Expectations vs. Fundamentals-driven Bank Runs: When Should Bailouts be Permitted?

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Abstract

Should policy makers be permitted to intervene during a financial crisis by bailing out financial institutions and their investors? We study this question in a model that incorporates two competing views about the underlying causes of these crises: self-fulfilling shifts in investors' expectations and deteriorating economic fundamentals. We show that – in both cases – the desirability of allowing intervention depends on a basic tradeoff between incentives and insurance. If policy makers can correct incentive distortions through effective regulation and supervision, then allowing intervention is always optimal. If regulation is imperfect and the risk-sharing benefit from intervention is absent, in contrast, it is optimal to prohibit intervention. Our results show that, in some cases, it is possible to provide meaningful policy analysis without taking a stand on the contentious issue of whether financial crises are driven by expectations or fundamentals.

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1 Introduction

The recent financial crisis saw governments and central banks undertake a range of unusual and, in some cases, unprecedented actions that could be characterized as "bailing out" financial institutions and investors. Many of these actions remain controversial and have led to calls for restricting policy makers' ability to intervene in future crises. Some restrictions of this type have already been put into place. For example, the Dodd-Frank Act in the United States requires any future Federal Reserve emergency lending programs to be approved by the Secretary of the Treasury, imposes stricter collateral and disclosure requirements on these programs, and prohibits programs that are designed to aid a particular financial institution. In addition, the Act prohibits the Treasury from issuing the type of guarantees offered to money market mutual funds beginning in September 2008. These legal changes raise an important question: When is it desirable to restrict policy makers' ability to intervene in a future crisis? While there has been much debate about the effects of such restrictions in policy circles, no clear principles have emerged to guide these decisions. One common view holds that the desirability of restricting intervention depends critically on the underlying cause of a financial crisis. Gorton (2010) argues that the recent crisis was – at its heart – a run on certain elements of the financial system, similar in structure to the events that plagued the U.S. banking system in the 19th century. In such an event, many investors withdraw their funds from banks and other financial institutions in a short period of time, placing severe strain on the financial system. Lacker (2008) proposes a simple rule to guide decisions about whether intervention should be allowed that focuses on the underlying cause of these runs:

> *Researchers have found it useful to distinguish between what I'll call 'fundamental' and 'non-fundamental' runs. … This distinction is important because the two types of runs have very different policy implications. Preventing a non-fundamental run avoids the cost of unnecessary early asset liquidation, and in some models can rationalize government or central bank intervention. In contrast, in the case of runs driven by fundamentals, the liquidation inefficiencies are largely unavoidable and government support interferes with market discipline and distorts market prices.*

In other words, Lacker (2008) argues that intervention may be useful when runs on the financial system are self-fulfilling in nature, caused by shifts in investors' expectations. In particular, if the economy has multiple equilibria, allowing intervention may help eliminate undesirable equilibria and thereby prevent a run from occurring. If, however, the economy has a unique equilibrium and runs are instead driven by deteriorating economic fundamentals, restricting policy makers from intervening is claimed to lead to better outcomes.

Support for this view can be found in the growing literature on bank runs and financial crises. In the classic paper of Diamond and Dybvig (1983), for example, a bank run is non-fundamental in nature; depositors who are not in immediate need of funds will run on their bank only if they expect other depositors to do so. In their setting, intervention in the form of deposit insurance is desirable if it can remove the strategic complementarity in depositors' actions and ensure that no run occurs. This pattern – where bank runs are driven by agents' expectations and where allowing intervention may be desirable – can be found in many subsequent papers; examples include Chang and Velasco (2000), Cooper and Kempf (2013) and Keister (2014), to name only a few. Other papers in the literature, in contrast, study environments where a crisis results from a fundamental shock and have the property that restricting intervention, if feasible, would generate a superior outcome by eliminating the incentive distortions that arise when investors anticipate being rescued in the event of a crisis. See, for example, Farhi and Tirole (2012) and Chari and Kehoe (2013) for environments with these features.

While the results in these papers are consistent with the view that allowing intervention may be desirable if runs are caused by shifting expectations but is otherwise undesirable, none of the papers directly *test* this view. The models studied differ across papers along a number of dimensions, making it difficult to isolate the precise source(s) of the differing policy prescriptions. In this paper, we investigate the desirability of restricting intervention using a model in which an equilibrium bank run may be driven by either expectations or fundamentals, depending on parameter values. By including both possibilities in a unified framework, we are able to study the extent to which the desirability of restricting intervention depends on the underlying cause of a crisis and the extent to which it depends on other factors.

Our model is in the tradition of Diamond and Dybvig (1983) and builds most closely on that in Keister (2014), where a bank run can occur when depositors' actions are coordinated on an extrinsic "sunspot" variable. We extend the model by introducing intrinsic uncertainty: the level of fundamental withdrawal demand is random. We say that a bank run in this expanded setting is driven by expectations when depositors' behavior depends on the sunspot variable and, hence, is driven in part by their beliefs about the actions of other depositors. In contrast, we say that a bank run is driven by fundamentals if a run necessarily occurs whenever fundamental withdrawal demand is high, independent of the sunspot variable. We ask whether the desirability of restricting intervention in this setting depends critically on which form a run takes, that is, on whether runs are driven by expectations or by fundamentals.

We show that the optimal policy regime in our model depends on a basic tradeoff between incentives and insurance. When banks and depositors anticipate that policy makers will intervene in the event of a crisis, they have less incentive to provision for bad outcomes. In response, banks increase their short-term liabilities, which distorts the allocation of resources and tends to make the financial system more susceptible to a run. At the same time, however, intervention can provide an important source of risk sharing in the economy. By mitigating the potential losses depositors suffer during a crisis, a "bailout" can both smooth depositors' consumption across states and encourage them to leave their funds in the financial system rather than trying to withdraw. Thus, while the incentive distortion associated with intervention tends to make the financial system more fragile and lower welfare, the insurance effect tends to raise welfare and promote stability. Importantly, this same tradeoff arises regardless of whether runs in the model are driven by expectations or by fundamentals.

The desirability of restricting intervention depends on which of these two effects dominates. If policy makers are able to eliminate the incentive distortion through effective regulation and supervision of banks, then allowing intervention is always optimal. If regulation is imperfect and the risk-sharing benefit from intervention is absent, in contrast, it is optimal to prohibit intervention. In between these extreme cases, we show that allowing intervention is optimal whenever regulation is sufficiently effective for the insurance effect to dominate. The precise cutoff point will depend on the specific features of the economy, including whether runs are driven by expectations or by fundamentals. However, the same tradeoff between incentives and insurance arises in both cases and the same basic principle should guide the policy choice. In this sense, our model provides meaningful policy advice that applies regardless of the underlying cause of these crises.

In the next section, we present the model and discuss the distinction between fundamental and non-fundamental runs in our framework. In Section 3, we study equilibrium outcomes when policy makers are restricted from intervening during a crisis. In section 4, we study equilibrium when intervention is allowed, highlighting both the resulting incentive distortion and the insurance benefit that arise. We compare these outcomes in Section 5, deriving conditions under which each regime is optimal and illustrating these conditions with a series of examples. Finally, in Section 6, we offer some concluding remarks that relate our results to the long-standing debate about the role of self-fulfilling expectations in financial crises.

2 The Model

Our model builds on that in Keister (2014), which is a version of the Diamond and Dybvig (1983) model augmented to include fiscal policy and a public good. We introduce aggregate uncertainty about the level of fundamental withdrawal demand to the model so that we can study runs caused by fundamental shocks in addition to runs triggered by shifts in expectations.

2.1 The environment

There are three time periods, $t = 0, 1, 2$. Each of a continuum of depositors, indexed by $i \in [0, 1]$, is endowed with one unit of the good at $t = 0$ and has preferences given by

$$U(c_1, c_2, g; \omega_i) = u\left(c_1 + \mathbb{I}_{(\omega_i=2)} c_2\right) + v(g),$$

where c_t is consumption of the private good in period t, $\mathbb{I}$ is the indicator function, and g is the level of public good. The preference type of depositor i, denoted ω_i, is a binomial random variable with support $\Omega = \{1, 2\}$. If $\omega_i = 1$, depositor i is *impatient* and only cares about consumption at $t = 1$, while if $\omega_i = 2$ she is *patient* and can consume at either $t = 1$ or $t = 2$. A depositor's type ω_i is revealed to her in period 1 and is private information. We assume the functions u and v to be of the constant relative risk-aversion form, with

$$u(c) = \frac{c^{1-\gamma}}{1-\gamma} \quad \text{and} \quad v(g) = \delta \frac{g^{1-\gamma}}{1-\gamma}. \tag{1}$$

The parameter $\delta \geq 0$ measures the relative importance of the public good and will be a key factor in determining the potential insurance benefit from intervention. As in Diamond and Dybvig (1983), the coefficient of relative risk-aversion γ is assumed to be greater than one.

At the beginning of period 1, the aggregate state of the economy is realized. This state has two components. The fundamental state (L or H) determines the fraction π of depositors who are impatient, with $\pi_L < \pi_H$. Conditional on the realized value of π, each depositor faces the same probability of being impatient. The "sunspot" state (α or β) is independent of the fundamental state and has no effect on preferences or technologies, but may serve to coordinate depositors' expectations in equilibrium. We denote the full state of the economy by

$$s \in S = \{L_\alpha, L_\beta, H_\alpha, H_\beta\}$$

and the probability of state s by q_s.

There is a single, constant-returns-to-scale technology for transforming endowments into private consumption in the later periods. A unit of the good invested in period 0 yields $R > 1$ units in period 2, but only one unit in period 1. This investment technology is operated by a set of banks in which depositors pool resources to insure individual liquidity risk. Each bank is large enough that the fraction of its depositors who are impatient will equal the economy-wide average π_s with probability 1, but small enough that its deposits are a negligible fraction of the aggregate endowment. Banks operate to maximize their depositors' expected utility at all times.

Depositors are isolated from each other in periods 1 and 2 and no trade can occur among them. Upon learning her preference type, each depositor chooses to withdraw in either period 1 or period 2. Depositors who choose to withdraw in period 1 arrive at their bank one at a time in a randomly-determined order and each exits the banking location before the next depositor arrives. As in Wallace (1988, 1990), this sequential-service constraint implies that the payment made to a depositor can only depend on the information received by the bank up to the point at which she withdraws; we discuss the implications of this constraint in detail below.

There is also a linear technology for transforming units of the private good into units of the public good in period 1. Without any loss of generality, we assume the transformation rate is one-for-one. This technology is available to all agents, but the fact that both depositors and banks are small relative to the overall economy implies that there is no private incentive to provide the public good. Instead, there is a benevolent policy maker who has the the ability to tax banks in period 1 and can use the revenue from this tax to produce the public good. The objective of the policy maker is to maximize the equal-weighted sum of individual expected utilities,

$$W = \int_0^1 E\left[U\left(c_1\left(i\right), c_2\left(i\right), g; \omega_i\right)\right] di. \tag{2}$$

Note that while banks and the policy maker both aim to maximize depositor welfare, a key difference is that each bank only cares about its own depositors while the policy maker cares about all depositors in the economy.

We follow Ennis and Keister (2009, 2010) in assuming that banks cannot commit to future actions. This inability to commit implies that they are unable to use the type of suspension of convertibility plans discussed in Diamond and Dybvig (1983) or the type of run-proof contracts studied in Cooper and Ross (1998) to eliminate undesirable equilibria. Instead, the payment given to each depositor who withdraws in period 1 will always be chosen as a best response to the current situation. The policy maker is also unable to commit to future plans and will choose the tax policy to maximize the objective (2) at each point in time in reaction to the situation at hand.

Depositors observe the realization of the state of nature at the beginning of period 1 and can, therefore, condition their withdrawal behavior on this information. Banks do not observe the state at this point and must make inferences about it from the flow of withdrawals.[1] In the equilibria we study below, a bank will be able to infer that the fundamental state is H whenever the measure of $t = 1$ withdrawals goes above π_L. To simplify the analysis, we allow banks to observe the sunspot state at this same point. In other words, after a fraction π_L of depositors have withdrawn, banks will learn the full state and, therefore, will know whether any surge in withdrawals has an expectations-driven component.[2] We place no restrictions on the payments a bank can make to its depositors other than those imposed by the information structure and sequential service constraint described above. In particular, a bank is always free to adjust the payment it gives to its remaining depositors and will choose to do so when this new information arrives. We assume the policy maker observes the same information as banks about withdrawal behavior and the sunspot state.

2.2 Intervention and Regulation

We study two policy regimes. In the *no intervention* regime, the policy maker collects taxes and provides the public good at the beginning of period 1, before any withdrawals have occurred.

[1] This inference problem has been studied in related settings by Green and Lin (2003), Peck and Shell (2003), Andolfatto, Nosal and Wallace (2007) and Ennis and Keister (2010), among others.

[2] If banks and the policy maker did not observe the sunspot state, their reaction to a surge of withdrawals at $t = 1$ in the type of equilibria we study here would occur in two stages, the first when the fundamental state is inferred (after π_L withdrawals) and the second when the sunspot state is inferred (after π_H withdrawals). This two-stage response would imply that different types of expectations-driven runs are possible. Patient depositors may, for example, run until the first reaction and then stop, or they may run until the second reaction and then stop. While the possibility of expectations-driven bank runs occurring in distinct waves is interesting (see Ennis and Keister, 2010, for a detailed analysis), our focus here is on comparing the policy implications of expectations-driven vs. fundamentals-driven runs. Assuming that the sunspot state is revealed after π_L withdrawals simplifies the analysis by allowing us to focus on a single type of expectations-driven run. The results we present below would be qualitatively unchanged if we instead allowed for a two-stage response and choose to focus only on equilibria in which a run stops after the first policy response.

Once withdrawals begin, any further fiscal policy is prohibited. In the regime *with intervention*, in contrast, the policy maker is able to learn the state s before collecting taxes. The policy maker will respond to this information by adjusting tax rates and the level of the public good. In particular, the policy maker will generally respond to a crisis by lowering taxes, thereby "bailing out" banks and their depositors. Figure 1 depicts the timeline of events under each policy regime.

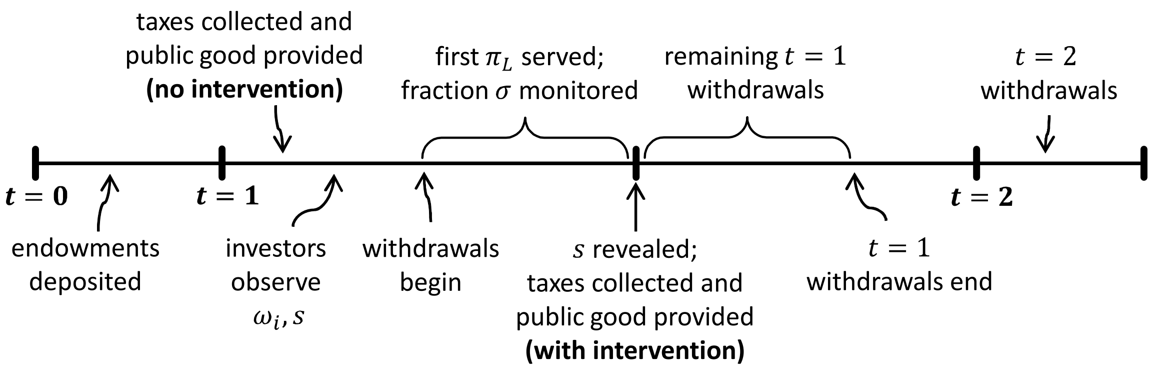


Figure 1: Timeline of events

We also give the policy maker a regulatory tool for mitigating potential incentive distortions. We show below that once the state has been fully revealed and any intervention has taken place, no such distortions arise and there is no role for regulation. As the first π_L withdrawals take place, however, the policy maker may wish to influence banks' choices. We assume the policy maker is able to encounter a fraction $\sigma \in [0, 1]$ of these depositors immediately after they have withdrawn from the bank and before they have consumed. When the policy maker encounters a depositor, he can observe the quantity of goods she holds and can confiscate some of these goods, if desired. Confiscated goods are rebated back to all banks in a lump-sum fashion. The identities of the depositors who will encounter the policy maker are determined randomly but, as each depositor withdraws, the bank observes whether or not she will be monitored. The bank can forecast the maximum amount of consumption allowed by the policy maker and will, in equilibrium, choose to give monitored depositors exactly that amount, which may differ from the level of consumption given to non-monitored depositors. In this way, the policy maker's ability to monitor some withdrawals effectively places a cap on the amount these depositors will receive from their bank.

