(\theta, n) = \sum_h R_h(\theta)u_h(n)$ where R_h is linear for all h , and the expected community error is 0, $\mathbb{E}\varepsilon_k = 0$, then equilibrium threshold θ_K^* is strictly decreasing in σ for any $K \in [2, \infty]$.*

Proof. It follows from the definition ?? of π_K that

$$\begin{aligned} \pi_K(x, x) &= \sum_h \mathbb{E}[R_h(\theta) | x_{K,i} = x] \mathbb{E}[u_h(n_K(x)) | x_{K,i} = x] + \sum_h \text{Cov}[R_h(\theta), u_h(n_K(x)) | x_{K,i} = x]. \end{aligned}$$

The second term is strictly positive for any $K \in [2, \infty]$, and for every h ,

$$\begin{aligned} &\text{Cov}\left[R_h(\theta), u_h(n_K) \mid x_{K,i} = x\right] \\ &= \text{Cov}\left[R_h(x - \sigma\varepsilon_{k(i)}), u_h\left(\int_0^1 \mathbb{1}\{\varepsilon_{k(i)} + \nu_i < \varepsilon_{k(j)} + \nu_j\} dj\right) \mid x_{K,i} = x\right] \\ &= \sigma \text{Cov}\left[R_h(x - \varepsilon_{k(i)}), u_h\left(\int_0^1 \mathbb{1}\{\varepsilon_{k(i)} + \nu_i < \varepsilon_{k(j)} + \nu_j\} dj\right)\right]. \end{aligned}$$

Thus, the second term is strictly increasing in σ . The first term does not depend on σ , because $\mathbb{E}[R_h(\theta) | x_{K,i} = x] = R_h(x)$ and $\mathbb{E}[u_h(n_K(x)) | x_{K,i} = x] = \int_0^1 u_h(n)dn$. Taken together, $\pi_K(x, x)$ is strictly increasing in σ . Since $x \mapsto \pi_K(x, x)$ is strictly increasing in x (??) and $\pi_K(\theta_K^*, \theta_K^*) = 0$, θ_K^* is strictly decreasing in σ .

□

Lemma 1 and thus **Corollary 2** are driven exclusively by our mechanism: A decline of σ shrinks the negative covariance between θ and n_K , reducing the expected willingness to stay and pushing up the equilibrium run threshold θ_K^* .

To show (2) and (3), we turn off the effect of the negative covariance by assuming $v(\theta, n) = R(\theta) + u(n)$. With such an additive form, the expected willingness to stay $\mathbb{E}[v(\theta, n_K) | x_{K,i}] = \mathbb{E}[R(\theta) | x_{K,i}] + \mathbb{E}[u(n_K) | x_{K,i}]$ does not depend on the negative covariance between θ and n_K . Neither does the equilibrium run threshold. In this case, the run threshold is constant in K if we fix the individual fundamental uncertainty σ , despite a varying aggregate uncertainty as K changes (**Proposition 7** Part (i)). In contrast, Part (ii) implies that the run threshold generically changes with K if we fix the aggregate uncertainty instead of the individual

uncertainty about θ .

Proposition 7. *If the willingness to stay is $v(\theta, n) = R(\theta) + u(n)$ where $R(\theta)$ is strictly increasing in fundamental θ and $u(n)$ is weakly decreasing in the proportion n of runners, then the model has a unique equilibrium surviving iterated deletion of dominated strategies, which is a switching equilibrium. (i) The equilibrium run threshold does not depend on the number K of communities. (ii) The equilibrium run threshold is increasing in σ if R is concave, decreasing if R is convex, and constant if R is linear.*

Proof. The proof of [Proposition 1](#) applies here, because it does not use the functional form of $v(\theta, n)$. It implies that the unique equilibrium is a switching equilibrium, and the equilibrium threshold θ_K^* solves the indifference condition $\mathbb{E}[v(\theta, n_K) | x_{K,i} = \theta_K^*] = 0$, which expands as

$$0 = \mathbb{E}[R(\theta) | x_{K,i} = \theta_K^*] + \mathbb{E}[u(n_K) | x_{K,i} = \theta_K^*] = \mathbb{E}[R(\theta) | x_{K,i} = \theta_K^*] + \int_0^1 u(n) \mathrm{d}n,$$

The first term is a function, that does not depend on K , of θ_K^* . Therefore, θ_K^* does not depend on K .

□

[Proposition 7](#) shows that the aggregate uncertainty about the fundamental is irrelevant for the equilibrium run threshold. It is the individual fundamental uncertainty that matters: A change in the individual fundamental uncertainty σ would push up or down the run threshold depending on depositors' aversion to the fundamental uncertainty as captured by the concavity R —an effect that [Section 3](#) turns off by keeping σ constant.

C Benchmarking the Impact of Deposit Clustering

How large is the impact of clustering in raising the real cost of liquidation? This section benchmarks this impact against that of a reduction in the quality of the bank's assets.

