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Anticipated Banking Panics[†]

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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. Early on there were "slow" runs where creditors began a steady stream of withdrawals. The panic then culminated with a series of "fast runs" in September 2008, leading to the nearly instantaneous collapse of the entire investment banking sector. The resulting disruption of financial intermediation, Bernanke argues, was likely the major factor that led the downturn to devolve into the Great Recession.

In Gertler and Kiyotaki (2015)—henceforth, GK—two of the authors of this paper develop a simple macroeconomic model with banking panics 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 a result, the model can capture the type of movement from slow to fast runs that was a feature of the Great Recession. As the market probability of a run increases, creditors 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 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 (e.g., 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. For tractability, GK posit that the run probability is a decreasing 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.[1] Our approach will lead to bank run probabilities that vary countercyclically for purely endogenous reasons. In particular, 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. To avoid building in arbitrary cyclicality we suppose that the latter is a fixed constant. On the other hand, the probability that a run equilibrium exists in the following period is endogenously determined by fundamentals: It is the probability that the recovery rate will be in the range where banking panics are self fulfilling. It remains the case that a run is not uniquely determined by fundamentals. However, as in the global games approach, the run probability is tied concretely to the rational forecast of the relevant fundamentals. A forecast of deteriorating fundamentals, for example, raises the run probability in a way that does not rely on arbitrariness in the belief function.

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I. Model

We now sketch our framework, an infinite horizon macroeconomic model of banking instability. See Gertler, Kiyotaki, and Prestipino (2015) for details. 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.

There is a durable asset, "capital," which yields a dividend stream of the nondurable good Z_t per unit at each time t. We assume capital is in fixed supply and we normalize its total stock at unity. The dividend process is given by

$$(1) \qquad (Z_{t+1} - 1) = \rho(Z_t - 1) + \varepsilon_{t+1},$$

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

Claims on capital may be held either by banks or directly by households. Let K_t^b be capital holdings by banks and K_t^h holdings by households. There is a competitive market for capital which implies that in equilibrium total holdings equal total supply:

$$(2) \qquad K_t^b + K_t^h = 1.$$

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_{t+1}^b, is given by

$$(3) \qquad R_{t+1}^b = \frac{Z_{t+1} + Q_{t+1}}{Q_t}.$$

We assume that in order to hold K_t^h units of capital that earns payoffs at $t + 1$ a household must pay a convex management cost $f(K_t^h)$ at t, with $f'(K_t^h) > 0$; $f''(K_t^h) > 0$. 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_{t+1}^h is given by

$$(4) \qquad R_{t+1}^h = \frac{Z_{t+1} + Q_{t+1}}{Q_t + f'(K_t^h)}.$$

Given $R_{t+1}^b > R_{t+1}^h$, absent financial frictions, banks will intermediate the entire capital stock. Households in turn will save entirely in the form of 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 fire-sale levels.

A. *Households and Bankers*

Households derive utility from consumption of the nondurable. Each household can save either by holding bank deposits or by holding claims on capital directly. In addition to returns on asset holdings, each household receives an endowment of the consumption good $Z_t W^h$ that varies proportionately with the aggregate productivity shock Z_t.

Intermediary deposits at t are one period bonds that promise to pay a noncontingent gross rate of return $\overline{R}_{t+1}$ 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 $p_t \epsilon [0, 1]$ be the probability of a run in $t + 1$. Then we can express the gross rate of return on the deposit contract R_{t+1} as

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

Absent a run, each household chooses a portfolio of deposits and capital. Under conditions that we describe later, however, households may participate in a panic run. In this instance,

households suddenly decide to not roll over their deposits, forcing the banks to liquidate.[2]

Bankers manage financial intermediaries. They fund capital investments by issuing deposits to households and also by using their own equity, or net worth. The aggregate balance sheet of the bank sector is given by

$$Q_t K_t^b = D_t + N_t, \tag{5}$$

where $Q_t K_t^b$ is the aggregate value of capital intermediated by banks, D_t is total deposits issued, and N_t is total bank net worth.

Each banker has an i.i.d. probability σ of surviving until the next period and a probability $1 - \sigma$ of exiting. We assume bankers' utility is linear in terminal consumption which is equal to their terminal net worth. Each period $1 - \sigma$ new bankers enter which keeps the total population constant. New bankers also receive an endowment ("startup net worth") in the first period of business.

We assume that surviving banks accumulate net worth through retained earnings. Then we can express the evolution of net worth in the bank sector given a realization of Z_t as

$$N_t = \sigma[R_t^b Q_{t-1} K_{t-1}^b - R_t D_{t-1}] + W^b, \tag{6}$$

where the first term is the total net worth of bankers that survived from $t - 1$ until t and W^b is the total endowment of entering bankers.

