Do Depositors Monitor Banks?

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Abstract

We use unique micro-level depositor data for a bank that faced a run due to a shock to its solvency to study whether depositors monitor banks. Specifically, we examine depositor withdrawal patterns in response to a timeline of private and public signals of the bank's financial health. In response to a public announcement of the bank's financial troubles, we find depositors with uninsured balances, depositors with loan linkages and staff of the bank are far more likely to run. Even before the run, a regulatory audit, which was in principle private information, found the bank insolvent. We find that depositors act on this private information and withdraw in a pecking order beginning at the time of the regulatory audit, with staff moving first, followed by uninsured depositors and finally other depositors. By comparing the response to this fundamental shock with an earlier panic at the same bank, we argue that withdrawals in the fundamental run are due in part to monitoring by depositors though the monitoring appears to be more of regulatory signals rather than of fundamentals. Our results give sharp empirical evidence on the importance of fragility in a bank's capital structure and may inform banking regulation.

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I. Introduction

Do depositors monitor banks? Can depositors distinguish fundamental shocks to bank solvency from noise? Are some depositors better at monitoring than others? These questions are central to the role of fragility in the bank capital structure. Leading theories of banking emphasize the importance of fragility—the possibility of liquidation by depositors making a bank insolvent—as a commitment mechanism for banks (Calomiris and Kahn, 1991; Diamond and Rajan, 2001). Calomiris and Kahn (1991) argue that the ability of depositors to withdraw deposits on demand provides an incentive for informed depositors to monitor banks and trigger a run if the bank is likely to expropriate depositor funds. Diamond and Rajan (2001) say that the threat of runs commits banks to share rents that accrue through their specific loan-collection skills, which, in turn, allows banks to make loans at low cost. While these theories emphasize how bank fragility solves agency problems, bank runs may be costly *ex post* for an individual bank or even *ex ante*, from the perspective of the whole financial system (Kaufman, 1994; Calomiris and Mason, 2003). Fragility allows panics, unjustified runs that lead to the failure of solvent but illiquid banks (Diamond and Dybvig, 1983).

In this paper, we study whether and how depositors monitor banks using a timeline of public and private signals about the bank health. We obtain a unique proprietary dataset with micro-level depositor data for a bank in India that experienced runs after a shock to its solvency. The bank experienced deterioration in asset quality and was subject to runs during and after a regulatory intervention that ultimately placed the bank in receivership. We obtain detailed data on every depositor transaction along with characteristics of depositors to examine the factors that affect depositor withdrawal. We also link the timing of private and public information that came out during this failure to the behavior of different types of depositors. The timeline we exploit is the following. The bank had a build-up of bad loans. This build-up is uncovered by an audit by the central bank, which is private information and documented the bank's negative net worth. This audit is followed, after several months, by public news that the central bank is imposing severe restrictions on the bank's activity.

We use this setting to address the following questions. Do depositors run based on public information? Which kind of depositors run; is there differential behavior for uninsured depositors, insiders, and relationship clients? Do certain kinds of depositor run based on private signals before the release of public information? Even prior to the private regulatory signal, do depositors run based on the fundamental health of the bank as shown in the bank's annual statement? Finally, how does depositor behavior compare in a fundamental run with a non-fundamental run?

We find that there is a large run by depositors immediately following the disclosure of regulatory action against the bank. Uninsured depositors are far more likely to run than insured depositors. The magnitude of runs by depositors that are insured is modest, despite the fact that there are large delays in settlement of deposit insurance claims. We also find that depositors that have loan linkages with the bank or who are bank staff, i.e. insiders, are more likely to run. Depositors are more likely to run if a member of their network has already done so; the effect of having a network member run on own liquidation is as large as the effect of being on the bank staff. Depositors with a longer relationship with the bank are less likely to run.

Was there any evidence of a run prior to the public release of information? If depositors actively monitor banks, one would expect informed depositors to withdraw deposits before the initiation of formal regulatory action. We find that there is a silent run, beginning at the time of the regulatory audit but prior to regulatory action, that is driven by uninsured depositors, depositors with loan linkages and staff members. The size of this silent run is smaller than that after the public release of information. A regulatory audit can be a precursor to regulatory action and the conduct of this audit was private information only available, in principle, to the bank. Indeed, staff of the bank withdraw first in response to the audit, followed closely by uninsured depositors. The results show that uninsured depositors and depositors with loan linkages are the most responsive to regulatory signals regarding bank solvency.

Did depositors act even before the regulatory audit based on their own monitoring of bank fundamentals? We do not find any significant depositor withdrawals before the regulatory audit. We also do not find any significant movements in the deposit rates of the bank over this early period that could have compensated for a change in risk. Our results suggest that staff, uninsured depositors and depositors with loan linkages monitor the bank but rely largely on monitoring the monitor, i.e. on private information obtained by the regulator.

Did depositors run because this was a fundamental shock to the solvency of the bank, ultimately resulting in bank failure? Or would they have taken the same action in response to a panic with no relation to the bank's solvency? If certain types of depositors simply run because they have more to lose, in response to any shock, it would be difficult to argue that they monitor the bank in the sense of gathering information. Thus to understand depositor monitoring it is important to contrast their behavior across fundamental and non-fundamental shocks, which contain very different information. We examine this question by studying an earlier, non-fundamental shock at the same bank. Eight years prior to the fundamental shock, the bank we are studying faced a run due to the failure of another large bank in the same city, which had illegally loaned money to a stock trader for a great loss. Our bank had no fundamental linkages to the failed bank and experienced a run for only a few days following this prior shock. We use this shock as the counterfactual of a panic or non-fundamental shock and examine whether the behavior of uninsured depositors and depositors with loan linkages differed across the two shocks.

We find weaker runs by uninsured depositors immediately after the non-fundamental shock, as compared to the fundamental shock. Depositors with loan linkages are actually *less* likely to run than other depositors in the non-fundamental shock, the opposite of the result found in the fundamental shock. Uninsured depositors and depositors with loan linkages are thus more likely to run when there is a shock to a banks' solvency as against a non-fundamental shock or panic, suggesting that they can distinguish the two events. To address the concern that unobservable characteristics of depositors may be correlated with being uninsured or with loan linkages, we estimate the determinants of running amongst the pool of depositors that held accounts during both shocks. This allows us to put fixed effects at the depositor level to control for time-invariant unobservables. The findings that uninsured depositors and depositors with loan linkages are much more likely to run in a fundamental shock are robust to adding depositor fixed effects. This constant sample is subject to a survivorship bias, in that any depositor present in the constant sample saw the bank survive the first, non-fundamental shock and still kept some deposits at the bank. We expect this bias would in fact make these depositors less likely to run in the later shock; however, we find that both uninsured and loan-linked depositors are more likely to run.

Our results can inform banking regulation. Deposit insurance policies across the world have been primarily set up to reduce fragility in the banking system. While these policies help in mitigating depositor panic, our results suggest that deposit insurance reduces the extent of monitoring. However, one needs to be careful while interpreting this finding. Theories of depositor monitoring are largely set in a pre-Glass-Steagall setting where depositors monitor absent regulatory monitoring. What is the optimal way for depositors to monitor in the presence of regulatory monitoring? One plausible answer is to free ride on the monitor. Our results are consistent with this idea. We find uninsured depositors only act in coordination with a strong regulatory signal, well after the bank is insolvent. Our results suggest that improving the quality of regulatory supervision and ensuring better information disclosure policies is very important for smaller banks.

