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Too-many-to-fail and the design of bailout regimes*

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Abstract

We analyze the design of bailout regimes when investment is distorted by a too-many-to-fail problem. The first-best allocation equalizes benefits from more banks investing in high-return projects with endogenously higher systemic risk due to more banks failing simultaneously. A standard bailout policy cannot implement the first-best, as bailouts cause herding by banks. However, a *targeted* bailout policy that assigns banks to separate bailout regimes eliminates herding and achieves the first-best. When such a policy is not feasible, targeted bailouts can be implemented by decentralizing bailout decisions to independent regulators. Our results have various implications for the optimal allocation of regulatory powers, both at the international level and domestically.

JEL Classification: G1, G2

Keywords: systemic risk, too-many-to-fail, optimal investment, bailouts

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1 Introduction

When banks are jointly in distress, regulators are often compelled to bail them out to prevent the systemic consequences of widespread failures - a problem known as "too-many-to-fail". The Global Financial Crisis and the European sovereign debt crisis serve as powerful reminders of large-scale bank bailouts.[1] The anticipation of future bailouts, in turn, creates incentives for banks to take on more risk. In particular, banks may herd and invest in more correlated assets (Duchin and Sosyura, 2014; Acharya et al., 2021), exacerbating the too-many-to-fail problem and increasing systemic risk.

While there have been significant regulatory reforms aimed at reducing systemic risk since the Global Financial Crisis, most of the efforts have focused on large financial institutions that are considered too-big-to-fail.[2] Recent bailouts and policy interventions following distress at mid-sized regional banks in the U.S. highlight the need to address the too-many-to-fail problem as well. This paper shows that a properly designed bailout regime can eliminate herding arising from too-many-to-fail, and thus lower systemic risk.

We study an economy with two central frictions: bank project choices are unobservable and bailouts have to be time-consistent. In our baseline model, banks can select among two risky projects that differ with respect to their expected returns (high and low). When a bank fails, its project can be continued at a surviving bank – at a loss. The loss is increasing in the number of additional projects a bank is continuing, reflecting for instance capacity constraints. As a consequence, the social cost of a bank's failure is increasing in the number

[1] For example, the sector-wide distress resulted in the U.S. government approving a $700 billion in funding for the Troubled Asset Relief Program. Similarly, European governments bailed out a large number of banks, to the extent that the resulting costs raised concerns over sovereign risks and subsequent needs to bail out certain European countries (Lane, 2012).

[2] For example, G20 launched a comprehensive programme of reforms, coordinated through the Financial Stability Board (Financial Stability Board 2021) that lead to significantly higher capital requirements and tighter supervision of large banks, such as through stress tests; the European Systemic Risk Board was established in 2011, while 2 additional pillars were added to the Banking Union in 2013-2014: the Single Supervisory Mechanism and the Single Resolution Mechanism.

of other banks failing at the same time, in other words: there is systemic risk.

We show that the economy's first-best investment can be interior, that is, not all banks should invest in the high project. The optimal (aggregate) fraction of investment in the more productive project trades off higher returns from this project against endogenously higher systemic costs arising because, when more banks invest in this project, correlated failures are more pronounced. Notably, interior investment can be optimal even though both projects are in constant supply in the economy. The first-best solution also requires bailing out whenever bank failures exceed a threshold. In these cases, banks are bailed out until the marginal systemic cost of bank failure is equalized with the cost of a bailout.

We show that the first-best cannot be implemented under a standard bailout regime. The reason is that bailout expectations are higher when investing in the high project, precisely because this project is invested in more frequently, and is hence associated with more correlated failures. In our model, with microfounded systemic risk, banks fully internalize the systemic implications of both failure and survival (the latter arising because surviving banks can acquire projects from failed banks). Absent bailouts, their incentives are thus undistorted. However, the presence of bailouts when the high-return project fails distorts their incentives in favour of the high project, causing overinvestment in this project.[3]

The "standard" bailout regime we have considered here is one in which the regulator selects randomly – among identical banks – which banks to bail out, that is, bailouts are non-discriminatory. Since optimal bailouts are always incomplete (as it is never optimal to bail out all failing banks), there are degrees of freedom in the design of the bailout policies. We show that this can be exploited using *targeted* bailout policies.

Consider the following bailout regime. Banks are allocated ex-ante (before they decide on investment) to two different bailout groups, with the sizes of the two groups reflecting the first-best investment in the two projects. Bailouts are ex-post only disbursed among

[3]This is a classic herding problem: many banks investing in a project result in more bailouts, further increasing the incentives to invest in the project. Notably, in our model herding occurs endogenously on the project that is also socially more desirable.

members of the group allocated to the project that fails. In particular, a member of the low group will only get bailed out when it fails when the low project fails, but not otherwise. By breaking the one-to-one link between project choice and bailouts, this regime eliminates herding incentives (specifically, a member of the low group will no longer benefit from more frequent bailouts if it chooses the high project).[4] The first-best can thus be implemented. It is important to note that this regime is still fully time-consistent, as total disbursements of bailouts are unchanged.

We consider several extensions to this result. For example, we study an extension to n ($n \geq 3$) projects that all differ in terms of their expected returns. We show that the first-best can still be implemented using two bailout groups. In another extension, we allow the productivity of projects to differ across banks, resulting for instance in the high project having lower returns at some banks. We show that targeted policies can still implement the first-best. However, there is a difference in the ex-ante design of the bailout regime. In our baseline model, the allocation of a single bank to one of the two groups is undetermined, as the first-best only pins down the aggregate allocation to the two groups. This is no longer the case: the high group should now be formed only with the banks that have the most productive high projects.

Targeted bailout policies may in practice be unfeasible, or only be implementable with limitations. We show that, if regulators are restricted to using bailout policies that do not discriminate among banks, there is scope for a decentralized bailout regime. We examine a decentralized regime in which bailout decisions are allocated to two separate regulators, each responsible for a subset of banks (and only concerned about the welfare of these banks). We show that such a bailout regime, if properly designed, effectively implements targeted policies and thus eliminates herding incentives as well. The reason is that in the decentralized system, it becomes endogenously rational for regulators to concentrate bailouts only on the banks that do not deviate from their group. To see the argument, consider the regulator who has authority over the group that is intended for the low project. If a bank from this group

[4] Discriminatory policies are only needed "off-equilibrium", when a bank deviates.

deviates and invests in the high project, it only fails when no other bank under the authority of this regulator fails. The regulator then has no incentives to bail out this bank, implying that all bailouts will be done by the other regulator. The presence of two regulators thus decentralizes the implementation of targeted policies.

Decentralization comes at a cost though. Each regulator does not internalize the impact bailouts can have on the banks under the authority of the other regulator. In particular, bailing out its own failing banks lowers the surplus at the surviving banks of the other regulator, as those banks can then acquire fewer failing projects. Due to this externality, individual regulators bail out more than what is socially efficient. Decentralization is thus subject to a trade-off: it leads to more efficient project choices by eliminating distortions in banks' incentives, but results in distorted bailout decisions.[5]

Our paper has several implications for policy. We show that there is a benefit to creating separate regulatory umbrellas, arising purely for systemic reasons. By contrast, allocating all banks to a single regulator who treats them similarly creates herding incentives. This provides a rationale for two-tiered financial architectures, such as the Banking Union in Europe (in which national and supranational supervisors co-exist) and the United States (with state and federal regulators). Importantly, our analysis also shows that the allocation of financial institutions to different regulators should not only depend on characteristics of institutions themselves (such as size) but should be governed by the desire to limit *economy-wide* herding. In particular, allocating too many institutions to one regulator exacerbates herding by creating high bailout expectations.[6] Our analysis also shows that there is a

[5]We show that either decentralized regulation or a single regulator can be optimal when (direct) targeted policies are not available. In particular, decentralized regulation becomes optimal when the cost of bailouts is sufficiently low, whereas a single regulator becomes optimal when the return advantage of the high project is small.

[6]Our analysis thus has direct implications for the design of the rule that determines to which regulator a specific financial institution should be allocated. In the Eurozone, for instance, allocation to the ECB is determined by an institution's balance sheet size. As our analysis implies that the *aggregate* fraction of (banking) assets that are under control of a given regulator should be limited, this size threshold should be

benefit to "egoistic" local regulation. National regulators, for instance, are less inclined to bail out banks that are failing because they have invested in assets in other countries (as their failure may then be occurring at times of good health of the domestic banking system). This limits herding at the international level and provides a rationale for maintaining some form of national regulation even in well-integrated financial systems.

Our analysis focuses on the *too-many-to-fail* problem, the tendency of policy-makers to be more forgiving towards financial institutions at times of general stress in the financial system.[7] Acharya and Yorulmazer (2007) have shown that regulators have ex-post incentives to bail out banks if they fail jointly, and that this provides banks with incentives to herd on the same asset. Our model generalizes the framework of Acharya and Yorulmazer by allowing for a potential benefit to correlated investments, arising because some assets have higher returns than others. As a result, the objective of the policy is not solely to prevent herding, but also to implement efficient investment choices at the aggregate level. Also, in Acharya and Yorulmazer the bailout regime is taken as given (the analysis considers a single regulator that is restricted to a random allocation of bailouts across failing banks), whereas we explicitly consider the design of bailouts.

Several papers have analyzed policies to mitigate collective moral hazard (e.g., Acharya and Yorulmazer (2008), Farhi and Tirole (2012), Stein (2012), Horvath and Wagner (2017) and Segura and Suarez (2017)). Acharya and Yorulmazer (2008) consider ex-post liquidity policies. They show that providing liquidity to surviving banks mimics the allocative effects

lowered when more banks exceed it.

[7]Studying a sample of developing countries, Brown and Dinc (2011) show that regulators are more likely to be forbearing towards a failing bank when the banking system is weak. In addition, several single-country studies also point to too-many-to-fail policies adopted by national regulators (Kane (1989), Barth (1991), White (1991), Kroszner and Strahan (1996), Hoshi and Kashyap (2001) and Amyx (2004)). Hoggarth et al. (2004) analyze resolution policies adopted in 33 systemic crises over the world and document that during systemic crises there is government involvement via liquidity support from the central bank and blanket guarantees, whereas in individual bank failures usually private solutions are applied and losses are passed on to shareholders.

of bailouts, and that such liquidity provision lowers ex-ante herding incentives (in our model there is no role for liquidity policies at surviving banks as the constraining factor is a capacity constraint). A countervailing force to collective moral hazard has been identified in Perotti and Suarez (2000), arising because surviving banks obtain higher rents when other banks fail. Perotti and Suarez show that a policy of promoting takeovers of failing banks by solvent banks improves incentives, and makes banks' risk choices strategic substitutes. In our paper, surviving banks also obtain rents as they can purchase assets of failing banks at discounted prices, which (in the absence of bailouts) results in strategic substitutability as well.

Phillipon and Wang (2022) show that allocating bailouts through tournaments can be used to address moral hazard in the form of traditional risk-taking. They show that focusing bailouts on ex-post stronger banks lowers their ex-ante incentives to take risks. In contrast, the friction in our model is moral hazard arising from correlated investments (i.e., too-many-to-fail), and we show that this provides a rationale for targeted policies based on an *ex-ante* grouping of (identical) banks. Several papers have studied other aspects of optimal bailout policies, for instance by employing constructive ambiguity (Freixas (1999)), in terms of affecting charter value (Cordella and Yeyati (2003)), and in the presence of bail-in capital (Keister and Mitkov (2020)).

