Federal Reserve Bank of New York
Staff Reports

Expectations versus Fundamentals: Does the Cause of Banking Panics Matter for Prudential Policy?

Todd Keister
Vijay Narasiman

Staff Report no. 519
October 2011

Expectations versus Fundamentals: Does the Cause of Banking Panics Matter for Prudential Policy?

Todd Keister and Vijay Narasiman

Federal Reserve Bank of New York Staff Reports, no. 519
October 2011
JEL classification: E61, G21, G28

Abstract

There is a longstanding debate about whether banking panics and other financial crises always have fundamental causes or are sometimes the result of self-fulfilling beliefs. Disagreement on this point would seem to present a serious obstacle to designing policies that promote financial stability. However, we show that the appropriate choice of policy is invariant to the underlying cause of banking panics in some situations. In our model, the anticipation of being bailed out in the event of a crisis distorts the incentives of financial institutions and their investors. Two policies that aim to correct this distortion are compared: restricting policymakers from engaging in bailouts, and allowing bailouts but taxing the short-term liabilities of financial institutions. We find that the latter policy yields higher equilibrium welfare regardless of whether panics are sometimes caused by self-fulfilling beliefs.

Key words: banking panics, financial regulation, bailouts

Keister: Federal Reserve Bank of New York (e-mail: todd.keister@ny.frb.org). Narasiman: Harvard University (e-mail: vnarasiman@fas.harvard.edu). The authors thank Huberto Ennis and Itay Goldstein for useful comments.

1 Introduction

The recent financial crisis has generated a lively discussion about what actions policy makers should take to promote financial stability and to guard against the possibility of future crises. A wide range of competing proposals have been put forth. Evaluating these proposals requires having a theory of financial instability. Gorton (2010) argues that the recent crisis was – at its heart – a *panic*, 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. A sizable literature studies banking panics and financial crises more generally; see Allen and Gale (2007) for an overview and references. The models in this literature provide a natural starting point for the analysis of current policy proposals.

There is, however, a long-standing debate in this literature about the underlying causes of financial panics and how these events are best captured in economic models. One view is that panics are invariably caused by some fundamental shock that makes the banking system insolvent. Gorton (1988), for example, argues that historical banking panics occurred when investors received information signalling an economic downturn (see also Allen and Gale, 1998). Since a downturn would likely cause banks to suffer significant losses on their loan portfolios, and possibly to fail, depositors would rush to withdraw their funds before this occurred.

The opposing view is that financial panics are often driven by the self-fulfilling beliefs of investors. If, for whatever reason, many investors attempt to withdraw their funds in a short period of time, the financial system will be unable to meet all of their demands even in the absence of a significant shock to fundamentals. An individual investor who expects a surge of withdrawals may, therefore, find it her best interest to join the "run" and attempt to withdraw her own funds before it is too late. In other words, the anticipated losses from a surge of withdrawals may itself lead investors to panic. This view also has a long history (see, for example, the discussion in Kindleberger, 1978) and was formalized in the language of modern economic theory by Diamond and Dybvig (1983).

Determining which of these two views more accurately describes actual events is an inherently difficult exercise. Financial crises are infrequent events and there is a limited amount of available data that can be used to distinguish between the two views. Existing empirical work focuses on establishing a correlation between economic fundamentals and the occurrence of financial panics. Miron (1986), Gorton (1988) and others argue that such a correlation implies that panics are *caused* by shifts in these fundamentals. Ennis (2003) points out, however, that models of self-fulfilling financial panics 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 panic requires answering a counterfactual question: would an individual investor have withdrawn even if she expected other investors to leave their funds in the financial system? Answering such questions on the basis of data from observed crises is intrinsically difficult.[1]

This situation would seem to present a serious problem for policy makers. Without broad agreement on whether or not financial panics can result from shifts in investors' beliefs, how can one choose between competing paradigms for prudential regulation and for financial stability policy more generally? In this paper, we show that, for some issues, the appropriate choice of policy regime is invariant to the view one holds on the underlying cause of panics. In other words, it may not be necessary to establish which of the two views is more accurate in order to provide useful policy advice. We construct a version of the model of Diamond and Dybvig (1983) in which a panic can result from either a fundamental shock or a shift in investors' beliefs. We study one particular policy question and show that the prescription coming out of the model does not depend on the type of panics to which the economy is susceptible.

The policy issue we study here relates to bailouts and the associated moral hazard problem. A number of different interventions by governments and central banks during the recent crisis can be considered bailouts, that is, transfers of public funds to private agents who are facing losses on their investments. The anticipation of receiving such a bailout is commonly believed to distort the incentives faced by financial institutions and their investors, leading these institutions to take on too much risk, leverage, and illiquidity from a social point of view. The difficult question is how policy makers should deal with this issue. Some observers claim that if policy makers could credibly commit not to engage in such bailouts in the future, the incentive distortions would be removed

[1] 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 panics will tend to generate the same correlations as a model of fundamentals-based panics.

and the reactions of financial institutions and their investors would lead to a more stable financial system. Others argue that it would be preferable to allow policy makers to retain discretion in using bailouts, but to use prudential policy tools to offset the resulting incentive distortion. Which approach is more effective? Is it better to restrict policy makers' reaction to a crisis, or to intervene ex ante to alter the incentives faced by intermediaries and their investors?

We address these questions in a model based on that in Keister (2010), which assumed that panics are the result of self-fulfilling beliefs. We extend the model by introducing intrinsic uncertainty: the level of fundamental withdrawal demand is assumed to be random. A realization of high withdrawal demand can spark a panic, in which all depositors attempt to withdraw, for one of two reasons. First, the level of fundamental withdrawal demand can simply serve as a coordination device for depositors' beliefs. We say a panic is caused by *expectations* when individual depositors' decisions to withdraw are based, at least in part, on the belief that withdrawals by other depositors will compromise the solvency of the banking system. In other situations, however, the realization of high withdrawal demand will itself be significant enough to provoke a panic, independent of depositors' beliefs about the actions of others. We say that a panic is caused by *fundamentals* if the realized configuration of parameter values is such that withdrawing is a dominant action for depositors.

We consider the problem facing an economy that must adopt one of two approaches to promoting financial stability. The first option is a no-bailouts restriction: policy makers will be prohibited from transferring any public resources to private agents. In the second option, policy makers are given full discretion in the choice of bailout policy and a tax is placed on the short-term liabilities of financial institutions. The idea behind this policy is to allow policy makers to react to a financial crisis in an unconstrained way while attempting to offset the associated incentive distortion through a Pigouvian tax (as advocated, for example, in Kocherlakota, 2010).

We ask which policy yields higher expected utility for depositors under two different views about the underlying cause of banking panics: one in which panics may be caused by expectations, and the other in which panics are only caused by fundamentals. We show that the discretionary bailouts policy with a tax on short-term liabilities generates higher equilibrium welfare under both views. In other words, broad agreement on the cause of financial panics is not required for choosing a policy regime in this model.

In the next section, we describe the model and the competing views of financial fragility. In Section 3, we derive the equilibrium strategy profiles and allocations under each of the two policy regimes. We present our main result in Section 4, showing that the discretionary bailouts regime with a tax on short-term liabilities is superior regardless of whether one views panics are being caused by expectations or fundamentals, and we offer some concluding remarks in Section 5.

2 The Model

Our model builds on that in Keister (2010), which is a version of the Diamond and Dybvig (1983) model augmented to include fiscal policy and a public good. We add aggregate uncertainty about the level of fundamental withdrawal demand to the model so that a panic can potentially be caused by either a shock to fundamentals or by a shift in beliefs.

2.1 The environment

There are three time periods, $t = 0$, 1, 2. Each of a continuum of depositors, indexed by $i \in [0, 1]$, has preferences given by

$$u\left(c_1 + \theta_i c_2\right) + v\left(g\right), \tag{1}$$

where c_t is consumption of the private good in period t and g is the level of public good. The parameter θ_i is a binomial random variable with support $\Theta = \{0, 1\}$. If the realized value of θ_i is zero, depositor i is *impatient* and only cares about early consumption. A depositor's type θ_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 (CRRA) form, with

$$u\left(c\right) = \frac{c^{1-\gamma}}{1-\gamma} \quad \text{and} \quad v\left(g\right) = \delta \frac{g^{1-\gamma}}{1-\gamma}. \tag{2}$$

As in Diamond and Dybvig (1983), the coefficient of relative risk-aversion γ is assumed to be greater than one.

Each depositor has an endowment of one unit of the good in period 0. There is a single, constant-returns-to-scale investment technology: goods invested at $t = 0$ yield a gross return of 1 if held for one period or $R > 1$ if held for two periods. This technology is operated by a set of competitive banks, each of which accepts deposits in period 0 and allows withdrawals in the later periods. Because depositors' types are private information, a bank allows each depositor to choose when she will withdraw. This arrangement, which resembles the type of demand-deposit contracts commonly used in reality, is well known to be capable of implementing desirable allocations in economies with private information. However, such arrangements may also create the possibility of a panic in which all depositors attempt to withdraw early, regardless of their realized preference type.