Absent any limits to arbitrage, banks will intermediate the entire capital stock. In doing so they will drive the expected excess return of capital to deposits, $E_t\{R_{t+1}^b - R_{t+1}\}$, to zero. Because in such a setting banks always offset withdrawals by raising new funds, a bank run equilibrium cannot exist. To motivate a limit on the bank's ability to issue deposits (which is thus critical for opening the possibility of a bank run equilibrium), we introduce the following moral hazard problem: We suppose that the banker may secretly divert a fraction of funds for personal use. The cost to the banker of siphoning funds is that depositors can force the bank into liquidation at the beginning of next period.

The incentive problem leads to a limit on the amount of assets a bank can intermediate that is a multiple $\overline{\phi}_t$ of its net worth. Intuitively, depositors limit the amount they lend to the bank to the point where the bank's gain from diverting funds is exactly balanced by the cost of losing the franchise value. Given that the bank's portfolio decision is homogeneous in its net worth, $\overline{\phi}_t$ is independent of bank specific factors. We can then aggregate across banks to obtain

$$Q_t K_t^b \leq \overline{\phi}_t \cdot N_t. \tag{7}$$

As GK show, $\overline{\phi}_t$ depends positively on the excess return $E_t\{R_{t+1}^b - R_{t+1}\}$. The latter varies countercyclically as the balance sheet constraint (7) tightens in recessions. The net effect is that $\overline{\phi}_t$ varies countercyclically.[3]

If the constraint does not bind, a bank's asset position 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 (2014), banks have a precautionary motive for scaling back their respective leverage (relative to net worth).

In either case, banks cannot operate with zero net worth. The balance sheet constraint is always violated with $N_t = 0$ for any positive value of $Q_t K_t^b$. If depositors lend money to a bank with zero net worth, the bank will simply steal the funds. As we show next, this consideration is key to the existence of a bank run equilibrium.

B. *Bank Run Equilibrium and Run Probability*

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

[2] Our modeling of runs as rollover crises follows the Cole and Kehoe (2000) model of self-fulfilling sovereign debt crises as opposed to Diamond and Dybvig (1983), where runs are due to early withdrawal. For this reason we do not need to impose a "sequential service constraint" which is necessary to generate runs in Diamond/Dybvig.

[3] For evidence on the countercyclicality of leverage in the banking sector see, e.g., Ang, Gorovyy, and van Inwegen (2011).

failure to roll over deposits as opposed to early withdrawal. 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 and only 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. For reasons we just discussed, this condition is satisfied if the liquidation makes the banking system insolvent, i.e., drives aggregate bank net worth to zero. If instead bank net worth is positive after liquidation, banks would be able to offer a profitable deposit contract to an individual household deciding to roll over.

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. Let Q_t^* be the liquidation price per unit of bank assets. Then the bank becomes insolvent in the event of a run if the value of assets in liquidation is less than total deposit obligations, i.e., if $(Q_t^* + Z_t)K_{t-1}^b < \overline{R}_t D_{t-1}$. It follows that the condition for a bank run equilibrium is simply that the depositor recovery rate x_t is below unity:

$$x_t = \frac{(Q_t^* + Z_t)K_{t-1}^b}{\overline{R}_t D_{t-1}} < 1. \tag{8}$$

The liquidation price Q_t^* is determined by the condition that households absorb the entire capital stock in the event of a run, taking into account that, beginning the period after the run, new bankers enter to rebuild the banking system. 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 households hold all the capital, Q_t^* is at a minimum, given the expected future path of K_{t+i}^h. Further, the longer it takes the banking system to recover (so K_t^h falls back to steady state) the lower will be Q_t^*. Finally, note that shocks to the dividend process Z_t will cause Q_t^* to move procyclically.

We next turn to the determination of the run probability. Let ω_t be the probability at t that a bank run equilibrium exists at $t+1$ and let π be the probability of a run at $t+1$ conditional on the existence of a bank run equilibrium. Then the probability p_t of a run at $t+1$ is given by

$$p_t = \omega_t \cdot \pi. \tag{9}$$

We keep π fixed to avoid building in arbitrary cyclicality into p_t (since the probability of the realization of the sunspot conditional on the equilibrium existing is not pinned down). The probability ω_t, however, depends explicitly on fundamentals and will vary countercyclically.