Our results also hold relevance for the debate on narrow banking proposals and regulatory policies regarding cross-selling products. We find that loan relationships help depositors monitor banks somewhat better. Thus having banks perform both deposit taking and lending under the same umbrella could improve monitoring.

Our results contribute to the literature on banking by providing evidence on what fragility means in practice. Models of banking highlight the fragile bank capital structure as necessary to induce depositor monitoring and to overcome agency problems (e.g., Calomiris and Kahn, 1991; Diamond and Rajan, 2001). Fragility can have aggregate consequences (Allen and Gale, 2000). The models listed assume a *laissez faire* environment where depositors had to gather information themselves with no regulatory framework in place. We find monitoring by uninsured depositors, consistent with the canonical models of banking, but it is driven by regulatory action.[1]

Our paper adds to the empirical literature on bank runs (Saunders and Wilson, 1994; Calomiris and Mason, 1997) by using micro-level data to empirically identify factors that affect depositor propensity to run during a fundamental shock.[2] Our paper also relates to the global games literature on bank runs and currency attacks, which model equilibrium responses to public signals, as we find that most depositors rely on public news of regulatory action as a coordination mechanism (Morris and Shin, 1998, 2002; Angeletos, Hellwig and Pavan, 2007) Our paper adds to the empirical literature that examines depositor disciplining of banks. [3] To the best of our knowledge we are the first paper to examine the exact timing of depositor withdrawals using a timeline of public and private signals to understand whether and how depositors monitor, and furthermore to compare depositor response between fundamental and non-fundamental shocks.

The rest of the paper is structured as follows. Section II discusses the bank and the timing of the shocks studied. Section III introduces the data on depositors and defines variables used in the empirical analysis. Section IV contains the empirical results on how

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[1] Merton (1978), in a model with free bank entry, shows that costs of regulatory surveillance are ultimately passed on to depositors through lower interest rates.

[2] One line of papers studies whether solvent banks failed during the depression by testing if banks with better fundamentals experienced lower deposit withdrawals (Saunders and Wilson, 1994; Calomiris and Mason, 1997). See Gorton and Metrick (2012) for events in the recent financial crisis.

[3] Park and Peristani (1998), Goldberg and Hudgins (1996, 2002) find that after initiation of regulatory action, thrifts attract smaller amounts of uninsured deposits and pay higher interest rates. The evidence from these papers is consistent with disciplining but also with the bank actively changing its strategy to attract a lower amount of uninsured deposits. Davenport and McDill (2006) study similar issues at Hamilton Bank, and Martinez-Peria and Schmukler (2001) in Argentina, Mexico and Chile. Unlike these other papers Iyer and Puri (2012) examine micro level withdrawal data in a non-fundamental bank run based on a single event. However, they cannot exploit a timeline of public and private signals, or compare depositor responses in fundamental vs. non-fundamental runs as we do in this paper.

depositor characteristics relate to liquidation during the fundamental shock, both before and after the public release of information, and during the non-fundamental shock. Section V concludes by discussing the policy implications of our findings.

II. Institutional Environment and Event Description

A. Institutional Details

The Indian banking system consists mainly of public sector banks, private banks and cooperative banks. The Reserve Bank of India (RBI) is the main regulatory authority of the banking system and monitors bank portfolios and capital requirements for all three types. Cooperative banks are additionally supervised by the state government on matters of governance, but not of finance.

Deposit insurance exists but coverage is incomplete. The Deposit Insurance and Credit Guarantee Corporation, part of the RBI, provides deposit insurance up to INR 100,000 (roughly USD 2,000) for each depositor at a bank. The deposit insurance is funded by a flat premium charged on insured deposits and required to be borne by the banks themselves. Though deposit insurance is present, there are several delays in processing the claims of depositors. The central bank first suspends convertibility when a bank approaches failure and then takes a decision of whether to liquidate a bank or arrange a merger with another bank. During this period depositors are allowed a one-time nominal withdrawal up to a maximum amount that is stipulated by the central bank.[4] If a bank fails, the deposits held by a depositor cannot be adjusted against loans outstanding. The stipulated cash reserve ratio and statutory liquidity ratio to be maintained by the banks are 5.5% and 25% respectively.[5]

[4] In most cases, depositors are allowed a withdrawal of up to INR 1,000 (USD 25) per account.
[5] The Statutory Liquidity Ratio (SLR) is the minimum allowable ratio of liquid assets, given by cash, gold and unencumbered approved securities, to the total of demand and time liabilities.

Cooperative banks are not different in kind than banks with other ownership structures. Depositors of cooperative banks are not required to hold an equity claim in the bank. Any depositor can avail of a loan from the bank and potential borrowers are not required to open a deposit account when taking a loan. Shareholders of cooperative banks have limited liability and generally do not receive dividends.[6] Thus the nature of cooperative banks does not select depositors with different characteristics than at banks with other ownership structures. Community banks are the closest analogues to cooperative banks in the United States and play an important role in the U.S. economy (Kroszner, 2007).[7]

B. Event Description

We now turn to the description of the event that we study in this paper. The Bank we study is a cooperative bank that functioned well until 2005. Thereafter, the management changed and the bank took heedless and possibly corrupt risks. In May, 2007 an RBI inspection privately noted that the bank had introduced proscribed insurance products and made two unsecured loans far in excess of the exposure ceiling. These two loans totaled INR 230 million (USD 6m) or 60% of the bank's total non-performing assets as of March 31, 2008. The fundamental reason for the bank's collapse was the non-performance of these large loans. After a routine inspection for the financial year showed the poor state of the bank's finances, the RBI brought the bank under greater scrutiny and conducted a further audit of the bank's books in November, 2008. The balance sheets of the bank in 2007 and 2008 did not reflect the true extent of non-performing assets that was uncovered

[6] The bank issues shares at face value. To be a borrower the bank, the bank asks a depositor to buy shares worth 2% of loan amount which can be redeemed at face value at the end of the loan. In general dividends are not paid by the bank as reserves are used to build up capital to meet capital-adequacy requirements.

[7] In a speech on March, 5, 2007, Federal Reserve Governor, Randall Kroszner states, "Community banks play an important role in the United States economy, as they have throughout our history…many community banks continue to thrive by providing traditional relationship banking services to members of their communities. Their local presence and personal interactions give community bankers an advantage in providing financial services to those customers for whom, despite technological advances, information remains difficult and costly to obtain...I believe that the most significant characteristics of community banks are: 1) their importance in small-business lending; 2) their tendency to lend to individuals and businesses in their local areas; 3) their tendency to rely on retail deposits for funding; and 4) their emphasis on personal service." Cooperative banks display the same four significant characteristics as community banks.

by the central bank audit. This audit by the central bank was private information and not announced to depositors. In response to the findings of the audit, the central bank ordered restrictions on bank activity including the partial suspension of convertibility. The information about the restrictions imposed on the bank by the regulator was widely covered in the press on January 28th 2009. Depositors were prevented from prematurely liquidating their term deposits. Critically for this study, there was no restriction on withdrawals from transaction accounts. The bank was also forbidden to take new deposits, make new loans or pay dividends. On May 13th, 2009, the central bank finally decided that the bank should be placed under receivership and mandated a withdrawal limit of INR 1,000 for all depositors. There were long delays in processing the deposit insurance claims.