At $t = 1$ the economy will be in one of two states, $s \in S \equiv \{L, H\}$. The probability of being impatient for an individual depositor in state s is given by π_s, with $\pi_H > \pi_L$. By a law of large numbers, the fraction of the population that is impatient will also equal π_s. In other words, state H represents a shock to fundamentals in which a high fraction of the population faces an immediate consumption need. Let $q \in (0, 1)$ denote the probability of state H. Banks are unable to directly observe the realization of the state s; they must try to infer this information from the flow of withdrawals by depositors.

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 either to withdraw her funds in period 1 or to wait until period 2. Depositors who choose to withdraw in period 1 arrive at their bank one at a time in a randomly-determined order. As in Wallace (1988, 1990), these depositors must consume immediately upon arrival. This sequential-service constraint implies that the payment made to such a depositor can only depend on the information received by the bank up to that point; we discuss the implications of this constraint in detail below.

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.[2] In particular, a bank is free to adjust the payment it gives to its remaining depositors when new information arrives. We follow Ennis and Keister (2009, 2010) in assuming that banks cannot commit to future actions; each acts to maximize the expected utility of its depositors at all times. 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). Instead, the payment given to each depositor who withdraws in period 1 will be an optimal response to the current situation.

There is also a benevolent policy maker who can tax endowments in period 0, store these resources until period 1, and then convert them one-for-one into units of the public good. Let τ

[2] We follow Green and Lin (2003), Peck and Shell (2003) and others in this respect.

denote the fraction of depositors' endowment collected in taxes at $t = 0$. The objective of the policy maker is to maximize the equal-weighted sum of individual expected utilities,

$$U = \int_0^1 E\left[u\left(c_1\left(i\right), c_2\left(i\right), g; \theta_i\right)\right] di.$$

The policy maker faces the same informational and limited-commitment frictions as banks. In particular, the policy maker must infer the state s by observing the flow of withdrawals and will choose its actions to maximize the above objective at each point in time.

The policy maker will also adopt one of two policy regimes in an attempt to mitigate the moral hazard problems that arise if there are bailouts, that is, transfers of tax revenue to banks at $t = 1$ in response to an adverse shock. One regime simply prohibits bailouts: all tax revenue must be used to provide the public good in both states. The other regime allows bailouts to occur in state H, and also allows the policy maker to place a Pigouvian tax on banks' short-term liabilities. The discrete nature of this choice between policy regimes is intended to reflect the difficulty of committing in advance to specific, state-contingent plans of action, particularly during times of crisis. The policy maker can thus commit not to engage in bailouts at all, but cannot commit in advance to the details of a bailout package. These details will be determined ex post, as a best response by the policy maker to the situation at hand. Both policy regimes are described in more detail in Section 3 below.

2.2 Strategies

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

$$y_i : \Theta \times S \rightarrow \{1, 2\}.$$

Let y denote a profile of withdrawal strategies for all depositors. Because impatient depositors only care about period 1 consumption, withdrawing in period 2 is a strictly dominated action and any equilibrium strategy profile will have all depositors withdrawing in period 1 when impatient. We focus on symmetric equilibria, in which all depositors follow the same strategy, and on equilibria in which patient depositors choose to wait until period 2 to withdraw in state L. The latter restriction serves only to simplify the presentation; we focus on crises that occur in state H and not in state L. In such an equilibrium, each depositor chooses one of two options: the *panic strategy* in which she withdraws early in state H when patient, and the *no-panic strategy* in which she does not. A strategy profile y can then be summarized by a single number: the fraction of depositors following the panic strategy, which we denote $\lambda(y)$.

Panics. We refer to the strategy profile associated with $\lambda = 1$ as a *panic*. In other words, a panic is a situation in which all depositors attempt to withdraw early in state H, regardless of their true consumption needs. Note that the number of early withdrawals is large in a panic for two distinct reasons: a higher-than-normal fraction of the population is impatient in state H *and* even those depositors who are patient are attempting to withdraw early. In this way, a panic in this model consists of a shock to fundamentals whose effect is amplified by the (endogenous) decisions of depositors. Such amplification effects are commonly believed to have been an important component of the recent financial crisis. For example, Bernanke (2010) states that

> "prospective subprime losses were clearly not large enough on their own to account for the magnitude of the crisis. ... Rather, the [financial] system's vulnerabilities ... were the principal explanations of why the crisis was so severe and had such devastating effects on the broader economy."

The model we present here captures, in a stylized way, one aspect of these vulnerabilities and their amplifying effects.

Best-response allocations. In principle, a bank can distribute its available resources across depositors in any way that is consistent with their 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, it are unable to make any inference about the state and will choose to give the same level of consumption to each withdrawing depositor; let $c_{1,j}$ denote this amount for bank j.

After π_L withdrawals have been made, one of two things will occur: either withdrawals will stop, in which case banks and the policy maker can infer the state is L, or withdrawals will continue, in which case they can immediately infer that the state must be H. In the former case, banks know that the remaining fraction $1 - \pi_L$ of their depositors are all patient and will withdraw in period 2. Bank j will divide the matured value of its remaining resources evenly between these depositors. Let $c_{2,j}$ denote the amount received by each of these depositors.

If, on the other hand, banks infer that state H has occurred, they realize that some impatient depositors have not yet been served. If no depositors are following the panic strategy profile (that is, if $\lambda(y) = 0$), then $\pi_H - \pi_L$ of the remaining $1 - \pi_L$ depositors are impatient. If, however, $\lambda(y) > 0$, then the first π_L withdrawals were made by a mix of patient and impatient depositors and the proportion of remaining impatient depositors will be higher. Let $\widehat{\pi}(\lambda)$ denote the fraction of the remaining $(1 - \pi_L)$ depositors who are impatient, that is,

$$\widehat{\pi}(\lambda) \equiv \frac{\pi_H}{1 - \pi_L}\left(1 - \frac{\pi_L}{\pi_H + \lambda(1 - \pi_H)}\right). \tag{3}$$

We assume that each bank is able to efficiently allocate its available resources among its remaining depositors, even if $\lambda(y) > 0$ and a panic is underway. In particular, we assume that the remaining patient depositors do not withdraw early, but instead withdraw in period 2.[3] The efficient allocation of bank j's remaining resources gives a common amount of consumption, denoted $\widehat{c}_{1,j}$, to each remaining impatient depositor in period 1 and a common amount $\widehat{c}_{2,j}$ 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.

In state L, the policy maker uses all of the tax revenue to provide the public good; let g denote the amount provided. In state H, the policy maker may (depending on the policy regime in place) choose to make bailout payments to banks in order to increase the resources available for the remaining depositors. Let $\widehat{g}$ denote the amount of public good that is provided in state H; this value will be lower than g if bailout payments are made.

The best response of banks and the policy maker to a given profile of withdrawal strategies can thus be summarized by a vector of six numbers,

$$\mathbf{c} \equiv (c_1, c_2, \widehat{c}_1, \widehat{c}_2, g, \widehat{g}).$$

We refer to this vector $\mathbf{c}$ as the *best-response allocation* associated with strategy profile y. It is straightforward to show that $\mathbf{c}$ depends only on the fraction λ of depositors following the panic strategy in y and not on the identities of these depositors. We therefore use $\mathbf{c}(\lambda)$ to denote this best-response relationship. In Section 3, we derive the allocation $\mathbf{c}(\lambda)$ under each policy regime.

---

[3] None of our results depend on this assumption. The issue of how banks and policy makers react to a panic, 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 the one used here can be used to study this interplay between the actions of depositors and the reactions of policy makers. We abstract from these issues here in order to focus more clearly on the matter at hand.

Given a best-response allocation $\mathbf{c}$ and the value of $\widehat{\pi}$ in (3), depositors' expected utility at $t = 0$ can be written as

$$\begin{aligned} U(\mathbf{c}, \lambda) &= \pi_L u(c_1) + (1-q)\left[(1-\pi_L) u(c_2) + v(g)\right] + \\ & \quad q\left[(1-\pi_L)\left[\widehat{\pi}(\lambda) u(\widehat{c}_1) + (1-\widehat{\pi}(\lambda)) u(\widehat{c}_2)\right] + v(\widehat{g})\right]. \end{aligned} \tag{4}$$

2.3 Equilibrium and fragility

An equilibrium of the model is a strategy profile y^* in which 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 $\mathbf{c}(\lambda(y^*))$ that results from the best-responses of banks and the policy maker to those strategies. Our analysis focuses on two possible symmetric, pure-strategy equilibria: a panic, in which patient depositors attempt to withdraw early in state H (that is, $\lambda = 1$) and a non-panic in which they do not (that is, $\lambda = 0$). In general terms, a panic occurs in equilibrium when the allocation $\mathbf{c}$ gives individual patient depositors an incentive to withdraw early in state H. A patient depositor who tries to withdraw early will receive either c_1 (if she is among the first π_L depositors to withdraw) or $\widehat{c}_2$ (if she is not). If she waits until period 2 to withdraw, she will receive $\widehat{c}_2$ for sure. She has an incentive to withdraw early, therefore, if and only if $c_1 \geq \widehat{c}_2$ holds. It will be useful to summarize this incentive as follows.