Our paper also relates to the literature analyzing optimal investment in the face of fire-sale risk. Whereas we consider the choice among illiquid assets, this literature has mostly analyzed the optimal mix of holding illiquid assets and holding liquidity (see, among many others, Shleifer and Vishny (1992), Allen and Gale (1994), Gorton and Huang (2004), Allen and Gale (2005), Acharya, Shin and Yorulmazer (2011)). A central insight here is that this investment mix trades off gains from investing in productive assets with losses due to being forced to sell at fire-sale prices. Wagner (2011) considers optimal portfolio allocations among different illiquid assets in the presence of liquidation risk, showing that at equilibrium, diversified portfolios trade off a lower probability of forced liquidation with higher liquidation costs due to more investors holding diversified portfolios and hence fire sales being deeper. In our model, the benefit to correlated investments arises from some assets having higher returns than others, not from diversification motives.

Our analysis of decentralized regulation is closely linked to the literature that has studied the optimal allocation of supervisory and regulatory powers (e.g., Acharya (2003), Dell'Ariccia and Marquez (2006), Calzolari, Colliard and Lóránth (2019), Carletti, Dell'Ariccia and Marquez (2020), Colliard (2020), Lóránth, Segura and Zeng (2022), Niepmann, and Schmidt-Eisenlohr (2013)). Whereas these papers have studied trade-offs for a single (representative) institution, the analysis in our paper is based on systemic considerations. In particular, we show that there are benefits to heterogeneous, and possibly decentralized, regulatory umbrellas, arising because they can limit herding by financial institutions.[8]

The remainder of the paper is organized as follows. Section 2 sets up the model and Section 3 solves for the first-best allocation. Section 4 considers a single regulator, showing that targeted policies can implement the first-best. Section 5 considers decentralized regulation. Section 6 analyzes the trade-off between centralized and decentralized regulation. Section 7 discusses implications for policy, and derives empirical predictions. The final section concludes.

2 The model

The model has three dates: $t = 0, 1, 2$. There is a continuum of banks of measure one. Banks are risk-neutral, and there is no time discounting. Each bank has one unit of funds at $t = 0$.

At $t = 0$, each bank decides to invest its unit of funds in either a high-return project (H), or a low-return project (L). At $t = 1$, each project fails with probability π ($< \frac{1}{2}$), with the

[8]Several papers have also analyzed hierarchical regulation and supervision, jointly undertaken by central and local supervisors (Repullo (2020), Colliard (2020), Carletti, Dell'Ariccia and Marquez (2020)). These papers have identified a benefit to hierarchical policy-making in terms of information collection, as a local supervisor may have advantages in information gathering but may face distorted incentives relative to a central supervisor. In our setting, separating regulatory responsibilities can be optimal as well, but the benefit from using a local supervisor (for a fraction of banks) arises because banks under its jurisdiction have less incentives to herd.

failures of the projects occurring in mutually exclusive states of the world. A failed project returns 0 at $t = 1$; if it succeeds it returns R_i ($i \in \{H, L\}$), with $R_H > R_L > 1$.

A bank with a successful project can continue to operate and realize an additional project payoff of $\bar{v}$ at $t = 2$. If its project fails at $t = 1$, and the bank is not bailed out, the project cannot be continued at the bank. In this case its project is sold to banks with successful projects, which we assume to occur in a competitive market. The value a successful bank can extract from a project declines in the total amount of project it has acquired, reflecting for instance capacity constraints. Specifically, a bank that acquires a mass a of projects generates $v(a)$ ($\leq \bar{v}$) from the a^{th}-unit of acquired projects (the average value of acquired projects is hence $\widetilde{v}(a) \equiv \int_0^a v(x)dx/a$).

Banks with failing projects can be bailed out by a regulator. This allows the bank to continue operating its project until $t = 2$ and realize the full value $\overline{v}$.[9] A bailout requires an equity injection $I > 0$ into the bank. The equity injection incurs social costs k, for example due to deadweight cost of public funds and/or the (unmodelled) reputation cost to the regulator.

In Appendix A, we provide a microfoundation for both the need to sell projects and for the bailouts. We consider banks that are financed though deposits and face a moral hazard problem in the continuation of their projects. Due to the moral hazard, banks with failed projects cannot continue projects absent bailouts. However, a sufficiently large bailout (of size I) provides incentives for continuation.

The sequence of events is summarized in Figure 1. We impose several parameter restrictions to ensure interior solutions and uniqueness of the equilibrium. First, we make assumptions on the function $v(a)$. In particular, we assume that the rate at which returns are diminishing is sufficiently strong, which allows for uniqueness of the equilibrium:

Assumption 1. *(i)* $v(0) = \bar{v}$ *and* $v(1) \geq 0$*, (ii)* $v'(a) \leq -(k + I) < 0$*, and (iii)* $v''(a) \leq 0$*.*

Second, we make assumptions on the bailout cost:

[9] We assume that bailed-out banks cannot acquire projects from other banks. Allowing for this would introduce an additional benefit to bailouts, but does not change the main trade-offs considered in the paper.

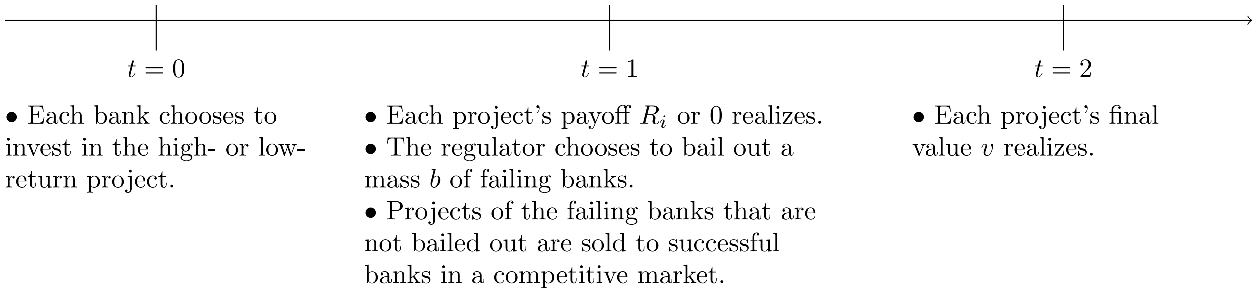

Figure 1: Timeline.

Assumption 2. *(i)* $k < \bar{v} - v(1)$, *and (ii)* $k > \frac{1-\pi}{\pi}(R_H - R_L)$.

The first inequality states that bailouts are optimal when the number of acquired projects becomes sufficiently large (in particular, they are optimal at $a = 1$). The second inequality implies that the bailout cost is high enough to make solely investing in the high-return project suboptimal.

Third, we assume that the equity injection I required to bail out a failing bank is not too high (which is also required for uniqueness of the equilibrium):

Assumption 3. $I \leq \frac{1}{1-(v^{-1}(-\bar{v}+k))^2} - k$.

3 First-best allocation

An allocation can be characterized by *i)* the fraction of banks $\lambda \in [0,1]$ that invest in the high-return project at $t = 0$ (with the remaining fraction $1 - \lambda$ of banks investing in the low-return project), *ii)* a bailout policy to bail out a measure $b(f)$ of banks when a measure f of projects fail at $t = 1$, and *iii)* project transfers for the measure $f - b$ of banks not bailed out. We solve the first-best backwards.

Project transfers. At $t = 1$, at the last stage, there is a mass of $f - b$ (≥ 0) of failing banks that have not been bailed out. As long as continuing projects at successful banks has positive value ($v(a) > 0$), all projects at the mass of $f - b$ banks should be transferred to successful banks (of which there is a mass $1-f>0$ in an interior solution). Since the return from continuing projects is declining at the bank-level ($v'(a)<0$), it is optimal to equally distribute projects among all successful banks. An individual successful bank thus continues

$$a(b,f)=\frac{f-b}{1-f} \tag{1}$$

acquired projects. We refer to a – the ratio of (forced) suppliers of projects to available acquirers – as the economy's *fire-sale pressure.*

Bailout policy. For a mass $f \geq 0$ of banks failing at $t=1$, the optimal bailout policy, $b^{FB}(f)$, minimizes costs arising because projects of failed banks that are not bailed out can only be continued at lower value, and the cost of bailouts itself:

$$C^{FB}(f) \equiv \min_{b \leq f} \quad (f-b)(\bar{v}-\widetilde{v}(a(b,f)))+bk. \tag{2}$$

We refer to $C^{FB}(f)$ as the total *systemic costs* in the economy. The first order condition is given by:

$$\bar{v}-v(a(b,f))=k, \tag{3}$$

where we have used that $\frac{\partial \widetilde{v}(a(b,f))}{\partial b}=\frac{v-\widetilde{v}}{f-b}$. The left hand side is the marginal benefit of bailout: Bailing out one more bank allows to have this bank continuing its project to realize a value of $\bar{v}$, instead of having to transfer the project to another bank and realizing only a value of $v(a)$. The right hand side is the marginal cost of bailout, k.

Lemma 1. *The first-best bailout policy is given by*

$$b^{FB}(f)=\begin{cases} 0 & \text{if } f \leq \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}, \\ -\bar{a}^{FB}+f(1+\bar{a}^{FB}) & \text{if } f > \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}, \end{cases} \tag{4}$$

where the fire-sale-pressure threshold $\bar{a}^{FB}$ ($\bar{a}^{FB}<1$) is defined by $\bar{v}-v(\bar{a}^{FB})=k$.

This lemma shows that bailouts are used only when the mass of failing banks is sufficiently large. This reason is that the benefit of a bailout increases in f since project transfers become more costly when f is large. For a small number of banks failing, the marginal benefit is small (in particular, it becomes zero for $f \to 0$ by Assumption 1*(i)*). Therefore, when the mass of failing banks is sufficiently low, the marginal benefit of bailing out a bank is lower than the cost k and bailouts are not optimal. When the mass of failing banks is large, it is optimal to bail out banks until the marginal benefit and cost of bailouts are equalized, which implies that bailouts are used until the fire-sale pressure is brought down to $\bar{a}^{FB}$. The economy's fire-sale pressure (after bailouts) is hence given by

$$a^{FB}(f) = \min\{\frac{f}{1-f}, \bar{a}^{FB}\}. \tag{5}$$

Two observations about the first-best bailout policy are worth noting. First, one additional bank failure results in bailing out more than one bank ($b^{FB'}(f) > 1$) in the range where bailouts are used. This is because project failure creates a failing bank as well as eliminates a potential acquirer. Second, bailouts are incomplete ($b^{FB} < f$), since eliminating all failures is not optimal when there are at least some successful banks ($1 - f > 0$) that can acquire projects.

Lemma 1 implies that the total systemic costs in (2) are (weakly) convex. To see this, consider the marginal systemic costs of an additional bank failure

$$c^{FB}(f) \equiv C^{FB\prime}(f) = s(a^{FB}(f)) + l(a^{FB}(f)), \tag{6}$$

where

$$s(a) \equiv a(\widetilde{v}(a) - v(a)) \tag{7}$$

is the surplus generated from a successful bank acquiring projects and

$$l(a) \equiv \bar{v} - v(a) \tag{8}$$

is the value loss in the failing bank's project (equal to the marginal benefit of bailout, given in the left-hand-side of (3)). For $f \leq \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$, we have that $c^{FB}(f)$ is increasing as no bailouts are used. When $f > \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$, we have $l(a^{FB}(f)) = k$, and $c^{FB}(f) = k + \bar{a}^{FB}(\widetilde{v}(\bar{a}^{FB}) - v(\bar{a}^{FB}))$ becomes a constant.