We interpret funds that will be withdrawn from a bank before the state is revealed as representing the bank's short-term liabilities. The activity of monitoring depositors is intended to represent, within the context of our model, a range of regulatory and supervisory activities that aim to limit such liabilities in practice. The Basel III accords, for example, introduce a Liquidity Coverage Ratio requirement that limits the short-term liabilities of a bank to be no larger than the quantity of safe, liquid assets it holds.[3] The parameter σ in our model represents the policy maker's ability to use these types of regulatory and supervisory powers effectively. When $\sigma = 1$, we say that prudential regulation is perfectly effective: the policy maker can completely control the amount of funds withdrawn from the banking system before the state is revealed. Having $\sigma < 1$ represents an environment where writing effective regulation is difficult or where banks can partially evade regulations by, for example, designing new legal or accounting structures. In the analysis below, we study how the effectiveness of regulation impacts the desirability of allowing the policy maker to intervene.

2.3 Runs and fragility

Each depositor chooses a strategy that lists the period in which she will withdraw (1 or 2) for each possible realization of her preference type ω_i and the state s,

$$y_i : \Omega \times S \to \{1, 2\}. \tag{3}$$

Let y denote a profile of withdrawal strategies for all depositors. An equilibrium of the model is a profile of withdrawal strategies, together with strategies for each bank and the policy maker, such that every agent is best responding to the strategies of others. Because the strategy sets of banks and the policy maker are more complex, we discuss them in the context of each policy regime separately in Sections 3 and 4. In this section, we discuss the types of withdrawal strategies that depositors may play in equilibrium.

Because depositors only care about $t = 1$ consumption when they are impatient, withdrawing at $t = 2$ is a strictly dominated action in this case and any equilibrium strategy profile will have $y_i(1, s) = 1$ for all s. The interesting question is how depositors will behave in each state when they are patient. We focus on symmetric equilibria, in which all depositors follow the same

[3] See BCBS (2013) for a detailed discussion of this requirement.

strategy, and on equilibria in which patient depositors choose to wait until period 2 to withdraw when the fundamental state is L. The latter restriction serves only to simplify the presentation; we focus on crises that occur when the fundamental shock is bad and not when it is good. We also impose a normalization on the sunspot variable to eliminate equilibria that are equivalent up to a relabelling of the sunspot states. In particular, we study equilibria in which the measure of withdrawals at $t = 1$ is at least as large in state H_β as in state H_α. In other words, we assume that depositors potentially view α to be the "good" sunspot state and β the "bad" state rather than the other way around.[4] Formally, while an individual depositor can follow any strategy (3), we only study equilibria in which the profile of withdrawal strategies lies in the set

$$Y = \left\{ \begin{array}{c} y : y_i\left(\omega_i, L\right) = \omega_i \text{ for all } i \text{ and} \\ \\ \lambda\left(y_i\left(2, H_\beta\right) = 1\right) \geq \lambda\left(y_i\left(2, H_\alpha\right) = 1\right) \end{array} \right\}, \tag{4}$$

where λ is the measure of depositors following a strategy with the indicated property.

We refer to an event in which some patient depositors choose to withdraw in period 1 as a *run*. Note that the number of early withdrawals is large in a run for two distinct reasons: a higher-than-normal fraction of the population is impatient in state H and some patient depositors are also withdrawing early. In this way, a run in this model consists of a shock to fundamentals whose effect is amplified by the (endogenous) decisions of depositors.

In this setting, two distinct types of runs may arise. We say that a run is driven by expectations if patient depositors' withdrawal behavior depends on the realization of the sunspot variable. In contrast, a run is driven by fundamentals if each depositor's optimal action is independent of the actions of other depositors and, hence, of the sunspot variable. We introduce the following definitions to formalize this distinction.

Definition 1: An economy is *weakly fragile* if there is an equilibrium in which depositors play strategy profile

$$y^E : y_i\left(\omega_i, s\right) = \left\{ \begin{array}{c} \omega_i \\ 1 \end{array} \right\} \text{ for } s = \left\{ \begin{array}{c} L, H_\alpha \\ H_\beta \end{array} \right\} \text{ for all } i. \tag{5}$$

In other words, we say that an economy is weakly fragile if there exists an equilibrium in which all depositors condition their withdrawal decisions in fundamental state H on the realization of the

[4] Focusing on the opposite case, where the measure of early withdrawals is weakly larger in state H_α than in state H_β, would lead to exactly the same results if the probabilities of states α and β are reversed. What matters is the set of possible probability distributions over actions and not the labels of the states.

sunspot variable. In this sense, a weakly-fragile economy is susceptible to an expectations-driven bank run. In contrast, we will say that an economy is strongly fragile if a run necessarily occurs whenever the realization of withdrawal demand is high.

Definition 2: An economy is *strongly fragile* if the only equilibrium profile of withdrawal strategies $y \in Y$ is

$$y^F : y_i(\omega_i, s) = \left\{ \begin{array}{c} \omega_i \\ 1 \end{array} \right\} \text{ for } s = \left\{ \begin{array}{c} L \\ H \end{array} \right\} \text{ for all } i. \tag{6}$$

When an economy is strongly fragile, the expectations-driven run specified in (5) is inconsistent with equilibrium because withdrawing early is a dominant action for patient depositors when the fundamental state is H. Instead, depositors necessarily follow (6) in equilibrium and bank runs are driven solely by fundamentals. Lastly, if there is no equilibrium in which patient depositors withdraw early in some state, we say that the economy is not fragile.

Definition 3: An economy is *not fragile* if the only equilibrium profile of withdrawal strategies $y \in Y$ is the no-run profile

$$y^N : y_i(\omega_i, s) = \omega_i \text{ for all } s, i. \tag{7}$$

We show in the analysis below that, under a given policy regime, an economy fits into exactly one of these three categories, which we refer to as the *fragility type* of the economy under that regime.

In the next two sections, we study fragility and equilibrium allocations under the two different policy regimes. In Section 5, we then ask when the policy maker should be allowed to intervene and when intervention should be prohibited. Of particular interest is the extent to which the answer to this question depends on the fragility type of the economy, that is, the extent to which the desirability of intervention depends on whether the economy is susceptible to runs driven by expectations or by fundamentals.

3 Equilibrium with no intervention

In this section, we study equilibrium outcomes under the policy regime with no intervention, in which taxes are collected and the public good is provided at the beginning of $t = 1$ (as shown in Figure 1). In this regime, the same amount of tax τ will be collected from each bank and the same level of the public good will be provided in all states, that is

$$g_s = \tau \text{ for all } s. \tag{8}$$

We begin the analysis of equilibrium by finding the best responses of banks and the policy maker to an arbitrary profile of withdrawal strategies y and to each other's actions. With these responses in hand, we then ask what profiles y are part of an equilibrium in a given economy.

3.1 The best-response allocation

Given a profile of withdrawal strategies for its depositors, bank j will allocate its available resources across depositors to maximize the sum of their expected utilities, taking as given the actions of other banks and the policy maker. In principle, a bank can distribute its resources in any way that is consistent with depositors' withdrawal decisions and its own information set. We can, however, simplify matters considerably by determining the general form an efficient response to any strategy profile y must take. A bank knows that at least a fraction π_L of its depositors will withdraw in period 1 in both states. As the first π_L withdrawals take place, therefore, the bank is unable to make any inference about the state and will choose to give the same level of consumption to each non-monitored depositor who withdraws; let c_1^j denote this amount for bank j. Similarly, the bank will choose to give an amount $\hat{c}_1^j$ to each monitored depositor who withdraws.

The bank will be able to infer the fundamental state after π_L withdrawals have been made by observing whether or not withdrawals continue. It will also observe the sunspot state at this point and will thus know both what fraction of its depositors are impatient and whether or not a run is underway. The bank can use this information to calculate the fraction of its remaining depositors who are impatient, which we denote $\hat{\pi}_s$. We assume that, once the state has been revealed, each bank is able to efficiently allocate its available resources among its remaining depositors, even if a run is underway. In particular, we assume that the remaining patient depositors do not withdraw early, but instead withdraw in period 2.[5] The efficient allocation of bank j's remaining resources gives a common amount of consumption, denoted c_{1s}^j, to each remaining impatient depositor in period 1 and a common amount c_{2s}^j to each remaining patient depositor in period 2. These amounts will be chosen to maximize the average utility of those depositors who have not yet withdrawn.[6]

[5] None of our results depend on this assumption. The issue of how banks and policy makers react to a run, and how this reaction affects the behavior of those depositors who have not yet withdrawn, is quite interesting. Ennis and Keister (2010) show how a model similar to ours can be used to study this interplay between the actions of depositors and the reactions of policy makers. The outcome we study here, where a run ends after π_L withdrawals, is one equilibrium that would emerge in such a setting. Focusing on this one outcome allows us to simplify the notation and focus more clearly on the distinction between expectations-driven and fundamentals-driven runs.

[6] The fact that this allocation is efficient implies that there is no role for regulation in improving the allocation of resources among the remaining $(1 - \pi_L)$ depositors under either policy regime. For this reason, our assumption that the policy maker monitors a fraction σ of only the first π_L depositors to withdraw is without any loss of generality.

This reasoning shows that a best-response strategy for bank j can be summarized by a vector $\left(c_1^j, \hat{c}_1^j, \left\{c_{1s}^j, c_{2s}^j\right\}_{s\in S}\right)$. We can derive the elements of this vector by working backward, starting with the allocation of the bank's remaining resources after it learns the state.

Post-crisis payments. Let ψ_s^j denote the quantity of resources available to bank j, in per-depositor terms, after a fraction π_L of its depositors have withdrawn. The bank will distribute these resources to solve

$$V\left(\psi_s^j; \hat{\pi}_s\right) \equiv \max_{\left\{c_{1s}^j, c_{2s}^j\right\}} \left(1-\pi_L\right)\left(\hat{\pi}_s u\left(c_{1s}^j\right) + \left(1-\hat{\pi}_s\right) u\left(c_{2s}^j\right)\right) \tag{9}$$

subject to the resource constraint

$$\left(1-\pi_L\right)\left(\hat{\pi}_s c_{1s}^j + \left(1-\hat{\pi}_s\right)\frac{c_{2s}^j}{R}\right) \leq \psi_s^j$$

and appropriate non-negativity conditions. Letting μ_s^j denote the multiplier associated with the resource constraint, the solution to this problem is characterized by the conditions

$$u'\left(c_{1s}^j\right) = Ru'\left(c_{2s}^j\right) = \mu_s^j. \tag{10}$$

Early payments. As the first π_L depositors withdraw, bank j is unable to make any inference about the state. The bank will choose the amount it gives to each monitored depositor, $\hat{c}_1^j$, and to each non-monitored depositor, c_1^j, to maximize

$$\pi_L\left[\sigma u\left(\min\left\{\hat{c}_1^j, \tilde{c}_1\right\}\right) + (1-\sigma) u\left(c_1^j\right)\right] + \sum_{s\in S} q_s V\left(1-\tau-\pi_L\left(\sigma\hat{c}_1^j + (1-\sigma)c_1^j\right); \hat{\pi}_s\right),$$

where $\tilde{c}_1$ denotes the cap for the consumption of monitored depositors set by the policy maker, which bank j takes as given. The $\min$ term in this expression shows that any resources above the cap will be confiscated from these depositors. Looking first at the optimal choice for non-monitored depositors, it is characterized by the first-order condition

$$u'\left(c_1^j\right) = \sum_{s\in S} q_s \mu_s^j. \tag{11}$$

This condition says that the bank will allocate resources to equate the marginal utility of a non-monitored depositor to the expected marginal utility from private consumption for the remaining $(1-\pi_L)$ depositors. In the absence of the cap $\tilde{c}_1$, the first-order condition for the consumption of monitored depositors would be identical to (11). The bank's optimal choice is, therefore, to give each monitored depositor the lesser of c_1^j, as defined in (11), and the cap set by the policy maker,

$$\hat{c}_1^j = \min\left\{c_1^j, \tilde{c}_1\right\}. \tag{12}$$

Since all banks face the same optimization problem, they will all choose the same levels of c_1^j and $\hat{c}_1^j$. As a result, all banks will have the same level of resources ψ_s^j available in a given state after taxes have been collected and the first π_L withdrawals have been made. This fact, in turn, implies that they all face the same optimization problem (9) and will choose the same values of $\left(c_{1s}^j, c_{2s}^j\right)$ in each state. We can, therefore, simplify the notation slightly by omitting the j subscripts when referring to the best-response payments $\left(c_1, \hat{c}_1, \{c_{1s}, c_{2s}\}_{s\in S}\right)$.

Prudential regulation. Like the banks, the policy maker is unable to make any inference about the state s as the first π_L withdrawals are made. When he encounters one of these depositors, the policy maker will choose to confiscate any resources she has above some cutoff amount $\tilde{c}_1$. The optimal cutoff value maximizes

$$\sigma\pi_L u\left(\tilde{c}_1\right) + \sum_{s\in S} q_s V\left(1 - \tau - \pi_L\left(\sigma\tilde{c}_1 + (1-\sigma)\, c_1\right); \hat{\pi}_s\right). \tag{13}$$

The policy maker recognizes that any confiscated resources will be rebated lump-sum to banks and, therefore, banks' remaining resources per depositor, ψ, will depend on the actual consumption levels of both monitored depositors, $\tilde{c}_1$, and non-monitored depositors, c_1.[7] The solution to this problem is characterized by the first-order condition

$$u'\left(\tilde{c}_1\right) = \sum_{s\in S} q_s \mu_s, \tag{14}$$

which is exactly the same as the condition governing an individual bank's choice in (11). In other words, in the policy regime with no intervention, banks' incentives are not distorted; the early payments c_1 are set at exactly the level a benevolent policy maker would choose,

$$c_1\left(y\right) = \tilde{c}_1\left(y\right) \quad \text{for all } y, \tag{15}$$

and the regulatory policy is never binding. In the remainder of this section, we use the relationship in (15) to simplify the notation by using c_1 to represent the consumption of both monitored and non-monitored depositors.

[7] Recall, however, that the decision rule (12) ensures that no funds are actually confiscated in equilibrium.