We find ω_t as follows. Define $\overline{Z}_{t+1}$ as the value of Z_{t+1} that makes the recovery rate x_{t+1} unity. That is

$$x(\overline{Z}_{t+1}) = \frac{(Q^*(\overline{Z}_{t+1}) + \overline{Z}_{t+1})K_t^b}{\overline{R}_{t+1} D_t} = 1. \tag{10}$$

For values of Z_{t+1} below $\overline{Z}_{t+1}$, x_{t+1} is below unity and a bank run equilibrium exists. Hence, the probability of a bank run equilibrium existing is the probability that Z_{t+1} is below $\overline{Z}_{t+1}$:

$$\omega_t = \text{prob}\{Z_{t+1} < \overline{Z}_{t+1} \mid Z_t\}.$$

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 ω_t and thus the higher p_t. In this way the model captures that a 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.

II. Numerical Examples

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 the 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 a negative 4 percent shock to the aggregate dividends process Z_t assuming no other shocks to Z_t occur in the future. Figure 1 shows the result of the experiment. In order to capture the movement from slow to fast run the dotted line portrays the case in which a fast run occurs four periods after the shock, while the solid line describes the case in which a run does not occur ex post.

Given our calibration, which is described in Gertler, Kiyotaki, and Prestipino (2015), the

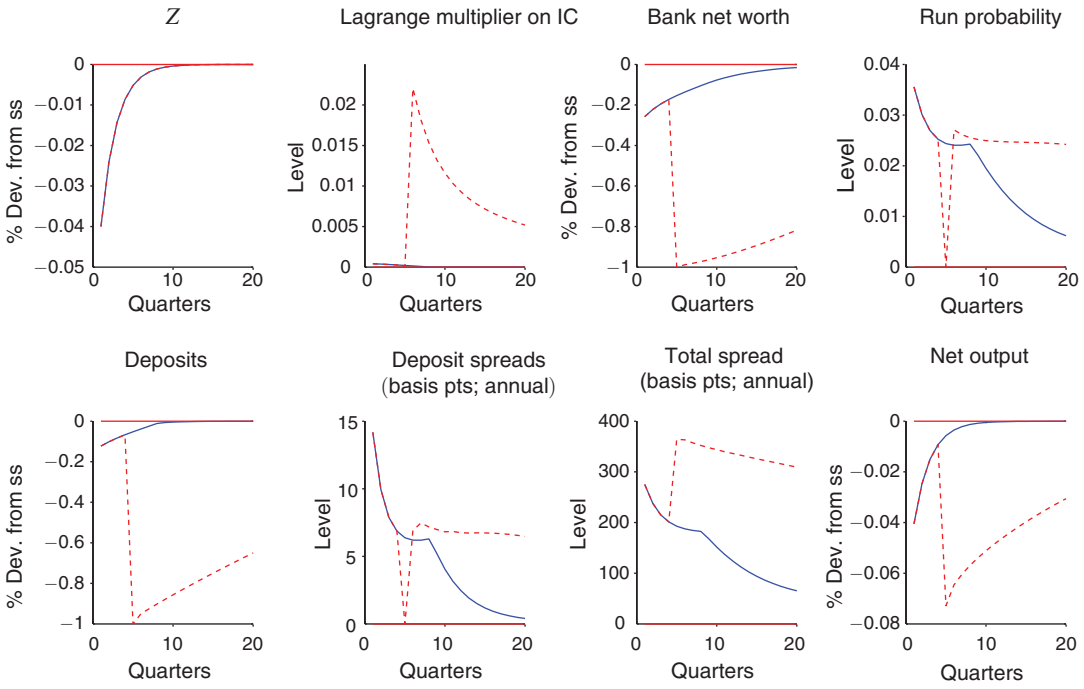

FIGURE 1. SLOW TO FAST RUN

Notes: The solid line shows the effect of a 4 percent drop in Z_t assuming no other shock in the future and no ex post run. The dotted line shows the effect of a run that happens at $t = 5$.

incentive constraint does not bind in steady state. However, the negative shock to Z_t leads to losses in returns on bank assets, causing bank net worth to fall 25 percent to the point where the incentive constraint binds. A symptom of the binding financial constraint is a sharp increase in the credit spread to nearly 300 basis points. The increase in the spread, in turn, raises the cost of capital, leading to a further drop in asset prices and a weakening of bank balance sheets. This is a common feature of financial accelerator and credit cycle models.

There is, however, an additional channel that opens up as the weakening of bank balance sheet increases market perceptions of the probability of a run p_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. This magnifies the financial accelerator. Further, the rise in the anticipation of a run intensifies the outflow of deposits from banks, which drop roughly 12 percent helping generate a slow run.

As shown by the dotted line, when the fast run is realized, 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 3.5 percent. Output net of management costs drops to 8 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, raises the run probability which has a dampening effect by

placing downward pressure on asset prices and upward pressure on spreads.

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