Definition 1: For a given allocation $\mathbf{c}$, the *incentive to run* is given by

$$\rho(\mathbf{c}) \equiv \frac{c_1}{\widehat{c}_2} - 1. \tag{5}$$

Notice that ρ is positive when c_1 is greater than $\widehat{c}_2$ and negative when the reverse is true. Using this notation, a panic equilibrium exists if

$$\rho(\mathbf{c}(1)) \geq 0,$$

that is, if an individual patient depositor has an incentive to withdraw early under the allocation $\mathbf{c}$ that results from the best response of banks and policy makers to the strategy profile with $\lambda = 1$. Similarly, a no-panic equilibrium exists if

$$\rho(\mathbf{c}(0)) \leq 0,$$

that is, if a patient agent has an incentive to wait until period 2 when **c** results from the best response to the strategy profile with $\lambda = 0$.

Our model is a generalization of that in Keister (2010), which studies the special case where $\pi_L = \pi_H$ holds. In that case, the no-panic equilibrium always exists and a panic equilibrium may or may not exist, depending on the policy regime and parameter values. The model we study here, in contrast, can have a unique equilibrium in which a panic necessarily occurs. We introduce the following terminology to distinguish these different situations.

Definition 2: An economy is *weakly fragile* if the strategy profile satisfying $\lambda(y^*) = 1$ is **an** equilibrium.

Definition 3: An economy is *strongly fragile* if the strategy profile satisfying $\lambda(y^*) = 1$ is **the only** equilibrium.

If an economy is weakly fragile, a patient depositor has an incentive to withdraw early in state H if she expects all other patient depositors to do the same. In this case, the belief that a panic will occur can be self-fulfilling. If an economy is strongly fragile, in contrast, a patient depositor's optimal action in state H does not depend on whether she expects other patient depositors to withdraw. The only outcome consistent with equilibrium in this case is for all patient depositors to attempt to withdraw early.

An economy e is defined by the parameters $(q, \pi_L, \pi_H, R, \gamma, \delta)$. Let Φ_W and Φ_S denote the subset of economies that are weakly fragile and strongly fragile, respectively. It follows immediately from the definitions above that

$$\Phi_S \subseteq \Phi_W,$$

that is, a strongly fragile economy is weakly fragile, but the reverse is often not true.

Competing views. The *fundamentals view* of panics discussed by Gorton (1988), Allen and Gale (1998) and others can be captured in this model by supposing that a panic occurs in state H if and only if the economy is strongly fragile. According to this view, then, a panic occurs only when the fundamental shock is large enough to give each depositor a positive incentive to run regardless of what actions she expects other depositors to take. The *expectations view* associated with Diamond and Dybvig (1983) and others can be captured by instead supposing that a panic occurs in state H whenever the economy is weakly fragile. In this view, a panic can also arise when the fundamental shock is small if the shock leads to a self-fulfilling shift in depositors' beliefs. Notice that the the difference between these competing views is a matter of equilibrium selection: when both a no-panic and a panic equilibrium exist, the fundamentals view selects the former as being relevant for policy analysis and the expectations view selects the latter.[4]

Our goal in this paper is to study the policy prescriptions that come out of the model under each of these views. In the next section, we introduce the policy regimes we consider: a no-bailouts restriction and a discretionary bailouts regime with a tax on short-term liabilities. In each case, we derive the best-response allocation associated with different profiles of withdrawal strategies and the resulting properties of equilibrium. In Section 4, we compare welfare under the two regimes and show that the discretionary regime with a tax on short-term liabilities is superior under both views. In this sense, the preferred policy regime in our model is invariant to one's view of the underlying cause of banking panics.

3 Best-response Allocations and Equilibrium Fragility

In this section, we derive the best response of banks and the policy maker to depositors' withdrawal strategies under two different policy regimes. In the first regime, the policy maker is restricted from providing any bailout payments. In the second, the policy maker has full discretion in bailout policy and uses a tax on banks' short-term liabilities to offset the resulting incentive distortion. We then use the allocations generated by these best responses to derive conditions under which an economy is weakly and strongly fragile in each policy regime.

3.1 The post-crisis payment schedule

We begin by deriving the efficient way for a bank to allocate its remaining resources if, after a fraction π_L of its depositors have withdrawn, it infers that the state is H. Let ψ_j denote the quantity of resources available to bank j, in per-depositor terms, after these withdrawals have taken place. Bank j will distribute these resources to solve

$$\widehat{U}\left(\psi_j;\lambda\right) \equiv \max_{\{\widehat{c}_{1,j},\widehat{c}_{2,j}\}} \left(1-\pi_L\right)\left(\widehat{\pi}\left(\lambda\right)u\left(\widehat{c}_{1,j}\right)+\left(1-\widehat{\pi}\left(\lambda\right)\right)u\left(\widehat{c}_{2,j}\right)\right) \tag{6}$$

[4] Other formulations of these views are possible, of course, as are other equilibrium selection rules. Goldstein and Pauzner (2005), for example, use a global-games approach in a related model to effectively select the risk-dominant equilibrium of the game played by depositors, which represents a hybrid of the fundamentals and expectations views.

subject to the resource constraint

$$(1-\pi_L)\left(\widehat{\pi}(\lambda)\,\widehat{c}_{1,j}+(1-\widehat{\pi}(\lambda))\,\frac{\widehat{c}_{2,j}}{R}\right)\leq\psi_j \tag{7}$$

and appropriate non-negativity conditions. Letting $\widehat{\mu}_j$ denote the multiplier on (7), the solution to this problem is characterized by the conditions

$$u'(\widehat{c}_{1,j})=Ru'(\widehat{c}_{2,j})=\widehat{\mu}_j. \tag{8}$$

3.2 The best-response allocation under a no-bailouts restriction

We now derive the entire allocation $\mathbf{c}$ that results from the best response of banks and the policy maker to depositors' withdrawal strategies under a no-bailouts restriction. This allocation can then be used to determine which strategy profiles are consistent with equilibrium.

Early payments. Suppose bank j expects depositors to follow a strategy profile in which the fraction of patient depositors attempting to withdraw early is λ. A fraction π_L of all depositors will withdraw, each receiving $c_{1,j}$, before the bank is able to infer the state. The payment $c_{1,j}$ will be chosen to solve

$$\max_{\{c_{1,j},c_{2,j}\}}\ \pi_L u(c_{1,j})+(1-q)(1-\pi_L)\,u(c_{2,j})+q\widehat{U}\left(\psi_j;\lambda\right)$$

subject to the resource constraints

$$\begin{aligned}\pi_L c_{1,j}+(1-\pi_L)\,\frac{c_{2,j}}{R} &= 1-g, &(9)\\ \psi_j &= 1-g-\pi_L c_{1,j}, &(10)\end{aligned}$$

and the incentive compatibility condition $c_{2,j}\geq c_{1,j}$. The objective function is the expected utility of bank j's depositors, measured before the state is known, which includes the utility value $\widehat{U}$ associated with the efficient response to a crisis from problem (6). The incentive compatibility constraint guarantees that withdrawing early is not a dominant strategy for patient depositors in state L; it is straightforward to show that this latter constraint never binds in the solution to this problem. This solution is characterized by the first-order condition

$$u'(c_{1,j})=(1-q)\,Ru'(c_{2,j})+q\widehat{U}'\left(\psi_j;\lambda_P\right). \tag{11}$$

Since all banks face the same optimization problem, they will all choose the same levels of $(c_{1,j}, c_{2,j})$. This fact implies that all banks will have the same level of resources ψ_j after the first π_L withdrawals have been made and, hence, will choose the same post-crisis payment schedule $(\widehat{c}_{1,j}, \widehat{c}_{2,j})$. We can, therefore, omit the j subscripts when referring to the best-response payments $(c_1, c_2, \widehat{c}_1, \widehat{c}_2)$.

Taxes. Under a no-bailouts restriction, all tax revenue collected by the policy maker must be used to provide the public good in both states, that is

$$g = \widehat{g} = \tau. \tag{12}$$

In period $0,$ the policy maker chooses the tax rate τ to maximize depositors' expected utility, solving

$$\max_{\{\tau\}} \pi_L u(c_1) + (1-q)(1-\pi_L)u(c_2) + q\widehat{U}\left(\psi_j; \lambda\right) + v(g) \tag{13}$$

subject to the constraint (12), where c_1 and c_2 are determined as functions of τ by conditions (9) and (11), and ψ_j is given by (10).