The tax rate. When choosing the tax rate at the beginning of $t = 1$, the policy maker recognizes that banks will allocate the resources available to them as described above and that prudential regulation will be non-binding. Taking banks' allocation rules into account and using (15), we can write the policy maker's objective as

$$\pi_L u\left(c_1\left(\tau\right)\right) + \sum_{s \in S} q_s V\left(1 - \tau - \pi_L c_1\left(\tau\right); \hat{\pi}_s\right) + v\left(\tau\right),$$

where the notation indicates that the payment c_1 will depend on the tax rate τ, as will banks' remaining resources after the state has been revealed. The first-order condition characterizing the policy maker's optimal choice is

$$\pi_L u'\left(c_1\left(\tau\right)\right) \frac{dc_1\left(\tau\right)}{d\tau} - \sum_{s \in S} q_s \mu_s \left(1 + \pi_L \frac{dc_1\left(\tau\right)}{d\tau}\right) + v'\left(\tau\right) = 0.$$

Using banks' decision rule for choosing c_1 in (11), this condition simplifies to

$$v'\left(\tau\right) = \sum_{s \in S} q_s \mu_s. \tag{16}$$

In other words, when the policy maker chooses the tax rate at the beginning of the period, the optimal choice equates the marginal value of public consumption with the expected marginal value of private consumption.[8]

For any profile y of withdrawal strategies, the discussion above shows how the best responses of banks and the policy maker are summarized by the vector

$$\mathbf{c}^{NI}\left(y\right) \equiv \left(c_1^{NI}, \tilde{c}_1^{NI}, \left\{c_{1s}^{NI}, c_{2s}^{NI}\right\}_{s \in S}, g^{NI}\right),$$

which we refer to as the *best-response allocation* associated with y under the policy regime with no intervention. The elements of this allocation are completely characterized by equations (8), (10), (11), (15), (16), and the resource constraint in each state. We provide an explicit derivation of this allocation in Appendix A. With these best responses in hand, we next ask what profiles y emerge as equilibria under this policy regime.

[8] Notice that, while the policy maker can use τ to influence banks' choice of c_1, as well as his own future choice of $\tilde{c}_1$, the term $dc_1/d\tau$ does not appear in (16). This fact reflects an envelope result: c_1 and $\tilde{c}_1$ are already being set efficiently from the policy maker's current point of view. Hence, there is no benefit in deviating from (16) in an attempt to influence these choices.

3.2 Fragility

A profile of withdrawal strategies y^* is part of an equilibrium under the policy regime with no intervention if each depositor is choosing the strategy y_i^* that maximizes her own expected utility, taking as given the strategies of other depositors and the allocation $\mathbf{c}^{NI}(y^*)$ that results from the best-responses of banks and the policy maker to those strategies. In Section 2.3, we defined the fragility type of an economy based on which withdrawal strategy(ies) are part of an equilibrium. Our first proposition determines which of these types applies to a given economy.

Proposition 1 *Under the policy regime with no intervention, the economy is:*

(a) *weakly fragile if and only if* $c_{2H_\alpha}^{NI}\left(y^E\right) \geq c_1^{NI}\left(y^E\right) \geq c_{2H_\beta}^{NI}\left(y^E\right)$,

(b) *strongly fragile if and only if* $c_1^{NI}\left(y^E\right) > c_{2H_\alpha}^{NI}\left(y^E\right)$, and

(c) *not fragile if and only if* $c_1^{NI}\left(y^E\right) < c_{2H_\beta}^{NI}\left(y^E\right)$.

Proofs of all propositions are given in Appendix B unless otherwise noted. Proposition 1 shows that determining the fragility type of a given economy only requires calculating the best-response allocation to the single strategy profile y^E defined in (5). If this profile together with the best responses of banks and the policy maker, $\mathbf{c}^{NI}\left(y^E\right)$, form an equilibrium, then the economy is weakly fragile by definition. If not, the proposition provides a simple test for determining whether the economy is strongly fragile or not fragile. In particular, if an individual patient depositor would prefer to withdraw early in state H_α, even though the sunspot state is "good" and she expects other patient depositors to wait until $t = 2$, then any equilibrium must feature all patient depositors withdrawing early whenever the fundamental state is H. Conversely, if an individual patient depositor would prefer to wait until $t = 2$ in state H_β even though the sunspot state is "bad" and she expects all other patient depositors to withdraw early, then patient investors will never withdraw early in equilibrium and the economy is not fragile.

The next result shows that the fragility type of an economy under this regime does not depend on the regulation parameter σ nor on the desirability of the public good.

Proposition 2 *Under the policy regime with no intervention, the fragility type of an economy is independent of the parameters σ and δ.*

The proof of this proposition is straightforward and is omitted. The first part is trivial: since prudential regulation is never binding under this regime, the entire allocation $\mathbf{c}^{NI}(y)$ is independent of the fraction σ of monitored depositors for any strategy profile y. The second part of the result follows from the functional form in (1), which implies that preferences over private consumption across states of nature are homothetic. An increase in the parameter δ would, therefore, raise consumption of the public good while lowering consumption of the private good in each state in proportion, leaving the ratios $c_1^{NI}(y)/c_{2s}^{NI}(y)$ unchanged for any s and any y.[9] Depositors' withdrawal incentives are thus independent of the size of the public sector under this policy regime.

Using Proposition 1, it is straightforward to find examples of economies that are strongly fragile under the policy regime with no intervention, as well as economies that are weakly fragile and not fragile. For each of these economies, our interest is in determining whether welfare would be increased by allowing the policy maker to intervene by adjusting tax rates after the state has been revealed. As discussed in the Introduction, one view holds that such intervention tends to be desirable when the economy is weakly fragile, but is undesirable when the economy is either strongly fragile or not fragile. To test the validity of this view, we next characterize equilibrium outcomes under a policy regime with intervention.

4 Equilibrium with intervention

Now suppose the policy maker collects taxes later in period 1, after a fraction π_L of depositors have withdrawn. (See Figure 1 in Section 2.2.) At this point, the policy maker has learned the state and thus knows both the level of fundamental withdrawal demand and whether a run has occurred. The benefit of acting at this later point is that the level of taxes can be state-contingent, which allows for risk sharing between the public and private sectors. The cost is that the policy maker will be tempted to set tax rates in a way that, from an ex ante point of view, will distort banks' incentives to provision for bad outcomes. We analyze equilibrium in the model with such intervention in this section, then study the desirability of allowing intervention in Section 5.

4.1 Bailouts

After a fraction π_L of depositors have withdrawn, the policy maker observes whether or not withdrawals stop. If they do, the policy maker is able to infer that the fundamental state is L. In this case, we assume the policy maker chooses a single tax rate τ_L and collects this tax per unit of

[9] This fact is easily verified using the expressions for the best-response allocation $\mathbf{c}^{NI}$ in Appendix A.

deposits from all banks. If withdrawals continue past π_L, however, the policy maker infers that the fundamental state is H. The policy maker then observes the sunspot state and the financial condition of each bank before choosing a tax rate τ_s^j for bank j. All tax rates are chosen with the objective of maximizing (2) given the current situation and anticipating that each bank will allocate its after-tax resources to solve (9). The difference

$$\tau_L - \tau_s^j$$

can be interpreted as the "bailout" of bank j in states $s = H_\alpha, H_\beta$. When fundamental withdrawal demand is high, the policy maker will tend to cut production of the public good in order to help mitigate the decline in private consumption of the remaining depositors in the banking system. In principle, however, this bailout can be either positive or negative; a bank in better-than-average condition might be required to pay a higher-than-normal tax to make up for the poor condition of other banks.[10]

4.2 The best response allocation

We characterize equilibrium under this regime following the same steps as in Section 3. For a given profile y of withdrawal strategies, we first determine the best responses of banks and the policy maker to this profile and to each other's actions. With these responses in hand, we then ask whether the strategy y_i is a best response for depositor i to the strategies of other depositors, banks, and the policy maker.

After a fraction π_L of depositors have withdrawn and taxes have been collected, each bank will again allocate its remaining resources to solve the problem in (9) and, as before, this allocation is characterized by the first-order conditions in (10). We begin, therefore, by studying how the policy maker will intervene, then work backward to determine the consumption of the first π_L depositors who withdraw.

Choosing tax rates. In state s, the policy maker will choose the tax rate τ_s^j per unit of deposits in

[10] The assumption that the policy maker does not set bank-specific tax rates in fundamental state L is designed to ensure that banks have an incentive to provision for $t = 2$ withdrawals in normal times. It can be justified in different ways, for example, by assuming that the detailed monitoring needed to accurately determine a bank's financial condition is only worthwhile in state H, or by appealing to reputational considerations that would arise in normal times in a more fully dynamic model. For our purposes, the important thing is that the policy maker's inability to commit creates a distortion in banks' incentives with respect to those states where a crisis occurs.

bank j to maximize

$$\int V\left(1-\tau_s^j-\pi_L c_1^j;\hat{\pi}_s\right)d\phi\left(j\right)+v\left(\tau_s\right),$$

where ϕ represents the distribution of investors across banks and τ_s denotes total tax revenue in state s, that is,

$$\tau_s\equiv\int\tau_s^j d\phi\left(j\right).$$

The tax rate must be the same for all banks in fundamental state L, but may differ across banks in state H. The solution will, therefore, equate the marginal value of public consumption in fundamental state L to the marginal value of private consumption averaged across banks,

$$v'\left(\tau_L\right)=\int\mu_s^j d\phi\left(j\right).$$

The marginal value of public consumption in fundamental state H, in contrast, will be set equal to the marginal value of private consumption in every bank j ,

$$v'\left(\tau_s\right)=\mu_s^j\;\text{ for all } j,\;\text{ for } s=H_\alpha,H_\beta. \tag{17}$$

In other words, when a crisis occurs, the policy maker will set the tax rate τ_s^j to equalize the consumption levels of the remaining depositors across banks, meaning that a bank that is in worse financial condition (because it set c_1^j higher and gave away more resources to the first π_L depositors) will receive a larger bailout. As a result, the resources available to bank j after taxes have been collected in a crisis state will depend on aggregate economic conditions and not on the bank's own actions. Specifically, we have

$$\psi_s^j=1-\tau_s-\pi_L\overline{c}_1\quad\text{for all } j,\;\text{ for } s=H_\alpha,H_\beta, \tag{18}$$

where $\overline{c}_1$ is defined to be the average early payment across all banks and all depositors,

$$\overline{c}_1\equiv\int\left(\sigma\hat{c}_1^j+\left(1-\sigma\right)c_1^j\right)d\phi\left(j\right).$$

The incentive problems caused by this bailout policy are clear: a bank with fewer remaining resources (because it chose a higher value of c_1^j) will be charged a lower tax, effectively receiving a larger "bailout". This bailout policy will lead all banks to set c_1^j too high from a social point of view.

Notice that this problem arises even when $\delta = 0$ and there is no value associated with the public good. In that case, the policy maker will set $\tau_L = 0$ and collect no revenue in normal times. When a crisis occurs, total tax revenue τ_s will be set to zero, but the policy maker will still choose to intervene by taxing banks that have more resources than average and making transfers to banks that have fewer resources than average. In equilibrium, of course, all banks will make the same choices and no taxes/transfers will occur. Nevertheless, the fact that these transfers would occur off the equilibrium path of play affects banks' decisions on the equilibrium path, as we show below.

Early payments. As the first π_L withdrawals take place, bank j will choose the amount it gives to each monitored depositor, $\hat{c}_1^j$, and to each non-monitored depositor, c_1^j, to maximize

$$\pi_L \left[\sigma u \left(\min\left\{\hat{c}_1^j, \tilde{c}_1\right\}\right) + (1-\sigma) u \left(c_1^j\right)\right] + q_L V \left(1 - \tau_L - \pi_L \left(\sigma \hat{c}_1^j + (1-\sigma) c_1^j\right); \hat{\pi}_L\right) \quad (19)$$
$$+ \sum_{s=H_\alpha, H_\beta} q_s V \left(1 - \tau_s - \pi_L \bar{c}_1; \hat{\pi}_s\right).$$

Since there are no bailouts in state L, the bank recognizes that giving an extra unit of resources to the first π_L depositors will leave one unit less for the remaining depositors in that state. However, when the fundamental state is H, the policy maker will intervene in such a way that the bank's remaining resources will be given by (18), independent of its choice of c_1^j. As a result, the terms on the second line of (19) are fixed from the individual bank's point of view and the first-order condition characterizing the solution to this problem is

$$u'\left(c_1^j\right) = q_L \mu_L^j. \quad (20)$$

Comparing (20) with (11) shows the distortion created by intervention: bank j no longer has an incentive to provision for the fundamental state H. Instead, the bank will balance the marginal value of resources for the earliest withdrawals against the marginal value of resources for later withdrawals in fundamental state L only. As a result, the bank will tend to set c_1^j too high from a social point of view. For monitored depositors, the bank's optimal choice again follows (12); it will give these agents the lesser of c_1^j, now defined in (20), and the cap $\tilde{c}_1$ set by the policy maker.

As above, all banks face the same decision problem and will choose the same values of c_1^j. Together with the bailout policy in (18), this fact implies that all banks also face the same decision problem in choosing the later payments $\left(c_{1s}^j, c_{2s}^j\right)$ and will again select the same values. We can, therefore, omit the j subscripts to simplify the notation in what follows.

Prudential regulation. When the policy maker encounters one of the first π_L depositors to withdraw, he will again choose the cutoff value $\tilde{c}_1$ to maximize (13), with the adjustment that tax revenue τ_s now varies across states. The key difference between the policy maker's objective function and that of an individual bank in (19) is that the policy maker recognizes that giving a unit of resources to one of the first π_L depositors decreases the resources available for the remaining depositors in all states, whereas the intervention policy in (18) makes this effect external to an individual bank when the fundamental state is H. The first-order condition that characterizes the policy maker's optimal choice is again given by (14), which shows how prudential regulation is now used to correct the distortion created by intervention. When a depositor is monitored by the policy maker, her marginal utility of consumption is equated to the expected future marginal value of consumption, taking all states into account, which is precisely what an individual bank chooses to do when there is no intervention and incentives are not distorted.

The best-response allocation under the policy regime with intervention, denoted

$$\mathbf{c}^I(y) \equiv \left(c_1^I, \tilde{c}_1^I, \{c_{1s}^I, c_{2s}^I, g_s^I\}_{s \in S}\right),$$

is characterized by equations (10), (14), (17), (20), and the resource constraint in each state. We provide an explicit derivation of the allocation in Appendix A. It is straightforward to show that prudential regulation is always active in this allocation, that is, the policy maker's cap $\tilde{c}_1$ is strictly lower than the consumption of non-monitored depositors c_1,

$$\tilde{c}_1^I(y) < c_1^I(y) \text{ for all } y \in Y. \tag{21}$$

4.3 Fragility

We now use the allocation $\mathbf{c}^I$ to identify conditions under which an economy is susceptible to runs driven by either expectations or fundamentals under the policy regime with intervention. We begin with a characterization result similar to Proposition 1. As in Keister (2014), we assume the states in which intervention occurs are relatively rare, with

$$q_{H_\alpha} + q_{H_\beta} < \frac{R-1}{R}, \tag{22}$$

which simplifies the analysis by placing an upper bound on the size of the incentive distortion. For notational convenience, we define

$$\mathcal{E}\left(\mathbf{c}^{I}\left(y\right)\right) \equiv \sigma u\left(\tilde{c}_{1}^{I}\left(y\right)\right) + \left(1-\sigma\right) u\left(c_{1}^{I}\left(y\right)\right), \tag{23}$$

which represents the expected utility of a depositor who is among the first π_L withdrawals before she knows whether or not she will be monitored. We then have the following result.