This failure was idiosyncratic in nature and not due to weak economic fundamentals. It occurred in an otherwise good economic environment; the state economy grew by just over 9 percent during the year the bank was under scrutiny. No other banks failed during the event window and most banks in the region were gaining deposits. Depositors at the bank under study were aware of other bank failures in the state, in the recent past, where uninsured depositors had not been made whole.

The aggregate pattern of withdrawals by depositors is presented in Figure 1. Prior to the RBI inspection on November 4, 2008, transaction balances had been largely stable over the fiscal year to date. After the regulatory audit by the central bank there is a gradual but significant run, in which deposits decline 16% from November 4th, the date of the audit, to January 27th. On January 28th, newspapers reported on the regulatory action against the bank including partial suspension of convertibility. In the week following this public release of information there is a large run on the bank and transaction balances decline by a further 25%, for a total 37% decline. Now we turn to describe the micro data that we will use to study the behavior of individual depositors over this event window.

III. Data

We obtain administrative data from the bank that experienced the above crisis in 2009. This bank had eight branches around the city. The data record all deposit balances, transactions and loans from January 2000 through December 2005 and from April 2007 through June 2009.[8] We describe the variables we use below; Table AI in the Data Appendix gives a summary of these variable definitions.

Transaction accounts are defined as current (i.e., checking) or savings account types, both of which hold demandable deposits. Daily transaction-account balances are directly available from the bank's database for the later period. For the earlier period, daily balances are calculated from monthly balance and daily transactions files at the account level. We confirmed the reliability of this calculation by matching balances at month-end to the opening balance for the same account the next month.

Liquidation in the cross-section is defined as the withdrawal of 50% of transaction balances over the 7 days beginning the day before the shock. (We will often refer to this group as "runners," as opposed to "stayers," and will vary this definition as a robustness check.) We also estimate hazard models, at a daily frequency, in which liquidation is defined as the withdrawal of 50% of transaction balances in any single day. Transaction balances 90 days prior to the shock (120 days prior in hazard specifications) are used to measure depositor liquid assets *ex ante* and to group depositors into balance tiers. We define three tiers of balances—less than INR 1,000, greater or equal to INR 1,000 but less than INR 100,000, and greater or equal to INR 100,000—using thresholds set by the regulator. We choose the lower boundary of INR 1,000 as the central bank permits withdrawals of INR 1000 per depositor even after full suspension of convertibility and the upper boundary of INR 100,000 as this is the threshold beyond which deposits are uninsured. To measure past account activity, we use the share of days over the year prior to the information release, excluding the 90 days immediately prior, on which the depositor had a transaction. Account age is defined as the duration an account has been opened in years as on the date before the shock, (either March 13th, 2001, for the non-

[8] The bank changed its database format and computer system in the interval between these periods. We have defined variables such as loan linkages to agree across the two events and note the few instances when the change in database may affect the analysis in Section IV.

fundamental shock or January 27th, 2009 for the fundamental shock). We top-code account age at seven years, as the age of accounts older than seven years were apparently not recorded or missing when the bank computerized its records.

Family identifiers and depositor loan linkages are defined based on depositor surnames and addresses. We compare each depositor to all others based on surname and address to classify them as belonging to families.[9] We also have data on borrowers from the bank. We define loan linkages for depositors by matching on customer surname and address across depositor and borrower files. Accounts are compared on surname and address using the same criteria as the family match and taken as belonging to the same customer if there is a match. Depositors matched in this manner are defined as having a loan linkage in each crisis if they, or any member of their family, have a current or past loan from the bank as of the date of each run. The definition of loan linkage excludes overdraft accounts against fixed deposits as such accounts may impose restrictions on the withdrawal of deposits. Note that depositors with loans are generally not allowed to offset loans outstanding against deposits in case of failure.[10] Accounts held by staff members have distinct account codes in the data, though they are identical in substance to the accounts held by non-staff. We define depositors as having a staff linkage if either they themselves or a member of their family holds an account with a staff code.

We define the introducer network of depositors based on depositor references when opening an account. It is commonplace in India for banks to ask a person opening an account to be introduced by an acquaintance who already holds an account with the same bank (Iyer and Puri, 2012). The main purpose of the introduction is to establish the identity of the new depositor, in the absence of widespread proof of identity, and the introducer does not incur liability or receive any incentives from the bank. We define a

[9] We calculate the ratio $R = 1 - L\ /\ MaxOps$, where L is the Levenshtein edit distance between strings, the minimal number of character operations required to change one string into another, and *MaxOps* the maximum number of character operations that could be required to change one string into another given the lengths of each. Accounts are declared as linked if $R_{Surname} > 0.75$ and $R_{Address} > 0.80$ for the surname and address, respectively; we consider this criteria fairly conservative.
[10] In some cases the central bank makes an exception.

depositor's introducer network as consisting of anyone who introduced that depositor, anyone introduced by the same person as that depositor, and anyone that the depositor himself or herself introduced. This definition is undirected or reciprocal in that each depositor is a member of the network of those who belong to their network. To measure network linkages, we define a dummy variable equal to one for a depositor on each date if any member of a depositor's introducer network has liquidated their balance by that date, during the long event window of 90 days before to 30 days after each run. We also define depositor neighborhoods, by drawing up a list of 292 precise neighborhoods in the bank's city and fuzzy-matching these neighborhoods to words within depositor addresses. Seventy-one percent of depositors have a detailed enough address to yield a neighborhood match and the rest are left in a single, missing neighborhood.

Some specifications use data on depositors present during both runs. This constant sample is determined using a match on depositor name, surname and address. This match uses the same procedure described above.

IV. Empirical Results

A. *Liquidation After the Public Information Release*

The tendency of depositors to withdraw after the public information release depends strongly on depositor characteristics. Table [1] shows summary statistics for all depositors and by liquidation status, comparing the characteristics of those depositors that withdrew more than 50% of their transaction balance over the week beginning at the information release to those that did not. Amongst all 29,852 depositors, 3.9% liquidate their accounts during the run week. On average, depositors hold a transaction balance of INR 5,460 and about one percent have a balance above the deposit insurance limit of INR 100,000. With respect to additional relationships with the bank, 1.5% of depositors have a loan linkage and 3.2% of depositors have a staff linkage. Account activity is generally modest, with any transaction on 1.5% of days and an unconditional mean transaction size of about INR 140.

Runners and stayers differ significantly on all observable dimensions. Runners have transaction balances seven times larger than stayers, are ten times more likely to have balances above the deposit insurance limit, and are much more active in terms of number and size of transactions. Runners have held their accounts for about a year less. Runners are much more likely to have a loan or a staff linkage.

Table [2] shows the magnitude of the run broken out by the level of transaction balance during the fundamental shock in 2009, where balance is defined 90 days prior to the public release of information. We group depositors into the three bins of INR [0,1000), [1000 to 100,000), [100,000 and above) as defined above. Panel A shows the share of depositors liquidating and the mean amount of their withdrawals during the run week, from the public release of information until 7 days after. Of depositors with balances above the insurance limit, 29% ran during the run week, withdrawing an average of INR 54,283, as compared to 9% of depositors with balances above INR 1,000 but below the insurance limit of INR 100,000. Panel B broadens the event window to include the 90 days leading up to the run. In this broader window, which includes the regulatory inspection of the bank, 65% of depositors above the insurance limit liquidate, on average taking INR 155,146 out of the bank. Again, this is far higher than the 17% of depositors with middle-level balances (between INR 1,000 and INR 100,000) that liquidate.

