Anticipated Banking Panics*

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1 Introduction

As argued by Bernanke (2012), a distinctive feature of the recent crisis was "run-like" behavior on the major financial institutions in the shadow banking sector. The runs began to gather steam early in the spring of 2008 around the time of the Bear Stearns collapse and culminated with the nearly instantaneous downfall of the entire investment banking sector that September. Though they differed in detail, the events had the basic features of a classic financial panic. As concern rose about asset quality, anxious depositors withdrew funds forcing asset firesales and leading to sharp declines in asset prices along with sharp increases in credit spreads. The resulting disruption of financial intermediation was likely the major factor that led the downturn to devolve into the Great Recession.

It is significant to note that the panic did not happen instantly but rather played out over nearly the entire course of 2008. Early on, there were "slow" runs where depositors began a steady stream of withdrawals leading up to a wave of "fast" runs that September, when panicky depositors withdrew rapidly. Any full characterization of the financial panic and how it affected real activity, accordingly, needs to provide an account of the transition from slow to fast runs.

In Gertler and Kiyotaki (2015; hereafter GK), two of the authors of this paper develop a simple macroeconomic model with bank runs to analyze the simultaneous feedback between real economic activity and banking instability. A corollary result of the paper is that allowing for anticipations of the possibility of a fast run can induce slow run-like behavior. As the market probability of a run increases, depositors withdraw some but not all of their funds, a pattern similar to the steady drain of credit from the shadow banking system that occurred prior to the outright collapse. Further, by pushing credit spreads up

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and asset prices down, the anticipation of a run can potentially have harmful
effects on the economy even if the run itself does not occur ex post.

Critical to the analysis is how beliefs about the probability of a run are
modeled. As in traditional models of runs (Diamond and Dybvig (1983) a run in
GK is a "sunspot" coordination failure. One important difference, though is that
whether a sunspot equilibrium exists depends on banks’ financial exposure to
systemic risk as measured by the depositor recovery rate in the event of failure.
In principle a way to pin down the probability of a run is to apply a global
games approach following Goldstein and Pauzner (2005) where by allowing for
noisy private signals a unique equilibrium emerges with run probabilities tied
to fundamentals. However, the complexity of this approach makes it difficult
to apply an infinite horizon general equilibrium model like GK. Accordingly,
GK instead follow the spirit of the global games approach by postulating that
the run probability is a function of the recovery rate, the key fundamental that
determines whether a run equilibrium exists. The run remains a sunspot but the
probability of the sunspot is endogenous. The parameters of the belief function,
however, are arbitrary.

In this paper we propose a simple alternative for forming beliefs about run
probabilities that is fully rational. We decompose the run probability into the
product of two factors: first the probability that a bank run equilibrium exists;
and second the probability that a sunspot run materializes conditional on the
existence of the run equilibrium. We suppose the latter is acyclical and occurs
with a fixed probability \( \pi \). On the other hand, the probability \( \omega_t \) that a run
equilibrium exists in the following period is endogenously determined by funda-
mentals: it is the probability that the recovery rate is in the range where
banking panics become self fulfilling. The run probability \( p_t \) is then given by
\( \omega_t \cdot \pi \). It remains the case that a run is not uniquely determined by funda-
mentals. However, as in the global games approach, the run probability is tied
concretely to the rational forecast of the relevant fundamentals.

Section 2 briefly summarizes the GK macroeconomic model of banking panics
and describes in detail our approach to modeling run probabilities. Section 3
presents some simulations of the model. Section 4 concludes.

2 The Basic Model

The framework is based on the infinite horizon macroeconomic model of banking
instability developed in Gertler and Kiyotaki (2015). There are two types of
agents - households and bankers - with a continuum of measure unity of each
type. Banks have expertise in making loans and thus intermediate funds between
households and productive assets. Households may also invest in productive
assets directly, but are less efficient in doing so than are banks.