Proposition 3 *Under the policy regime with intervention, the economy is:*

(a) *weakly fragile if and only if* $u\left(c_{2H_\alpha}^{I}\left(y^E\right)\right) \geq \mathcal{E}\left(\mathbf{c}^{I}\left(y^E\right)\right) \geq u\left(c_{2H_\beta}^{I}\left(y^E\right)\right)$,

(b) *strongly fragile if and only if* $\mathcal{E}\left(\mathbf{c}^{I}\left(y^E\right)\right) > u\left(c_{2H_\alpha}^{I}\left(y^E\right)\right)$, and

(c) *not fragile if and only if* $\mathcal{E}\left(\mathbf{c}^{I}\left(y^E\right)\right) < u\left(c_{2H_\beta}^{I}\left(y^E\right)\right)$.

As with Proposition 1 in Section 3, this result demonstrates that every economy has a unique fragility type under a given policy regime and that determining this type only requires calculating the best-response allocation for the single strategy profile y^E defined in (5).

The next two propositions study how the fragility type of an economy depends on the effectiveness of regulation, measured by the parameter σ, and on the importance of the public good, measured by δ. Recall that Proposition 2 showed the fragility type of an economy to be independent of these two parameters under the policy regime with no intervention. These relationships change when intervention is allowed. Let e denote the vector of all parameter values except σ, so that $e = \left(R, \gamma, \delta, \{q_s, \pi_s\}_{s\in S}\right)$ and an economy is defined by the pair (e, σ). Then we have the following result.

Proposition 4 *Under the policy regime with intervention, the fragility type of an economy* (e, σ) *is weakly decreasing in* σ.

In other words, more effective regulation promotes financial stability when the prospect of intervention distorts banks' incentives. The intuition for this result is straightforward. The first-order condition (20) illustrates how intervention leads banks to increase their short-term liabilities by offering relatively large payments to the non-monitored depositors who withdraw before the policy reaction occurs. Condition (21) shows that the policy maker will cap the consumption of monitored depositors at a lower level. An increase in the fraction of depositors who are monitored thus tends to make withdrawing early less attractive for patient investors. At the same time, the smaller payments made to monitored depositors imply that banks will have more resources left after the first π_L withdrawals have been made, which also makes waiting to withdraw at $t = 2$ more attractive. For both of these reasons, more effective regulation lowers the incentive for a patient depositor to run and thus tends to reduce fragility.

The next result highlights the insurance benefit of bailouts: when regulation is sufficiently effective, financial fragility will be lower in economies where the public sector is larger. For this result, we need to impose a fairly weak condition on parameter values:

$$q_{H_\alpha} > \frac{1}{R}\left(1 - \frac{\pi_H (1-\pi_L)}{\pi_L (1-\pi_H)}\left(\frac{(1-\pi_L) R^{\frac{1-\gamma}{\gamma}}}{(\pi_H - \pi_L) + (1-\pi_H) R^{\frac{1-\gamma}{\gamma}}}\right)^{\gamma}\right) \equiv \overline{q}_{H_\alpha}. \tag{24}$$

In many economies, the lower bound $\overline{q}_{H_\alpha}$ is negative and this condition is automatically satisfied. In some cases, however (when R is very large, for example), this condition sets a small, positive floor on the probability q_{H_α}.

Proposition 5 *Under the policy regime with intervention, if* (24) *holds, then for any* e *there exists* $\bar{\sigma} < 1$ *such that the fragility type of all economies* (e, σ) *with* $\sigma > \bar{\sigma}$ *is weakly decreasing in* δ.

When δ is higher, the public sector is larger and, as a result, the policy maker will choose bailouts that are larger relative to the level of private consumption. These larger bailouts decrease the losses suffered by investors who are not among the first π_L to withdraw and, therefore, tend to lower the incentive for patient depositors to withdraw early. However, there is an offsetting effect: because the larger bailout payments mitigate the effects of a crisis, the policy maker will choose to allow a higher level of consumption for monitored depositors who withdraw before the policy reaction. This fact makes withdrawing early more attractive and tends to increase the incentive for patient depositors to run. In general, either effect can dominate and increasing the parameter δ can either increase or decrease fragility. Proposition 5 demonstrates that when regulation is sufficiently effective and (24) holds, however, the first effect always dominates and having a larger public sector will (weakly) decrease financial fragility.

5 Comparing Policy Regimes

The analysis in the previous two sections has illustrated the costs and benefits of allowing the policy maker to intervene during a crisis. We now turn to the question of when the benefits outweigh the costs, providing two analytical results followed by some illustrative examples. We first study the case where regulation is very effective, that is, the parameter σ is close to one. We show that, in this case, allowing intervention is always desirable, regardless of the fragility type of the economy under each regime. We then study the case where $\delta = 0$, meaning that depositors get no utility from the public good. In this case, we show that there is no insurance benefit from allowing intervention and, as a result, intervention is never desirable. Away from these two limiting cases, either of the two effects can dominate. We use a series of examples to show that intervention tends to be desirable when it improves the economy's fragility type, but can be desirable even if it does not because the increased risk sharing between private and public consumption may more than compensate for the distorted allocation of private consumption.

5.1 When regulation is very effective

Our first result identifies situations where regulation is effective enough to guarantee that the insurance benefit from intervention outweighs the incentive costs. Specifically, assume investors value the public good $(\delta > 0)$ and fix all parameter values except the effectiveness of prudential regulation σ. When σ is close enough to 1, allowing intervention is always desirable.

Proposition 6 *Assume* (24) *holds. For any e with $\delta > 0$, there exists $\overline{\sigma} < 1$ such that allowing intervention strictly increases equilibrium welfare for all economies (e, σ) with $\sigma > \overline{\sigma}$.*

The intuition for this result can be seen in two steps. First, imagine that we hold depositors' withdrawal behavior fixed. When private consumption levels vary across states, an efficient allocation of resources requires public consumption levels to vary across states as well. By collecting higher taxes in good states and lower taxes in bad states, the policy maker helps smooth depositors' private consumption, which raises expected utility. In addition, this type of consumption smoothing lowers the incentive for patient depositors to withdraw early. In fact, the proof of Proposition 6 (given in Appendix B) shows that when σ is close enough to one, allowing intervention weakly decreases fragility relative to the regime with no intervention. In other words, when regulation is sufficiently effective, allowing intervention improves both the allocation of resources conditional on depositor behavior *and* depositors' equilibrium withdrawal behavior; hence, it is always desirable.

In a model of expectations-driven runs, Keister (2014) shows that allowing bailouts is always desirable when policy makers can completely offset the associated incentive distortion using Pigouvian taxes. Proposition 6 shows that this type of result obtains even when prudential regulation is somewhat imperfect and, more importantly, regardless of whether runs are driven by expectations or fundamentals.

5.2 When the insurance benefit is absent

Our next result focuses on economies where $\delta = 0$, that is, depositors do not value the public good. The policy maker can still collect taxes and monitor some withdrawals, but there is no longer a potential gain from sharing risk between the public and private sectors because the optimal amount of public consumption is zero. In this case, if the incentive distortions associated with bailouts cannot be fully corrected through regulation (that is, $\sigma < 1$), allowing intervention is undesirable.[11]

Proposition 7 *For any economy with $\delta = 0$ and $\sigma < 1$, allowing intervention strictly decreases equilibrium welfare.*

This result highlights the importance of the insurance benefit of bailouts in our setting. When this benefit is absent, allowing intervention still distorts banks' incentives because the policy maker is able to reallocate resources across banks following a crisis. This distortion leads to a misallocation of resources and lowers depositors' welfare if regulation is imperfect. In this special case, our model yields the same prescription as others in the literature in which bailouts distort incentives but do not generate any ex ante benefits; see, for example, Farhi and Tirole (2012) and Chari and Kehoe (2013). In this way, Proposition 7 demonstrates that the desirability of prohibiting intervention in these frameworks stems not from the assumptions about what causes a crisis (fundamentals vs. expectations), but rather from the fact that there is no insurance benefit from bailouts that could potentially offset the distortion in incentives.[12]

5.3 Examples

Propositions 6 and 7 identify situations in which one of the two competing effects – incentives or insurance – is clearly dominant and thus determines the optimal policy choice. In between these limiting cases, interesting patterns arise. We illustrate some of these patterns using a series of three

[11] If regulation is perfectly effective $(\sigma = 1)$, the two policy regimes lead to exactly the same outcome when $\delta = 0$. In this case, the incentive distortion created by intervention is completely corrected through regulation, leaving the allocation of consumption across depositors unchanged.

[12] This type of insurance benefit of bailouts also appears, in different settings, in Cooper et al. (2008), Green (2010) and Bianchi (2013).

related examples.

An economy that is weakly fragile with no intervention. For our first example, we set $R = 1.05$, $\pi_L = 0.45$, $\pi_H = 0.55$, $q_{H_\alpha} = q_{H_\beta} = 0.02$ and $\gamma = 4$. At these values, the economy is weakly fragile under the policy regime with no intervention for all (σ, δ) pairs.[13] Panel (a) of Figure 2 depicts the fragility type of the economy under the regime with intervention. For a broad range of (σ, δ) pairs in the middle of the panel, the economy is also weakly fragile under this regime. If σ and δ are both large enough, however, the run equilibrium is eliminated and the economy is no longer fragile. If σ and δ are small enough, in contrast, allowing intervention makes withdrawing early a dominant strategy for patient depositors and the economy is strongly fragile.

(a) Fragility with intervention

(b) Optimal policy regime

Figure 2: An economy that is weakly fragile with no intervention

Panel (b) of the figure shows which policy regime generates higher welfare. Allowing intervention is desirable in this example in two situations. First, if allowing intervention eliminates the run equilibrium and makes the economy not fragile, then doing so is always desirable. Second, even if allowing intervention leaves the economy weakly fragile, it is desirable whenever σ is close enough to one, as established in Proposition 6.

An economy that is strongly fragile with no intervention. Now suppose π_H is raised to 0.65. This larger value for the fundamental shock makes the economy strongly fragile under the policy regime with no intervention. Panel (a) of Figure 3 shows the fragility type of the economy when

[13] Recall that Proposition 2 shows the fragility type of an economy under the regime with no intervention to be independent of σ and δ.

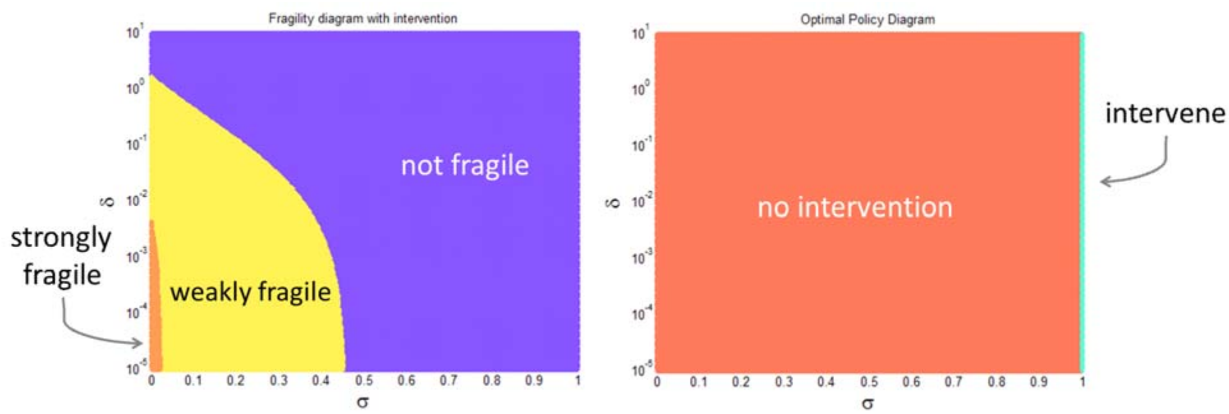
intervention is allowed. If σ and δ are low enough, the economy remains strongly fragile. For these cases, panel (b) of the figure indicates that intervention is undesirable. When σ and δ are higher, however, the fragility type of the economy improves under the regime with intervention, becoming either weakly fragile or, if σ and δ are high enough, not fragile. In both of these cases, panel (b) of the figure indicates that allowing intervention raises welfare.

(a) Fragility with intervention (b) Optimal policy regime

Figure 3: An economy that is strongly fragile with no intervention

The example in Figure 2 showed that allowing intervention may be desirable because it eliminates a bad equilibrium, moving the economy from weakly fragile to not fragile. The example in Figure 3 shows that allowing intervention may be desirable because it *introduces* a better equilibrium. In this case, the economy with no intervention has a unique equilibrium profile of withdrawal strategies $y^* \in Y$. Bank runs in this equilibrium are driven by fundamentals, which might tempt one to conclude that runs are inevitable and that allowing intervention cannot change the level of fragility or improve welfare. However, as the figure shows, allowing intervention in this case can introduce an equilibrium in which patient depositors only run in state H_β, rather than in both H_α and H_β. In this new equilibrium, where bank runs are driven by expectations, depositors have higher expected utility. If δ and σ are larger still, allowing intervention can eliminate runs entirely. This second example illustrates the importance of recognizing that whether runs are driven by fundamentals or expectations can depend on the policy regime in place. Even when runs are driven by fundamentals under one regime, it is possible for their incidence to be lessened or even eliminated under another regime.

An economy that is not fragile with no intervention. Figure 4 presents the results when π_H is lowered back to 0.55 and γ is lowered to 2. The smaller coefficient of relative risk aversion leads banks to provide less liquidity insurance and, in this example, makes the economy not fragile under the policy regime with no intervention. Panel (a) of the figure shows how, in terms of fragility, allowing intervention can only make the situation worse in this case. If σ and δ are high enough the economy remains not fragile under this regime; otherwise it can become weakly or even strongly fragile. Panel (b) of the figure shows that, in this case, prohibiting intervention is the optimal policy for the vast majority of (σ, δ) pairs. However, in line with Proposition 6, allowing intervention is desirable if σ is very close to 1.



(a) Fragility with intervention

(b) Optimal policy regime

Figure 4: An economy that is not fragile with no intervention

Taken together, these three examples present a clear pattern. Allowing intervention tends to reduce fragility and raise welfare in the upper-right corner of the graphs, where the insurance benefit is significant and regulation is effective in mitigating the incentive distortion. Prohibiting intervention tends to be desirable in the lower-left corner, where the potential for risk-sharing is small and regulation is ineffective. While the precise boundary between these two areas depends on the particulars of the economy, including whether runs are driven by expectations or by fundamentals when there is no intervention, the same general pattern arises in each case. The examples thus illustrate how the key tradeoff facing policy makers, as well as the factors that should guide the decision to allow or prohibit intervention, are independent of the underlying cause of bank runs.

6 Concluding Remarks

Policy makers and academics around the world are currently engaged in a wide-ranging discussion about how to best reform banking and financial regulation in light of recent experience. There is widespread agreement that the anticipation of being bailed out in the event of a crisis distorts the incentives of financial institutions and their investors, leading them to take actions that are socially inefficient and may, in addition, leave the economy more susceptible to a crisis. There is no consensus, however, about the best way to design a policy regime to mitigate these problems.