During the run week, we use both linear probability and probit models for the likelihood of liquidation to test the relationships suggested by Tables [1] and [2] in a multivariate framework. We apply the linear probability model, though liquidation is a binary outcome, in part because it allows the inclusion of a large number of fixed effects in later specifications that use data on depositors present in both shocks.

The estimates in Table [3] support the conclusions of the earlier tables that depositor characteristics are strongly associated with liquidation. Columns (1) and (2) show linear probability models, and (3) and (4) the marginal effects from comparable probit models. The earlier column in each pair has a linear control for transaction balances and the latter column has dummies for balance categories. Looking at column (1), depositors with loan linkages are 4.4 percentage points more likely to run, which is significant at the five-percent level. Recall that about four percent of depositors run, so this is a doubling of the tendency to liquidate. Each additional year of a depositor having an account with the bank decreases the tendency to run by about 0.66 percentage points. Being a staff member increases the tendency to run by over two percentage points, consistent with staff having better information about the fundamentals of the bank. The mean daily transaction dummy gives the average share of days over the prior year, excluding the 90 days immediately prior, on which a depositor had any transactions, as a control for past account activity. As the mean of this variable is 0.015 it makes sense to scale the coefficient of 0.90 downwards: having a transaction on average one more day per month increases the likelihood of running by a significant 3 percentage points.[11] A one-standard deviation (About INR 32,000) increase in transaction balances prior to the run increases the tendency to liquidate by 0.00055 x 32 = 1.8 percentage points, comparable to the effect of being a member of bank staff.

Columns (2) and (4) show that the effect of balance is coming largely through depositors with balances above the insurance limit, who are about twenty percentage points more likely to run than the omitted category of depositors holding less than INR 1,000 in balance. Depositors with high balances may be better informed and also stand to lose more in the event of a failure due to temporary loss of funds below the insurance limit and permanent loss above the limit. The incentive to withdraw is in principle continuous around INR 100,000, as depositors with balances just above the limit remain mostly insured, with only the marginal balance above the threshold at risk. Alternative specifications (not shown) test for a discontinuity at the insurance limit and indeed do not find evidence that liquidation changes discretely at that point.

The magnitude of these effects is generally steady across the specifications shown and in alternative specifications where liquidation is defined as withdrawal of 25 or 75 percent

[11] Using alternative transaction controls, such as the mean of a dummy for past liquidation, does not change the main results.

of balances instead of 50 percent (not shown). The results here are also not affected by adding fixed effects for eight branches or for 292 detailed geographic neighborhoods.[12]

Depositor balances and relationships with the bank are important, robust correlates of the tendency to run. Consistent with their relationships providing more information about the bank, depositors with loan linkages and staff linkages are more likely to withdraw during the run. Depositors who hold balances above the deposit insurance threshold are far more likely to run. Recall that balances above INR 1,000 may receive insurance payouts only after a significant delay and that balances above INR 100,000 are not insured. Exposure above this insurance limit is the single strongest predictor of liquidation.

B. *Liquidation Prior to the Public Information Release*

The models above considered liquidation in cross-section after the public release of information. We now examine the timing of earlier depositor withdrawals, before the public release of information, to see what depositors may have acted on private information and when. Depositors acting on private information, even that revealed by a regulatory audit, may be more effective as monitors.

As shown in Figure [1], balances declined significantly prior to the public release of information. To measure what depositors run in the period before the public release of information, we estimate Cox hazard models, both strictly proportional and with time-varying coefficients. Failure is defined as withdrawal of 50% of balances during any given day.[13] [14] The model with time-varying coefficients holds the *ex ante* characteristics

[12] For example, in the linear-probability model specification of column 2, the coefficient on loan linkage is 0.042 with neighborhood effects vs. 0.044 without, -0.0047 (vs. -0.0043) for age of account, 0.027 (vs. 0.026) for staff and is unchanged at 0.17 for balance above INR 100,000.
[13] As the unconditional likelihood of transactions on any given day is very low, this definition in practice is similar to the definition employed in the cross-section of withdrawal of 50% over the run week.
[14] We exclude depositors with balances less than INR 100 as of 120 days before the run to make the model simpler to estimate by maximum likelihood. As these accounts generally have low activity, the omission will have little effect, but the omitted category for balances in the hazard models should be taken as INR [100,1000).

of depositors fixed over the event window, from 120 days before to 30 days after the shock, and estimates how the effects of these characteristics change over time. This model specifies the hazard as:

$$\Lambda_i(t) = \Lambda_0(t)\ exp\{\ \beta_1(t)\ AccountAge_i + \beta_2(t)\ StaffLinkage_i + \beta_3(t)\ LoanLinkage_i + \beta_4(t)\ NetworkMemberHasRun_{it} + \beta_5(t)\ Bal1kTo100k_i + \beta_6(t)\ BalAbove100k_i + \beta_7(t)\ DailyTransactions_i\ \}.$$

The only difference from the baseline Cox proportional hazard model is that each coefficient is allowed to vary over time. Each time-varying coefficient is modeled with a basis of cubic B-splines with knots every 30 days from 120 days before to 30 days after the day of the public information release, for a total of eight parameters. This specification allows the coefficient on each characteristic to change smoothly as a cubic function within each 30-day window and constrains the first and second derivatives of each $\beta(t)$ to be constant at the knots that mark out the boundaries between 30-day windows.

Hazard ratios from the base hazard model, reported in Table [4] Column (1), agree with the cross-sectional models that focused on the week of the run. Having an older account decreases the likelihood of liquidation. Staff linkages roughly triple the propensity to liquidate and loan linkages increase it by a factor of 1.58. The relative strength of these effects is reversed, as compared to the cross-sectional analysis, where loan linkages were more powerful than staff linkages. The hazard model covers a broader window than just the run week and staff were more likely to move earlier in this period than other depositors, so the staff effect is larger in the hazard model. A network member having run by a given date increases the hazard that a depositor will run by nearly three-fold, the same increase in hazard as being a member of the bank staff.[15] Having a balance, prior to the event window, above the insurance limit increases liquidation hazard by a factor of four. This very large magnitude is generally consistent with the magnitude from the

[15]Kelly and O'Grada (2000) also document the importance of network effects in bank runs. See also He and Manela (2012) for a theory of information acquisition in rumor-based runs.

cross-sectional regressions, where uninsured depositors had a propensity to withdraw 17 to 23 percentage points greater than the overall average of 3.9%. Daily transactions are highly predictive of liquidation.

Table [4] Column (2) reports hazard ratios from the time-varying hazard model as on the day of the public information release. These are formally the exponentiated coefficients on the constant value for each characteristic, which are interpretable as the effect of that characteristic on the run date, because the b-spline corresponding to the knot at that date has been omitted from each coefficient basis. Staff are more likely to liquidate around the run, relative to the hazard ratio estimated over the event window. High-balance depositors are far more likely to liquidate relative to the proportional specifications. The hazard ratio for depositors above the deposit insurance limit, relative to those in the omitted balance bin INR [100,1000), is twenty-five. This ratio is far larger than the ratio of four reported in the proportional hazard model, and captures that high balance depositors, like staff, become more likely to liquidate around times when information about the bank's solvency is revealed. As this coefficient difference suggests, a likelihood-ratio test of the alternative time-varying model against the null proportional hazards model rejects the null model with a p-value of 0.000 ($\chi^2_{(42)} = 261.74$).