Proposition 8. *An increase in the degree of deposit clustering from K to $K-1$ communities raises the ex-ante social cost $\mathbb{E}c(\theta, n_K)$ of runs by weakly more than a downward shift of $\theta_{K-1}^* - \theta_K^*$ in the fundamental's prior distribution.*

Proposition 8 states that clustering into one fewer community is equivalent to a reduction of at least $\theta_{K-1}^* - \theta_K^*$ in the bank's fundamental in terms of raising the expected liquidation cost from runs. Clustering raises the equilibrium run threshold by $\theta_{K-1}^* - \theta_K^*$, which has the same impact on the mass of runners as lowering the fundamental by the same magnitude. Having one fewer community also makes the mass of runners more volatile, further raising the liquidation cost.

In a numerical example, moving from $K = 2$ to $K = 1$ community is equivalent to a reduction of 4.17% in the project's return. We let $v(\theta, n) = (1 + \theta) \left(1 - \frac{n}{B+1}\right) - 1$, $\sigma = 1$, $\varepsilon \sim \text{Uniform}(-\frac{1}{2}, \frac{1}{2})$, and define $p(\theta, \theta_K^*) = \frac{1}{2} + \theta_K^* - \theta$.

The marginal depositor's indifference condition is

$$\begin{aligned} 1 &= \mathbb{E}[v(\theta, n(\theta_K^*)) \mid x_{K,i} = \theta_K^*] \\ &= \frac{1}{\sigma} \int_{\theta_K^* - \frac{\sigma}{2}}^{\theta_K^* + \frac{\sigma}{2}} (1 + \theta) \mathbb{E} \left[1 - \frac{n_K}{B+1} \mid x_{K,i} = \theta_K^*, \theta \right] d\theta \\ &= \frac{1}{\sigma} \int_{\theta_K^* - \frac{\sigma}{2}}^{\theta_K^* + \frac{\sigma}{2}} (1 + \theta) \left[1 - \frac{1}{(B+1)K} \left(\frac{1}{2} + (K-1)p(\theta, \theta_K^*) \right) \right] d\theta. \end{aligned}$$

Solving for θ_K^* , we obtain $\theta_K^* = \frac{(6-\sigma)}{6(1+2B)} + \frac{\sigma}{6(1+2B)} \frac{1}{K}$. **Figure C.1** plots the equilibrium run threshold θ_K^* as a function of the number K of communities.

To evaluate the liquidation cost, we first assume a linear cost $c(\theta, n) = c \cdot n$. With K communities, the ex-ante cost of liquidation is $\mathbb{E}(cn_K) = c \frac{\theta_K^* - \theta}{\theta - \theta}$. Thus, moving from $K = 2$ to $K = 1$ community is equivalent to a reduction of $\theta_1^* - \theta_2^* = \frac{\sigma}{24} = 4.17\%$ in the project's expected return in terms of raising the ex-ante liquidation cost.

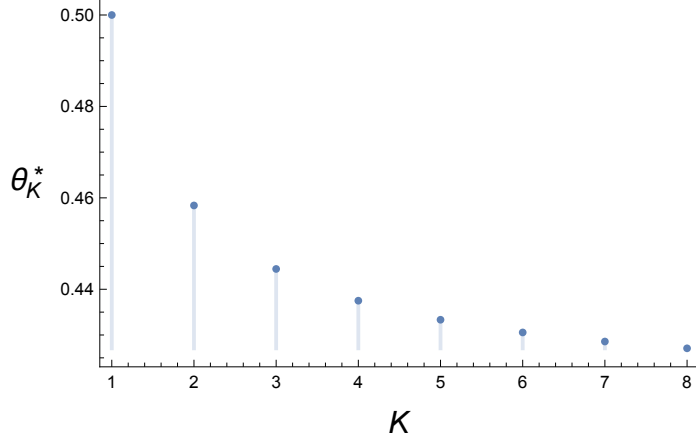


Figure C.1. The equilibrium run threshold. In the graph, we consider a setting in which $v(\theta, n) = (1 + \theta) \left(1 - \frac{n}{B+1}\right) - 1$ with $B = 0.5$ and $\sigma = 1$, $\varepsilon \sim \text{Uniform} \left(-\frac{1}{2}, \frac{1}{2}\right)$.

Alternatively, we assume a quadratic liquidation cost $c(\theta, n_K) = c \cdot n_K^2$. With K communities, the *ex-ante* cost of liquidation is $\mathbb{E}(cn_K^2) = \frac{c}{\bar{\theta} - \underline{\theta}} \left(\theta_K^* - \underline{\theta} - \frac{\sigma}{6} + \frac{\sigma}{6} \frac{1}{K}\right)$. Thus, moving from $K = 2$ communities to $K = 1$ community is equivalent to a reduction of $\theta_1^* - \theta_2^* + \frac{\sigma}{6} \frac{1}{2} = \frac{\sigma}{8} = 12.5\%$ in the project's expected return in terms of raising the *ex-ante* liquidation cost.

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