A number of recent papers examine bailout policy in models that include moral hazard concerns and account for the possible time inconsistency of policy makers' objectives.[14] Each of these papers makes some assumption about the underlying causes of a crisis: it either is the unique equilibrium outcome following some real shock to the economy or it arises, in part, from the self-fulfilling beliefs of agents in the model. There is a long-standing debate about which of these two approaches best captures the complex array of forces that combine to generate real-world financial crises.[15] Financial crises are infrequent events and there is a limited amount of available data that can be used to distinguish between the two approaches. Existing empirical work focuses on establishing a correlation between economic fundamentals and the occurrence of banking panics. Miron (1986), Gorton (1988) and others argue that such a correlation implies that runs are caused by shifts in these fundamentals. Ennis (2003) points out, however, that models of self-fulfilling bank runs will tend to generate this same type of correlation under reasonable equilibrium selection rules, so that the presence of this correlation alone cannot be used to distinguish between the two views. Moreover, establishing the importance (or unimportance) of self-fulfilling beliefs in causing a run requires answering a counterfactual question: would an individual depositor have withdrawn even if she expected other depositors to remain invested? Answering such questions on the basis of data from observed crises is intrinsically difficult.[16]

This ongoing debate would seem to present a serious hindrance to using such models for policy

[14] See, for example, Bianchi (2013), Chari and Kehoe (2013), Farhi and Tirole (2012), Green (2010), and Keister (2014).

[15] See Kindleberger (1978), Gorton (1988), Allen and Gale (1998, 2007), and Goldstein and Pauzner (2005) for different views of this debate.

[16] Some authors have argued that the degree to which depositors discriminate between banks during a panic provides evidence on the underlying cause of the event. See, for example, Saunders and Wilson (1996), Calomiris and Mason (1997, 2003) and Schumacher (2000). However, the Ennis (2003) critique again applies: all but the simplest models of self-fulfilling runs will tend to generate the same correlations as a model of fundamentals-based runs.

analysis. Without knowing the underlying cause of observed crises, how can one decide which type of model should be used to evaluate alternative policy regimes? We have shown how, in some cases, it is possible to perform meaningful policy analysis without taking a stand on the question of whether financial crises are driven by expectations or fundamentals. We constructed a model in which, depending on parameter values, a bank run may be driven by either of these two forces. We used this model to evaluate the desirability of allowing policy makers to intervene in the event of a crisis and provide bailouts. We showed that the same broad policy prescription comes out of the model regardless of whether runs are driven by expectations or fundamentals. In particular, intervention should be permitted only when prudential regulation and supervision are sufficiently effective that the insurance benefit from bailouts outweighs the resulting incentive distortion.

While our focus in this paper is on a single policy issue, we also aim to make a more general point. Much effort has been devoted to trying to determine the extent to which financial crises can be caused by self-fulfilling beliefs. This work has generated important insights, but has not led to a definitive answer to this difficult question. The lack of a clear answer does not imply, however, that the insights gained from this work cannot be used to inform the current policy debate. Our analysis here shows how these insights can be useful in studying one particular policy issue. Future work could examine other issues in banking and financial stability policy, or could seek to identify conditions under which a more general invariance result might hold.

Appendix A. Best-Response Allocations

In this appendix, we derive the allocation of resources that results from the best responses of banks and the policy maker to an arbitrary profile of withdrawal strategies under each policy regime. The expressions derived here are used in the proofs of the propositions given in Appendix B as well as in the examples presented in Section 5. For any strategy profile $y \in Y$, let $\hat{\pi}_s(y)$ denote the fraction of the remaining depositors who are impatient after π_L withdrawals have been made. Since we focus on equilibria in which there is no panic when the fundamental state is L, the first π_L withdrawals in that state represent all of the impatient depositors and we have

$$\hat{\pi}_L(y) = 0. \tag{25}$$

When the fundamental state is H, the first π_L withdrawals may be a mix of patient and impatient investors. Using the assumption that β is the "bad" sunspot state, as introduced in (4), we have

$$\frac{\pi_H - \pi_L}{1 - \pi_L} \leq \hat{\pi}_{H_\alpha}(y) \leq \hat{\pi}_{H_\beta}(y) \leq \pi_H \tag{26}$$

for all $y \in Y$. Given the values of $\hat{\pi}_s$ associated with a particular profile y, we can derive the best responses of banks and the policy maker under each regime as follows.

A.1 No intervention

Under the policy regime with no intervention, the best-responses of banks and the policy maker are characterized by equations (8), (10), (11), (15), (16), and the resource constraint in each state. It can be shown that these same conditions also characterize the solution to the problem of choosing an allocation vector **c** to maximize (2) subject to the basic resource constraints

$$\pi_L(\sigma\tilde{c}_1 + (1-\sigma)c_1) + (1-\pi_L)\left(\hat{\pi}_s(y)c_{1s} + (1-\hat{\pi}_s(y))\frac{c_{2s}}{R}\right) + g \leq 1$$

for all $s \in S$. Using the functional form (1), the solution to this problem can be shown to be

$$\begin{aligned}
\tilde{c}_1^{NI}(y) &= c_1^{NI}(y) = \frac{1}{\pi_L + \delta^{\frac{1}{\gamma}} + \bar{x}(y)^{\frac{1}{\gamma}}}, & (27)\\
c_{1s}^{NI}(y) &= \left(\frac{\bar{x}(y)}{x_s(y)}\right)^{\frac{1}{\gamma}} c_1^{NI}(y) \quad \text{and} \quad c_{2s}^{NI}(y) = R^{\frac{1}{\gamma}} c_{1s}^{NI}(y) \quad \text{for all } s, & (28)\\
g(y) &= \delta^{\frac{1}{\gamma}} c_1^{NI}(y), & (29)
\end{aligned}$$

where

$$x_s(y) \equiv \left((1-\pi_L)\left(\hat{\pi}_s(y) + (1-\hat{\pi}_s(y)) R^{\frac{1-\gamma}{\gamma}}\right)\right)^{\gamma} \text{ and} \tag{30}$$

$$\bar{x}(y) \equiv \sum_{s \in S} q_s x_s(y). \tag{31}$$

Note that this solution depends on depositors' withdrawal strategies y only through the values of $\hat{\pi}_s(y)$.

A.2 With intervention

Under the policy regime with intervention, the best-responses of banks and the policy maker are characterized by equations (10), (14), (17), and (20), together with the resource constraint in each state,

$$\pi_L(\sigma \tilde{c}_1 + (1-\sigma) c_1) + (1-\pi_L)\left(\hat{\pi}_s(y) c_{1s} + (1-\hat{\pi}_s(y)) \frac{c_{2s}}{R}\right) + g_s \leq 1.$$

Again using the functional form (1), the unique solution to these equations can be shown to be

$$\tilde{c}_1^I(y) = \left(\sigma \pi_L + (1-\sigma) \pi_L \left(\frac{\overline{z}(y)}{q_L z_L(y)}\right)^{\frac{1}{\gamma}} + \overline{z}(y)^{\frac{1}{\gamma}}\right)^{-1}, \tag{32}$$

$$c_1^I(y) = \left(\frac{\overline{z}(y)}{q_L z_L(y)}\right)^{\frac{1}{\gamma}} \tilde{c}_1^I(y), \tag{33}$$

$$c_{1s}^I(y) = \left(\frac{\overline{z}(y)}{z_s(y)}\right)^{\frac{1}{\gamma}} \tilde{c}_1^I(y) \quad \text{and} \quad c_{2s}^I(y) = R^{\frac{1}{\gamma}} c_{1s}^I(y) \quad \text{for all } s, \tag{34}$$

$$g_s(y) = \left(\delta \frac{\overline{z}(y)}{z_s(y)}\right)^{\frac{1}{\gamma}} \tilde{c}_1^I(y), \tag{35}$$

where

$$z_s(y) \equiv \left((x_s(y))^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}}\right)^{\gamma}, \tag{36}$$

$$\bar{z}(y) \equiv \sum_{s \in S} q_s z_s(y) \tag{37}$$

and $x_s(y)$ is defined in (30).

Appendix B. Proofs of Propositions

Proposition 1: *Under the policy regime with no intervention, the economy is:*

(a) *weakly fragile if and only if* $c_{2H_\alpha}^{NI}\left(y^E\right) \geq c_1^{NI}\left(y^E\right) \geq c_{2H_\beta}^{NI}\left(y^E\right)$,

(b) *strongly fragile if and only if* $c_1^{NI}\left(y^E\right) > c_{2H_\alpha}^{NI}\left(y^E\right)$, and

(c) *not fragile if and only if* $c_1^{NI}\left(y^E\right) < c_{2H_\beta}^{NI}\left(y^E\right)$.

Proof: For part (a), recall that the economy is defined to be weakly fragile if there exists an equilibrium in which depositors follow the strategy profile y^E in (5). Consider the decision problem of depositor i if she expects all other depositors to follow this profile. Her best response clearly requires withdrawing at $t = 1$ when she is impatient. When she is patient, withdrawing at $t = 1$ in state s is part of a best response if and only if $c_1^{NI}\left(y^E\right) \geq c_{2s}^{NI}\left(y^E\right)$ holds, while withdrawing at $t = 2$ is part of a best response if and only if this inequality is reversed. The definitions in (30) and (31), together with (25) and the inequalities in (26), imply that $\overline{x}(y) \geq x_L(y)$ holds for any $y \in Y$. Using (28), we then have

$$c_1^{NI}(y) < c_{2L}^{NI}(y) \tag{38}$$

for any $y \in Y$ and, hence, the depositor will always choose to wait until $t = 2$ when patient and the fundamental state is L. Therefore, the strategy in profile y^E, where she withdraws early in state H_β but not in H_α, represents a best response if and only if the two inequalities in part (a) of the proposition hold. In this case, there is an equilibrium in which all depositors follow y^E and, hence, the economy is weakly fragile if and only if these inequalities hold.

Before moving to parts (b) and (c) of the proposition, we establish some useful inequalities. Note that the definitions of y^E and $\hat{\pi}_s$ imply

$$\hat{\pi}_{H_\alpha}\left(y^E\right) = \frac{\pi_H - \pi_L}{1 - \pi_L} \quad \text{and} \quad \hat{\pi}_{H_\beta}\left(y^E\right) = \pi_H. \tag{39}$$

The inequalities in (26) thus imply that, of all strategy profiles in the set Y, y^E has the minimum proportion of remaining investors who are impatient in state H_α and the maximum proportion in state H_β. Using the definition of $x_s(y)$ in (30), it follows that for any $y \in Y$, we have

$$x_L(y) = x_L\left(y^E\right) < x_{H_\alpha}\left(y^E\right) \quad \text{and} \tag{40}$$

$$x_{H_\alpha}\left(y^E\right) \leq x_{H_\alpha}(y) \leq x_{H_\beta}(y) \leq x_{H_\beta}\left(y^E\right). \tag{41}$$

We can use the definition of $\bar{x}(y)$ in (31) to write

$$\frac{\bar{x}(y)}{x_{H_\alpha}(y)} = q_L \frac{x_L(y)}{x_{H_\alpha}(y)} + q_{H_\alpha} + q_{H_\beta} \frac{x_{H_\beta}(y)}{x_{H_\alpha}(y)}$$

and

$$\frac{\bar{x}(y)}{x_{H_\beta}(y)} = q_L \frac{x_L(y)}{x_{H_\beta}(y)} + q_{H_\alpha} \frac{x_{H_\alpha}(y)}{x_{H_\beta}(y)} + q_{H_\beta}.$$

Using (40) and (41), it is then straightforward to show that for all $y \in Y$, we have

$$\frac{\bar{x}(y)}{x_{H_\alpha}(y)} \leq \frac{\bar{x}(y^E)}{x_{H_\alpha}(y^E)} \quad \text{and} \quad \frac{\bar{x}(y)}{x_{H_\beta}(y)} \geq \frac{\bar{x}(y^E)}{x_{H_\beta}(y^E)}.$$

In addition, the middle inequality in (41) implies

$$\frac{\bar{x}(y)}{x_{H_\beta}(y)} \leq \frac{\bar{x}(y)}{x_{H_\alpha}(y)}$$

for any $y \in Y$. Combining the two previous lines, we have

$$\frac{\bar{x}(y^E)}{x_{H_\beta}(y^E)} \leq \frac{\bar{x}(y)}{x_{H_\beta}(y)} \leq \frac{\bar{x}(y)}{x_{H_\alpha}(y)} \leq \frac{\bar{x}(y^E)}{x_{H_\alpha}(y^E)} \tag{42}$$

for any $y \in Y$.

Now suppose the inequality in part (b) of the proposition holds. Then the expression for the best-response allocation $\mathbf{c}^{NI}$ in (28) implies

$$\frac{\bar{x}(y^E)}{x_{H_\alpha}(y^E)} < \frac{1}{R}.$$

Using the two right-most inequalities in (42) together with (28), it then follows that

$$c_1^{NI}(y) > c_{2s}^{NI}(y)$$

holds for $s = (H_\alpha, H_\beta)$ and for all $y \in Y$. In other words, if an investor's best response when all other investors are playing y^E requires withdrawing early in state H_α, then her best response to **any** strategy profile in Y will involve withdrawing early whenever the fundamental state is H. As a result, y^F is the only possible equilibrium strategy profile in Y. The fact that y^F is indeed an equilibrium profile follows from these inequalities together with (38). We have, therefore, shown that y^F is the unique equilibrium strategy profile and the economy is strongly fragile.

For the converse, suppose the economy is strongly fragile. Then y^E is not an equilibrium strategy profile and one of the two inequalities in part (a) of the proposition must be violated. Using (28), the fact that y^F is an equilibrium strategy profile implies

$$\frac{\bar{x}\left(y^F\right)}{x_{H_\alpha}\left(y^F\right)} < \frac{1}{R}.$$

It is straightforward to show that $\bar{x}\left(y^F\right) > \bar{x}\left(y^E\right)$ and $x_{H_\alpha}\left(y^F\right) = x_{H_\beta}\left(y^E\right)$. Together with the previous line, these two conditions imply

$$\frac{\bar{x}\left(y^E\right)}{x_{H_\beta}\left(y^E\right)} < \frac{1}{R}.$$

Using (28) again, we then have

$$c_1^{NI}\left(y^E\right) > c_{2H_\beta}^{NI}\left(y^E\right).$$

In other words, when the economy is strongly fragile, the second inequality in part (a) of the proposition is satisfied. The first inequality on that line must, therefore, be violated, which establishes that the inequality in part (b) of the proposition holds.

Now suppose the inequality in part (c) of the proposition holds. Again using the expression for the best-response allocation $\mathbf{c}^{NI}$ in (28), this inequality implies

$$\frac{\bar{x}\left(y^E\right)}{x_{H_\beta}\left(y^E\right)} > \frac{1}{R}.$$

Using (28) and the two left-most inequalities in (42), together with (38), it follows that

$$c_1^{NI}\left(y\right) < c_{2s}^{NI}\left(y\right)$$

for all s and for all $y \in Y$. In other words, if an investor's best response when all other investors are playing y^E involves waiting until $t = 2$ in state H_β if she is patient, then her best response to **any** profile in Y will be to wait until $t = 2$ in all states if she is patient. We have, therefore, established that y^N, defined in (7), is the unique equilibrium strategy profile and the economy is not fragile.