Investment choice. We now turn to the first-best project choices at $t = 0$. Given optimal project transfers and optimal bailout policies, the expected welfare when a fraction λ of banks invests in the high-return project is given by

$$W(\lambda) = (1-\pi)(\lambda R_H + (1-\lambda)R_L) + \overline{v} - \pi C^{FB}(\lambda) - \pi C^{FB}(1-\lambda). \tag{9}$$

The first term is the expected project return at $t = 1$. The second term is the project return at $t = 2$ if all projects are continued at their originating banks. The last two terms are the expected systemic costs from failures of the high- and low-return projects, respectively.

The derivative with respect to λ is given by

$$W'(\lambda) = (1-\pi)(R_H - R_L) - \pi(c^{FB}(\lambda) - c^{FB}(1-\lambda)). \tag{10}$$

Equation (10) highlights a trade-off. On the one hand, investing more in the high-return project will lead to higher payoffs in the case of project success. On the other hand, it increases the mass of banks failing in the states where the high-return project fails, while lowering bank failures when the low-return projects fails. Since systemic costs of project failure are convex in the aggregate investment in the project, an interior investment choice λ can be optimal. The second part of Assumption 2 (which gives $W'(1) < 0$) ensures that this is indeed the case ($\lambda^{FB} < 1$).

The efficient investment level trades off the higher project return against its higher marginal systemic costs. At the interior solution, the marginal systemic cost of a high-return project's failure $c^{FB}(\lambda)$ thus has to exceed that of a low-return project's failure $c^{FB}(1-\lambda)$. Recall that Lemma 1 implies that bailouts are used when half of the banks fail simultaneously (as $\bar{a}^{FB} < 1$ following from Part *(i)* of Assumption 2). Since the total costs are only convex when no bailouts are used, this implies the first-best λ is sufficiently high ($\lambda > 1 - \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$), such there are bailouts only when the high-return project fails, but no bailouts when the low return project fails:

Proposition 1. *The first-best* ***investment choice*** λ^{FB} *lies in* $(1 - \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}, 1)$ *and is defined* *through* $W'(\lambda^{FB}) = 0$*:*

$$W'(\lambda^{FB}) = (1-\pi)(R_H - R_L) - \pi(s(\bar{a}^{FB}) + l(\bar{a}^{FB}) - s(\frac{1-\lambda^{FB}}{\lambda^{FB}}) - l(\frac{1-\lambda^{FB}}{\lambda^{FB}})) = 0. \quad (11)$$

The first-best ***bailout policy*** $b^{FB}(f)$ *is given by Lemma 1. The first-best* ***project transfer*** *is to equally allocate the projects of all failing banks to the successful banks.*

4 Single regulator

In this section we analyze outcomes under a single regulator. This regulator maximizes welfare but faces two frictions in doing so. First, banks' investment choices are unobservable. Second, bailout decisions have to be time-consistent.

Since the regulator maximizes welfare, the decision of *how many* banks to bail out at $t = 1$ is identical to that analyzed in the previous section. The total amount of bailouts is thus $b^{FB}(f)$, as characterized in Lemma 1). The regulator is indifferent though (at $t = 1$) about *which* failing banks to bail out, so there are degrees of freedom in the implementation of the bailout policy. We first show that *uniform* bailouts (that is, when recipients of bailouts are randomly chosen) cannot implement the first best. Following this we show that *targeted* bailouts, where bailouts depend on the identity of (failing) banks, can implement the first best.

4.1 Inefficiency of uniform bailouts

In this section, we examine whether the first-best investment allocation is incentive compatible under a uniform bailout policy; that is, if banks' individual project choices can result in an aggregate allocation λ^{FB} when bailouts $b^{FB}(f)$ are randomly allocated across failing banks. We postpone the full characterization of the equilibrium under uniform policies to Section 6.

A bank's incentive at $t = 0$ to undertake the high-return project is driven by the same principal considerations as in Section 3: Investing in the high-return project provides a higher payoff upon project success, but also means that the bank's project fails in a state in which a mass λ (instead of $1-\lambda$) of other projects fail. The difference in expected profits from investing in the high- and low-return project is given by

$$\Delta\Pi^S(\lambda) = (1-\pi)(R_H - R_L) - \pi(c^S(\lambda) - c^S(1-\lambda)), \tag{12}$$

which is identical to marginal social value of investing in the high-return project (10), except that the cost of failure are now c^S, where

$$c^S(f) = c^{FB}(f) - \frac{b^{FB}(f)}{f}(l(a^{FB}(f)) + I). \tag{13}$$

The first term in (13) reflects the fact that, absent bailouts, banks' private costs of failure are identical to the social ones.[10] This is because the competitive market price for projects at $t=1$ correctly reflects the social value of a project that needs to be transferred, $v(a^{FB}(f))$. As a result, the bank enjoy both the profit from acquiring a mass a of failing banks, $s(a^{FB}(f))$, and suffer the loss of having to sell projects when failing, $l(a^{FB}(f))$, summing up to the social costs of failure $c^{FB}(\cdot)$ given by (6). More importantly, the second term in (13) reflects the bailout distortion: In the case of a bailout (occurring with a likelihood of $\frac{b^{FB}(f)}{f}$), the bank avoids the loss $l(a^{FB}(f))$ and also gains the equity injection I.[11]

Evaluating (12) at the first-best allocation (that is, when $W'(\lambda^{FB}) = 0$), we have

$$\Delta\Pi^S(\lambda^{FB}) = \pi\frac{b^{FB}(\lambda^{FB})}{\lambda^{FB}}(k + I) > 0. \tag{14}$$

Equation (14) shows that a bank perceives higher benefit from investing in the high return project, compared to the social benefits. This is because of the too-many-to-fail problem: If the bank invests in the high-return project, it fails when a large mass of banks fail ($\lambda^{FB} > 1 - \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$) and gets bailed out with positive probability ($\frac{b^{FB}(\lambda^{FB})}{\lambda^{FB}} > 0$), whereas if it invests in the low-return project, it does not get bailed out ($\frac{b^{FB}(1-\lambda^{FB})}{1-\lambda^{FB}} = 0$).

[10] Dávila and Korinek (2018) provides a discussion on when pecuniary externalities result in inefficiencies. Like in our setting, they show that in an economy in which risk markets are complete, fire sale does not lead to inefficiencies. In a different context, Biais, Heider and Hoerova (2021) also obtain the result that fire sale does not lead to inefficiencies when markets are complete.

[11] A formal derivation of (12) is in the proof of Proposition 2.

It follows that the first best is not implementable under uniform policies: Banks that should invest in the low-return project strictly prefer to deviate and invest the high-return project.

4.2 Optimality of targeted bailouts

In this section we show that targeted bailouts can implement the first best. Specifically, suppose that at $t = 0$ banks are assigned to two groups, a high-return project (H) group and a low-return project (L) group. The size of these two groups are λ^{FB} and $1-\lambda^{FB}$, respectively. A targeted policy stipulates that when the high-return project fails, the regulator only bails out (failing) banks from the H group, whereas when the low-return project fails, the regulator only bails out banks from the L group.

This targeted policy has the consequence that, if a bank in the L-group chooses the high-return project, it will not be bailed out when it fails (and similarly if a bank in the H-group chooses the low-return project). The bailouts still have to be time-consistent, that is, total bailouts in the case the high-return and the low-return project fails are equal to $b^{FB}(\lambda^{FB})$ and $b^{FB}(1-\lambda^{FB})$, respectively. The only difference to the uniform policy is that the allocation of bailouts across failing banks depends on the (ex-ante) group assignment.

Proposition 2. *The first best can be implemented by separating banks into a high-return project group of measure* λ^{FB} *and a low-return project group of measure* $1-\lambda^{FB}$*, and only bailing out banks that fail when the project of their group fails.*

To understand this result, recall from Section 4.1 that, under uniform bailout policies, at the first-best allocation banks investing in the low-return project prefer to deviate and invest in the high-return project, but solely so because this provides them with the chance to receive a bailout (see equation 14). This is no longer the case: these banks are now in the L-group and will not be bailed out when the high-return project fails. As a consequence, their benefit from switching to the high-return project is zero.[12]

[12]Because equation (14) is positive, the banks in the H-group strictly prefer to invest in the high-return

4.3 Discussion

In contrast to uniform policies, targeted policies require that the regulator treat identical banks differently when it comes to bailouts. Whether such policies are feasible in practice is an open question. On one hand, the allocation of government (and regulatory) support, such as bailouts, to individual banks are highly discretionary in practice. This provides ample room for policy-makers to direct bailouts towards specific groups. On the other hand, if such a policy is formalized, it may raise questions of fairness.

One possibility to mitigate such concern is to allow banks to voluntarily determine their group membership at a cost. That is, suppose an H group and an L group are established, as in Section 4.2, such that a targeted policy stipulates that when the H (L) project fails, the regulator only bails out failing banks from the H (L) group. The following corollary demonstrates that imposing a cost of joining the H group can similarly implement the first best:

Corollary 1. *Imposing a cost equal to $\Delta^S(\lambda^{FB})$ of joining the H group implements the first best.*

Intuitively, this cost exactly offsets the expected bailout benefit obtained from joining the H group. In practice, this cost could be the cost of obtaining a banking license or the cost of deposit insurance.

4.4 Extensions

We demonstrate that the main insight regarding targeted policy extends to a model with more than two projects and when project endowment varies across banks.

project. This implies that there is slackness for the H-group, in other words, a targeted bailout policy that implements the first best allocation is not uniquely defined.

4.4.1 Many projects

Our analysis can also be extended to more than two projects. In Appendix C.1 we consider a general number of projects that differ with respect to their return upon success. As shown in the appendix, in this case it is optimal to invest (strictly) higher amounts in projects with higher returns. In an interior equilibrium, benefits from higher returns are exactly offset by higher (marginal) cost of failure in the event of project failure, arising because more banks investing in the project. Yet, it can still be optimal to invest positive amounts in lower-yielding assets. The reason is that they offer diversification benefits: due to the (weakly) increasing nature of the cost of bank failures, isolated project failures are preferred, which is achieved by spreading investments among many projects. The extension also shows that the first-best can still be implemented with targeted bailouts. Even though there are now multiple projects, two bailout groups are still sufficient. The reason is that, as we show, it is never optimal to use bailouts for two different projects, and hence there is a single distortion as in the baseline model (which can be corrected by splitting banks in two groups).

4.4.2 Project endowments varies across banks

We have assumed that all banks have identical investment opportunities, and in particular that $R_H - R_L$ is the same for all banks. We have done this purely for expositional clarity: We wanted to show that it can be optimal – solely for systemic reasons – to allocate banks to different bailout regimes. In order to do this, we have assumed away any other heterogeneity across banks that could "hard-wire" separating banks into groups.

The more realistic setting is for $R_H - R_L$ to vary across banks. In Appendix C.2 we consider an extension to the baseline model where the productivity of the high-project differs across banks (and possibly is also lower than the one of the low-project). We show that targeted policies can still achieve the first-best. However, there are two consequences for optimal allocations. First, project choices at the level of individual banks are no longer undetermined. In particular, for a given aggregate λ, it is optimal to allocate the banks with the highest productivities to the high-project, and the remaining to the low project. Second, there is a new reason (unrelated to systemic risk) for why an interior fraction of λ is optimal, arising because increasing λ means that banks with increasingly lower productivities of the high project have to choose this project.