Looking at the full path of coefficients over the event window shows that staff and uninsured depositors are both more responsive even before the public release of information. For the same time-varying hazard specification as shown in Table [4] Column (2), Figure [3] shows three coefficients of interest, on staff linkages, loan linkages and uninsured depositors, continuously on each date over the event window. The hazard ratio corresponding to the staff linkage, shown in Panel (a), is around four and significantly different from one both at the time of the private audit by the central bank and just before the public release of information, whereas staff are no more likely to run than other depositors in the middle of the event window. This camel-backed pattern suggests that staff are responding to private information about the fundamentals of the bank. Panel (b) shows that, while depositors with loan linkages are generally more likely to withdraw over the event window, this effect is not any stronger during any particular period. Panel (c) shows the time-varying hazard of liquidation for depositors above the insurance limit. These depositors, like staff, are significantly more likely to withdraw during the period after the central bank audit. After a lull in the middle of the event window, the hazard associated with high balance increases enormously just before the date of the public release of information to reach the factor of 25 reported in Table [4], Column (2).

The hazard specifications show significant effects of depositors holding balances above the insurance threshold and depositor ties to the bank, via staff and loan linkages. We find a pecking order of withdrawals in response to the private information of the regulatory audit. The staff of the bank withdraw first, followed closely by uninsured depositors. The results suggest that uninsured depositors, staff, and depositors with loan linkages run based on their private information, likely including the fact that an audit had occurred, after the regulatory audit by the central bank.

C. *Reaction of Depositors Prior to the Regulatory Audit*

Did depositor runs begin even before the regulatory audit? The bank we study was in poor financial health well before the regulatory audit and subsequent regulatory action. The regulatory audit pointed out that the financial position of the bank was deteriorating over the prior fiscal year even though the annual reports of the bank did not reveal the true extent of the solvency risk. To understand whether some depositors were actively monitoring the bank and acting on private information even before the regulatory audit, we examine depositor withdrawals around the release of the bank's annual report for the prior fiscal year, ending March 31st, 2008, which was released on September 2nd, 2008. This was about two months before the audit. We do not find any significant depositor withdrawals except for the staff in this period. We interpret this as a placebo test supporting that the regulatory audit was a coordinating signal for depositor monitoring and withdrawals more powerful than the bank's own public reports.

As shown in Figure 1, aggregate balances were roughly flat in the period after the annual report was released on September 2nd. To measure the response of different depositors, we replicate, in Table 5, our earlier cross-sectional regression for liquidation, in the week following the release of the annual report. Staff are a significant 1.6 percentage points more likely to withdraw than other depositors (column 1) over this week. Depositors with loan linkages and uninsured balances show no response to the annual report. The coefficient on loan linkages is not significantly different from zero in any specification and point estimates are always less than 1.1 percentage points. Uninsured depositors ("Bal ge Rs 100k"), have point estimates of -0.02 (2 percentage points) and 0.009 (1 percentage point) in the LPM and Probit models, respectively. These coefficients are both small and not statistically different than zero. These results suggest that depositor monitoring in the period before the regulatory audit is limited. Depositors begin running based on the private information only after the regulatory audit. One possible explanation could be that it is difficult for depositors to obtain private information about the solvency of the bank.

It is possible that depositors did not withdraw before the audit because they were being compensated for solvency risk with higher interest rates. We find that this was not the case, since interest rates were steady or declining over the period before the run. Figure 4 shows the deposit rates paid on newly-opened term deposit accounts over the year and a half prior to the run. The interest rates paid on fresh deposits are around 10 percent over this period and are declining slightly leading up to the run. Interest rates on demandable savings deposits are not recorded at high frequency in the data. Bank management has told us that these rates were constant at 8.5 percent over the same period. Thus, depositor inaction is not a response to higher deposit rates.

D. *What Do Depositors Know? Comparison to Non-Fundamental Shock*

Did depositors know the bank was failing? Or would they have taken the same action in response to a panic with no relation to the bank's solvency? If uninsured depositors run simply because they have more to lose incase of failure, it is tough to argue they actually monitor banks. Thus to understand the monitoring role played by depositors we contrast the behavior of depositors in response to the fundamental shock with the response to another shock to the same bank that was non-fundamental in nature. The bank under study experienced a prior run in 2001, which was triggered by a fraud in another bank in the same neighborhood. Our bank had no fundamental linkages with the failed bank in terms of interbank loans outstanding. Furthermore, our bank faced runs for only a few days after the date of failure of the large bank, with activity returning to pre-run levels in the subsequent period.[16] Our depositor data encompass this earlier episode.

To test that the differential nature of the shock is what shifted borrower behavior, we first compare the magnitude of runs by different depositor characteristics across the shocks. Comparison of Figures 1 and 5 shows that the fundamental shock was greater in magnitude and duration than the non-fundamental shock. During the panic, aggregate transaction balances declined by 11% in the week after the shock; during the fundamental shock they declined by 25% in the same week, on top of the 16% decline in aggregate balances that had already occurred following the regulatory audit, which is also visible in Figure 1.

To compare the behavior of individual depositors across these shocks, we estimate several liquidation regressions in a sample of depositors present both during the fundamental shock of 2009 and during the earlier, non-fundamental shock of 2001. To be present in this constant sample a depositor must have stayed with the bank after the early shock. Table [5] presents coefficients from linear probability models analogous to those shown in Table [3] but estimated in this constant sample. Columns (1) and (2) estimate the propensity to liquidate as a function of depositor characteristics in the fundamental and non-fundamental shocks, respectively. The loan linkage coefficient in the constant sample during the fundamental shock is somewhat smaller than that reported in the full sample. The coefficient during the non-fundamental shock is -0.012, not significantly different than zero and very close to the -0.014 reported by Iyer and Puri (2012) (Table 2, Column 2). Column (3) estimates a pooled regression across both runs

[16] See Iyer and Puri (2012) for a detailed description of the shock.

with interaction terms for the fundamental shock. The coefficient on loan linkages is positive and similar in magnitude to that in Table [3], but insignificant (p-value 0.16). Notably, the effect of being above the insurance limit is large and positive, but only in the fundamental shock. The main effect for being above the insurance limit in the pooled sample, which captures the response of uninsured depositors during the panic, is not statistically different than zero. Finally, column (4) adds fixed effects to the pooled regression in column (3), so that the interaction terms reflect the different in the behavior of individual borrowers across the two shocks. The loan linkage interaction term with the fundamental shock is positive and different from zero in this specification. The effect of being above the insurance limit remains large and positive in the fundamental shock after adding fixed effects.

The difference in the behavior of depositors with loan linkages appears to be due to the nature of the shock. Prior to the non-fundamental shock, the failure of a large but unrelated bank, depositors at the bank under study with loan linkages are neither more nor less likely than others to liquidate, but they are significantly less likely to do so at the time of the shock. In contrast, loan linkages increase the tendency of depositors to withdraw during the fundamental shock. This suggests that depositors with loan linkages are more responsive to information about the bank's fundamentals.

This constant sample is subject to a survivorship bias, in that any depositor present in the constant sample saw the bank survive the first, non-fundamental shock and still kept some deposits at the bank. We expect this bias would in fact make these depositors less likely to run in the later shock; however, we find that both uninsured and loan-linked depositors are more likely to run. The constant sample also helps to control for time-invariant unobservables at the depositor level. Even after introducing fixed effects at the depositor level, we find that uninsured depositors, depositors with loan linkages are much more likely to run in a fundamental shock. Supporting the idea that these observed characteristics are what matter, Iyer and Puri (2012) surveyed the depositors of another bank similar to ours and found that uninsured depositors and depositors with loan linkages do not significantly differ from other depositors in terms of wealth and education level. Thus, it seems unlikely that the behavior of uninsured depositors and depositors with loan linkages is driven by other omitted characteristics like wealth or education.