Households and bankers each get utility from consuming a perishable nondur-
able good. There is a durable asset, "capital", which yields a dividend stream
of the nondurable good \( Z_t \) per unit at each time \( t \) and which is fixed in aggregate
supply. The dividend process is given by

\[(Z_{t+1} - 1) = \rho(Z_t - 1) + \varepsilon_{t+1} \]

where the random disturbance \(\varepsilon_{t+1}\) is i.i.d. with mean zero and is uniformly distributed over the closed support \([-\overline{z}, \overline{z}]\). In addition to the dividend stream generated by capital, both households and bankers also receive endowments of the nondurable good as we describe later.

We assume capital does not depreciate and we normalize the total stock at unity. Claims on the capital may be either held by banks or directly by households. Let \(K^b_t\) be capital holdings by banks and \(K^h_t\) holdings by households. Given that total holdings must equal total supply:

\[K^b_t + K^h_t = 1 \]

Claims on capital may be traded in competitive markets as we discuss below. Let \(Q_t\) be the market price of a claim on a unit of capital. Then the gross rate of return on capital intermediated by banks, \(R^b_{t+1}\), is given by

\[R^b_{t+1} = \frac{Z_{t+1} + Q_{t+1}}{Q_t} \]

To capture that households are less efficient than banks at holding capital we assume that they must pay a management cost each period that is increasing and convex in the size of their respective portfolios. In particular, to hold \(K^h_t\) units of capital that earns payoffs at \(t + 1\) a household must pay a management fee \(f(K^h_t)\) at \(t\), with \(f'(K^h_t) > 0; f''(K^h_t) > 0\). The management fee captures the household’s relative disadvantage in evaluating and monitoring direct capital holdings. The convex cost, further, is meant to capture limits on the capacity of households to manage a capital portfolio. Given the management cost, the household’s return on capital \(R^h_{t+1}\) is given by

\[R^h_{t+1} = \frac{Z_{t+1} + Q_{t+1}}{Q_t + f'(K^h_t)} \]

Given \(R^b_{t+1} > R^h_{t+1}\), absent financial frictions banks will intermediate the entire capital stock. Households in turn will save entirely in the form deposits. However, when banks are limited in their ability to obtain deposits, households will directly hold some of the capital. As the constraints tighten in a recession, as will happen in our model, the share of capital held by households will expand, forcing asset prices down. In the event of a run, which will become more likely in a recession, the household share will temporarily rise to unity as banks liquidate all their holdings, pushing asset prices down to firesale levels.

2.1 Households

Each household consumes and saves either by holding banks deposits or by holding claims on capital directly. In addition to returns on asset holdings, each
household receives an endowment of the consumption good $Z_t W^h_t$ that varies proportionately with the aggregate productivity shock $Z_t$.

Intermediary deposits at $t$ are one period bonds that promise to pay a non-contingent gross rate of return $R_{t+1}$ in the absence of a run. In the event of a run at $t + 1$, depositors receive the fraction $x_{t+1}$ of the promised return, where the recovery rate $x_{t+1}$ is the total liquidation value of bank assets per unit of promised deposit obligations. As we will discuss, bank runs are possible if and only if this ratio is strictly below unity. Let $p_t \in [0,1]$ be the probability of run in $t + 1$. Then we can express the gross rate of return on the deposit contract $R_{t+1}$ as

$$ R_{t+1} = \begin{cases} R_{t+1} \text{ with probability } 1 - p_t \\ x_{t+1} R_{t+1} \text{ with probability } p_t \end{cases} $$

A run in our model corresponds to a panic failure of households to roll over deposits as opposed to early withdrawal of demand deposits, as in the classic Diamond and Dybvig (1983) model.\(^1\) For this reason we do not need to impose a "sequential service constraint" which is necessary to generate runs in Diamond/Dybvig. Instead we make the weaker assumption that all households receive the same pro rata share of output in a run. Later we describe the conditions that lead to the existence of an equilibrium where a "failure to rollover" run is possible.