Finally, for the converse, note that if y^N is the unique equilibrium strategy profile, it follows immediately from parts (a) and (b) of the proposition that the inequality in part (c) must hold. ■

Proposition 3: *Under the policy regime with intervention, the economy is:*

(a) *weakly fragile if and only if* $u\left(c^I_{2H_\alpha}\left(y^E\right)\right) \geq \mathcal{E}\left(\mathbf{c}^I\left(y^E\right)\right) \geq u\left(c^I_{2H_\beta}\left(y^E\right)\right)$,

(b) *strongly fragile if and only if* $\mathcal{E}\left(\mathbf{c}^I\left(y^E\right)\right) > u\left(c^I_{2H_\alpha}\left(y^E\right)\right)$, and

(c) *not fragile if and only if* $\mathcal{E}\left(\mathbf{c}^I\left(y^E\right)\right) < u\left(c^I_{2H_\beta}\left(y^E\right)\right)$.

Proof: The proof is broadly similar to that of Proposition 1, but with some important differences. For part (a), consider the decision problem of depositor i if she expects all other depositors to follow the profile y^E in (5). Her best response clearly requires withdrawing at $t = 1$ when she is impatient. When she is patient, withdrawing at $t = 1$ in state s is part of a best response if and only if

$$\mathcal{E}\left(\mathbf{c}^I\left(y^E\right)\right) \geq u\left(c^I_{2s}\left(y^E\right)\right)$$

holds, while withdrawing at $t = 2$ is part of a best response if and only if this inequality is reversed. Using (22) together with the definition (23) and the expressions for the best-response allocation $\mathbf{c}^I$ in (33) - (34), it is straightforward to show that

$$\mathcal{E}\left(\mathbf{c}^I\left(y\right)\right) \leq u\left(c^I_{2L}\left(y\right)\right) \tag{43}$$

holds for any $y \in Y$ and, hence, the depositor will always choose to wait until $t = 2$ when she is patient and the fundamental state is L. The strategy in profile y^E, under which she withdraws early in state H_β but not in H_α, then represents a best response if and only if the two inequalities in part (a) of the proposition hold. In this case, there is an equilibrium in which investors follow y^E and, hence, the economy is weakly fragile if and only if these two inequalities hold.

Next, note that the definition of $z_s\left(y\right)$ in (36) combined with (40) and (41) implies that for any $y \in Y$, we have

$$\begin{aligned} z_L\left(y\right) &= z_L\left(y^E\right) < z_{H_\alpha}\left(y^E\right) \quad \text{and} & (44)\\ z_{H_\alpha}\left(y^E\right) &\leq z_{H_\alpha}\left(y\right) \leq z_{H_\beta}\left(y\right) \leq z_{H_\beta}\left(y^E\right). & (45)\end{aligned}$$

In addition, using the same steps that led to (42), we can show

$$\frac{\bar{z}\left(y^E\right)}{z_{H_\beta}\left(y^E\right)} \leq \frac{\bar{z}\left(y\right)}{z_{H_\beta}\left(y\right)} \leq \frac{\bar{z}\left(y\right)}{z_{H_\alpha}\left(y\right)} \leq \frac{\bar{z}\left(y^E\right)}{z_{H_\alpha}\left(y^E\right)}. \tag{46}$$

Suppose the inequality in part (b) of the proposition holds. Using (23) together with the expressions for the best-response allocation $\mathbf{c}^I$ in (33) - (34), and recalling that $\gamma > 1$, this inequality implies

$$\sigma + (1-\sigma)\left(\frac{\bar{z}\left(y^E\right)}{q_L z_L\left(y^E\right)}\right)^{\frac{1-\gamma}{\gamma}} < R^{\frac{1-\gamma}{\gamma}}\left(\frac{\bar{z}\left(y^E\right)}{z_{H_\alpha}\left(y^E\right)}\right)^{\frac{1-\gamma}{\gamma}}$$

or

$$\sigma\left(\frac{\bar{z}\left(y^E\right)}{z_{H_\alpha}\left(y^E\right)}\right)^{\frac{\gamma-1}{\gamma}} + (1-\sigma)\left(\frac{q_L z_L\left(y^E\right)}{z_{H_\alpha}\left(y^E\right)}\right)^{\frac{\gamma-1}{\gamma}} < R^{\frac{1-\gamma}{\gamma}}.$$

Combined with (44) and (45), we then have

$$\sigma\left(\frac{\bar{z}(y)}{z_s(y)}\right)^{\frac{\gamma-1}{\gamma}} + (1-\sigma)\left(\frac{q_L z_L(y)}{z_s(y)}\right)^{\frac{\gamma-1}{\gamma}} < R^{\frac{1-\gamma}{\gamma}}$$

for $s = (H_\alpha, H_\beta)$ and for all $y \in Y$. Again using (23) and (33) - (34), this inequality implies that

$$\mathcal{E}\left(\mathbf{c}^I(y)\right) > u\left(c_{2s}^I(y)\right)$$

holds for $s = (H_\alpha, H_\beta)$ and for all $y \in Y$. In other words, if an investor's best response when all other investors are playing y^E requires withdrawing early in state H_α, then her best response to **any** strategy profile in Y will involve withdrawing early whenever the fundamental state is H. As a result, y^F is the only possible equilibrium strategy profile in Y. The fact that y^F is indeed an equilibrium profile follows from these inequalities together with (43). We have, therefore, shown that y^F is the unique equilibrium strategy profile and the economy is strongly fragile.

For the converse, suppose the economy is strongly fragile. Then y^E is not an equilibrium strategy profile and one of the two inequalities in part (a) of the proposition must be violated. Using (33) - (34), the fact that y^F is an equilibrium strategy profile implies

$$\sigma\left(\frac{\bar{z}\left(y^F\right)}{z_{H_\alpha}\left(y^F\right)}\right)^{\frac{\gamma-1}{\gamma}} + (1-\sigma)\left(\frac{q_L z_L\left(y^F\right)}{z_{H_\alpha}\left(y^F\right)}\right)^{\frac{\gamma-1}{\gamma}} < R^{\frac{1-\gamma}{\gamma}}.$$

Using the definitions in (36) and (37), it is easy to show that $\bar{z}\left(y^F\right) > \bar{z}\left(y^E\right)$, $z_L\left(y^F\right) = z_L\left(y^E\right)$ and $z_{H_\alpha}\left(y^F\right) = z_{H_\beta}\left(y^E\right)$. Together with the previous line, these three conditions imply

$$\sigma\left(\frac{\bar{z}\left(y^E\right)}{z_{H_\beta}\left(y^E\right)}\right)^{\frac{\gamma-1}{\gamma}} + (1-\sigma)\left(\frac{q_L z_L\left(y^E\right)}{z_{H_\beta}\left(y^E\right)}\right)^{\frac{\gamma-1}{\gamma}} < R^{\frac{1-\gamma}{\gamma}}.$$

Using (33) and (34) again, we then have

$$\mathcal{E}\left(\mathbf{c}^I\left(y^E\right)\right) > u\left(c^I_{2H_\beta}\left(y\right)\right).$$

In other words, when the economy is strongly fragile, the second inequality in part (a) of the proposition is satisfied. The first inequality on that line must, therefore, be violated, which establishes that the inequality in part (b) of the proposition holds.

Now suppose the inequality in part (c) of the proposition holds. Again using (23) together with (33) and (34), this inequality implies

$$\sigma + (1-\sigma)\left(\frac{\bar{z}\left(y^E\right)}{q_L z_L\left(y^E\right)}\right)^{\frac{1-\gamma}{\gamma}} > R^{\frac{1-\gamma}{\gamma}}\left(\frac{\bar{z}\left(y^E\right)}{z_{H_\beta}\left(y^E\right)}\right)^{\frac{1-\gamma}{\gamma}}$$

or

$$\sigma\left(\frac{\bar{z}\left(y^E\right)}{z_{H_\beta}\left(y^E\right)}\right)^{\frac{\gamma-1}{\gamma}} + (1-\sigma)\left(\frac{q_L z_L\left(y^E\right)}{z_{H_\beta}\left(y^E\right)}\right)^{\frac{\gamma-1}{\gamma}} > R^{\frac{1-\gamma}{\gamma}}.$$

Using the inequalities in (44) - (46), we then have

$$\sigma\left(\frac{\bar{z}\left(y\right)}{z_s\left(y\right)}\right)^{\frac{\gamma-1}{\gamma}} + (1-\sigma)\left(\frac{q_L z_L\left(y\right)}{z_s\left(y\right)}\right)^{\frac{\gamma-1}{\gamma}} > R^{\frac{1-\gamma}{\gamma}}$$

for $s = (H_\alpha, H_\beta)$ and for all $y \in Y$. Using (33) and (34) together with the definition (23) and the inequality in (43), we then have

$$\mathcal{E}\left(\mathbf{c}^I\left(y\right)\right) < u\left(c^I_{2s}\left(y\right)\right)$$

for all s and for all $y \in Y$. In other words, if an investor's best response when all other investors are playing y^E involves waiting until $t = 2$ in state H_β if she is patient, then her best response to **any** profile in Y will be to wait until $t = 2$ in all states if she is patient. This fact establishes that y^N is the unique equilibrium strategy profile and the economy is not fragile.

Finally, for the converse, note that if y^N is the unique equilibrium strategy profile, it follows immediately from parts (a) and (b) of the proposition that the inequality in part (c) must hold. ■

Proposition 4: *Under the policy regime with intervention, the fragility type of an economy* (e, σ) *is weakly decreasing in* σ.

Proof: To establish this result, we need to show that for any e and any $\sigma' > \sigma$,

(a) if (e, σ) is not fragile, then (e, σ') is not fragile, and

(b) if (e, σ) is weakly fragile, then (e, σ') is either weakly fragile or not fragile.

For part (a), if (e, σ) is not fragile, then from Proposition 3 we have

$$\mathcal{E}\left(\mathbf{c}^I\left(y^E;\sigma\right)\right) < u\left(c^I_{2H_\beta}\left(y^E;\sigma\right)\right).$$

Using the definition in (23) and the expressions for the best-response allocation $\mathbf{c}^I$ in (33) and (34), this inequality is equivalent to

$$\sigma + (1-\sigma)\left(\frac{\bar{z}\left(y^E\right)}{q_L z_L\left(y^E\right)}\right)^{\frac{1-\gamma}{\gamma}} > R^{\frac{1-\gamma}{\gamma}}\left(\frac{\bar{z}\left(y^E\right)}{z_{H_\beta}\left(y^E\right)}\right)^{\frac{1-\gamma}{\gamma}}.$$

The definitions of z_s and $\bar{z}$ in (36) and (37) show that these terms are independent of σ. Moreover, $\bar{z}\left(y^E\right) > q_L z_L\left(y^E\right)$ and $\gamma > 1$ imply that the left-hand side of this inequality is strictly increasing in σ. Therefore, for any $\sigma' > \sigma$ we have

$$\sigma' + (1-\sigma')\left(\frac{\bar{z}\left(y^E\right)}{q_L z_L\left(y^E\right)}\right)^{\frac{1-\gamma}{\gamma}} > R^{\frac{1-\gamma}{\gamma}}\left(\frac{\bar{z}\left(y^E\right)}{z_{H_\beta}\left(y^E\right)}\right)^{\frac{1-\gamma}{\gamma}}.$$

Again using (23), (33), and (34), this inequality implies

$$\mathcal{E}\left(\mathbf{c}^I\left(y^E;\sigma'\right)\right) < u\left(c^I_{2H_\beta}\left(y^E;\sigma'\right)\right),$$

which establishes that economy (e, σ') is not fragile as well.

The argument for part (b) is similar. If (e, σ) is weakly fragile, then we have

$$\mathcal{E}\left(\mathbf{c}^I\left(y^E;\sigma\right)\right) \leq u\left(c^I_{2H_\alpha}\left(y^E;\sigma\right)\right).$$

Following the same steps used in part (a) then shows that for any any $\sigma' > \sigma$, we have

$$\mathcal{E}\left(\mathbf{c}^I\left(y^E;\sigma'\right)\right) < u\left(c^I_{2H_\alpha}\left(y^E;\sigma'\right)\right).$$

This inequality establishes that the economy (e, σ') is not strongly fragile, implying that it is either weakly fragile or not fragile, as desired. ■

Proposition 5: *Under the policy regime with intervention, if* (24) *holds, then for any* e *there exists* $\bar{\sigma} < 1$ *such that the fragility type of all economies* (e, σ) with $\sigma > \bar{\sigma}$ *is weakly decreasing in* δ.

Proof: Let e' denote a vector of parameters that differs from e only in the parameter δ, with $\delta' > \delta$.

To establish the result, we need to show there exists $\bar{\sigma} < 1$ such that $\sigma > \bar{\sigma}$ implies

(a) if (e, σ) is not fragile, then (e', σ) is not fragile, and

(b) if (e, σ) is weakly fragile, then (e', σ) is either weakly fragile or not fragile.

The proof is divided into three steps.

Step (i) : Establish part (a) . If (e, σ) is not fragile, then from Proposition 3 we have

$$\mathcal{E}\left(\mathbf{c}^I\left(y^E; e\right)\right) < u\left(c^I_{2H_\beta}\left(y^E; e\right)\right).$$

Using the definition in (23) and dividing both sides by $u\left(c^I_{2H_\beta}\right)$, this inequality can be written as[17]

$$\sigma\frac{u\left(\tilde{c}^I_1\left(y^E; e\right)\right)}{u\left(c^I_{2H_\beta}\left(y^E; e\right)\right)} + (1-\sigma)\frac{u\left(c^I_1\left(y^E; e\right)\right)}{u\left(c^I_{2H_\beta}\left(y^E; e\right)\right)} > 1.$$

Using the expressions in (33) and (34), this inequality reduces to

$$\sigma\left(R\frac{\bar{z}\left(y^E; e\right)}{z_{H_\beta}\left(y^E; e\right)}\right)^{\frac{\gamma-1}{\gamma}} + (1-\sigma)\left(R\frac{q_L z_L\left(y^E; e\right)}{z_{H_\beta}\left(y^E; e\right)}\right)^{\frac{\gamma-1}{\gamma}} > 1. \tag{47}$$

Using the definitions in (36) and (37), the ratio of $\bar{z}(y)$ to $z_{H_\beta}(y)$ for any y can be written as

$$\frac{\bar{z}(y)}{z_{H_\beta}(y)} = q_L\left(\frac{x_L(y)^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}}}{x_{H_\beta}(y)^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}}}\right)^{\gamma} + q_{H_\alpha}\left(\frac{x_{H_\alpha}(y)^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}}}{x_{H_\beta}(y)^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}}}\right)^{\gamma} + q_{H_\beta}.$$

The definitions in (30) show that $x_s(y)$ is independent of δ for all s. It is then straightforward to show that (41) implies this expression is strictly increasing in δ for any y. Therefore, since e' differs from e only in that $\delta' > \delta$, we have

$$R\frac{\bar{z}\left(y^E; e'\right)}{z_{H_\beta}\left(y^E; e'\right)} > R\frac{\bar{z}\left(y^E; e\right)}{z_{H_\beta}\left(y^E; e\right)}. \tag{48}$$

The same steps can be used to show that the ratio of $z_L(y)$ to $z_{H_\beta}(y)$ is strictly increasing in δ for any y. Combining this fact with (47) and (48) yields

$$\sigma\left(R\frac{\bar{z}\left(y^E; e'\right)}{z_{H_\beta}\left(y^E; e'\right)}\right)^{\frac{\gamma-1}{\gamma}} + (1-\sigma)\left(R\frac{q_L z_L\left(y^E; e'\right)}{z_{H_\beta}\left(y^E; e'\right)}\right)^{\frac{\gamma-1}{\gamma}} > 1.$$

[17] Recall that $\gamma > 1$ implies $u(c)$ is a negative number, which is why the inequality reverses direction in this step.