5 Decentralized regulation

Targeted bailout policies can address the herding problem arising from too-many-to-fail. In this section we show that if such policies are not feasible, we can still mimic their benefits by decentralizing bailout decisions. As we will see, this comes at a cost though, in terms of making the *amount* of bailouts inefficient.

Specifically, we consider the delegation of responsibilities to two independent regulators. The banks in the economy are partitioned into two sets and allocated to the regulators. Each regulator maximizes the expected payoff of the banks under its control, and it does so by deciding on how many of its (failing) banks to bail out. Both regulators are restricted to using uniform bailout policies and their bailouts have to be time-consistent.

We henceforth refer to the two regulators as the H-regulator and the L-regulator, respectively. We focus on equilibria in which all banks under the umbrella of the H-regulator choose high-return project, whereas all banks under that of the other regulator choose the low-return project.[13] We first analyze the regulators' bailout policies in such an equilibrium. We then characterize the optimal allocation of banks to regulators, and show this indeed implements the desired investment choice.

Bailout policies. In the interesting equilibrium, when a project $i \in \{H, L\}$ fails, all banks under the umbrella of the i-regulator fail (and only those banks fail). The i-regulator's bailout

[13] There is potentially also an equilibrium in which project choices do not differ among regulatory groups, but in this case there is no benefit to decentralized regulation.

policy minimizes the sum of failure costs to its banks plus bailout costs:

$$\min_{b\leq f} \quad (f-b)l(a(f,b)) + bk. \tag{15}$$

The difference to the problem of a single regulator in (2) is that the cost of bank failure is given by $l(a) = \bar{v} - v(a)$ instead of $\overline{v} - \widetilde{v}(a)$. This is because the i-regulator ignores $\widetilde{v}(a) - v(a)$ (> 0), which is the surplus earned by acquiring banks under the umbrella of the other regulator. As a result, the regulator's perceived marginal cost of bank failure is higher than the social one. This is reflected in the new first order condition:

$$\bar{v} - v(a(b,f)) - a(b,f)v'(a(b,f)) = k, \tag{16}$$

which, compared to (3), has the additional term $-av'(a) > 0$ on the left-hand side.

Lemma 2. *The decentralized bailout policy under equilibrium project choices is given by*

$$b^D(f) = \begin{cases} 0, & \text{if } f \leq \frac{\bar{a}^D}{1+\bar{a}^D}, \\ -\bar{a}^D + f(1+\bar{a}^D) & \text{if } f \geq \frac{\bar{a}^D}{1+\bar{a}^D}, \end{cases} \tag{17}$$

where $\bar{a}^D$ $(< \bar{a}^{FB})$ *is defined by* $\bar{v} - v(\bar{a}^D) - \bar{a}^D v'(\bar{a}^D) = k$.

Lemma 2 shows that, in equilibrium, the decentralized regulator appears more bailout-prone: we have $b^D(f) \geq b^{FB}(f)$, with strictly inequality whenever $f > \frac{\bar{a}^D}{1+\bar{a}^D}$. The reason is that in equilibrium, bank failures are concentrated within one regulatory jurisdiction, so that the responsible regulator does not internalize that bailouts lower the amount of projects transferred to banks under the umbrella of the other regulator, reducing surplus at these banks.

Next, we analyze bailout decisions when a bank unilaterally chooses another project than its equilibrium project.

Lemma 3. *A bank that deviates from the equilibrium project choice at* $t = 0$ *is never bailed out under decentralized regulation.*

The intuition for Lemma 3 is the exact opposite of Lemma 2. The deviating bank would fail precisely when bank failures are concentrated in the other jurisdiction. As a result, the bank is not bailed out, since its decentralized regulator considers only this one failing bank and does not internalize that a bailout alleviates the fire-sale pressure for the all the other failing banks under the umbrella of the other regulator, raising surplus for those banks.[14]

Lemmas 2 and 3 imply that banks are bailed out with positive probability if and only if they fail together with the other banks in their group. In other words, decentralization of regulation results in an allocation of bailouts that is optimally targeted (as analyzed in Section 4.2).

Investment choice. In equilibrium, all banks under the umbrella of the H (L) regulator choose the H (L) project. Assigning a mass of λ banks to the H-regulator and the remaining mass $1-\lambda$ to the L-regulator would thus implement an aggregate investment of λ in the H project. We proceed to characterize the optimal investment policy λ that maximizes welfare, and show that this can indeed be implemented as an equilibrium.

Expected welfare for a given λ is

$$W^D(\lambda) = (1-\pi)(\lambda R_H + (1-\lambda)R_L) + \bar{v} - \pi C^D(\lambda) - \pi C^D(1-\lambda). \tag{18}$$

This expression only differs from (9) because the decentralized regulators follows a bailout policy of $b^D(f)$ characterized in Lemma 2, resulting in total systemic costs of $C^D(f)$ rather than $C^{FB}(f)$.

Proposition 3. *The optimal investment policy under decentralized regulation can be implemented by allocating a measure λ^D of banks to the H-regulator and the remaining measure $1-\lambda^D$ to the L-regulator, where λ^D lies in $(\lambda^{FB}, 1)$ and is defined through $W^{D\prime}(\lambda^D) = 0$:*

$$W^{D\prime}(\lambda^D) = (1-\pi)(R_H - R_L) - \pi(s(\bar{a}^D) + l(\bar{a}^D) - s(\frac{1-\lambda^D}{\lambda^D}) - l(\frac{1-\lambda^D}{\lambda^D})) = 0. \tag{19}$$

[14] It is then clear that this argument does no reply on a single bank deviating and holds also when a small mass of banks jointly deviate.

The proposition shows that, at the optimal investment policy λ^D, it is indeed incentive compatible for banks under the umbrella of the i-regulator, $i \in \{H, L\}$, to choose the i-project. This is not surprising: since decentralized regulation implements optimal targeted policies, there is no distortion in banks' project choices.

The proposition also shows that investment in the high-return project should exceed the investment-level in the first best allocation ($\lambda^D > \lambda^{FB}$). The reason is that a higher λ helps here to mitigate ineffiencies in the *amount* of bailouts disbursed. As we have shown in Lemma 2, the H-regulator bails out more banks than in the first-best, essentially because it does not internalize that bailouts reduce the surplus for the banks of the L-regulator. Choosing a higher λ lowers the size of the externality on the L-regulator, simply because there are then fewer banks under its umbrella. The H-regulator will thus internalize a larger share of the social value of bailouts, resulting in more efficient bailout decisions. Compared to the first-best analysis, there is hence an additional benefit to increasing λ, making it desirable to have $\lambda^D > \lambda^{FB}$.

6 Optimal regulatory form

We know that under uniform policies, neither a single regulator nor decentralized regulation can achieve the first-best (Section 4 has shown this for a single regulator, and the preceding section for decentralized regulation). In this section we compare welfare under both regulatory regimes, and analyze when which regime is optimal.

We start by characterizing the outcome under a single regulator. The bailout policy is then given by $b^{FB}(\cdot)$. The equilibrium project choices are pinned down by incentive compatibility, which requires that (at an interior solution) banks are indifferent between the high- and the low-return project: $\Delta\Pi^S(\lambda) = 0$, where $\Delta\Pi^S(\lambda)$ is defined in (12).

Proposition 4. *There exists a unique equilibrium under a single regulator employing uniform bailout policies. In this equilibrium a mass $\lambda^S > \lambda^{FB}$ of the banks invest in the high-return project.*

The reason why the equilibrium level of investment in the high-return project exceeds the first best has already been established in Section 4.1: Because under the first best there are bailouts when the high-return project fails (but not when the low return project fails), banks have an incentive to invest in the high-return project even if this is not socially desirable.

What is less obvious is whether our setting allows for an unique equilibrium. More banks investing in the high-return project will result in even more bailouts in the event this project fails, increasing the incentives for banks to invest even more in high-return projects. Such strategic complementarity may lead to multiple equilibria. However, there is also a countervailing effect. More banks investing in the high-return project also means fewer potential acquirers when this project fails. This implies that the transfer value of the project becomes very low, providing large incentives to be an acquirer of such assets, and hence to invest in low-return projects (this is essentially the "last-bank-standing" effect of Perotti and Suarez (2002)). Our assumptions (specifically 1 and 3) guarantee that this effect is sufficiently strong relative to the first effect,[15] guaranteeing an unique solution.

We are now equipped to compare welfare under the two regulatory forms (single regulator and decentralized regulation). We already know that there are inefficencies under either regulatory form. A single regulator causes excessive investment in the high-return project due to herding (Proposition 4) but decentralized regulation results in bailouts that are higher than in a first best (Lemma 2).[16] The optimal regulatory form will thus trade off the welfare losses from inefficient project choices against those from inefficient bailout decisions.

The following proposition shows that either mode of regulation can be optimal.

[15] The strength of the last-bank-standing effect is determined by $v'(a)$, the more negative this derivative the larger is the benefit from being an acquiror when a larger amount of high-return projects fail. The strength of the first effect, by contrast, is determined by the wedge between banks' private benefit of bailouts and the social costs, given by $k + I$.

[16] Proposition 3 shows that investment in the high-return asset exceeds the first-best level also in the case of decentralized regulation. However, in this case investment is optimally chosen (and hence not "excessive" in terms of welfare). The reason that it is chosen to exceed the first-best is that this results in bailout decisions that are less distorted.

Proposition 5. *There exist thresholds* $\underline{k} > 0$ *and* $\overline{\Delta}_R > 0$*, such that decentralized regulation strictly maximizes welfare for all* $k < \underline{k}$ *and for all* $R_H - R_L > \overline{\Delta}_R$*. There also exist thresholds* $\overline{k} > \underline{k}$ *and* $\underline{\Delta}_R \in (0, \overline{\Delta}_R)$*, such that a single regulator strictly maximizes welfare for all* $k > \overline{k}$ *and* $R_H - R_L < \underline{\Delta}_R$*.*

This proposition shows that decentralized regulation is optimal when the bailout costs (k) is small and/or when the return advantage of the high-return project ($\Delta_R \equiv R_H - R_L$) is large. While Proposition 5 only proves this result for extreme values of the parameters, numerical analysis (see for example, Figure 2) suggests that the result holds also for the intermediate values of the parameters.

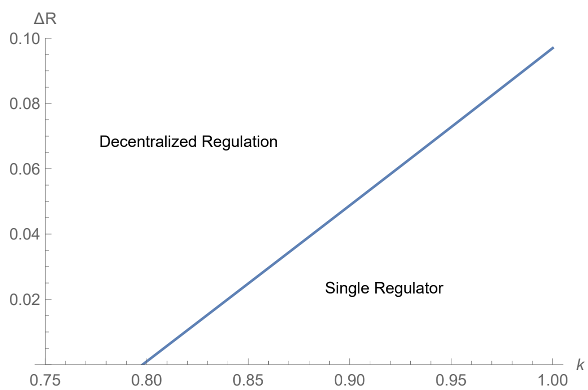

Figure 2: Parameter space in (k, Δ_R) for which centralized and decentralized regulation is optimal. The functional form of $v(a)$ is assumed to be $v(a) = \bar{v} - a$, and the numerical values are: $\bar{v} = 1$, $\pi = 0.2$, $R_L = 1$, and $I = 0.05$.