The solution to (13), combined with equations (7) – (12), defines the allocation of resources that results from the best response by banks and the policy maker to a given strategy profile under a no-bailouts restriction. Let $\mathbf{c}^{NB}(\lambda)$ denote this allocation. Using the form of the utility function in (2), we can derive a closed-form expression for this allocation; this expression is presented in Appendix A.1.

Fragility. With the allocation $\mathbf{c}^{NB}$ in hand, we can now precisely identify the conditions under which an economy is weakly and strongly fragile under a no-bailouts restriction. We begin with the following proposition.

Proposition 1 $\rho\left(\mathbf{c}^{NB}(\lambda)\right)$ *is strictly increasing in* λ.

This result shows that the game played by depositors exhibits strategic complementarities: withdrawing early becomes more attractive to an individual depositor when the fraction of other depositors withdrawing early is higher. As more patient depositors withdraw early in state $H,$ more impatient depositors will need to be served from the post-crisis resources $\psi,$ which implies that the payments $(\widehat{c}_1, \widehat{c}_2)$ made from these resources will be smaller. Attempting to withdraw early and receive c_1 instead of $\widehat{c}_2$ thus becomes a more attractive option for a patient depositor. A proof of this result is presented in Appendix B.

Let Φ_W^{NB} denote the set of economies e that are weakly fragile and Φ_S^{NB} the set of economies that are strongly fragile under a no-bailouts policy. Then the next result follows directly from Proposition 1.

Corollary 1 *(i) $e \in \Phi_W^{NB}$ iff $\rho\left(\mathbf{c}^{NB}(1)\right) \geq 0$, and (ii) $e \in \Phi_S^{NB}$ iff $\rho\left(\mathbf{c}^{NB}(0)\right) > 0$.*

Definition 2 states that an economy is weakly fragile if and only if there exists an equilibrium in which all patient depositors attempt to withdraw early in state H. In order for such an equilibrium to exist, the incentive to run $\rho\left(\mathbf{c}^{NB}(\lambda)\right)$ must be non-negative for some value of λ. Proposition 1 implies that $\rho\left(\mathbf{c}^{NB}(\lambda)\right)$ is non-negative for some λ if and only if it is non-negative for $\lambda = 1$, which establishes the first half of the result. For the second half, recall that Definition 3 states an economy is strongly fragile if and only if all patient depositors attempt to withdraw early in state H in every equilibrium. For this to be true, the incentive to run $\rho\left(\mathbf{c}^{NB}(\lambda)\right)$ must be strictly positive for all values of λ, which, using Proposition 1, occurs if and only if $\rho\left(\mathbf{c}^{NB}(0)\right) > 0$.

Using Corollary 1 and the solution for $\mathbf{c}^{NB}$ presented in Appendix A.1, it is straightforward to show that the set Φ_S^{NB} is nonempty and strictly contained in Φ_W^{NB}, which is itself strictly contained in the set of all economies. In other words, some economies are strictly fragile under a no-bailouts restriction, others are only weakly fragile, and some are not fragile at all.

3.3 The best-response allocation with discretionary bailouts and liabilities tax

Next, we derive the best-response allocation $\mathbf{c}$ under the alternative policy regime.

Taxing short-term liabilities. The prospect of receiving a bailout in the event of a crisis introduces a distortion by removing banks' incentive to provision for realizations of high withdrawal demand. To offset this distortion, the policy maker may choose to tax banks' short-term liabilities. Since a fraction π_L of bank j's depositors will be allowed to each withdraw an amount $c_{1,j}$ before the bank and the policy maker are able to infer the state of nature, we can think of $\pi_L c_{1,j}$ as measuring the bank's short-term liabilities per depositor – these are the liabilities that can exit the banking system before the bank or policy maker can react to an incipient crisis. Suppose each intermediary must pay a fee that is proportional to this value; let η denote the tax rate. Then the resource constraint facing intermediary j in state L is given by

$$\pi_L c_{1,j} + (1-\pi_L)\frac{c_{2,j}}{R} = 1 - \tau - \eta\pi_L c_{1,j}. \tag{14}$$

The revenue from the liabilities tax is also used for the provision of the public good. Letting σ_j denote the fraction of depositors in the economy who have deposited with bank j, the policy maker's resource constraint in state L is

$$g = \tau + \eta\pi_L \sum_j \sigma_j c_{1,j} \tag{15}$$

In state H, when bailouts occur, the constraint is

$$\widehat{g} = \tau + \eta\pi_L \sum_j \sigma_j c_{1,j} - \sum_j \sigma_j b_j. \tag{16}$$

where $b_j \geq 0$ represents the bailout payment received by bank j in per depositor terms. We begin by deriving the best-response bailout policy. We then proceed in the same way as in the previous section, deriving banks' and the policy maker's best ex ante responses to depositors' withdrawal strategies.

Bailouts. We assume that the policy maker cannot commit to a specific bailout plan in advance; instead, the bailout payments to each bank will be chosen as a best response to the current situation. In particular, the bailout payments in state H are allocated across banks in an ex post efficient manner. The problem of choosing the efficient bailout policy can be written as

$$\max_{\{b_j,\widehat{g}\}} \sum_j \sigma_j \widehat{U}\left(\psi_j;\lambda\right) + v\left(\widehat{g}\right)$$

subject to

$$\psi_j = 1 - \tau - (1+\eta)\,\pi_L c_{1,j} + b_j \tag{17}$$

and the budget constraint (16). The solution to this problem is characterized by first-order conditions

$$\widehat{U}'\left(\psi_j;\lambda\right) = v'\left(\widehat{g}\right) \qquad \text{for all } j, \tag{18}$$

which immediately imply

$$\psi_j = \psi \qquad \text{for all } j. \tag{19}$$

In other words, the ex post efficient bailout payments equalize the resources available for private consumption across banks. The incentive problems that will be caused by this bailout policy are clear: a bank with fewer remaining resources (because it chose a higher value of $c_{1,j}$) will receive a larger bailout payment, which will lead all banks to set $c_{1,j}$ too high from a social point of view. The tax on short-term liabilities described above aims to correct this distortion.

Early payments. Suppose bank j expects depositors to follow a strategy profile in which the fraction of patient depositors attempting to withdraw early is λ. The bank anticipates that the bailout payment b_j will be set according to (18). In particular, the bank recognizes that the consumption of its remaining depositors in state H will be independent of its own choice of $c_{1,j}$. In choosing $c_{1,j}$, therefore, the bank will treat the utility of these investors as a constant, which we denote $\widehat{U}$. The bank will set $c_{1,j}$ to solve

$$\max_{\{c_{1,j},c_{2,j}\}} \pi_L u\left(c_{1,j}\right) + (1-q)\left(1-\pi_L\right) u\left(c_{2,j}\right) + q\widehat{U} \tag{20}$$

subject to the resource constraint (14) and the incentive compatibility condition $c_2 \geq c_1$. The first-order condition characterizing the solution when the incentive compatibility constraint does not bind is

$$u'\left(c_{1,j}\right) = (1+\eta)\left(1-q\right) Ru'\left(c_{2,j}\right). \tag{21}$$

The distortion of incentives is again evident: the equilibrium payment $c_{1,j}$ balances the marginal value of resources in the early period against the marginal value of resources in the late period in state L only, ignoring the value of resources in state H. As above, all banks face the same decision problem and will choose the same values of $\left(c_{1,j}, c_{2,j}\right)$. The fact that the bailout payments equalize resources ψ_j across banks implies that all banks also face the same decision problem in choosing the post-run payments $\left(\widehat{c}_{1,j}, \widehat{c}_{2,j}\right)$ and will select the same values. We can, therefore, omit all j subscripts in what follows.

The policy maker chooses the tax rates τ and η to solve

$$\max_{\{\tau,\eta\}} \pi_L u\left(c_1\right) + (1-q)\left((1-\pi_L)u\left(c_2\right) + v\left(g\right)\right) + q\left(\widehat{U}\left(\psi_j;\lambda\right) + v\left(\widehat{g}\right)\right) \tag{22}$$

subject to the constraints (15) and (16), where c_1 and c_2 are determined by the first-order condition (21) and the constraint (14), and where ψ_j is given by (17). Notice that the policy maker's objective function differs from that of banks because the policy maker recognizes that the value $\widehat{U}$ depends on the total quantity of resources remaining after the first π_L withdrawals have taken place, whereas individual banks take this value as given.

The solution to (22), combined with the earlier first-order conditions and resource constraints defines the allocation that represents the best response by banks and the policy maker to a given strategy profile under a discretionary bailouts regime with a tax on short-term liabilities. Let $\mathbf{c}^{DT}(\lambda)$ denote this allocation. A closed-form expression for the allocation is presented in Appendix A.2.

Fragility. We now use the allocation $\mathbf{c}^{DT}$ to identify conditions for weak and strong fragility under this policy regime. We begin with a monotonicity result similar to Proposition 1.