Each period households choose consumption $C^h_t$, bank deposits $D_t$, and direct capital holding $K^h_t$ to maximize an expected discounted stream of utility from consumption subject to a period budget constraint that equates consumption and saving to current asset and endowment income. Period utility is logarithmic in consumption and $\beta \in (0, 1)$ is the subjective discount factor. The first order condition for deposits is then given by

$$ 1 = [(1 - p_t) E_t \{ A_{t,t+1} \mid \text{NoRun} \} + p_t E_t \{ A_{t,t+1} x_{t+1} \mid \text{Run} \}] \cdot R_{t+1} $$

Observe that the promised deposit rate $R_{t+1}$ that satisfies equation (5) depends on the run probability $p_t$ as well as $x_{t+1}$.

The first order condition for direct capital holdings is given in turn by

$$ 1 = E_t \{ A_{t,t+1} R^h_{t+1} \} $$

So long as households have some direct capital holdings, the first order condition given by (6) will be key in determining the market price of capital (see also equation (4)). Further, the market price of capital will tend to be decreasing in the share of capital since the marginal management cost $f''(K^h_t)$ is increasing. As will become clear, in a panic run banks will sell all their securities to households, leading to a sharp contraction in asset prices.\(^2\) The severity of the drop will

\(^1\)Our modeling of runs as rollover crises follows the Cole and Kehoe (2000) model of self-fulfilling sovereign debt crises.

\(^2\)In practice, the runs during the crisis occurred in wholesale funding markets where banks lend to one another, as opposed to retail markets where households lend to banks. Gertler, Kiyotaki and Prestipino, forthcoming, extend the GK model to allow for runs in wholesale markets.
depend on the quantity of sales and the convexity of the management cost function.

2.2 Bankers

Bankers manage financial intermediaries. They fund capital investments \( Q_t k^b_t \) by issuing deposits \( d_t \) to households and also by using their own equity, or net worth \( n_t \):

\[
Q_t k^b_t = d_t + n_t
\]  

Due to financial market frictions bankers may be constrained in their ability to obtain deposits from households.

Each banker has an i.i.d. probability of surviving until the next period and a probability \( 1 - \sigma \) of exiting. The expected lifetime is then \( 1/(1 - \sigma) \). We introduce finite expected lifetimes for bankers to keep them from accumulating retained earnings to the point where they can fully self finance their investments. Each period \( 1 - \sigma \) new bankers enter which keeps the total population constant.

Bankers consume their net worth upon exit. We assume each banker’s utility is linear in terminal consumption (which is the same as their terminal net worth). Accordingly, we can express the expected utility of a surviving banker at \( t \), \( V_t \), which we refer to as the bank franchise value, as

\[
V_t = E_t\{\beta \Omega_{t,t+1} n_{t+1}\}
\]

where the bank uses the stochastic discount factor \( \beta \Omega_{t,t+1} \) to value net worth realized in \( t + 1 \), and \( \Omega_{t,t+1} \) is the banker’s shadow value of a unit of net worth at \( t + 1 \), averaged across the likelihood of exit and the likelihood of survival, given by

\[
\Omega_{t,t+1} = 1 - \sigma + \sigma \frac{V_{t+1}}{n_{t+1}}
\]  

With probability \( 1 - \sigma \) the banker exits, implying a unit of net worth equals unity (the number of consumption goods it can purchase). With probability \( \sigma \) the banker survives implying the marginal value of \( n_t \) is \( \frac{V_{t+1}}{n_{t+1}} \), the franchise value of the bank per unit of net worth. As will become clear, to the extent that an additional unit of net worth relaxes the financial market friction, \( \frac{V_{t+1}}{n_{t+1}} \) in general will exceed unity.

We assume that surviving banks accumulate net worth through retained earnings. Conditional on the realization of \( Z_t \), \( n_t \) for surviving bankers is given by

\[
n_t = R^b_t Q_{t-1} k^b_{t-1} - R_t d_{t-1}.
\]  

We suppose that for each new banker, \( n_t \) equals simply a "startup" endowment \( w^b \), received only in the first period of business.