V. Conclusion

This paper examines the importance of fragility in the bank capital structure. We examine the extent to which depositors can monitor banks and whether some depositors are better at monitoring than others. Finally, we study whether depositors can distinguish fundamental shocks to bank solvency from irrelevant noise. We find monitoring by depositors that are uninsured and depositors with loan linkages. Even these more vigilant depositors respond to private information only after an audit by the central bank.

A central debate regarding the extension of deposit insurance cover has been how much insurance weakens the incentives of depositors to monitor banks. While our results suggest that deposit insurance reduces the extent of monitoring, runs by uninsured depositors only begin after the central bank audit, when the bank is already insolvent. Thus, while uninsured depositors run based on private information, their actions rely on regulatory intervention and did not independently discipline the management of this bank.[17] Our results suggest depositors rely to a great extent on regulatory supervision for information regarding bank solvency risk. Thus, improving the quality of regulatory supervision and ensuring better information disclosure policies could be very important for smaller banks and may be complementary to depositor monitoring.

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[17] Such *ex post* monitoring may serve as a discipline device for bank management in general (Diamond and Rajan, 2001).

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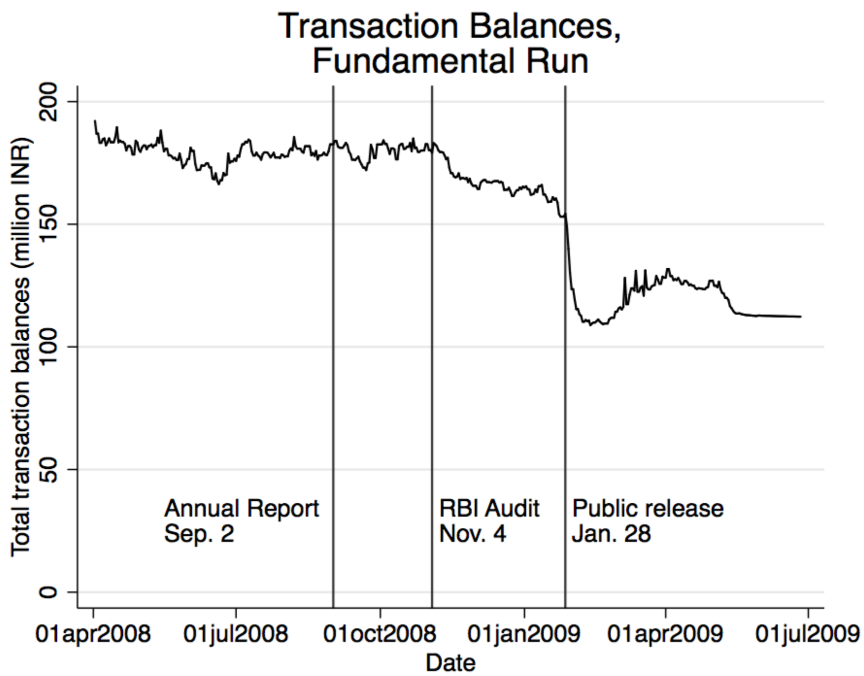
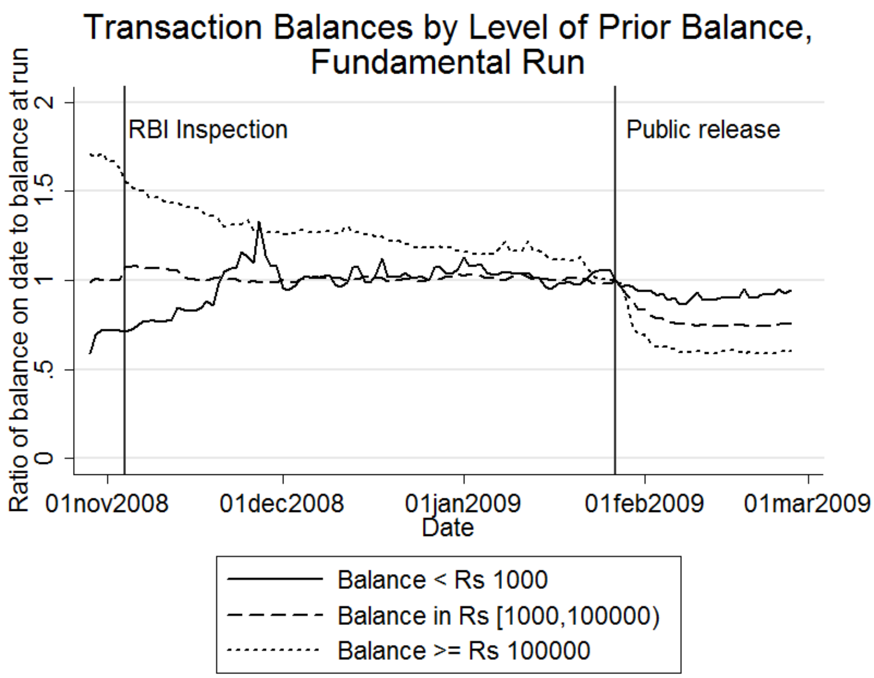
VII Figures

Figure 1



The figure shows aggregate transaction account balances for depositors in the bank from 300 days before the public release of information on regulatory action against the bank, which occurred on January 27, 2009, through 150 days after. The vertical lines indicate the dates of (i) the bank's annual report, (ii) the Reserve Bank of India's (RBI; i.e., the primary regulator) audit of the bank's finances and (iii) the public release of information on RBI's actions following this audit. The lines are labeled with the date of the event itself but are drawn to intersect the closing balance of the day before the event.

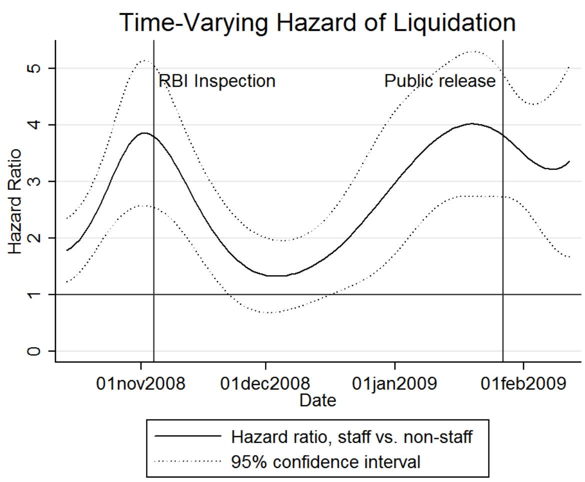
Figure 2



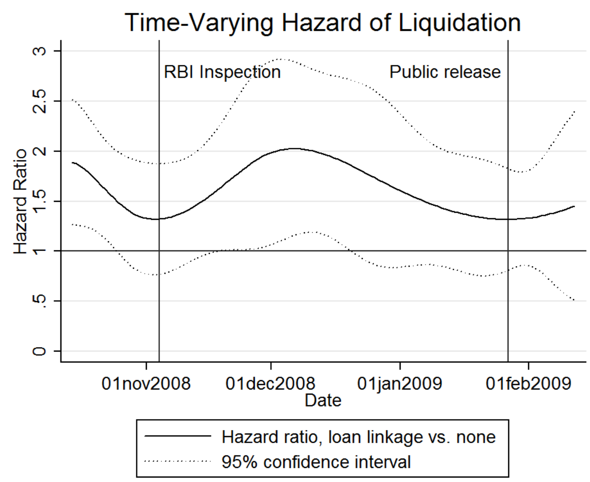
The figure shows aggregate transaction account balances for depositors in the bank from 90 days before the public release of information on the bank's finances and restrictions on account activity, which occurred on January 27, 2009, through 30 days after, broken out by depositor's initial balance. Depositors are grouped into balance categories depending on whether their balance was less than INR 1,000, greater than INR 1,000 but less than INR 100,000, or greater than INR 100,000 and the aggregate balance for each group is normalized to one on the date of the public release of information.