There are in fact several reasons why for low bailout costs decentralized regulation is optimal. When bailout costs are low, the propensity for a regulator to bail out a failing bank is high. Under a single regulator with uniform policies, this results in high incentives for banks to choose the high-return project, over and above the social benefits from doing so. The inefficiency under a single regulator is, therefore, high. At the same time, the inefficiencies under decentralized regulation is low. This is because, first, while decentralized regulation results in excessive bailouts, the welfare costs associated with that are low (because the deadweight loss k is small). Second, low bailout costs make it optimal to have a high investment in the high-return project; this implies that the H-regulator has command over a large fraction of the banking system. The regulator hence internalizes a larger fraction of the impact of its actions, lowering the extent to which bailouts are excessive under decentralized regulation (see the last paragraph of Section 5).

The effects associated with the bailout costs k are also illustrated in the top panel of Figure 3. As k increases, the investment inefficiency under a single regulator reduces (that is λ^S converges to λ^{FB}, except for when we reach a corner solution for λ), while the bailout inefficiency under decentralized regulation increases (b^D diverges from b^{FB}). As a result, welfare is higher under decentralized regulation for sufficiently low k, but higher for a single regulator for sufficiently high k.

The reason why a single regulator is preferred when the high-return project has a small return advantage is the following. In such a situation, a lower aggregate investment in this project is optimal, moving λ closer to $\frac{1}{2}$. The propensity to bail out when this project fails is then low, and the too-many-to-fail problem is limited. Banks' incentives to overinvest in the high-return project are small as a result, and hence single regulation only induces small welfare losses. At the same time, under decentralization regulation, the L-regulator is responsible for a large fraction of the overall banking system when optimal λ is close to $\frac{1}{2}$. This means that there are large externalities from bailouts undertaking by the H-regulator, resulting in a high bailout inefficiency. This is illustrated in the bottom panel of Figure 3: As Δ_R increases, investment inefficiency under a single regulator increases, while the bailout inefficiency under decentralized regulation reduces. Overall, welfare is higher under a single regulator for a sufficiently small return differential Δ_R but higher for decentralized regulation for a sufficiently high return differential Δ_R.

7 Implications

This section discusses some implications of our analysis for the allocation of regulatory powers as well as derives empirical predictions about the behaviour of regulators and banks under

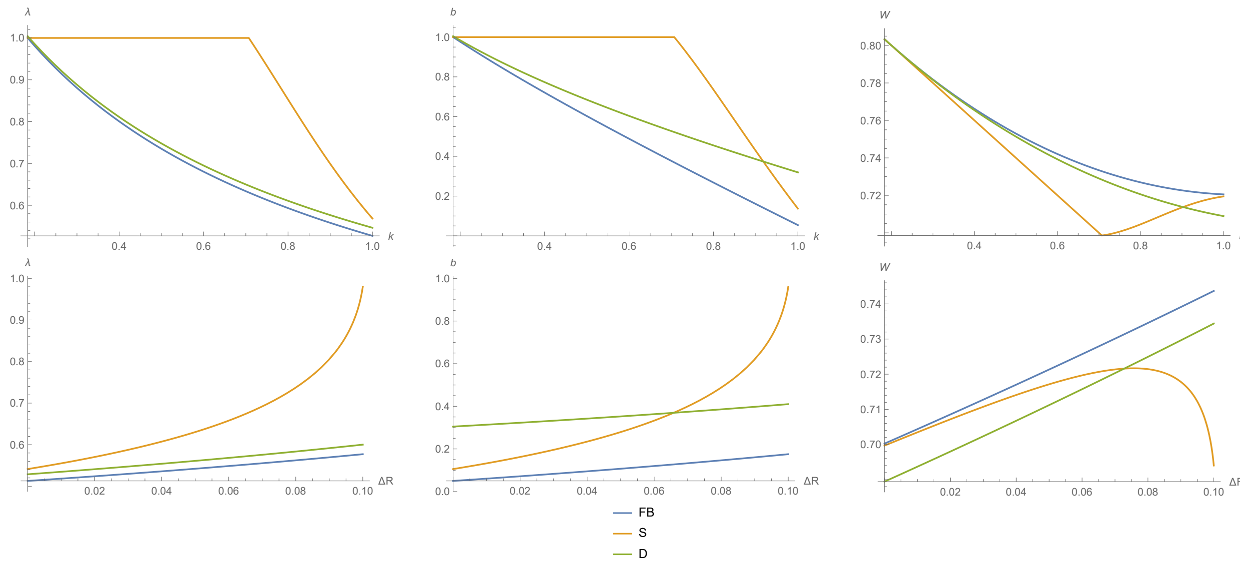

Figure 3: Each column from left to right plots investment (λ), bailouts when the high-return project fails (b), and welfare (W) under first-best allocation (blue line), a single regulator (orange line), and decentralized regulation (green line). The functional form of $v(a)$ is assumed to be $v(a) = \bar{v} - a$, and the numerical values are: $\bar{v} = 1$, $\pi = 0.2$, $R_L = 1$, and $I = 0.05$. In addition, the top panel assumes $R_H = 1.05$, and the bottom panel assumes $k = 0.95$.

different regulatory arrangements.

Optimal regulatory form. Our analysis contrasts between two regulatory forms. On the one hand, the regulation of banks in the United States can be interpreted as a model of *decentralized regulation*. The regulation of U.S. banks are broadly divided between three agencies: the Office of the Comptroller of the Currency (OCC) for nationally chartered banks, the Federal Reserve System (FRS) for state chartered member banks, and the Federal Deposit Insurance Corporations (FDIC) for state charted nonmember banks. On the other hand, with the establishment of the Single Supervisory Mechanism (SSM) and subsequently the Single Resolution Mechanism (SRM), bank regulation in Europe has moved in the direction of a *single regulator*, in which the European Central Bank (ECB) and the national supervisory authorities of the participating countries cooperate via the Joint Supervisory Teams to ensure the implementation of a uniform standard.

Our model predicts that decentralized regulation is more likely to be optimal in economies with lower bailout costs k (Proposition 5). In the U.S., the costs of bailouts are likely to be relatively low, evident by the rapid implementation of the Troubled Asset Relief Program (TARP) and other bailouts during the Global Financial Crisis. In contrast, bailout costs are likely to be high, especially during crises, due to national authorities' inability to provide monetary stimulation and due to the presence of a bank-sovereign doom loop (Acharya, Drechsler, and Schnabl, 2014; Fahri and Tirole, 2018).

Our model also predicts that a single regulator is more likely to be optimal in economies with lower dispersion among investment opportunities Δ_R (Proposition 5). Such dispersion across Europe is likely to have decreased overtime as European economies become more and more financially and economically integrated. In light of such development, a recent statement by the European Council (2022) suggests that "as an immediate step, work on the Banking Union should focus on strengthening the common framework for bank crisis management and national deposit guarantee schemes."

Implications for bailout policies. Key to our analysis of decentralization (Section 5) is that a decentralized regulator is more likely to bail out a failing banks at times of stress in the domestic financial system, while less likely to bail out when troubles are concentrated within the other regulator's jurisdiction (Lemmas 2 and 3). Consistent with this prediction, Beck, Todorov and Wagner (2013) find that regulators are less likely to intervene in cross-border banks with a larger part of operations are outside the country.

Implications for investment and systemic risk. Our model predicts that changes in regulatory form affects banks' incentive to invest in correlated assets and thereby systemic risk.

First, banks under decentralized regulation tend to have more correlated investment *within* the jurisdiction of each regulator. As a result, systemic risk tends to be concentrated within regulatory jurisdictions. By contrast, banks under a single regulator have incentives to correlate across the entire system. Our model thus suggests that the move within the Banking Union towards a common framework of bank regulation may increase systemic risk at the European level (but lower national systemic risk).

Second, and related, we derive the following corollary from Proposition 5:

Corollary 2. *In economies in which both regulatory forms obtain identical welfare, investment in the high-return project and systemic risk are higher under a single regulator (with uniform policies) than under decentralized regulatrion ($\lambda^C > \lambda^D$ and $C^{FB}(\lambda^C) > C^D(\lambda^D)$).*

This corollary identifies the main channel of our model, namely that decentralized regulation can be optimal precisely because it limits herding into systemically risky investment. Assuming that in practice, underlying parameters in a given economy changes overtime in a relatively continuous manner, and that prevailing regulatory form is optimal given the underlying parameter, one should observe changes in regulatory form precisely when the underlying parameters are such that both regulatory forms achieve identical welfare. This corollary thus generates predictions on how (endogenously adopted) regulatory changes affect banks' investment decisions.

Following the Global Financial Crisis, many jurisdictions adopted a regulatory framework that applies different standards for the so-called "systemically significant institutions". This can be interpreted as a form of regulatory decentralization. Our model predicts that while such a change results in concentration of systemic risk-taking among these banks, it nevertheless reduces overall systemic risk within the economy. Conversely, as Europe moves towards a common framework for bank regulation, our model predicts that while this reduces systemic cost due to more efficient bailout policies carried out by a single regulator, it also increase overall systemic risk-taking by banks. Nonetheless, such risk-taking is not indicating any inefficiency as it is associated with investing in higher-return assets, suggesting an increase in growth.

8 Conclusions

This paper analyzes optimal investment and the design of bailout regimes in the presence of a "too-many-to-fail" problem. In the economy under consideration, bank project choices are unobservable and bailouts have to be time-consistent. We show that the resulting first-best allocation equalizes the benefits from investing in high-return projects with higher systemic risk, due to more banks investing in such projects, and entails bailouts whenever bank failures exceed a threshold. Implementing the first-best requires limiting bank herding on the high-return project, which can be achieved by assigning banks to multiple bailout regimes. Alternatively, herding can be avoided by decentralizing bailout decisions, as individual regulators perceive lower benefits from bailing out deviating banks. We show that such decentralization results in higher systemic risk than the first-best, but can also be optimal when the cost of bailouts is small. Our results have various implications for the optimal allocation of regulatory powers, both at the international level and domestically.

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Appendices

A Microfoundation of banks' project sales and bailouts

Our baseline model abstracts away from financing issues at banks and assumes that i) a bank must sell its project if its project fails at $t = 1$, and ii) a bailout allows the bank to continue operating the project. In this section, we provide a microfoundation: We consider banks that are deposit financed and face a moral hazard problem in the continuation of their projects at $t = 1$. This microfoundation results in banks' investment decisions at $t = 0$ and regulators' bailout decisions at $t = 1$ that are identical to those presented in the main model.

A.1 Baseline microfoundation

In this section, we endogenize i) the bank's decision to continue or sell its project depending on the the success or failure of its project at $t = 1$, and ii) the equity injection required to bail out a bank and ensure its continuation. We maintain the assumption that a bank whose project fails at $t = 1$ cannot acquire other failing banks' projects and discuss the implications of relaxing this assumption in Section A.2.

In this microfoundation, we modify the baseline model in two aspects. First, we assume that each bank is financed at $t = 0$ by 1 unit of deposits that mature at $t = 1$. In addition, we assume that there are deep-pocketed competitive investors who can supply funds to the banks at $t = 1$. There is no time discounting, and the bank enjoys limited liability.

At $t = 1$, the bank can continue operating only if it repays the maturing deposits. Otherwise, the bank defaults and must sell its project to repay the depositors. The bank receives the residual payoff, if any. We supplement Assumption 1 with the following stronger condition:

Assumption 1'. $v(1) \geq 1$.