Absent a run at \( t \) (i.e. a failure of depositors to roll over), the bank pays its creditors the promised rate \( R_t \). In the event of a run, however, it liquidates its assets (by selling to households) and uses the proceeds to pay its creditors. Let
$Q_t^*$ be the liquidation price of bank assets conditional on a run. Then we can express the recovery rate on banks deposits

$$x_t = \min[1, \frac{(Q_t^* + Z_t)k_t^b}{R_t d_{t-1}}] \quad (10)$$

Note that in this instance the bank's net worth goes to zero in the event of a run.

To motivate a limit on the bank's ability to issue deposits (which is also critical for open the possibility of a bank run equilibrium), we introduce the following moral hazard problem: After accepting deposits at the beginning of $t$ and purchasing assets, but still during the period, the banker has the option of diverting a fraction $\theta$ of assets for personal use. The banker can do so by secretly selling the assets on the secondary market. Because this process takes time (in order to remain undetected), the banker must decide whether to divert at time $t$ prior to the realization of uncertainty at $t + 1$. The cost to the banker of siphoning funds is that the depositors can force the bank into liquidation at the beginning of next period.

The banker’s decision over whether to divert funds at $t$ reduces to comparing the franchise value of the bank, $V_t$, which measure the benefit in discounted profits from operating honestly, with the gain from diverting funds, $\theta Q_t k_t^b$. Rational depositors will not agree to lend funds if the bank prefers to divert them. Accordingly, any financial arrangement between the bank and its depositors must satisfy the following condition, which eliminates the bank's incentive to divert:

$$\theta Q_t k_t^b \leq V_t \quad (11)$$

Given the linearity in the bank’s portfolio decision problem we conjecture and then verify subsequently, that the bank’s franchise value $V_t$ is proportional to it’s net worth $n_t$. We can then restate the objective as to maximize $V_t/n_t$. Let $\phi_t \equiv Q_t k_t^b / n_t$ be the ratio of bank assets to net worth, which we will refer to as the "leverage multiple". Combining equations (7) and (9) with the expression for $V_t$ yields the following representation of the bank’s objective

$$\frac{V_t}{n_t} = \max_{\phi_t} \frac{1}{\phi_t} \E_t \{ \beta \Omega_{t+1} (R_{t+1} - \bar{R}_{t+1}) \phi_t + \bar{R}_{t+1} | \text{no run} \} \quad (12)$$

subject to the incentive constraint (obtained from equation (11)):

$$\theta \phi_t \leq \frac{V_t}{n_t} \quad (13)$$

and the deposit rate constraint (obtained from equations (5) and (10)):

$$\bar{R}_{t+1} = \left[ (1 - p_t) \E_t \{ \Lambda_{t,t+1} | \text{no run} \} + p_t \E_t \left\{ \frac{\Lambda_{t,t+1}}{\phi_t} \left| \frac{R_{t+1}^{bs}}{\bar{R}_{t+1}} | \text{run} \right. \right\} \right]^{-1} \quad (14)$$
where \( R_{t+1}^* = \frac{Z_{t+1} + Q_t}{Q_t} \) is the gross return on bank asset conditional on a run and where \( \phi_t R_{t+1}^*/(\phi_t - 1) \) is the run level of net worth, considered to be a constant.

In what follows we restrict our attention to a symmetric equilibrium in which all banks choose the same leverage multiple \( \phi_t \) and all depositors coordinate on the same rollover decision. It follows that all banks will default in the event of a run and will survive without a run. Given this, \( p_t \) will be common across banks and we can proceed to characterize the representative bank’s optimal choice of the leverage multiple \( \phi_t \). Let \( \mu_t \) be the expected discounted excess return on banks assets relative to deposit costs and let \( \nu_t \) be the expected discounted return from reducing deposits a unit:

\[
\mu_t = (1 - p_t) E_t \{ \beta \Omega_{t,t+1} ((R_{t+1}^* - \bar{R}_{t+1}) \mid \text{no run} \}\}
\]