Proposition 2 *$\rho\left(\mathbf{c}^{DT}(\lambda)\right)$ is strictly increasing in λ.*

In other words, the game played by depositors also exhibits strategic complementarities under this policy regime. A proof is given in Appendix B. The result allows us to state precise conditions for weak and strong fragility in a way that mirrors Corollary 1. Let Φ_W^{DT} and Φ_S^{DT} denote the set of economies that are weakly and strongly fragile, respectively, under this regime. Then the next result follows directly from Proposition 2.

Corollary 2 *(i) $e \in \Phi_W^{DT}$ iff $\rho\left(\mathbf{c}^{DT}(1)\right) \geq 0$, and (ii) $e \in \Phi_S^{DT}$ iff $\rho\left(\mathbf{c}^{DT}(0)\right) > 0$.*

Using this result and the solution for $\mathbf{c}^{DT}$ presented in Appendix A.2, it is straightforward to show that some economies are strongly fragile under this policy regime, others are only weakly fragile, and some are not fragile at all.

Corollaries 1 and 2 can be used to identify the equilibrium values of λ in our model under each of the two policy regimes for any given economy e. Together with the best-response allocations $\mathbf{c}^{NB}(\lambda)$ and $c^{DT}(\lambda)$, these values of λ characterize the equilibrium allocation of resources in our model. With this information in hand, we are now ready to address the question of which policy regime yields higher expected utility for depositors.

4 Comparing Policies

Our main interest is in determining whether the policy prescriptions that come out of the model depend on the view one takes of the underlying cause of banking panics. In this section, we compare the expected utility of depositors under the policy regimes studied above in two different ways. First, we adopt the fundamentals view by supposing that a panic occurs in state H only when the economy is strongly fragile. We show that under this view the discretionary bailouts regime with a tax on short-term liabilities yields higher expected utility than the no-bailouts regime for every economy. We then show that the same conclusion holds under the expectations view, in which a panic occurs in state H in all weakly fragile economies. Together, these results show that the optimal choice of policy regime in this model is invariant to one's view on the underlying cause of panics.

To establish these results, it is helpful to introduce some additional notation. Let $r \in \{NB, DT\}$ denote the policy regime. For a given economy $e,$ depositors' expected utility according to the fundamentals view is given by

$$V_F^r(e) = \left\{ \begin{array}{ll} U(\mathbf{c}^r(1);1) & \text{if } e \in \Phi_S^r \\ U(\mathbf{c}^r(0);0) & \text{otherwise} \end{array} \right\} \quad \text{for } r = NB,\ DT.$$

If the economy is strongly fragile, a panic occurs in state H and the fraction of patient depositors withdrawing early in this state is $\lambda = 1$. The allocation of resources under regime r is then given by $\mathbf{c}^r(1)$. If the economy lies outside of the strongly fragile set, however, no panic occurs under this view, so the fraction of patient depositors withdrawing early is zero and the allocation of resources is given by $\mathbf{c}^r(0)$. The function V_F^r thus measures, for any economy $e,$ the expected utility of depositors under policy regime r according to the fundamentals view. The preferred policy regime for economy e is determined by comparing the values $V_F^{NB}(e)$ and $V_F^{DT}(e)$.

Depositors' expected utility according to the expectations view can be written in a similar way,

$$V_E^r(e) = \left\{ \begin{array}{ll} U(\mathbf{c}^r(1);1) & \text{if } e \in \Phi_W^r \\ U(\mathbf{c}^r(0);0) & \text{otherwise} \end{array} \right\} \quad \text{for } r = NB,\ DT.$$

In this view, a panic occurs in state H whenever the economy is weakly fragile, so the set Φ_W^r replaces the strongly-fragile set Φ_S^r. The preferred policy regime under the expectations view is determined by comparing the values $V_E^{NB}(e)$ and $V_E^{DT}(e)$. With these expressions in hand, we now state our main result.

Proposition 3 $V_F^{DT}(e) > V_F^{NB}(e)$ *and* $V_E^{DT}(e) > V_E^{NB}(e)$ *for all* e.

A proof of this proposition is presented in Appendix B. The result is portrayed graphically in the top panels of Figure 1, where panel A represents the fundamentals view and panel B represents the expectations view. The parameters $(\pi_L, \pi_H, R, \gamma, \delta)$ are held fixed at $(0.5, 0.75, 1.1, 6, 0.01)$. These two panels plot the gain in ex ante welfare from choosing the discretionary regime over the no-bailouts regime, $V^{DT} - V^{NB}$, as the probability of state H ranges from zero to one. As established by the proposition, this difference is always positive, meaning that the discretionary regime generates higher expected utility for all values of $q \in (0,1)$ under both views.

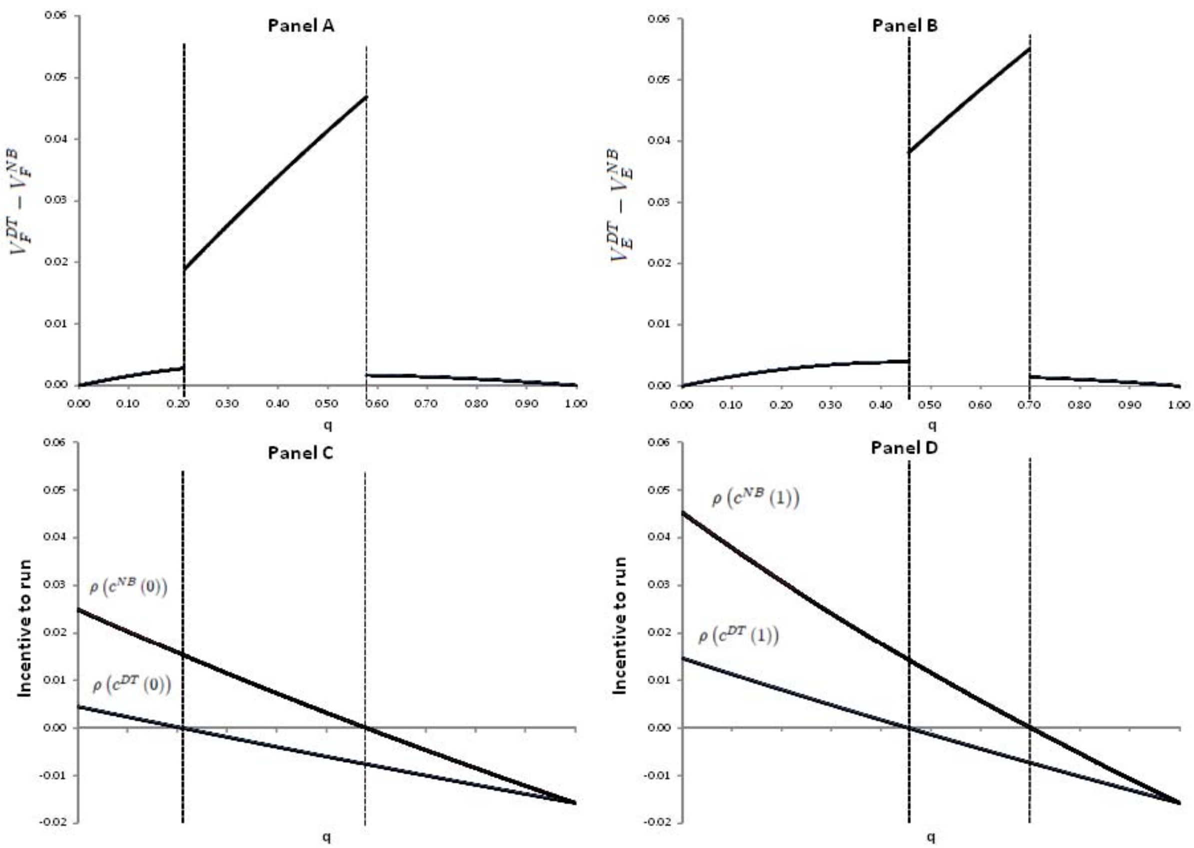

Figure 1: Comparing policy regimes under two different views

There are two reasons why the discretionary regime is superior. First, conditional on depositors' withdrawal behavior, the discretionary regime generates a more efficient allocation of resources. By permitting bailouts, this regime allows the policy maker to vary the level of public good across states of nature in a way that matches the variation in the marginal value of private consumption. Under the no-bailouts regime, in contrast, the level of public good is the same in both states, which leaves it inefficiently high in state H (and inefficiently low in state L). The tax on banks' short-term liabilities is also essential for this result, as it offsets the incentive distortion that arises from the bailout policy. Together, the flexible bailouts and Pigouvian tax actually generate the allocation $\mathbf{c}$ that maximizes depositors' expected utility conditional on the profile of withdrawal strategies. The allocation generated by the no-bailouts regime for the same profile of withdrawal strategies always yields lower expected utility.[5]

The second benefit of the discretionary regime is that it promotes financial stability by making the set of fragile economies strictly smaller than under the no-bailouts regime. This fact can be seen in the bottom panels in Figure 1. Consider first panel C, which plots the incentive to run ρ under the best-response allocation associated with no patient depositors withdrawing early (that is, with $\lambda = 0$) for each policy regime. The graph shows that this incentive is always higher under the no-bailouts regime. Recall that an economy is strongly fragile whenever this incentive is positive. The graph shows that for low enough values of q, the economy is strongly fragile under both regimes. For intermediate values of q, however, the economy is strongly fragile under the no-bailouts regime but not under the discretionary regime. For the economies in this region, the discretionary policy has a *macro-prudential* effect: not only does it improve the allocation of resources conditional on depositors' behavior, it actually changes depositors' equilibrium behavior and prevents a panic from occurring in state H. Panel D shows that this same pattern holds for the set of weakly fragile economies.