This assumption ensures that, in equilibrium, the bank does not default on its deposits if it sells its project (as in the main model).

As a second modification, we assume that there is a moral hazard problem in the continuation of the banks projects: The bank must exert unobservable (costless) effort in order to generate the continuation payoff described in the baseline model; otherwise, the projects generate 0 and the bank enjoys a non-pecuniary private benefit B. We make the following assumption regarding the bank's private benefit:

Assumption 4. *$\bar{v} - 1 < B < \bar{v}$.*

A.1.1 Banks' continuation decision

We now analyze the bank's continuation decision at $t = 1$ in the absence of bailouts. We will show that, under this microfoundation, the bank sells its project at $t = 1$ if it fails, and continues operating its project (with effort) if it succeeds.

First, consider the case in which the bank's project fails at $t = 1$. We will show that the bank is unable to continue, and must sell its project at $t = 1$. Suppose by contradiction that the bank continues by raising 1 from competitive investors to repay the maturing deposits. Since continuation without effort generates 0 at $t = 2$, the bank can only raise funds if it exerts continuation effort. As effort results in a certain payoff of $\bar{v}$ at $t = 2$, the competitive investors require a repayment equal to 1. Given the bank's continuation, it is incentive compatible for the bank to exert effort if and only if its payoff with effort, less the repayment to the competitive investors, is greater than its private benefit from shirking:

$$\bar{v} - 1 \geq B. \tag{20}$$

This is not true by the first inequality in Assumption 4. Therefore, the bank is unable to continue its project if its project fails at $t = 1$.

It then follows that bank defaults and must sell its project to repay the maturity deposits. This results in a payoff of $v(a^e) - 1 > 0$, where a^e denotes the equilibrium fire-sale pressure. Notice that this payoff is strictly positive. This is because, as Lemmas 1 and 2 show, $a^e < 1$

in any equilibrium. Assumption 1' then ensures that the bank's payoff from project sales is strictly positive.

Next, consider the case in which the bank's project succeeds at $t = 1$. We will show that the bank is able to and prefers to continue (with effort), instead of selling its project at $t = 1$, by comparing the bank's expected payoff in these two cases. Suppose first that the bank sells its project. This results in a payoff of $R_i + v(a^e) - 1 > 0$.

Suppose instead that the bank continues by repaying its maturing deposits. In addition, the successful bank may acquire a unit of the failing banks' projects at the competitive market price $v(a^e)$. If $1 + av(a^e) - R_i > 0$, then the bank must raise this amount from competitive investors at $t = 1$, who require the same amount of repayment at $t = 2$. Following backward induction, we first analyze the bank's effort decision upon continuation, then consider the bank's optimal choice of project acquisition. Given the bank's continuation, the bank's payoff with and without effort are given by, respectively,

$$\max\{0, R_i + \bar{v} + \int_0^a v(x)dx - av(a^e) - 1\}, \tag{21}$$

$$\max\{0, R_i + B - av(a^e) - 1\}, \tag{22}$$

where the max operator captures the bank's limited liability. It then follows that the bank always prefers to exert effort upon continuation, as (21) is greater than (22). Next, we consider the bank's optimal choice of project acquisition a that maximizes (21). Due to the optimality of the bank's project acquisition decision, the bank's expected payoff from continuation is greater than $R_i + \bar{v} - 1 > 0$. This also implies that the bank is able to raise $1 + av(a^e) - R_i$ (whenever this is positive) from competitive investors at $t = 1$. Therefore the bank is able to continue with effort, and realizes a payoff that is greater than $R_i + \bar{v} - 1$.

Finally, this continuation payoff is greater the bank's payoff from project sale, $R_i + v(a^e) - 1$, analyzed above, by the second inequality in Assumption 4. That is, if the bank's project succeeds at $t = 1$, it is able to and prefers to continue (with effort).

A.1.2 Equity injection during bailouts

The previous section has shown that a bank whose project fails at $t = 1$ must sell its project to repay the deposits in the absence of bailouts. We now characterize the equity injection I required to enable a failing bank's continuation, i.e., a bailout.

If a failing bank receives an equity injection I and continues, it must raise $1 - I$ from competitive investors to repay the deposits.[17] Since continuation without effort generates 0 at $t = 2$, the bank can only raise funds if it exerts continuation effort. The incentive compatibility constraint is given by

$$\bar{v} - 1 + I \geq B. \tag{23}$$

Notice that Assumption 4 implies that (23) is not satisfied for $I = 0$ and is indeed satisfied for $I = 1$. Therefore a minimum equity injection $I = B + 1 - \bar{v} \in (0, 1)$ is required to enable a failing bank's continuation.

A.2 Project acquisition by failing banks

In Section A.1, we have maintained the assumption that a failing bank cannot acquire other failing banks' projects even if it were to continue.

If a failing bank would be allowed to do so, the only difference is that the incentive compatibility constraint for a failing bank to exert effort upon continuation, previous given in (20), becomes

$$\bar{v} + -1 + \int_0^a v(x)dx - av(a^e) \geq B. \tag{24}$$

Compared to (20), the two extra terms on the left-hand side of (24) reflects the (potential) profit for the bank from acquiring other failing banks' projects. As a result, in order to ensure that a failing bank is unable to continue, i.e., (24) does not hold for all a and for all $a^e \in [0, 1)$, we supplement Assumption 4 with the following stronger condition:

[17] Recall that we have assumed for simplicity that a bailed-out bank does not acquire other failing banks' projects.

Assumption 4'. $\bar{v} - 1 + \int_0^1 v(a) - v(1)da < B.$

B Proofs

B.1 Proof of Lemma 1

The first-best bailout policy is defined by the minimization problem in (2). The first order condition of this problem is given in (3), with the second order condition:

$$v'(\frac{f-b}{1-f})\frac{1}{1-f} < 0. \tag{25}$$

This lemma then follows. First, for all $f \leq \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$, we have $a(b,f) \leq a(0,f) \leq \bar{a}^{FB}$. This implies that the left-hand side of the first order condition in (3) is less than the right-hand side for all $b \geq 0$, and therefore the optimal bailout policy is $b^{FB}(f) = 0$. Second, for all $f > \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$, we have $a(0,f) \leq \bar{a}^{FB} > a(f,f) = 0$. This implies that the optimal bailout policy binds the first order condition in (3) and satisfies $a(b^{FB}(f), f) = \bar{a}^{FB}$. Therefore the optimal bailout policy is $b^{FB}(f) = -\bar{a}^{FB} + f(1+\bar{a}^{FB})$.

B.2 Proof of Proposition 1

Recall that Lemma 1 implies that the optimal bailout policy results in an equilibrium fire-sale pressure $a^{FB}(f)$ given by (5). Notice that $a^{FB}(f)$ is strictly increasing in f for all $f \leq \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$ and constant in f otherwise. Similarly, Lemma 1 implies the same property for the marginal systemic costs of an additional bank failure $c^{FB}(f)$ given in (6): it is strictly increasing in f for all $f \leq \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$ and constant in f otherwise. This follows from the the properties of $a^{FB}(f)$ and the fact that both $s(a)$ and $l(a)$ are strictly increasing in a.

We are now equipped to solve for the optimal investment λ^{FB}. We first characterize piecewise the properties of the welfare function $W(\lambda)$ given by (9). There are three cases:

1. $\lambda \leq \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$. In this case, $W'(\lambda)$ given in (10) is strictly positive. This follows because $c^{FB}(\lambda) \leq c^{FB}(\frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}) = c^{FB}(1-\lambda)$ due to the properties of $c^{FB}(f)$ described above.

2. $\lambda \in [\frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}, 1 - \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}]$. In this case, $W'(\lambda)$ given in (10) is strictly positive. This follows because $c^{FB}(\lambda) = c^{FB}(1-\lambda) = c^{FB}(\frac{\bar{a}^{FB}}{1+\bar{a}^{FB}})$ due to the properties of $c^{FB}(f)$ described above.

3. $\lambda \geq 1 - \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$. In this case, we have $a^{FB}(\lambda) = \bar{a}^{FB}$ and $a^{FB}(1-\lambda) = \frac{1-\lambda}{\lambda}$. This implies that $W'(\lambda)$ is given by (11). Since both $s(a)$ and $l(a)$ are increasing in a, we have that $W'(\lambda)$ is strictly decreasing in λ.

These properties of $W(\lambda)$ implies that $W(\lambda)$ is strictly increasing for all $\lambda \leq 1 - \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$ and strictly concave for all $\lambda > 1 - \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$.

Next, we show that the optimal investment λ^{FB} that maximizes $W(\lambda)$ is defined through the first order condition $W'(\lambda) = 0$ and lies in $(1 - \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}, 1)$. First, we have

$$W'(1 - \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}) = (1-\pi)(R_H - R_L) > 0.$$

Second, we have

$$W'(1) = (1-\pi)(R_H - R_L) - \pi(c^{FB}(1) - c^{FB}(0))$$

Since $c^{FB}(0) = 0$, and $c^{FB}(1) = s(\bar{a}^{FB}) + l(\bar{a}^{FB}) = s(\bar{a}^{FB}) + k$ which is implied by the definition of $\bar{a}^{FB}$ in Lemma 1, we have

$$W'(1) < (1-\pi)(R_H - R_L) - \pi k < 0,$$

where the second inequality follows from Part (ii) of Assumption 2. Therefore we have $W'(1 - \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}) > 0 > W'(1)$, implying that a unique solution to $W'(\lambda) = 0$ exists in $(1 - \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}, 1)$ and maximizes $W(\lambda)$.

B.3 Proof of Proposition 2

In this proof, we first derive the expression $\Delta\Pi^S(\lambda)$ given in (12). A bank's profit from investing in the H, when the total mass of banks choosing the H project is λ and the bailout policy is $b^{FB}(\cdot)$, is given by

$$\Pi_H(\lambda; b^{FB}(\cdot)) = (1-\pi)R_H + \bar{v} + \pi\left[\frac{b^{FB}(\lambda)}{\lambda}I - \frac{\lambda - b^{FB}(\lambda)}{\lambda}l(a^{FB}(\lambda))\right] + \pi s(a^{FB}(1-\lambda)). \tag{26}$$

The first two terms reflects the expected payoff of the H project, assuming that the bank is able to continue operating. The second term reflects the incremental payoffs from failing when the H project fails (with probability π). With probability $\frac{b^{FB}(\lambda)}{\lambda}$, the bank is bailed out, and the bank enjoys an additional bailout benefit I; with complementary probabilty, the bank is not bailed out and must sell its project, resulting in a loss $l(\cdot)$, which is given by (8). The last term reflects the incremental payoffs from succeeding when the L project fails (with probability π). In this case, the bank purchases the projects of the failing banks and enjoys a surplus of $s(\cdot)$, which is given by (7). Analogously, the bank's project from investing in the L project is

$$\Pi_L(\lambda; b^{FB}(\cdot)) = (1-\pi)R_L + \bar{v} + \pi s(a^{FB}(\lambda)) + \pi\left[\frac{b^{FB}(1-\lambda)}{1-\lambda}I - \frac{1-\lambda - b^{FB}(1-\lambda)}{1-\lambda}l(a^{FB}(1-\lambda))\right]. \tag{27}$$

After collecting terms, we have that $\Delta\Pi^S(\lambda) \equiv \Pi_H(\lambda; b^{FB}(\cdot)) - \Pi_L(\lambda; b^{FB}(\cdot))$ is given by (12).