Next define \( \mu_t^r \) as the expected discounted marginal excess return to bank assets

\[
\mu_t^r = \mu_t - \nu_t \frac{(\phi_t - 1) d\bar{R}_{t+1} (\phi_t)}{d\phi_t} < \mu_t
\]

The second term on the right of equation (16) reflects the effect of the increase in \( \bar{R}_{t+1} \) that arises as the bank increases \( \phi_t \). An increase in \( \phi_t \) reduces the recovery rate, forcing \( \bar{R}_{t+1} \) up to compensate depositors, as equation (14) suggests. The term \( \nu_t \) \( (\phi_t - 1) \) then reflects the reduction in the bank franchise value that results from each percentage increase in \( \bar{R}_{t+1} \). Due to the marginal effect on \( \bar{R}_{t+1} \) from expanding \( \phi_t \), the marginal excess return \( \mu_t^r \) is below the average excess return \( \mu_t \).

The solution for \( \phi_t \) depends on whether or not the incentive constraint (13) is binding. In the case where it binds, \( \phi_t \) is given by

\[
\phi_t = \frac{\nu_t}{\theta - \mu_t}; \quad \text{with } \mu_t^r > 0
\]

Conversely, when the constraint is not binding,

\[
\mu_t^r = 0; \quad \text{with } \phi_t < \frac{\nu_t}{\theta - \mu_t}
\]
per unit of net worth of losing the franchise value, which is measured by $V_t/n_t = \mu_t \phi_t + \nu_t$. Note that the excess return $\mu_t$ tends to move countercyclically since the spread between $R_{t+1}^b - R_{t+1}$ widens as the borrowing constraint tightens in recessions. As a results, $\phi_t$ tends to move countercyclically.

If the constraint does not bind, banks asset positions may still be limited by its net worth, so long as there is a possibility that the incentive constraint could bind in the future. In this instance, as in Brunnermeier and Sannikov (2014) and He and Krishnamurthy (2015) banks have a precautionary motive for scaling back their respective leverage multiples. The precautionary motive is captured by the presence of the discount factor $\Omega_{t,t+1}$ in the measure of the discounted excess return. The multiplier $\Omega_{t,t+1}$, which reflects the shadow value of net worth, tends to vary countercyclically given that borrowing constraints tighten in downturns. By reducing their leverage multiples, banks reduce the risk of taking losses when the shadow value of net worth is high.

In either case, as we conjectured, the franchise value of the bank $V_t$ is proportionate to $n_t$ by a factor that is independent of bank-specific factors. When the incentive constraint is binding, $V_t = \theta \phi_t \cdot n_t$. When is not currently binding, $V_t = \left\{ [\nu_t \phi_t n_t] dR_{t+1}^b (\phi_t) \phi_t + \nu_t \cdot n_t \right\} (\text{since } \mu_t^r = 0)$. An important corollary is that the bank cannot operate with zero net worth. In this instance $V_t$ falls to zero, implying that the incentive constraint (11) would always be violated if the bank tried to issue deposits. As we show, a necessary condition for a bank run is that banks cannot operate with zero net worth.

### 2.3 Aggregation and equilibrium without bank runs

Given that individual bank portfolio decisions are homogenous in net worth, the leverage multiple $\phi_t$ is independent of bank-specific factors. Accordingly, we can aggregate across banks to obtain the following relation between aggregate bank asset holdings $Q_t K_t^b$ and the aggregate quantity of net worth in the banking sector:

$$\frac{Q_t K_t^b}{N_t} = \phi_t$$  \hspace{1cm} (19)

Summing across both surviving and entering bankers yields the following expression for the evolution of net worth

$$N_t = \sigma \left[ (R_t^b - R_t) \phi_{t-1} + R_{t-1} \right] N_{t-1} + W^b$$  \hspace{1cm} (20)

where $W^b = (1 - \sigma) w^b$ is the total endowment of entering bankers. The first term is the total net worth of bankers that operated at $t - 1$ and survived until $t$.