To see the intuition for this second benefit, recall that the incentive to run ρ depends on the ratio $c_1/\widehat{c}_2$. Under the no-bailouts regime, each bank chooses the payment c_1 taking into consideration the resources it will have remaining to make the payments $(\widehat{c}_1, \widehat{c}_2)$ in the event of a crisis. A discretionary bailouts policy alters this decision by making $(\widehat{c}_1, \widehat{c}_2)$ depend on aggregate conditions rather than on an individual banks' actions. This fact gives banks an incentive to increase c_1, which – by itself – would raise depositors' incentive to run. However, a bailout also increases the total pool of resources available for private consumption in state H. For a given level of c_1, a bailout makes $\widehat{c}_1$ and $\widehat{c}_2$ larger, which – by itself – would lower the incentive to run. Discretionary bailouts thus have two, competing effects on financial stability, as discussed in Keister (2010). By choosing

[5] See the derivations and proofs in the appendices for a formal presentation of these arguments.

the tax rate on short-term liabilities appropriately, the policy maker can offset the former effect while leaving the latter effect in place. The net result is a lower incentive to run in this regime, as depicted in panels C and D in the figure.

The top panels in the figure show the combined effect of these two benefits of the discretionary regime with a tax on short-term liabilities under each view about the causes of banking panics. For small values of q, the economy is fragile under both regimes, while for large values of q it is fragile under neither regime. In these regions, the discretionary regime yields higher expected utility because it results in a more efficient allocation of resources. For intermediate values of q, the benefit of the discretionary regime is much larger because it also eliminates the panic in state H. The precise gain is different in panels A and B because the two views are based on different notions of fragility and, hence, the cutoff points for the three regions are different. However, the basic forces at work are identical and the same general result obtains under both views: for every economy e, depositors' expected utility is higher under the discretionary bailouts regime with a tax on banks' short-term liabilities. This result demonstrates that it is possible, at least in some cases, to provide policy advice without having to first determine which of the two views more accurately describes the underlying causes of financial panics.

5 Concluding Remarks

Policy makers and academics around the world are currently engaged in a wide-ranging discussion about the reform of financial regulation and prudential banking policy. One element of this discussion is how to deal with the issues created by bailouts. 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.[6] 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 is one of several equilibria and hence

[6] See, for example, Bianchi (2011), Chari and Kehoe (2009), Farhi and Tirole (2009), Green (2010), and Keister (2010).

results, 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. This ongoing debate would seem to present a serious hindrance to using such models for policy analysis. Without knowing whether or not panics can result from self-fulfilling beliefs, 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 panics are driven by expectations or fundamentals. We constructed a model in which, depending on parameter values, a panic may be part of the unique equilibrium, one of multiple equilibria, or inconsistent with equilibrium. We evaluated alternative policy regimes in this model under two competing views about the underlying cause of crises. According to the fundamentals view, a panic occurs only if it is the unique equilibrium outcome following an adverse shock. The expectations view, in contrast, holds that a panic occurs whenever it is *an* equilibrium outcome; if there are multiple equilibria, the panic is then driven by the self-fulfilling beliefs of investors. We showed that the policy prescriptions that come out of the model are the same under both views. In particular, a discretionary bailouts regime with a tax on the short-term liabilities of financial institutions yields higher welfare than a strict no-bailouts regime regardless of whether one adopts the fundamentals view or the expectations view.

While our focus in this paper is on a single policy issue, the point we aim to make is more general. 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 policy questions, or could seek to identify conditions under which a more general invariance result might hold.

Appendix A. Best-Response Allocations

A.1 Best-response allocations under a no-bailouts policy

The best-responses of banks and the policy maker to a profile of withdrawal strategies y under a no-bailouts restriction generates an allocation $\mathbf{c}^{NB}$ that is characterized by the resource constraints (7), (9), (10) and (12); the first-order conditions (8) and (11); and the solution to problem (13). It can be shown that these same conditions also characterize the solution to the problem of maximizing (4) subject to

$$\pi_L c_1 + (1-\pi_L)\frac{c_2}{R} + g \leq 1, \tag{23}$$

$$\pi_L c_1 + (1-\pi_L)\left(\widehat{\pi}(\lambda)\widehat{c}_1 + (1-\widehat{\pi}(\lambda))\frac{\widehat{c}_2}{R}\right) + \widehat{g} \leq 1, \tag{24}$$

and the no-bailouts restriction $\widehat{g} = g$. In other words, $\mathbf{c}^{NB}$ is the allocation that maximizes depositors' ex ante expected utility subject to the basic resource constraints (23) and (24) and the no-bailouts restriction. Using the functional form (2), the allocation $\mathbf{c}^{NB}$ is given by

$$\begin{aligned}
g^{NB} &= \widehat{g}^{NB} = \frac{\delta^{\frac{1}{\gamma}}}{\delta^{\frac{1}{\gamma}} + (\alpha_2)^{\frac{1}{\gamma}}}, \\
c_1^{NB} &= \left(\frac{1}{\alpha_2}\right)^{\frac{1}{\gamma}}\left(1 - g^{NB}\right), \\
c_2^{NB} &= R\left(\frac{(1-q)R^{1-\gamma} + q\alpha_1}{\alpha_2}\right)^{\frac{1}{\gamma}}\left(1 - g^{NB}\right), \\
\widehat{c}_1^{NB} &= \left(\frac{1}{\alpha_1}\right)^{\frac{1}{\gamma}}\left(\frac{1 - g - \pi_L c_1^{NB}}{1-\pi_L}\right), \quad \text{and} \\
\widehat{c}_2^{NB} &= \left(\frac{R}{\alpha_1}\right)^{\frac{1}{\gamma}}\left(\frac{1 - g - \pi_L c_1^{NB}}{1-\pi_L}\right),
\end{aligned}$$

where

$$\begin{aligned}
\alpha_1 &\equiv \left(\widehat{\pi}(\lambda) + (1-\widehat{\pi}(\lambda))R^{\frac{1-\gamma}{\gamma}}\right)^{\gamma}, \\
\alpha_2 &\equiv \left(\pi_L + (1-\pi_L)\left((1-q)R^{1-\gamma} + q\alpha_1\right)^{\frac{1}{\gamma}}\right)^{\gamma},
\end{aligned} \tag{25}$$

and $\widehat{\pi}(\lambda)$ is given by (3). Note that this solution depends on the profile of withdrawal strategies y only through the fraction λ of depositors following the panic strategy.

A.2 Best-response allocations under a discretionary bailouts policy

The best-responses of banks and the policy maker under a discretionary bailouts policy with a tax on short-term liabilities generates an allocation $\mathbf{c}^{DT}$ that is characterized by the resource constraints (7) and (14) – (17); the first-order conditions (8), (18), and (21); and the solution to (22). We begin the process of deriving this allocation by restating the maximization problem (22) in different terms. The policy maker can be viewed as directly choosing the allocation $\mathbf{c}$ subject to the constraint that this allocation (i) is feasible under some tax policy (τ, η), (ii) reflects banks' optimal choice of payment schedules, and (iii) reflects the bailout policy that will be followed if state H occurs. That is, problem (22) is equivalent to choosing the allocation $\mathbf{c}$ that maximizes (4) subject to the constraint that $\mathbf{c}$ is an element of the set

$$\Omega^{DT} \equiv \left\{ \begin{array}{c} \mathbf{c} : \exists\, \eta \text{ such that (7) and (14) – (17) hold,} \\ u'(\widehat{c}_1) = Ru'(\widehat{c}_2) = v'(\widehat{g}), \text{ and} \\ u'(c_1) = (1+\eta)(1-q)\, Ru'(c_2) \end{array} \right\}. \tag{26}$$

Note that the last equality on the second line follows from (8) and (18) using the envelope condition $\widehat{U}' = \widehat{\mu}$.