We now proceed to prove this proposition. We need to show that, given the optimal investment λ^{FB} and a bailout policy of only bailing out banks that fail when the project of their group fails, each bank indeed finds it optimal to choose its equilibrium project.

Consider first a bank in the L group. If the bank deviates and invests in the high-return project, it is not bailed out; whereas if it invests in the low-return project, it is also not bailed out, given the equilibrium bailout policy $b^{FB}(1-\lambda^{FB}) = 0$. In the absence of bailouts, the net incentive for this bank to invest in the project-return project coincides with the social value of a marginal increase in the investment in the high-return project W'^{FB}, which is zero due to the optimality of the first-best investment. A bank in the L group thus does not benefit from deviating to the high-return project.

Consider next a bank in the H group. If the bank invests in the high-return project, it is bailed out with probability $\frac{b^{FB}(\lambda^{FB})}{\lambda^{FB}}$, given the equilibrium bailout policy; whereas if it deviates and invests in the low-return project, it is not bailed out. The net incentive for this bank to invest in the high-return project thus coincides with that under a uniform policy and is equal to $\Delta\Pi^S(\lambda^{FB}) > 0$, which is give in (14). A bank in the H group thus finds it optimal to invest in the high-return project.

B.4 Proof of Lemma 2

The decentralized regulator's bailout policy is defined by the minimization problem in (15). The first order condition of this problem is given in (16), with the second order condition:

$$[2v'(a(b,f)) + a(b,f)v''(a(b,f))]\,\frac{1}{1-f} < 0. \tag{28}$$

This lemma then follows from analogous arguments as those in the proof of Lemma 1.

B.5 Proof of Lemma 3

In order to formalize the regulator's optimization problem when a single bank under its umbrella deviates and chooses another project than its equilibrium one, we characterize the regulator's problem when a positive mass of banks do so, and then consider the limit as this mass approach 0. In this case, when the equilibrium project of the other regulator fails, both regulators face failing banks under their respective umbrella and chooses their bailout policies taking that of the other regulator as given.

Let f_i and f_{-i} denote the mass of banks under the umbrella of regulator i and $-i$ that fail, respectively, with $f = f_i + f_{-i}$, and let b_i and b_{-i} denote the mass of failing banks bailed out by the two regulators, respectively, with $b = b_i + b_{-i}$. In the state in which the $-i$ project fails, we have $f_i \to 0$, since there is only one bank under the umbrella of the i regulator that deviates and invests in the $-i$ project. We now consider the optimization problem of each regulator separately.

First, the i regulator's bailout policy is given by

$$\min_{b_i \leq f_i} \quad (f-b)(\bar{v}-\tilde{v}(a(b,f))) - (f_{-i}-b_{-i})l(a(b,f)) + b_i k, \tag{29}$$

where $f_i \to 0$. The difference from the problem of a single regulator in (2) is that a decentralized regulator ignores the value loss $l(a)$ in the projects of those failing banks under the umbrella of the other regulator (that are not bailed out). As a result, the former regulator perceives a lower marginal benefit of bailout than the single regulator, whose incentives coincide with the social trade-off. This is reflected by the additional term, $a(b,f)v'(a) < 0$, on the left-hand side of the first-order condition below, as $f_i, b_i \to 0$:

$$\bar{v} - v(a(b,f)) + a(b,f)v'(a(b,f)) = k. \tag{30}$$

Importantly, this result suggests that the decentralized regulator is less bailout-prone in the state in which the high-return project fails, in stark contrast to the result from Lemma 2. This is because, in this case, bank failures are concentrated within the other regulator's jurisdiction; the i regulator, thus, fails to internalize the fact that bailouts help to alleviate fire-sale pressure and raise the competitive equilibrium price $v(a)$, lowering the losses from project transfers borne by the mass $(f-b)$ of failing banks under the umbrella of the other regulator.

Second, as $f_i, b_i \to 0$, the $-i$ regulator's objective function is given by (15), with its first order condition given by (16), since (almost) all failing banks are under its umbrella.

In equilibrium, this implies that the i regulator strictly prefers not to bail out its single failing bank, as (16) implies that the left-hand side of (30) is strictly less than the right-hand side; that is, the marginal benefit of bailout is strictly lower for the i regulator than for the $-i$ regulator. Therefore, in equilibrium, if one bank under the umbrella of the i regulator deviates and chooses another project than its equilibrium one, it is not bailed out. That is, as $f_i \to 0$, the optimal bailout policy satisfies $\frac{b_i}{f_i} = 0$.

B.6 Proof of Proposition 3

We first note that welfare has a similar structure as in the first-best (equation (9)), with the only difference being the total systemic cost in equilibrium: Since the bailouts are carried out by the decentralized regulators, this results in a total systemic cost $C^D(f)$ defined as the objective function in (2) when evaluated at $b = b^D(f)$, compared to $C^{FB}(f)$ in the first best. Analogous to the marginal systemic costs of an additional bank failure under the first-best bailout policy given in (6), the marginal systemic cost under a decentralized regulator's optimal bailout policy is:

$$c^D(f) \equiv C^{D'}(f) = s(a^D(f)) + l(a^D(f)),$$

where $s(a)$ and $l(a)$ are defined in (7) and (8), respectively, and $a^D(f) = \min\{\frac{f}{1+f}, \bar{a}^D\}$ is the equilibrium fire-sale pressure given the decentralized regulator's bailout policy.

The remainder of the proof of this proposition follows three steps. We first show that the investment choice that maximizes welfare given the decentralized regulators' bailout policies, $W^D(\lambda)$, is defined through $W^{D'}(\lambda^D) = 0$. We then show that this investment choice is incentive compatible. We finally show that $\lambda^D > \lambda^{FB}$.

The first step is analogous to the proof of Proposition 1. Following similar arguments, we can show that $W^D(\lambda)$ is strictly increasing for all $\lambda \leq 1 - \frac{\bar{a}^D}{1+\bar{a}^D}$, and strictly concave for all $\lambda > 1 - \frac{\bar{a}^D}{1+\bar{a}^D}$. We can then show that $W^D(1 - \frac{\bar{a}^D}{1+\bar{a}^D}) > 0 > W^D(1)$. Therefore a unique solution to $W^{D'}(\lambda) = 0$ exists in $(1 - \frac{\bar{a}^D}{1+\bar{a}^D}, 1)$ and maximizes $W^D(\lambda)$.

The second step is analogous to the proof of Proposition 2. Following similar arguments, we can show that the net incentive for a bank in the L group to invest in the high-return project is equal to $W^{D'}(\lambda^D) = 0$, whereas that for a bank in the H group is equal to $W^{D'}(\lambda^D) + \frac{b^D(\lambda^D)}{\lambda^D}(k + I) > 0$. Therefore banks in each group find it optimal to choose their equilibrium project.

Finally, we show that $\lambda^D > \lambda^{FB}$. Recall that λ^{FB} is defined by (14), while λ^D is defined by (19). Notice that these two expressions differ only in that the former has $\bar{a}^{FB}$ while the latter has $\bar{a}^D$. Therefore, for a given λ, the left-hand side of (14) is smaller than that of (19), because i) $\bar{a}^D$, defined in Lemma 2 is strictly smaller than $\bar{a}^{FB}$, defined in Lemma 1, and ii) $s(a)$ and $l(a)$, defined in (7) and (8), are both increasing in a. Lastly, since the left-hand sides of both (14) and (19) are strictly decreasing in λ, we have $\lambda^D > \lambda^{FB}$.

B.7 Proof of Proposition 4

We first show the existence and uniqueness of the equilibrium. We begin by characterizing the piecewise properties of the banks' net incentive to invest in the high-return project, $\Delta\Pi^S(\lambda)$ given in (12). Using (13), we can write it as

$$\Delta\Pi^S(\lambda) = W'(\lambda) + \pi(\frac{b^{FB}(\lambda)}{\lambda}(l(a^{FB}(\lambda)) + I) - \frac{b^{FB}(1-\lambda)}{1-\lambda}(l(a^{FB}(1-\lambda)) + I)) \quad (31)$$

There are three cases:

1. $\lambda \leq \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$. In this case, we have $b^{FB}(\lambda) = 0 < b^{FB}(1-\lambda) = -\bar{a}^{FB} + (1-\lambda)(1+\bar{a}^{FB})$, and $a^{FB}(\lambda) = \frac{\lambda}{1-\lambda} < a^{FB}(1-\lambda) = \bar{a}^{FB}$. After some algebraic manipulation, we have

$$\frac{\partial \Delta\Pi^S(\lambda)}{\partial \lambda} = \frac{\pi}{(1-\lambda)^3}(\bar{a}^{FB}(k+I)(1-\lambda) + v'(\frac{\lambda}{1-\lambda}))$$

   Using the fact that $\bar{a}^{FB} < 1$ by Lemma 1, we have

$$\frac{\partial \Delta\Pi^S(\lambda)}{\partial \lambda} < \frac{\pi}{(1-\lambda)^3}((k+I) + v'(\frac{\lambda}{1-\lambda})).$$

   Part (ii) of Assumption 1 then implies that the above expression is strictly negative. That is, $\Delta\Pi^S(\lambda)$ is strictly decreasing for all $\lambda \leq \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$.

   Moreover, this implies that, for all $\lambda \leq \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$, we have

$$\begin{aligned}\Delta\Pi^S(\lambda) \geq \Delta\Pi^S(\frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}) &= (1-\pi)(R_H - R_L) - \pi\frac{b^{FB}(\frac{1}{1+\bar{a}^{FB}})}{\frac{1}{1+\bar{a}^{FB}}}(k+I) \\ &= (1-\pi)(R_H - R_L) - \pi(1-(\bar{a}^{FB})^2)(k+I) > 0, \quad (32)\end{aligned}$$

   where the last inequality follows from Assumption 3. That is, $\Delta\Pi^S(\lambda) > 0$ for all $\lambda \leq \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$.

2. $\lambda \in [\frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}, 1 - \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}]$. In this case, we have $b^{FB}(\lambda) = -\bar{a}^{FB} + \lambda(1+\bar{a}^{FB})$ and $b^{FB}(1-\lambda) = -\bar{a}^{FB} + (1-\lambda)(1+\bar{a}^{FB})$, and $a^{FB}(\lambda) = a^{FB}(1-\lambda) = \bar{a}^{FB}$. After some algebraic manipulation, we have

$$\frac{\partial \Delta\Pi^S(\lambda)}{\partial \lambda} = \pi \bar{a}^{FB}(\frac{1}{(1-\lambda)^2} + \frac{1}{\lambda^2})(k+I) > 0. \tag{33}$$

Therefore $\Delta\Pi^S(\lambda)$ is strictly increasing for all $\lambda \in [\frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}, 1 - \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}]$.

3. $\lambda \geq 1 - \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$. In this case, we have $b^{FB}(\lambda) = -\bar{a}^{FB} + \lambda(1+\bar{a}^{FB}) > b^{FB}(1-\lambda) = 0$, and $a^{FB}(\lambda) = \bar{a}^{FB} > a^{FB}(1-\lambda) = \frac{1-\lambda}{\lambda}$. After some algebraic manipulation, we have

$$\frac{\partial \Delta\Pi^S(\lambda)}{\partial \lambda} = \frac{\pi}{\lambda^3}(\bar{a}^{FB}(k+I)\lambda + v'(\frac{1-\lambda}{\lambda})). \tag{34}$$

Following similar arguments are for Case (i), we have that $\Delta\Pi^S(\lambda)$ is strictly decreasing for all $\lambda \geq 1 - \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$.