Conversely, exiting bankers consume the fraction $1 - \sigma$ of net earnings on assets:

$$C_t^b = (1 - \sigma) \left[ (R_t^b - R_t) \phi_{t-1} + R_t \right] N_{t-1}$$

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5One difference from these papers is that because default is possible (in the event of a run), the bank’s decision over its leverage multiple also affects to promised deposit rate, which affects the cost of funds at the margin. This effect provides an additional motive for the bank to reduce its leverage multiple.
Finally, output net management costs is consumed by bankers and households.

\[ C_t^h + C_t^b = Z_t + W^h + W^b - \frac{\alpha}{2} (K^h)^2 \]

### 2.4 Condition for a bank run equilibrium

As in Diamond and Dybvig (1983), the runs we consider are runs on the entire banking system and not an individual bank. A run on an individual bank will not have aggregate effects as depositors simply shuffle their funds from one bank to another. We differ from Diamond and Dybvig though in that runs reflect a panic failure to roll over deposits as opposed to early withdrawal (similar to Cole and Kehoe 2000). In addition, runs are anticipated.

Consider the behavior of a household that acquired deposits at \( t - 1 \). The household must then decide whether to roll over deposits at \( t \). A self-fulfilling "run" equilibrium is possible if the household perceives that in the event all other depositors run, forcing the banking system into liquidation, the household will lose money if it rolls over its deposits. Note that this condition is satisfied if the liquidation makes the banking system insolvent, i.e. drives aggregate bank net worth to zero. Given the moral hazard problem, a household that deposits in a zero net worth bank will simply lose its money (as the bank runs away with it).

The condition for a bank run equilibrium at \( t \), accordingly, is that in the event of liquidation following a run, bank net worth goes to zero. Recall that earlier we defined the depositor recovery rate, \( x_t \), as the ratio of the value of bank assets in liquidation to promised obligations to depositors. Accordingly, the condition for a bank run equilibrium is simply that the recovery rate is below unity:

\[ x_t = \frac{(Q_t^h + Z_t)K_t^{bh}}{R_tD_{t-1}} < 1 \]  
\[ x_t = \frac{R_t^{bh}}{R_t} \cdot \frac{1}{1 - 1/\phi_{t-1}} < 1 \]

where as earlier \( R_t^{bh} \) is the return on bank assets conditional on liquidation.

### 2.5 Liquidation prices and recovery after a run

Key to the condition for a bank run equilibrium is the behavior of the liquidation price \( Q_t^* \). A depositor run at \( t \) induces all banks to liquidate their assets by selling them to households. Accordingly in the wake of the run:

\[ K_t^h = \bar{K} = 1 \]  

The banking system then rebuilds itself over time as new banks enter. We suppose that new banks enter one period after the panic. The evolution of net
worth following the run at \( t \) is given by
\[
N_{t+1} = W^b + \sigma W^b, \tag{23}
\]
\[
N_{t+i} = \sigma[(Z_{t+i} + Q_{t+i})K^b_{t+i-1} - R_{t+i}D_{t+i-1}] + W^b, \text{ for all } i \geq 2.
\]

To obtain \( Q^*_t \), we invert the household Euler equation to obtain:
\[
Q^*_t = E_t \left[ \sum_{j=1}^{\infty} \Lambda_{t,t+i}(Z_{t+i} - f'(K^b_{t+i})) \right] - f'(1) \tag{24}
\]

The liquidation price is thus equal to the expected discounted stream of dividends net marginal management costs. Since marginal management costs are at a maximum when \( K^b_t \) equal unity, \( Q^*_t \) is at a minimum, given the expected future path of \( K^b_t \). Further, the longer it takes the banking system to recover (so \( K^b_t \) to falls back to steady state) the lower will be \( Q^*_t \). Finally, note that shocks to \( Z_t \) will cause \( Q^*_t \) to move procyclically.