Now consider an alternate problem: choosing the allocation $\mathbf{c}$ to maximize (4) subject to the basic resource constraints (23) and (24). Let Ω denote the constraint set for this problem, that is,

$$\Omega \equiv \left\{ \ \mathbf{c} : \text{(23) and (24) hold} \ \right\}$$

and let $\mathbf{c}^*$ denote the solution. This solution is characterized by the first-order conditions

$$u'(\widehat{c}_1^{\,*}) \;=\; Ru'(\widehat{c}_2^{\,*}) \;=\; v'(\widehat{g}^{\,*}), \quad \text{and} \tag{27}$$

$$u'(c_1^*) \;=\; (1-q)\, Ru'(c_2^*) + qRu'(\widehat{c}_2^{\,*}) \;=\; v'(g^*). \tag{28}$$

It is straightforward to show that $\Omega^{DT} \subset \Omega$ holds, meaning that the second optimization problem has a strictly larger constraint set. If the solution to this second problem, $\mathbf{c}^*$, lies in the smaller constraint set Ω^{DT}, then it must be the case that $\mathbf{c}^*$ also solves the more constrained problem, or that $\mathbf{c}^{DT} = \mathbf{c}^*$ holds.

We show that $\mathbf{c}^* \in \Omega^{DT}$ in three steps. First, comparing the first equality in (28) with the third line of (26) shows that $\mathbf{c}^*$ will satisfy the latter if η is set to

$$\eta^* \equiv \frac{qu'\left(\widehat{c}_2^*\right)}{(1-q)\,u'\left(c_2^*\right)} > 0. \tag{29}$$

Second, the equalities in (27) are the same as the second line of (26), so $\mathbf{c}^*$ necessarily satisfies these conditions. Finally, it straightforward to show that resource constraints in the first line of (26) reduce to the basic basic resource constraints (23) and (24) for any value of η, including η^* as defined in (29). These steps demonstrate that $\mathbf{c}^* \in \Omega^{DT}$ holds and, hence, that $\mathbf{c}^{DT} = \mathbf{c}^*$.

Using the first-order conditions (27) and (28), together with the resource constraints (23) and (24) and the functional form (2), $\mathbf{c}^{DT}$ can be shown to equal

$$\begin{aligned}
c_1^{DT} &= \frac{1}{\pi_L + (\alpha_5)^{\frac{1}{\gamma}}} \\
c_2^{DT} &= \frac{R^{\frac{1}{\gamma}}}{\pi_L + (\alpha_5)^{\frac{1}{\gamma}}}\left(\frac{\alpha_5}{\alpha_4}\right)^{\frac{1}{\gamma}} \\
\widehat{c}_1^{DT} &= \frac{1}{\pi_L + (\alpha_5)^{\frac{1}{\gamma}}}\left(\frac{\alpha_5}{\alpha_3}\right)^{\frac{1}{\gamma}} \\
\widehat{c}_2^{DT} &= \frac{R^{\frac{1}{\gamma}}}{\pi_L + (\alpha_5)^{\frac{1}{\gamma}}}\left(\frac{\alpha_5}{\alpha_3}\right)^{\frac{1}{\gamma}} \\
g^{DT} &= \frac{\delta^{\frac{1}{\gamma}}}{\pi_L + (\alpha_4)^{\frac{1}{\gamma}}}\left(\frac{\alpha_5}{\alpha_4}\right)^{\frac{1}{\gamma}} \\
\widehat{g}^{DT} &= \frac{\delta^{\frac{1}{\gamma}}}{\pi_L + (\alpha_4)^{\frac{1}{\gamma}}}\left(\frac{\alpha_5}{\alpha_3}\right)^{\frac{1}{\gamma}}
\end{aligned}$$

where

$$\alpha_3 = \left(\delta^{\frac{1}{\gamma}} + (1-\pi_L)\,(\alpha_1)^{\frac{1}{\gamma}}\right)^{\gamma} \tag{30}$$

$$\alpha_4 \equiv \left(\delta^{\frac{1}{\gamma}} + (1-\pi_L)\,R^{\frac{1-\gamma}{\gamma}}\right)^{\gamma} \tag{31}$$

$$\alpha_5 \equiv (1-q)\,\alpha_4 + q\alpha_3. \tag{32}$$

Appendix B. Proofs of Propositions

Proposition 1: $\rho\left(\mathbf{c}^{NB}(\lambda)\right)$ is strictly increasing in λ.

Proof: Using the expressions for the elements of $\mathbf{c}^{NB}$ presented in Appendix A.1, straightforward algebra yields

$$\begin{aligned}
\rho\left(\mathbf{c}^{NB}(\lambda)\right) &\equiv \frac{c_1^{NB}(\lambda)}{\widehat{c}_2^{NB}(\lambda)} - 1 \\
&= \left(\frac{\alpha_1}{R}\right)^{\frac{1}{\gamma}} \left((1-q)\, R^{1-\gamma} + q\alpha_1\right)^{-\frac{1}{\gamma}} - 1 \\
&= \left(\frac{1}{R}\right)^{\frac{1}{\gamma}} \left((1-q)\, R^{1-\gamma}\alpha_1^{-1} + q\right)^{-\frac{1}{\gamma}} - 1. \qquad (33)
\end{aligned}$$

Recall from (25) that α_1 depends on $\widehat{\pi}$, which in turn depends on λ. It is easy to see from (3) that $\widehat{\pi}$ is strictly increasing in λ. From (25), the assumption $\gamma > 1$ implies α_1 is strictly increasing in $\widehat{\pi}$ and, hence, strictly increasing in λ. The calculations in (33) show that ρ^{NB} is strictly increasing in α_1, and hence must also be strictly increasing in λ. ■

Proposition 2: $\rho\left(\mathbf{c}^{DT}(\lambda)\right)$ is strictly increasing in λ.

Proof: Using the expressions for the elements of $\mathbf{c}^{DT}$ presented in Appendix A.2, we have

$$\rho\left(\mathbf{c}^{DT}(\lambda)\right) \equiv \frac{c_1^{DT}(\lambda)}{\widehat{c}_2^{DT}(\lambda)} - 1 = \left(\frac{\alpha_3}{R\alpha_5}\right)^{\frac{1}{\gamma}} - 1.$$

Using the definition of α_5 in (32), this expression can be rewritten as

$$\begin{aligned}
\rho\left(\mathbf{c}^{DT}(\lambda)\right) &= \left(\frac{\alpha_3}{R\left((1-q)\,\alpha_4 + q\alpha_3\right)}\right)^{\frac{1}{\gamma}} - 1 \\
&= \left(\frac{1}{R\left((1-q)\,\alpha_4\alpha_3^{-1} + q\right)}\right)^{\frac{1}{\gamma}} - 1.
\end{aligned}$$

Since α_1 is strictly increasing in λ (as established in the proof of Proposition 1), it is clear from (30) that α_3 is strictly increasing in λ as well. From (31) we see that α_4 does not depend on λ. It follows immediately from the expression above, therefore, that ρ^{DT} is strictly increasing in λ, as desired. ■

Proposition 3: $V_F^{DT}(e) > V_F^{NB}(e)$ *and* $V_E^{DT}(e) > V_E^{NB}(e)$ *for all* e.

We begin by establishing two lemmas, the first of which shows that the incentive to run is always higher under the no-bailouts regime.

Lemma 1: $\rho\left(\mathbf{c}^{NB}(\lambda)\right) > \rho\left(\mathbf{c}^{DT}(\lambda)\right)$ *for all* $\lambda \in [0,1]$.

Proof of the lemma: From the definition of ρ in (5), the above inequality is equivalent to

$$\frac{\widehat{c}_2^{NB}(\lambda)}{c_1^{NB}(\lambda)} < \frac{\widehat{c}_2^{DT}(\lambda)}{c_1^{DT}(\lambda)}. \tag{34}$$

Using the solutions from Appendix A, the left side of (34) simplifies to

$$R^{\frac{1}{\gamma}}\left(\frac{\alpha_5}{\alpha_3}\right)^{\frac{1}{\gamma}}$$

and the right-hand side simplifies, after considerable algebra,

$$\left(\frac{R}{\alpha_1}\right)^{\frac{1}{\gamma}}\left((1-q)R^{1-\gamma} + q\alpha_1\right)^{\frac{1}{\gamma}}.$$

Establishing the lemma thus requires demonstrating

$$\frac{(1-q)R^{1-\gamma} + q\alpha_1}{\alpha_1} < \frac{\alpha_5}{\alpha_3}. \tag{35}$$

Using the definition of α_5 in (32), this inequality can be rewritten as

$$(1-q)\frac{R^{1-\gamma}}{\alpha_1} + q < (1-q)\frac{\alpha_4}{\alpha_3} + q$$

or, using (25) and (30),

$$\frac{R^{\frac{1-\gamma}{\gamma}}}{(\alpha_1)^{\frac{1}{\gamma}}} < \frac{\delta^{\frac{1}{\gamma}} + (1-\pi_L)R^{\frac{1-\gamma}{\gamma}}}{\delta^{\frac{1}{\gamma}} + (1-\pi_L)(\alpha_1)^{\frac{1}{\gamma}}}.$$

Cross-multiplying yields

$$\delta^{\frac{1}{\gamma}}R^{\frac{1-\gamma}{\gamma}} + (1-\pi_L)(\alpha_1)^{\frac{1}{\gamma}}R^{\frac{1-\gamma}{\gamma}} < \delta^{\frac{1}{\gamma}}(\alpha_1)^{\frac{1}{\gamma}} + (1-\pi_L)(\alpha_1)^{\frac{1}{\gamma}}R^{\frac{1-\gamma}{\gamma}}$$

or

$$R^{\frac{1-\gamma}{\gamma}} < (\alpha_1)^{\frac{1}{\gamma}}. \tag{36}$$

It follows immediately from (25) and the assumption $\gamma > 1$ that (36) holds for any $\lambda \in [0,1]$. ■

The second lemma shows the set of fragile economies is strictly smaller under the policy regime with discretionary bailouts and a tax on short-term liabilities than under a no-bailouts regime.