Using (33) and (34) together with the definition in (23), we then have

$$\mathcal{E}\left(\mathbf{c}^I\left(y^E;e'\right)\right) < u\left(c^I_{2H_\beta}\left(y^E;e'\right)\right),$$

which establishes that the economy (e',σ) is also not fragile. Note that no restriction on σ is required for this step of the proof.

Step (ii) : Establish a useful intermediate result: If (24) holds and the ratio $R\bar{z}\left(y^E\right)/z_{H_\alpha}\left(y^E\right)$ is greater than 1 for some value of δ, then it is greater than 1 for all $\delta' > \delta$. We establish this result by showing that whenever this ratio is smaller than 1, the ratio is a strictly increasing function of δ. Since the ratio is a continuously differentiable function of δ, its value can never cross 1 from above as δ is increased.

We begin this step by using the definitions in (36) and (37) to show that $R\bar{z}\left(y^E\right)/z_{H_\alpha}\left(y^E\right) < 1$ is equivalent to[18]

$$\frac{\bar{z}}{z_{H_\alpha}} = q_L\left(\frac{(x_L)^{\frac{1}{\gamma}}+\delta^{\frac{1}{\gamma}}}{(x_{H_\alpha})^{\frac{1}{\gamma}}+\delta^{\frac{1}{\gamma}}}\right)^{\gamma} + q_{H_\alpha} + q_{H_\beta}\left(\frac{(x_{H_\beta})^{\frac{1}{\gamma}}+\delta^{\frac{1}{\gamma}}}{(x_{H_\alpha})^{\frac{1}{\gamma}}+\delta^{\frac{1}{\gamma}}}\right)^{\gamma} < \frac{1}{R}. \tag{49}$$

This expression is a differentiable function of δ for all $\delta > 0$ and we can write the derivative as

$$\frac{d}{d\delta}\left(\frac{\bar{z}}{z_{H_\alpha}}\right) = \delta^{\frac{1-\gamma}{\gamma}}\left(z_{H_\alpha}\right)^{-\frac{2}{\gamma}}\left(\begin{array}{c} q_L\left(\frac{z_L}{z_{H_\alpha}}\right)^{\frac{\gamma-1}{\gamma}}\left((x_{H_\alpha})^{\frac{1}{\gamma}}-(x_L)^{\frac{1}{\gamma}}\right) \\ -q_{H_\beta}\left(\frac{z_{H_\beta}}{z_{H_\alpha}}\right)^{\frac{\gamma-1}{\gamma}}\left((x_{H_\beta})^{\frac{1}{\gamma}}-(x_{H_\alpha})^{\frac{1}{\gamma}}\right)\end{array}\right). \tag{50}$$

In general, the sign of this expression can be either positive or negative. Our interest, however, is in signing the expression when condition (49) holds. We can rewrite (49) as

$$q_{H_\beta}\frac{z_{H_\beta}}{z_{H_\alpha}} < \frac{1}{R} - q_{H_\alpha} - q_L\frac{z_L}{z_{H_\alpha}}.$$

Combined with (50), we then have

$$\frac{d}{d\delta}\left(\frac{\bar{z}}{z_{H_\alpha}}\right) > \delta^{\frac{1-\gamma}{\gamma}}\left(z_{H_\alpha}\right)^{-\frac{2}{\gamma}}\left(\begin{array}{c} q_L\left(\frac{z_L}{z_{H_\alpha}}\right)^{\frac{\gamma-1}{\gamma}}\left((x_{H_\alpha})^{\frac{1}{\gamma}}-(x_L)^{\frac{1}{\gamma}}\right) \\ -\left[\frac{1}{R}-q_{H_\alpha}-q_L\frac{z_L}{z_{H_\alpha}}\right]\left(\frac{z_{H_\beta}}{z_{H_\alpha}}\right)^{-\frac{1}{\gamma}}\left((x_{H_\beta})^{\frac{1}{\gamma}}-(x_{H_\alpha})^{\frac{1}{\gamma}}\right)\end{array}\right) \tag{51}$$

[18] The terms z_s and x_s are all evaluated at the strategy profile y^E throughout this step. We omit this dependence from the notation here to save space.

The inequalities in (44) and (45) imply

$$\left(\frac{z_L}{z_{H_\alpha}}\right)^{-\frac{1}{\gamma}} > \left(\frac{z_{H_\beta}}{z_{H_\alpha}}\right)^{-\frac{1}{\gamma}}.$$

Using this inequality to replace the penultimate term in (51) and simplifying, we have

$$\frac{d}{d\delta}\left(\frac{\bar{z}}{z_{H_\alpha}}\right) > \delta^{\frac{1-\gamma}{\gamma}} \left(z_{H_\alpha}\right)^{-\frac{2}{\gamma}} \left(\begin{array}{c} q_L \left(\frac{z_L}{z_{H_\alpha}}\right)^{\frac{\gamma-1}{\gamma}} \left(\left(x_{H_\beta}\right)^{\frac{1}{\gamma}} - \left(x_L\right)^{\frac{1}{\gamma}}\right) \\ -\left[\frac{1}{R} - q_{H_\alpha}\right] \left(\frac{z_L}{z_{H_\alpha}}\right)^{-\frac{1}{\gamma}} \left(\left(x_{H_\beta}\right)^{\frac{1}{\gamma}} - \left(x_{H_\alpha}\right)^{\frac{1}{\gamma}}\right) \end{array}\right). \tag{52}$$

Note that (22) implies $q_L \geq 1/R$ and, therefore, a sufficient condition for the derivative in (52) to be positive is

$$\frac{1}{R}\left(\frac{z_L}{z_{H_\alpha}}\right)^{\frac{\gamma-1}{\gamma}} \left(\left(x_{H_\beta}\right)^{\frac{1}{\gamma}} - \left(x_L\right)^{\frac{1}{\gamma}}\right) > \left[\frac{1}{R} - q_{H_\alpha}\right] \left(\frac{z_L}{z_{H_\alpha}}\right)^{-\frac{1}{\gamma}} \left(\left(x_{H_\beta}\right)^{\frac{1}{\gamma}} - \left(x_{H_\alpha}\right)^{\frac{1}{\gamma}}\right).$$

Using the definitions (30) and (36) together with (25) and (39), it is straightforward to show that this inequality is equivalent to (24). In other words, as long as (24) holds, we have established that the ratio $R\bar{z}\left(y^E\right)/z_{H_\alpha}\left(y^E\right)$ strictly increasing in δ whenever the value of the ratio is less than 1. If the ratio is greater than 1 for some value of δ, therefore, it must be greater than 1 for all $\delta' > \delta$ since continuity implies that it cannot cross 1 from above as δ is increased.

Step (iii) : Establish part (b). If the economy (e, σ) is weakly fragile, then from Proposition 3 we have

$$\mathcal{E}\left(\mathbf{c}^I\left(y^E; e\right)\right) \leq u\left(c^I_{2H_\alpha}\left(y^E; e\right)\right).$$

Following the same approach as in step (i) above, this inequality can be written as

$$\sigma\left(R\frac{\bar{z}\left(y^E; e\right)}{z_{H_\alpha}\left(y^E; e\right)}\right)^{\frac{\gamma-1}{\gamma}} + (1-\sigma)\left(R\frac{q_L z_L\left(y^E; e\right)}{z_{H_\alpha}\left(y^E; e\right)}\right)^{\frac{\gamma-1}{\gamma}} \geq 1. \tag{53}$$

It follows immediately from the definition of $\bar{z}$ in (37) that $\bar{z}(y) > q_L z_L(y)$ holds for any y. If the inequality in (53) holds, therefore, it must be the case that

$$R\frac{\bar{z}\left(y^E; e\right)}{z_{H_\alpha}\left(y^E; e\right)} > 1.$$

The result from step (ii) above together with $\delta' > \delta$ then implies

$$R\frac{\bar{z}\left(y^E; e'\right)}{z_{H_\alpha}\left(y^E; e'\right)} > 1.$$

It follows from continuity that we can find $\bar{\sigma} < 1$ such that if $\sigma > \bar{\sigma}$, we have

$$\sigma\left(R\frac{\bar{z}\left(y^E; e'\right)}{z_{H_\alpha}\left(y^E; e'\right)}\right)^{\frac{\gamma-1}{\gamma}} + (1-\sigma)\left(R\frac{q_L z_L\left(y^E; e'\right)}{z_{H_\alpha}\left(y^E; e'\right)}\right)^{\frac{\gamma-1}{\gamma}} > 1.$$

Using (23), (33) and (34), we then have

$$\mathcal{E}\left(\mathbf{c}^I\left(y^E; e'\right)\right) < u\left(c^I_{2H_\alpha}\left(y^E; e'\right)\right).$$

By Proposition 3, this inequality demonstrates that the economy (e', σ) is not strongly fragile, implying that it is either weakly fragile or not fragile, as desired. ■

Lemma 1: *For any* e *with* $\delta > 0$ *and any* $y \in Y$, *there exists* $\overline{\sigma} < 1$ *such that* $W^I(y) > W^{NI}(y)$ *for all economies* (e, σ) *with* $\sigma > \overline{\sigma}$.

Proof: The proof of this lemma is divided into four steps as follows.

Step (i) : Calculate the level of welfare associated with y under policy regime NI. For this case, the value of the objective function (2) can be written as a function of the elements of the best-response allocation vector $\mathbf{c}^{NI}$ as follows:[19]

$$W^{NI}(y) = \pi_L u\left(c_1^{NI}\right) + (1-\pi_L)\sum_{s\in S} q_s\left(\hat{\pi}_s u\left(c_{1s}^{NI}\right) + (1-\hat{\pi}_s)\, u\left(c_{2s}^{NI}\right)\right) + v\left(g^{NI}\right).$$

Using the solutions in (27) - (29) and simplifying terms, this expression can be reduced to

$$W^{NI}(y) = \frac{1}{1-\gamma}\left(\pi_L + \delta^{\frac{1}{\gamma}} + \bar{x}^{\frac{1}{\gamma}}\right)^{\gamma}. \tag{54}$$

Step (ii) : Find a lower bound for the welfare level associated with y under regime I. The value of the objective function (2) in this case can be written as

$$\begin{aligned} W^I(y) &= \sigma\pi_L u\left(\tilde{c}_1^I\right) + (1-\sigma)\,\pi_L u\left(c_1^I\right) + \\ & \sum_{s\in S} q_s\left((1-\pi_L)\left(\hat{\pi}_s u\left(c_{1s}^I\right) + (1-\hat{\pi}_s)\, u\left(c_{2s}^I\right)\right) + v\left(g_s^I\right)\right). \end{aligned}$$

[19] Note that each element of $\mathbf{c}^{NI}$ depends on the profile of withdrawal strategies y, but the dependence is omitted in this expression to save space. The same is true for the terms x_s and z_s in the equations that follow.

Using the solutions in (32) - (35) and simplifying terms, this expression can be reduced to

$$W^I(y) = \frac{1}{1-\gamma} \frac{\sigma\pi_L + (1-\sigma)\pi_L \left(\frac{\bar{z}}{q_L z_L}\right)^{\frac{1-\gamma}{\gamma}} + \bar{z}^{\frac{1}{\gamma}}}{\left(\sigma\pi_L + (1-\sigma)\pi_L \left(\frac{\bar{z}}{q_L z_L}\right)^{\frac{1}{\gamma}} + \bar{z}^{\frac{1}{\gamma}}\right)^{1-\gamma}}. \tag{55}$$

The definition of $\bar{z}$ in (37) shows that $\bar{z} > q_L z_L$ holds. Using this fact and $\gamma > 1$, we have

$$\left(\frac{\bar{z}}{q_L z_L}\right)^{\frac{1-\gamma}{\gamma}} < \left(\frac{\bar{z}}{q_L z_L}\right)^{\frac{1}{\gamma}}$$

and, therefore,

$$W^I(y) > \frac{1}{1-\gamma} \left(\sigma\pi_L + (1-\sigma)\pi_L \left(\frac{\bar{z}}{q_L z_L}\right)^{\frac{1}{\gamma}} + \bar{z}^{\frac{1}{\gamma}}\right)^{\gamma}.$$

Step (iii) : Establish a useful intermediate result. Define

$$h(\delta) \equiv \bar{x}^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}} - \bar{z}^{\frac{1}{\gamma}}.$$

Using the definitions of $\bar{x}$ and $\bar{z}$ in (31) and (37), we then have

$$h(\delta) = \left(\sum_{s\in S} q_s x_s\right)^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}} - \left(\sum_{s\in S} q_s \left((x_s)^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}}\right)^{\gamma}\right)^{\frac{1}{\gamma}}.$$

It is easy to see from this expression that $g(0) = 0$. Differentiating with respect to δ and simplifying terms yields

$$h'(\delta) = \frac{1}{\gamma}\delta^{\frac{1-\gamma}{\gamma}} \left[1 - \frac{\sum_{s\in S} q_s \left((x_s)^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}}\right)^{\gamma-1}}{\left(\sum_{s\in S} q_s \left((x_s)^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}}\right)^{\gamma}\right)^{\frac{\gamma-1}{\gamma}}}\right]. \tag{56}$$

Note that for any distinct numbers $\{d_s\} > 0$ and $\varepsilon > 1$, Jensen's inequality implies

$$\sum_{s\in S} q_s d_s < \left(\sum_{s\in S} q_s d_s^{\varepsilon}\right)^{\frac{1}{\varepsilon}}.$$

Setting

$$d_s = \left((x_s)^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}}\right)^{\gamma-1} \qquad \text{and} \qquad \varepsilon = \frac{\gamma}{\gamma-1},$$

we then have

$$\sum_{s\in S} q_s \left((x_s)^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}} \right)^{\gamma-1} < \left(\sum_{s\in S} q_s \left((x_s)^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}} \right)^{\gamma} \right)^{\frac{\gamma-1}{\gamma}}$$

for all $\delta > 0$, which implies that the term in the square brackets in (56) is strictly positive. In other words, we have established that function h is strictly positive and strictly increasing for all $\delta > 0$.

Step (iv) : Find $\bar{\sigma}$ such that $\sigma > \bar{\sigma}$ implies welfare is necessarily higher with intervention. Using the expressions above, a sufficient condition for $W^I(y)$ to be larger than $W^{NI}(y)$ is

$$\frac{1}{1-\gamma} \left(\sigma\pi_L + (1-\sigma)\pi_L \left(\frac{\bar{z}}{q_L z_L} \right)^{\frac{1}{\gamma}} + \bar{z}^{\frac{1}{\gamma}} \right)^{\gamma} > \frac{1}{1-\gamma} \left(\pi_L + \delta^{\frac{1}{\gamma}} + \bar{x}^{\frac{1}{\gamma}} \right)^{\gamma}$$

or

$$\sigma\pi_L + (1-\sigma)\pi_L \left(\frac{\bar{z}}{q_L z_L} \right)^{\frac{1}{\gamma}} + \bar{z}^{\frac{1}{\gamma}} < \pi_L + \delta^{\frac{1}{\gamma}} + \bar{x}^{\frac{1}{\gamma}}$$

or

$$(1-\sigma)\pi_L \left(\left(\frac{\bar{z}}{q_L z_L} \right)^{\frac{1}{\gamma}} - 1 \right) < \bar{x}^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}} - \bar{z}^{\frac{1}{\gamma}} = h(\delta).$$

In step (iii) we showed that $h(\delta) > 0$ for all $\delta > 0$. The definitions of $\bar{x}$, $\bar{z}$, and z_L in (31), (36), and (37) show that each of these terms is independent of σ. Therefore, if we define

$$\bar{\sigma} \equiv 1 - \left[\frac{\bar{x}^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}} - \bar{z}^{\frac{1}{\gamma}}}{\pi_L \left(\left(\frac{\bar{z}}{q_L z_L} \right)^{\frac{1}{\gamma}} - 1 \right)} \right] < 1,$$

then $\sigma > \bar{\sigma}$ implies that welfare is strictly higher under the policy regime with intervention, as desired. ■

Lemma 2: *Assume* (24) *holds. For any* e with $\delta > 0$, *there exists* $\overline{\sigma} < 1$ *such that allowing intervention weakly reduces the fragility type of all economies* (e, σ) with $\sigma > \overline{\sigma}$.