2.6 The run probability

We next turn to the determination of the run probability. Let \( \xi_{t+1} \) be a binary variable that takes on a value of 1 with probability \( \pi \) and a value of 0 with probability \( 1 - \pi \). In the event of 1, depositors coordinate on a run if a bank run equilibrium exists. Accordingly, a bank run arises at \( t + 1 \) iff (i) a bank run equilibrium exists at \( t + 1 \) and (ii) \( \xi_{t+1} = 1 \). Let \( \omega_t \) be the probability at \( t \) that a bank run equilibrium exists at \( t + 1 \). Then the probability \( p_t \) that a run at \( t + 1 \) is given by
\[
p_t = \omega_t \cdot \pi \tag{25}
\]

We find \( \omega_t \) as follows. Define \( Z_{t+1} \) as the value of \( Z_{t+1} \) that makes the recovery rate \( x_{t+1} \) unity. That is
\[
x(Z_{t+1}) = \frac{(Q^*(Z_{t+1})x_{t+1} + Z_{t+1})K^b_t}{R_{t+1}D_t} = 1 \tag{26}
\]

For values of \( Z_{t+1} \) below \( Z_{t+1} \), \( x_{t+1} \) is below unity and a bank run equilibrium exists. The probability of a bank run equilibrium existing is accordingly the probability that \( Z_{t+1} \) is below \( Z_{t+1} \):
\[
\omega_t = \text{prob}\{Z_{t+1} < Z_{t+1} \mid Z_t\}
\]

It follows that the probability of a run varies inversely with \( E_t x_{t+1} \). The lower the forecast of the depositor recovery rate, the higher \( \omega_t \) and thus the higher \( p_t \). As discussed in Gertler and Kiyotaki (2015), negative shocks to banks returns \( Z_t \) will increase the probability of future runs through two channels: first by

\[\text{footnote}{Within our framework the management cost provides a simple way to motivate resale prices being substantially below normal prices. For a more explicit modelling of this phenomenon, see Kurlat (forthcoming).}\]
increasing banks’ leverage they decrease expected recovery rates; second, as long as shocks are persistent, a negative shock to $Z_t$ lowers the expected liquidation value of banks assets. In this way the model captures that an unexpected weakening of the banking system raises the likelihood of a run. As we show next, there is an interesting feedback: a rise in the run probability will weaken the banking system.

3 Numerical Examples

In this section we present several simulations to illustrate the dynamic interaction between the macroeconomy and banking panics. We focus in particular on how the model produces slow versus fast runs.

We begin with a description of the calibration and then turn to the simulations.

3.1 Parameter Choices

The numerical examples here are meant to be illustrative of the model’s mechanisms that explain how banking fragility interacts with the real economy as opposed to any kind of serious attempt to explain the data. In this spirit Table 1 lists the parameter values we use in the numerical experiments. We set the discount factor $\beta$ to its conventional value of $0.99$. Households’ endowment $W_h$; which is meant to capture employment income, equals three times average capital income. The rest of the parameters are calibrated by comparing moments from model simulations to their empirical counterparts as explained below.

We choose the value of $\alpha$, the parameter controlling households managerial costs, in order for the average proportion of capital intermediated by households, $E\{K^h_t\}$, to equal one third of total capital. The parameters governing banker’s survival probability, $\sigma$, and their seizure rate, $\theta$, are set to obtain an average level of banks leverage, $E\{\phi_t\}$, of seven and an annual spread between the expected return on bank assets and the deposit rate of two hundred basis points.

The endowment of new bankers $W_b$ is key in determining the dynamics of the economy after a run, as total banks net worth in the period right after a run has happened is given by $(1 + \sigma)W_b$. Therefore, we set this parameter so that the increase in credit spreads upon a bank run matches the increase in the excess bond premium after the collapse of Lehmann in 2008.

We choose a value for the probability of observing a sunspot, $\pi$, in order for bank runs to occur once every twenty years on average. The standard deviation of productivity shocks is set to 2% in order to match the unconditional standard deviation of linearly detrended US consumption from 1983Q1 to 2014Q4. And finally, we choose a relatively low value for the serial correlation of $Z_t$ in order to emphasize how transitory shocks to banks returns are endogenously propagated within our setup.
### 3.2 Impulse Responses: Recessions and Runs

Here we illustrate the workings of the model by showing the impulse response of the economy to a transitory shock to productivity $Z_t$. We first solve the model nonlinearly, allowing for the incentive constraint to be only occasionally binding. We next define a steady state for economy as the (non-run) state where all variables remain constant as long as $Z_t$ stays at its mean. With the economy in steady state we then trace out the effect of an unanticipated shock to $Z_t$ assuming no other shocks occur in the future.