Figure 3: Time-varying Hazard Ratios

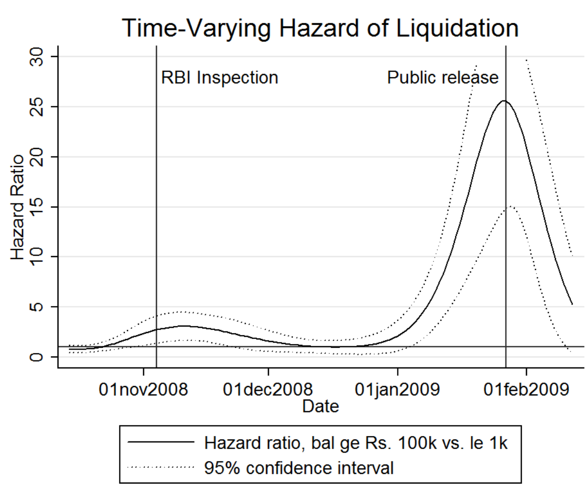
(a) Staff



(b) Loan Linkage

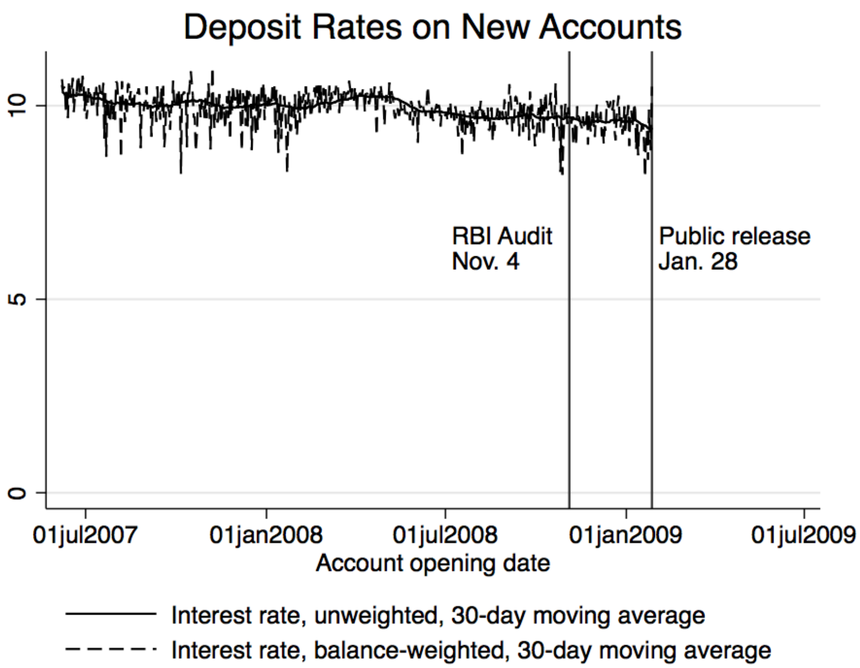


(c) Balance above Insurance Limit



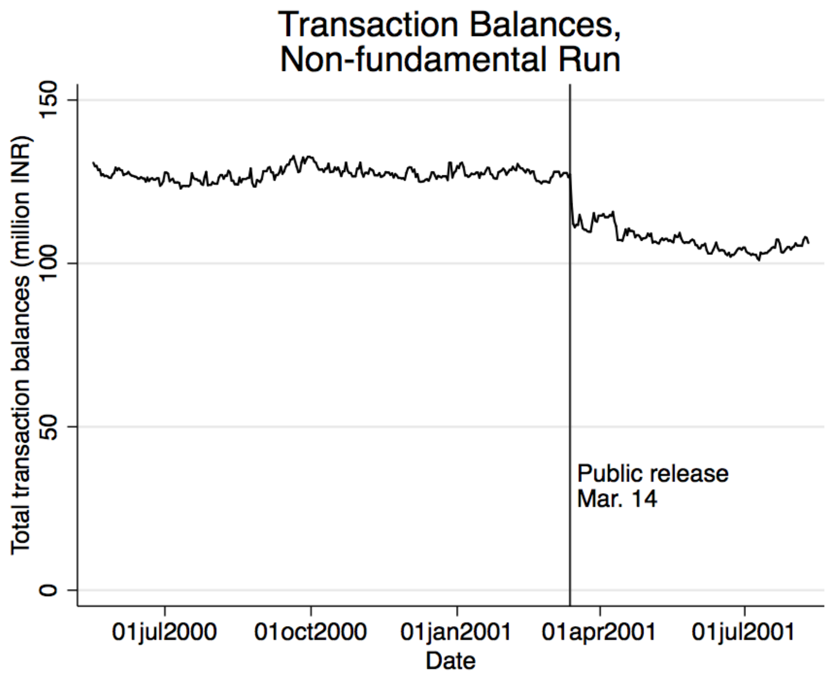
The figure shows estimated time-varying hazard ratios for depositor characteristics from a Cox proportional hazard model of liquidation (withdrawal of 50% of transaction balance in one day) on depositor characteristics. The event window is 90 days before the public release of information on January 27, 2009 through 30 days after. The coefficient on each depositor characteristic is allowed to vary smoothly over time according to a cubic spline with knots at 30-day intervals. The resulting hazard ratio and confidence intervals for the coefficient on staff status are plotted here for four different coefficients.

Figure 4



The figure shows the unweighted and balance-weighted interest rates on newly-opened term deposit accounts, where both series are plotted as 30-day moving averages.

Figure 5



The figure shows aggregate transaction account balances for depositors in the bank from 300 days before the public release of information about a fraud at another bank, which occurred on March 13, 2001, through 150 days after. The vertical line indicates the date of newspaper reports of the fraud, which caused the failure of another Cooperative bank to which the bank under study had no exposure. The line is labeled with the date of the event itself but is drawn to intersect the closing balance of the day before the event.