Lemma 2: $\Phi_W^{DT} \subset \Phi_W^{NB}$ *and* $\Phi_S^{DT} \subset \Phi_S^{NB}$.

Proof of the lemma: For the first part, the definition of weak fragility states that an economy e is in Φ_W^{DT} if $\rho\left(c^{DT}(1)\right) \geq 0$ and in Φ_W^{NB} if $\rho\left(c^{NB}(1)\right) \geq 0$. Lemma 1 establishes $\rho\left(c^{NB}(1)\right) > \rho\left(c^{DT}(1)\right)$ and, hence, any economy in Φ_W^{DT} must also be in Φ_W^{NB}. The fact that the inclusion relationship is strict follows from the strict inequality in Lemma 1; it is also established by the example depicted in Figure 1. The second part of the lemma can be established in the same way, using the fact that Lemma 1 implies $\rho\left(c^{NB}(0)\right) > \rho\left(c^{DT}(0)\right)$. ■

With these lemmas in hand, we are ready to prove Proposition 3.

Proof of the proposition: For the first part of the proposition, we begin by listing the possible values of V_E^{DT} and V_E^{NB} depending on whether or not the economy is weakly fragile under each policy.

$e \in \Phi_W^{DT}$	$e \in \Phi_W^{NB}$	V_E^{DT}	V_E^{NB}
yes	yes	$U\left(\mathbf{c}^{DT}(1)\right)$	$U\left(\mathbf{c}^{NB}(1)\right)$
no	yes	$U\left(\mathbf{c}^{DT}(0)\right)$	$U\left(\mathbf{c}^{NB}(1)\right)$
no	no	$U\left(\mathbf{c}^{DT}(0)\right)$	$U\left(\mathbf{c}^{NB}(0)\right)$

Note that there are only three possibilities because Lemma 2 rules out the scenario in which $e \in \Phi_W^{DT}$ and $e \notin \Phi_W^{NB}$. According to the table, the result $V_E^{DT} > V_E^{NB}$ can be established by showing both

(a) $U\left(\mathbf{c}^{DT}(\lambda)\right) > U\left(\mathbf{c}^{NB}(\lambda)\right)$, and
(b) $U\left(\mathbf{c}^{DT}(\lambda)\right)$ is non-increasing in λ.

For (a): Appendix A.2 shows that the allocation $\mathbf{c}^{DT}(\lambda)$ maximizes (4) subject to the basic resource constraints (23) and (24). Appendix A.1 shows that $\mathbf{c}^{NB}(\lambda)$ solves the same problem with one additional constraint: $g = \widehat{g}$. Therefore, given that $\mathbf{c}^{DT} \neq \mathbf{c}^{NB}$ and (4) is strictly concave, it must be the case that $U\left(\mathbf{c}^{DT}(\lambda)\right)$ is strictly greater than $U\left(\mathbf{c}^{NB}(\lambda)\right)$.

For (b): the solution presented in Appendix A.2 implies

$$U\left(c^{DT}(\lambda)\right) = \frac{1}{1-\gamma}\left(\pi_L + (\alpha_5)^{\frac{1}{\gamma}}\right)^{\gamma}.$$

Showing that $U\left(c^{DT}(\lambda)\right)$ is non-increasing in λ is therefore equivalent to showing that α_5 is non-decreasing in λ or, using (32), that α_3 is non-decreasing in λ. This latter fact was established in the proof of Proposition 2. We have thus established that $V_F^{DT}(e) > V_F^{NB}(e)$ holds for all e.

The second part of the proposition, $V_F^{DT} > V_F^{NB}$, can be proven in the exact same fashion. ■

References

[1] Allen, Franklin and Douglas Gale (1998) “Optimal financial crises,” *Journal of Finance* 53: 1245–84.

[2] Allen, Franklin and Douglas Gale (2007) *Understanding financial crises*, Oxford University Press.

[3] Bernanke, Ben S. (2010) “Causes of the recent financial and economic crisis,” Testimony delivered to the Financial Crisis Inquiry Commission, Sept. 2.

[4] Bianchi, Javier (2011) “Efficient bailouts?” mimeo., University of Maryland.

[5] Calomiris, Charles W. and Joseph R. Mason (1997) “Contagion and bank failures during the great depression: The June 1932 Chicago banking panic,” *American Economic Review* 87: 863-883.

[6] Calomiris, Charles W. and Joseph R. Mason (2003) “Fundamentals, panics and bank distress during the depression,” *American Economic Review* 93: 1615-1647.

[7] Chari, V.V. and Patrick J. Kehoe (2009) “Bailouts, time inconsistency and optimal regulation,” Federal Reserve Bank of Minneapolis Staff Report, November.

[8] Cooper, Russell and Thomas W. Ross (1998) “Bank runs: liquidity costs and investment distortions,” *Journal of Monetary Economics* 41: 27-38.

[9] Diamond, Douglas W. and Phillip H. Dybvig (1983) “Bank runs, deposit insurance, and liquidity,” *Journal of Political Economy* 91: 401-419.

[10] Ennis, Huberto M. (2003) “Economic Fundamentals and Bank Runs,” Federal Reserve Bank of Richmond *Economic Quarterly* 89: 55-71.

[11] Ennis, Huberto M. and Todd Keister (2009) “Bank runs and institutions: The perils of intervention,” *American Economic Review* 99: 1588-1607.

[12] Ennis, Huberto M. and Todd Keister (2010) “Banking panics and policy responses,” *Journal of Monetary Economics* 57: 404-419.

[13] Farhi, Emmanuel and Jean Tirole (2009) “Collective moral hazard, maturity mismatch and systemic bailouts,” NBER Working Paper 15138, July.

[14] Goldstein, Itay and Ady Pauzner (2005) “Demand deposit contracts and the probability of bank runs,” *Journal of Finance* 60: 1293-1327.

[15] Gorton, Gary (1988) “Banking panics and business cycles.” *Oxford Economic Papers* 40: 751–81.

[16] Gorton, Gary (2010) *Slapped by the invisible hand: The panic of 2007*, Oxford University Press.

[17] Green, Edward J. (2010) “Bailouts” Federal Reserve Bank of Richmond *Economic Quarterly* 96:11-32.

[18] Green, Edward J. and Ping Lin (2003) "Implementing efficient allocations in a model of financial intermediation," *Journal of Economic Theory* 109: 1-23.

[19] Keister, Todd (2010) "Bailouts and Financial Fragility," Federal Reserve Bank of New York Staff Report 473.

[20] Kindleberger, Charles P. (1978) *Manias, panics, and crashes: A history of financial crises*, New York: Basic Books.

[21] Kocherlakota, Narayana (2010) "Taxing risk and the optimal regulation of financial institutions," Federal Reserve Bank of Minneapolis *Economic Policy Paper* 10-3, May.

[22] Miron, Jeffrey (1986) "Financial panics, the seasonality of the nominal interest rate, and the founding of the Fed." *American Economic Review* 76: 125–40.

[23] Peck, James and Karl Shell (2003) "Equilibrium bank runs," *Journal of Political Economy* 111: 103-123.

[24] Saunders, Anthony, and Berry Wilson (1996) "Contagious bank runs: Evidence from the 1929–1933 period." *Journal of Financial Intermediation* 5: 409–23.

[25] Schumacher, Liliana (2000) "Bank runs and currency run in a system without a safety net: Argentina and the 'tequila' shock." *Journal of Monetary Economics* 46: 257–77.

[26] Wallace, Neil (1988) "Another attempt to explain an illiquid banking system: the Diamond and Dybvig model with sequential service taken seriously," Federal Reserve bank of Minneapolis *Quarterly Review* 12 (Fall): 3-16.

[27] Wallace, Neil (1990) "A banking model in which partial suspension is best," Federal Reserve bank of Minneapolis *Quarterly Review* 14 (Fall): 11-23.