We consider two types of experiments. The first is a negative shock to $Z_t$ which raises market anticipations of a run but where a run does not occur ex post. In the second we allow for a run after two periods.

Figure 1 shows the first experiment. Here we consider a negative two standard deviation shock to $Z_t$, which correspond to a four percent drop. Given our calibration, the incentive constraint does not bind in steady state. However, the negative shock to $Z_t$ leads losses in returns on bank assets, causing bank net worth to fall roughly twenty-five percent to the point where the incentive constraint binds. Symptomatic of the binding balance sheet constraint is a sharp increase in the credit spread to nearly two hundred fifty basis points. The increase in the spread, in turn, raises the cost of capital, magnifying the drop in asset prices. In a production economy, the magnified increase in the cost of capital would enhance the decline in investment and output. This kind of financial accelerator/credit cycle mechanism occurs independently of outright banking panics (see e.g., Gertler and Kiyotaki 2010)).

There is however an additional channel that opens up as the weakening of bank financial positions increases market perceptions of the probability of a run $\rho_t$, which increases from a steady state value of roughly 0.25 percent per quarter to 3.50 percent per quarter in response to the shock. The increase in the run probability places upward pressure on deposit spreads and downward pressure on asset prices, weakening bank’s financial positions. The net effect is to magnify the financial accelerator. Further, as a consequence, the rise in the anticipation of a run magnifies the outflow of deposits from banks, which drop roughly 12 percent helping generate something like the kind of "slow run" that we described earlier.
In Figure 2 we consider the same experiment, but this time we allow the run to occur two periods after the shock. At least qualitatively, the experiment captures the movement from a slow to fast run. In the first period the negative shock produces an increase in the credit spread and withdrawal of a fraction of the deposits, as depositors become increasingly nervous that the banks might collapse. In the second period, there is a complete collapse of the banking system as depositors coordinate on a "no rollover" equilibrium. As a result, banks liquidate all their assets leading to a sharp drop in asset prices and rise in spreads. Asset prices drop 20 percent to their liquidation values while spreads increase to more than 300 basis points. Output (net management costs) drops to eight percent below steady state, more than double the drop in $Z_t$, reflecting the inefficiency from the complete loss of banking services.

Absent a government policy intervention, recovery from the run is quite slow. It takes time for banks to rebuild their balance sheets. Hindering the process is that the probability of a subsequent run stays high. High excess returns after the run permit banks to raise their leverage multiples. Doing so, however, raise the run probability which has a dampening effect by placing downward pressure on asset prices and upward pressure on spreads.

4 Conclusion

A salient feature of the Great Recession was a protracted period of turmoil in financial markets that started with the credit crunch in the summer of 2007 and culminated an year later with the collapse of the entire shadow banking system. The steady withdrawal of funds from major financial institutions that took place over the period was akin to a "slow run" that eventually turned into a "fast run" around the collapse of Lehman Brothers in the fall of 2008. The resulting disruption of financial intermediation was likely the major factor that led the downturn to devolve into the Great Recession.

In this paper we build on existing literature to develop a model that can endogenously generate this transition from a slow run to a fast run. Slow runs in the model arise as negative returns on banks assets raise creditors concerns about financial stability, leading them to increase their assessment of the probability that a bank run will materialize in the future and hence withdraw deposits from banks. This in turn weakens banks balance sheet positions by forcing asset prices down and increasing the cost of banks borrowing, so that depositors worries are self confirming. When agents actually coordinate on a run equilibrium, a fast run ensues where the entire banking sector is forced to liquidate assets at firesale prices and the economy suffers a very long and deep recession.

References