Proof: To establish this result, we need to show that for any e with $\delta > 0$, there exists $\bar{\sigma} < 1$ such that $\sigma > \bar{\sigma}$ implies

(a) if (e, σ) is not fragile under NI, it is not fragile under I, and

(b) if (e, σ) is weakly fragile under NI, it is either weakly fragile or not fragile under I.

For part (a), if (e, σ) is not fragile under regime NI, then by Proposition 1 we know $c_1^{NI}(y^E) <$

$c_{2H_\beta}^{NI}\left(y^E\right)$ holds. Using (28), we then have

$$\frac{\bar{x}\left(y^E\right)}{x_{H_\beta}\left(y^E\right)} = q_L \frac{x_L\left(y^E\right)}{x_{H_\beta}\left(y^E\right)} + q_{H_\alpha} \frac{x_{H_\alpha}\left(y^E\right)}{x_{H_\beta}\left(y^E\right)} + q_{H_\beta} > \frac{1}{R}. \tag{57}$$

Note that all of the terms in this expression are independent of the parameter δ. Next, the ratio of $\bar{z}\left(y^E\right)$ to $z_{H_\beta}\left(y^E\right)$ can be written as

$$\frac{\bar{z}\left(y^E\right)}{z_{H_\beta}\left(y^E\right)} = q_L \left(\frac{x_L\left(y^E\right)^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}}}{x_{H_\beta}\left(y^E\right)^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}}}\right)^\gamma + q_{H_\alpha} \left(\frac{x_{H_\alpha}\left(y^E\right)^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}}}{x_{H_\beta}\left(y^E\right)^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}}}\right)^\gamma + q_{H_\beta}. \tag{58}$$

This ratio is identical to the one in (57) when δ is set to zero. Moreover, it is straightforward to show that (41) implies that (58) is strictly increasing in δ. It follow that for any economy in which (57) holds, we also have

$$\frac{\bar{z}\left(y^E\right)}{z_{H_\beta}\left(y^E\right)} > \frac{1}{R}.$$

Using (34), we then have $\tilde{c}_1^I\left(y^E\right) < c_{2H_\beta}^I\left(y^E\right)$. Continuity and (23) then imply that we can find $\bar{\sigma} < 1$ such that $\sigma > \bar{\sigma}$ implies

$$\mathcal{E}\left(\mathbf{c}^I\left(y^E;\sigma\right)\right) < u\left(c_{2H_\beta}^I\left(y^E;\sigma\right)\right),$$

which, by Proposition 2, shows that (e,σ) is not fragile under policy regime I.

For part (b), if the economy is weakly fragile under regime NI, then by Proposition 1 we know that $c_1^{NI}\left(y^E\right) \leq c_{2H_\alpha}^{NI}\left(y^E\right)$ holds. Using (28), we then have

$$\frac{\bar{x}\left(y^E\right)}{x_{H_\alpha}\left(y^E\right)} = q_L \frac{x_L\left(y^E\right)}{x_{H_\alpha}\left(y^E\right)} + q_{H_\alpha} + q_{H_\beta} \frac{x_{H_\beta}\left(y^E\right)}{x_{H_\alpha}\left(y^E\right)} \geq \frac{1}{R}. \tag{59}$$

Note that, as with (57), all of the terms in this expression are independent of the parameter δ. Next, the ratio of $\bar{z}\left(y^E\right)$ to $z_{H_\alpha}\left(y^E\right)$ can be written as

$$\frac{\bar{z}\left(y^E\right)}{z_{H_\alpha}\left(y^E\right)} = q_L \left(\frac{x_L\left(y^E\right)^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}}}{x_{H_\alpha}\left(y^E\right)^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}}}\right)^\gamma + q_{H_\alpha} + q_{H_\beta} \left(\frac{x_{H_\beta}\left(y^E\right)^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}}}{x_{H_\alpha}\left(y^E\right)^{\frac{1}{\gamma}} + \delta^{\frac{1}{\gamma}}}\right)^\gamma. \tag{60}$$

This ratio is identical to the one in (59) when δ is set to zero. Moreover, step (ii) in the proof of Proposition 5 establishes that, assuming (24) holds, whenever the ratio $\bar{z}\left(y^E\right)/z_{H_\alpha}\left(y^E\right)$ is less than $1/R$, it is strictly increasing in δ.[20] Starting from (59), which is independent of δ, and using the fact that this ratio is a continuously differentiable function of δ, it follows that

$$\frac{\bar{z}\left(y^E\right)}{z_{H_\alpha}\left(y^E\right)} \geq \frac{1}{R} \tag{61}$$

holds for any $\delta > 0$. Therefore, any economy for which (59) holds will also satisfy (61) and, using (34), will necessarily have $\tilde{c}_1^I\left(y^E\right) \leq c_{2H_\alpha}^I\left(y^E\right)$. Following the same logic as in step (i) above, continuity and (23) then imply that we can find $\bar{\sigma} < 1$ such that $\sigma > \bar{\sigma}$ implies

$$\mathcal{E}\left(\mathbf{c}^I\left(y^E;\sigma\right)\right) \leq u\left(c_{2H_\alpha}^I\left(y^E;\sigma\right)\right).$$

By Proposition 2, therefore, the economy is not strongly fragile under regime I, implying that it is either weakly fragile or not fragile, which completes the proof. ■

Proposition 6: *Assume* (24) *holds. For any* e *with* $\delta > 0$, *there exists* $\overline{\sigma} < 1$ *such that allowing intervention strictly increases equilibrium welfare for all economies* (e, σ) with $\sigma > \overline{\sigma}$.

Proof: The proof of the proposition is divided into two steps.

Step (i): Show $W^P\left(y^N\right) > W^P\left(y^E\right) > W^P\left(y^F\right)$ *for* $P = NI, I$.

Proof: Using the definitions of these three strategy profiles in (5) – (7), together with the definition of $\hat{\pi}_s(y)$ as the fraction of the remaining depositors who are impatient after π_L withdrawals have been made, we have

$$\begin{aligned}\hat{\pi}_{H_\alpha}\left(y^N\right) &= \hat{\pi}_{H_\alpha}\left(y^E\right) < \hat{\pi}_{H_\alpha}\left(y^F\right), \quad \text{and} \\ \hat{\pi}_{H_\beta}\left(y^N\right) &< \hat{\pi}_{H_\beta}\left(y^E\right) = \hat{\pi}_{H_\beta}\left(y^F\right).\end{aligned}$$

[20] The role of assumption (24) in the analysis can be seen by comparing equations (58) and (60). The expression in (58) is always a strictly increasing function of δ, which implies that when σ is close to 1 and the incentive distortions associated with bailouts are small, having a larger public sector always reduces the incentive for depositors to run in state H_β. Working with the expression in (60) shows that the same is **not** true in state H_α. The larger bailout payments associated with a higher value of δ will lead the policy maker to be less conservative in setting the early payment $\tilde{c}_1$. In some cases, the ratio $\tilde{c}_1/c_{2H_\alpha}$ will actually *rise* when δ is increased, meaning that larger bailouts can *increase* the incentive for depositors to run in state H_α. Step (ii) of the proof shows that this effect cannot arise when the economy is strongly fragile if (24) holds. In step (iii), we use this intermediate result to show that allowing intervention cannot move the economy from weakly fragile to strongly fragile when σ is close to 1 and (24) holds, which allows us to establish the desirability of allowing intervention in such cases in Proposition 6 below.

Using (25) and the definition of $\bar{x}(y)$ in (31), we then have

$$\bar{x}\left(y^N\right) < \bar{x}\left(y^E\right) < \bar{x}\left(y^F\right). \tag{62}$$

Equation (54) shows that the level of welfare generated by the best-response allocation $\mathbf{c}^{NI}$ is a strictly decreasing function of $\bar{x}(y)$ (recall that $\gamma > 1$). Therefore, we have

$$W^{NI}\left(y^N\right) > W^{NI}\left(y^E\right) > W^{NI}\left(y^F\right).$$

For policy regime I, combining (62) and the definition of $\bar{z}(y)$ in (37), we have

$$\bar{z}\left(y^N\right) < \bar{z}\left(y^E\right) < \bar{z}\left(y^F\right).$$

Working from equation (55), it can be shown that the level of welfare generated by the best-response allocation $\mathbf{c}^I$ is a strictly decreasing function of $\bar{z}(y)$.[21] Therefore, we have

$$W^I\left(y^N\right) > W^I\left(y^E\right) > W^I\left(y^F\right),$$

as desired.

Step (ii): Establish the result. Consider any e with $\delta > 0$ and let $y^*_{NI} \in \left\{y^N, y^E, y^F\right\}$ denote equilibrium strategy profile in the policy regime with no intervention if the economy is not/weakly/strongly fragile under that regime. Then equilibrium welfare is $W^{NI}\left(y^*_{NI}\right)$. Lemma 1 establishes that there exists $\bar{\sigma}_1 < 1$ such that $\sigma > \bar{\sigma}_1$ implies

$$W^I\left(y^*_{NI}\right) > W^{NI}\left(y^*_{NI}\right).$$

Lemma 2 establishes that there exists another cutoff point $\bar{\sigma}_2 < 1$ such that $\sigma > \bar{\sigma}_2$ implies the fragility type of the economy under the policy regime with intervention is weakly lower than under the regime with no intervention. Step (i) above establishes that lowering the fragility type of the economy always raises equilibrium welfare. Combining these results shows that whenever $\sigma > \max\left\{\bar{\sigma}_1, \bar{\sigma}_2\right\}$, we have

$$W^I\left(y^*_I\right) > W^{NI}\left(y^*_{NI}\right)$$

[21] To see this result, differentiate the expression for W^I with respect to $\bar{z}$. The resulting expression is lengthy, but can be shown to be strictly positive.

and allowing intervention strictly increases equilibrium welfare. ■

Lemma 3: *For any economy with $\delta = 0$ and $\sigma < 1$, $W^{NI}(y) > W^{I}(y)$ holds for all $y \in Y$.*

Proof: The proof is divided into two steps.

Step (i) : Show that when $\delta = 0$ and $\sigma = 1$, the allocations $\mathbf{c}^{NI}(y)$ and $\mathbf{c}^{I}(y)$ are equivalent for any y. This result follows from the expressions given for the two allocations in Appendix A. When $\delta = 0$, equation (36) shows that $z_s(y) = x_s(y)$ for all s and y. When $\sigma = 1$ also holds, equations (27) and (32) show that $c_1^{NI}(y) = \tilde{c}_1^{I}(y)$ for all y; equations (28) and (34) then show that $c_{ts}^{NI}(y) = c_{ts}^{I}(y)$ for $t = 1$, 2, for all s, and for all y. Using $\delta = 0$ in equations (29) and (35) shows that no public good is provided in either allocation. The only difference between the two allocations, therefore, is that the "distorted" payment $c_1^{I}(y)$ appears in the allocation under regime I. When $\sigma = 1$, however, no depositors receive this consumption level. In this sense, the two allocations are equivalent and necessarily generate the same level of welfare,

$$W^{NI}(y) = W^{I}(y).$$

Step (ii) : Establish the result. The intuition for this step is clear: the two regimes are equivalent when $\delta = 0$ and $\sigma = 1$, and lowering σ below 1 will decrease welfare under regime I while having no effect under regime NI. However, $W^{I}(y)$ does not necessarily change monotonically with σ for all $\sigma < 1$. To establish the result, therefore, we consider the the auxiliary problem of maximizing

$$\sigma\pi_L u(\tilde{c}_1) + (1-\sigma)\pi_L u(c_1) + (1-\pi_L)\sum_{s\in S} q_s\left(\hat{\pi}_s u(c_{1s}) + (1-\hat{\pi}_s) u(c_{2s})\right) \tag{63}$$

subject to

$$\sigma\pi_L\tilde{c}_1 + (1-\sigma)\pi_L c_1 + (1-\pi_L)\left(\hat{\pi}_s c_{1s} + (1-\hat{\pi}_s)\frac{c_{2s}}{R}\right) \leq 1. \tag{64}$$

The solution to this problem is the best feasible allocation of resources in an economy where investors follow a given strategy profile y and do not value the public good (that is, $\delta = 0$). It is straightforward to show that the first-order conditions characterizing this solution are given by (10), (11) and (14). In other words, the solution to this problem is equivalent to the best-response allocation under the policy regime with no intervention, $\mathbf{c}^{NI}(y)$. Note that the best-response allocation under the regime with intervention, $\mathbf{c}^{I}(y)$, is in the feasible set (64), but is clearly not equal to the solution because (33) shows that $\tilde{c}_1^{NI}(y) \neq c_1^{NI}(y)$. Since (63) is strictly concave, $\mathbf{c}^I(y)$ generates strictly lower welfare than $\mathbf{c}^{NI}(y)$ when $\delta = 0$ and $\sigma < 1$, that is,

$$W^{NI}(y) > W^I(y)$$

for any $y \in Y$, as desired.

■

Lemma 4: *For any economy with $\delta = 0$ and $\sigma < 1$, allowing intervention weakly increases the fragility type of the economy.*

Proof: Step (i) of the proof Lemma 3 established that when $\delta = 0$ and $\sigma = 1$, $\mathbf{c}^{NI}(y)$ and $\mathbf{c}^I(y)$ are equal and, hence, we have

$$\frac{c_1^{NI}(y)}{c_{2s}^{NI}(y)} = \frac{\tilde{c}_1^I(y)}{c_{2s}^I(y)}$$

for all s and y. It then follows from Propositions 1 and 3 that the fragility type of the economy is the same under both regimes. Proposition 2 established that the fragility type of an economy is independent of σ under regime NI, while Proposition 4 established that it is weakly decreasing in σ under regime I. Therefore, for any $\sigma < 1$, the fragility type of the economy must be weakly higher under regime I than under regime NI. ■

Proposition 7: *For any economy with $\delta = 0$ and $\sigma < 1$, allowing intervention strictly decreases equilibrium welfare.*

Proof: Using the result from Lemma 3 with the equilibrium strategy profile under regime NI, when $\delta = 0$ and $\sigma < 1$ we have

$$W^{NI}(y_{NI}^*) > W^I(y_{NI}^*). \tag{65}$$

Lemma 4 establishes that the fragility type of the economy under regime I is at least as high as under regime NI, while step (i) of the proof of Proposition 6 establishes that increasing the fragility type of an economy strictly lowers welfare under either regime. Combining these two results with (65) yields

$$W^{NI}(y_{NI}^*) > W^I(y_I^*),$$

which establishes the proposition. ■

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