The properties of $\Delta\Pi^S(\lambda)$ characterized above then implies that $\Delta\Pi^S(\lambda) > 0$ for all $\lambda \leq 1 - \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$. Therefore, since $\Delta\pi^S(\lambda)$ is strictly decreasing for all $\lambda \geq 1 - \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$, an equilibrium exists and is unique: If $\Delta\Pi^S(1) \geq 0$, then $\lambda^S = 1$; if $\Delta\Pi^S(1) < 0$, then $\lambda^S \in (1 - \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}, 1)$ and is defined by $\Delta\Pi^S(\lambda^S) = 0$. The resulting welfare is given by (11).

Finally, the fact that $\lambda^S > \lambda^{FB}$ follows from the fact that $\Delta\Pi^S(\lambda^{FB}) > 0$ as established by (14).

B.8 Proof of Proposition 5

First, we prove the existence of a threshold $\underline{k} > 0$ such that decentralized regulation strictly maximizes welfare for all $k < \underline{k}$. Recall that, by the proof of Proposition 4, $\lambda^S = 1$ if and only if $\Delta\Pi^S(1) \geq 0$. Using (12) and after some algebraic manipulation, we have

$$\Delta\Pi^S(1) = (1-\pi)(R_H - R_L) - \pi s(\bar{a}^{FB}) + \pi I, \tag{35}$$

where $s(a)$ is defined in (7) and is increasing in a. It then follows that $\Delta\Pi^S(1)$ is decreasing in a^{FB}, which is defined in Lemma 1 and is increasing in k. Therefore $\Delta\Pi^S(1)$ is decreasing in k. Moreover, as $k \to 0$, we have that $\bar{a}^{FB} \to 0$ and $\Delta\Pi^S(1) \to (1-\pi)(R_H - R_L) + \pi I > 0$. That is, $\lambda^S \to 1$ as $k \to 0$. In this limit, decentralized supervision strictly maximizes welfare, as

$$W(\lambda^S) = W(1) = W^D(1) < \max_{\lambda} W^D(\lambda) = W^D(\lambda^D).$$

By continuity, there exists $\underline{k} > 0$, such that decentralized supervision strictly maximizes welfare for all $k < \underline{k}$.

Second, we prove the existence of a threshold $\overline{\Delta}_R > 0$, such that decentralized regulation strictly maximizes welfare for all $\Delta_R \equiv R_H - R_L > \overline{\Delta}_R$. $\Delta\Pi^S(1)$ given in (35) is increasing in $(R_H - R_L)$. Therefore as $\Delta_R \to \infty$, $\Delta\Pi^S(1) > 1$ and $\lambda^S \to 1$. It then follows from similar arguments as above that, in this limit, decentralized supervision maximizes welfare. By continuity, there exists $\overline{\Delta}_R > 0$, such that decentralized regulation strictly maximizes welfare for all $\Delta_R \equiv R_H - R_L > \overline{\Delta}_R$.

Finally, we show that there exist thresholds $\overline{k} > \underline{k}$ and $\underline{\Delta}_R \in (0, \overline{\Delta}_R)$, such that a single supervisor strictly maximizes welfare for all $k > \overline{k}$ and $R_H - R_L < \underline{\Delta}_R$. As $k \to \bar{v} - v(1)$ and $\Delta_R \to 0$, we have $\bar{a}^{FB} \to 1$, $\lambda^{FB} \to \frac{1}{2}$, and $b^{FB}(\lambda^{FB}) \to 0$. This implies that $\Delta\Pi^S(\lambda^{FB}) \to 0$, and $\lambda^S \to \lambda^{FB}$. In this limit, a single supervisor strictly maximizes welfare, as $W(\lambda^S) = W(\lambda^{FB}) > W^D(\lambda^D)$. By continuity, there exists $(\overline{k}, \underline{\Delta}_R)$, such that a single supervisor strictly maximizes welfare for all $k > \overline{k}$ and $R_H - R_L < \underline{\Delta}_R$. Moreover, the first parts of this result imply that $\overline{k} > \underline{k}$ and $\underline{\Delta}_R \in (0, \overline{\Delta}_R)$.

C Extensions

C.1 Many projects

We now generalize the model to more than two projects. Specifically, consider that there are n ($n \geq 3$) projects that can be strictly ordered according to their returns R_i ($1 < R_1 < R_2 < ... < R_n$) and that fail in disjunct states of the world.

Assumption 5. *(i) $k < \bar{v} - v(\frac{1}{n})$, and ii) $k > \frac{1-\pi}{\pi}(R_n - R_{n-1})$.*

This is the updated version of Assumption 2. The first part states that bailouts are optimal when a fraction $\frac{1}{n}$ of projects fail, the second part states that the (excess) return on the highest asset should not be too high, as otherwise, it may become optimal to only invest in that asset.

C.1.1 First best

We denote an arbitrary project allocation by $\{\lambda_1, \lambda_2, ..., \lambda_n\}$ ($\lambda_i \geq 0$, $\sum_{i=1}^{n} \lambda_i = 1$).

Project transfers. Consider that project i fails. All other projects then survive, so $f = \lambda_i$. The f failing project should then be distributed equally among $f - b$ surviving banks, as in the baseline model. Equation (1) continues to hold.

Bailout policy. Since we have f banks with failing projects and $1-f$ banks with successful projects, the optimization problem is the same as before. Lemma 1 continues to hold.

Optimal investment. The marginal gain from increasing the fraction of banks investing in project i is given by (derivation identical to equation 10)

$$W'(\lambda_i) = (1-\pi)R_i - \pi c^{FB}(\lambda_i). \tag{36}$$

We consider an economy without redundant projects, that is, it is optimal to invest positive amounts in all projects ($\lambda_i^* > 0$). Coupled with our assumption that the highest-return project does not dominate, it follows that we have an interior solution for all projects. Hence $W'(\lambda_i)$ is constant across all projects. It follows that $c^{FB\prime}(\lambda_1) < c^{FB\prime}(\lambda_2) < ... < c^{FB\prime}(\lambda_n)$, that is, higher return projects are associated with higher (marginal) failure costs. Given that $c^{FB}(\lambda)$ is weakly convex, this implies that $\lambda_1 \leq \lambda_2 \leq ... \leq \lambda_3$, that is, projects with higher returns are invested in (weakly) higher proportions. It follows that project n is chosen with a measure of at least $1/n$ ($\lambda_n \geq 1/n$), which by our updated Assumption 2 implies that bailouts are still used when the highest-return project fails ($\lambda_n > \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$). Given that $c^{FB}(\lambda)$ is linear in the domain where bailouts are used (that is, when $\lambda > \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$), it follows that bailouts are only used for the highest-return asset (otherwise we would have $W'(\lambda_n^{FB}) > W'(\lambda_{n-1}^{FB})$. It follows that $\lambda_{n-1}^{FB} < \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}$, and since $c^{FB}(\lambda)$ is (strictly) convex on $[0, \frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}]$, we have that $\lambda_1^{FB} < \lambda_2^{FB} < ... < \lambda_n^{FB}$.

Summarizing, at an optimal allocation bailouts are only used for the highest return project, and projects with lower returns are held in strictly lower proportions than projects with higher returns. Note that there is still a benefit from investing in lower-return projects (like in the baseline model) as those projects offer diversification benefits (due to the increasing cost of failures, it is preferable to spread investment among different projects as those fail in different states of the world).

C.1.2 Targeted policies

Consider two bailout groups, as in the baseline model. One for the λ_n^{FB} measure of banks that invest in the highest return project, and one for a measure $1 - \lambda_n^{FB}$ banks that choose other projects. Banks in a group are only bailed out when projects of the group fail (in other words, they are never bailed out when they fail when project(s) from the other group fail). Recall that bailouts only occur when the highest project fails, but not when any other project fails. The analysis in Section 4.2 has shown that distortions only arise because banks without bailout expectations want to switch to a project with bailout expectations. By no longer providing bailouts in such cases for the low group, this distortion is removed, and the first-best is implemented.

C.2 Projects endowments vary across banks

In this section we consider banks that are endowed with high projects that differ in their return R_H. Specifically, we consider a continuous distribution function of high-project returns across banks. We can then order banks on the unit interval in terms of *decreasing* productivity of the high project, with a corresponding return function $R_H(\cdot)$ with $R_H(\cdot)$ defined on $[0,1]$ that is decreasing and assumed to be differentiable. We assume that $R_H(\frac{1}{2}) > R_L$ (that is, for the median bank the high project is more productive) but do not restrict the high project to always have higher returns than the low project.

We first analyze the *first best allocation*. As date-1 asset transfers and the bailout policy do not depend on the (date-1) project return, they are unchanged. As for the date-0 investment choice, consider again an allocation where a mass λ of banks invests in the high project. Since banks differ with respect to the productivity of their high project, it is strictly optimal to allocate all banks with an index below λ to the high-projects and all banks with a higher index than λ to the low project. Similar to (9), welfare is now given by

$$W(\lambda) = (1-\pi)(\int_0^\lambda R_H(\lambda)d\lambda + (1-\lambda)R_L) + \overline{v} - \pi C^{FB}(\lambda) - \pi C^{FB}(1-\lambda), \tag{37}$$

and the corresponding derivative is

$$W'(\lambda) = (1-\pi)(R_H(\lambda) - R_L) - \pi(c^{FB}(\lambda) - c^{FB}(1-\lambda)). \tag{38}$$

This expression is identical to the baseline model (equation 10), except that the benefit from increasing the fraction of banks investing in the high project is now no longer a constant, but declines as we increase the fraction of banks investing in the high project (as $R'_H(\lambda) < 0$).

Assumption 6. $R_H(\frac{\bar{a}^{FB}}{1+\bar{a}^{FB}}) > R_L$ *and* $k > \frac{1-\pi}{\pi}(R_H(1) - R_L)$.

The first assumption ensures that the optimal solution still uses bailouts, which requires the high-return project to be sufficiently attractive so that a sufficiently large fraction is invested in that project. The second assumption is the updated version of the second part of Assumption 2, ensuring that investing only in high projects is not desirable.

Following similar arguments as in Section 3, one can show that Proposition 1 still holds (with $W'(\lambda^{FB}) = 0$ now determined by (38)). The analysis of the first-best hence does not change materially. The only difference is that there is now a second reason for why the marginal return from investing in high projects is declining (due to assumed declining project returns), thus providing an additional reason for an interior solution.

We next analyze *targeted bailouts*. As in Section 4.2, banks are allocated to two groups. We assume that bank types are observable, so allocation to groups can be based on banks' investment opportunities. For the same reason as in the first best – when using group sizes of λ and $1-\lambda$ – it is optimal to allocate the banks with an index up to λ to the high group, and the remaining banks to the low group.[18]

As before, bailout policies have to be time-consistent, and we consider bailouts that are not used for a bank that fails when the project of the other group fails. The incentive constraints are analogous to those analyzed in the proof of Proposition 2, with R_H in the expressions being replaced by $R_H(\lambda)$. Identical to Proposition 2 we can show that the first-best is still incentive compatible, hence Proposition 2 still applies.

[18]The assumption on bank types being not observable is hence not an important one as the private benefits from joining the high group are also higher for the low λ-group. In fact, an appropriately set tax (on joining the high-group) can implement optimal group selection when types are not observable.