VIII Tables

Table 1
Summary Statistics by Liquidation, Fundamental Shock

	Sample mean [sd]			
	All	Run	Stay	Run-Stay
Liquidation dummy (Withdraw 50%=1)	0.039	1	0	1
	[0.19]	[0]	[0]	(0)
Trans. balance, '000s, 90 days prior	5.46	31.1	4.43	26.6***
	[32.6]	[77.7]	[28.9]	(0.97)
Balance above 100k, 90 days prior	0.0093	0.068	0.0069	0.061***
	[0.096]	[0.25]	[0.083]	(0.0029)
Age of account in years at run	6.30	5.29	6.34	-1.05***
	[1.70]	[2.31]	[1.66]	(0.051)
Depositor or family has loan	0.015	0.048	0.014	0.034***
	[0.12]	[0.21]	[0.12]	(0.0037)
Depositor or family is staff	0.032	0.059	0.031	0.028***
	[0.17]	[0.24]	[0.17]	(0.0052)
Daily transactions, year prior to run	0.015	0.093	0.012	0.081***
	[0.054]	[0.13]	[0.046]	(0.0016)
Daily withdrawal, year prior to run	142.3	996.7	107.8	888.9***
	[1332.6]	[3883.5]	[1099.6]	(39.6)
Daily deposit, year prior to run	140.9	1011.7	105.7	906.0***
	[1318.2]	[3762.1]	[1098.0]	(39.2)
Observations	29852	1157	28695	

Summary statistics for depositor characteristics for all depositors (column 1) and by whether or not the depositor liquidated during the run (column 2) or did not (column 3). Liquidation is a dummy for withdrawing 50% of transaction balances on any one day. Daily transactions is a dummy for whether or not the transaction balance changed on a given day, whereas daily withdrawal and daily deposit are the withdrawal and deposit amounts. All variables are defined in Data Appendix Table AI.

Table 2
Liquidation by Balance Bin, Fundamental Shock

	Initial transaction balance		
	lt Rs 1k	in Rs [1k,100k)	ge Rs 100k
Panel A. During Run Week (Public release to 7 days after)			
Liquidation (Withdraw 50%=1)	0.01	0.09	0.29
Withdrawal (Amount)	32.25	1,701.56	54,283.26
Panel B. Including Pre-period (90 days before to 7 days after)			
Liquidation (Withdraw 50%=1)	0.01	0.17	0.65
Withdrawal (Amount)	-146.20	1,672.06	155,146.08
Observations	29852		

The table shows summary statistics for liquidation (withdrawal of 50% of transaction balances) wnd withdrawals by balance bin for depositors whose initial balance was less than INR 1,000, greater than INR 1,000 but less than INR 100,000, or greater than INR 100,000. Withdrawal is the change in balance in either direction with a negative withdrawal indicating a deposit.

Table 3
Liquidation During the Week After Public Information Release

	(1) LPM	(2) LPM	(3) Probit	(4) Probit
Depositor or family has loan (d)	0.050**	0.044**	0.038**	0.020**
	(0.021)	(0.021)	(0.015)	(0.0092)
Age of account in years at run	−0.0066***	−0.0043***	−0.0055***	−0.0026***
	(0.0010)	(0.0010)	(0.00049)	(0.00036)
Depositor or family is staff (d)	0.021**	0.026***	0.022***	0.026***
	(0.0092)	(0.0092)	(0.0077)	(0.0074)
Mean daily trans. dummy, year prior	0.90***	0.82***	0.29***	0.14***
	(0.055)	(0.053)	(0.016)	(0.010)
Trans. balance, 100k's, 90 days prior	0.055***		0.016***	
	(0.014)		(0.0038)	
Bal in Rs [1k,100k) (d)		0.053***		0.059***
		(0.0028)		(0.0028)
Bal ge Rs 100k (d)		0.17***		0.23***
		(0.030)		(0.034)
Observations	29852	29852	29852	29852

The table shows coefficient estimates for linear-probability and probit models of the probability of liquidation during the week following the public release of information on January 27, 2009. Liquidation is defined as withdrawing at least 50% of one's prior balance. For definitions of the remaining variables please see Data Appendix Table AI. Estimates from probit models are marginal effects and (d) indicates a discrete change of dummy variable from 0 to 1. Standard errors in parentheses with * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$.

Table 4
Hazard Model for Liquidation, Fundamental

	(1) Cox	(2) Time varying
Age of account in years at run	0.84***	0.88***
	(0.01)	(0.01)
Depositor or family is staff	2.80***	3.82***
	(0.18)	(0.55)
Depositor or family has loan	1.53***	1.32
	(0.11)	(0.26)
Network member has run	2.80***	3.32***
	(0.25)	(0.55)
Bal in Rs [1k,100k)	4.19***	10.17***
	(0.17)	(1.22)
Bal ge Rs 100k	3.85***	25.59***
	(0.34)	(5.48)
Mean daily trans. dummy, year prior	534.18***	237.06***
	(49.73)	(86.21)
Time-varying splines	*No*	*Yes*
Observations	2867528	2867528

The table shows exponentiated coefficient estimates (i.e., hazard ratios) for Cox proportional hazard models of the probability of liquidation from 90 days before till 30 days after the public release of information on January 27, 2009. The model in the first column assumes the coefficients on each characteristic have a constant effect on liquidation over time. The model in the second column allows the coefficient on each characteristic to vary according to a cubic spline function with knots at 30-day intervals over the event window. The hazard ratios reported for the model estimate in the second column are the effect of each variable evaluated *as on* the date of the public release of information. The path of the full time-varying hazard ratios over time are shown in Figures **??**- **??**. Standard errors in parentheses with * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$ indicating significant differences from a hazard ratio of one.

Table 5
Models for Liquidation, Constant

	(1) Fundamental	(2) Panic	(3) Pooled	(4) Fixed Effects
Depositor or family has loan	0.022	−0.012	−0.013	−0.0053
	(0.027)	(0.0089)	(0.0090)	(0.012)
Age of account in years at run	0.00035	−0.0023***	−0.0022***	−0.0024***
	(0.0045)	(0.00058)	(0.00058)	(0.00077)
Depositor or family is staff	0.0082	−0.021	−0.022	0.017
	(0.013)	(0.020)	(0.020)	(0.036)
Mean daily trans. dummy, year prior	1.50***	1.30***	1.39***	1.28***
	(0.14)	(0.13)	(0.095)	(0.15)
Bal in Rs [1k,100k)	0.040***	0.072***	0.070***	0.074***
	(0.0036)	(0.0053)	(0.0053)	(0.0080)
Bal ge Rs 100k	0.18***	−0.0072	−0.013	0.013
	(0.049)	(0.044)	(0.044)	(0.062)
Loan linkage X fund. shock			0.039	0.080**
			(0.028)	(0.032)
Account Age X fund. shock			0.00080**	0.00010
			(0.00040)	(0.00049)
Staff X fund. shock			0.031	0.030
			(0.024)	(0.032)
Bal in Rs [1k,100k) X fund.			−0.029***	−0.020***
			(0.0064)	(0.0069)
Bal ge Rs 100k X fund. shock			0.20***	0.24***
			(0.065)	(0.081)
Constant	−0.0018	0.012***	0.011***	0.011***
	(0.031)	(0.0023)	(0.0023)	(0.0039)
Observations	10864	10864	21728	21728

The table shows coefficient estimates for linear-probability models of the probability of liquidation during the week following the two public releases of information in a constant sample of depositors present during both events. The first column estimates the model after the fundamental shock on January 27, 2009 and the second during the panic on March 13, 2001. Column 3 pools both of these run events and column 4 adds depositor fixed effects to control for unobserved depositor characteristics that are constant across the two events. Standard errors in parentheses with * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$.

A Data Appendix

Table AI
Variable Definitions

Variable	Definition
Liquidation dummy (Withdraw 50%=1)	Dummy variable equal to one if a depositor withdrew 50% of transaction account balances in the week beginning from the close the day before the run. In hazard models, liquidation is 50% withdrawal in a single day.
Trans. balance, '000s, 90 days prior	Total transaction balances in thousand INR, 90 days prior to the run.
Balance above 100k, 90 days prior	Dummy variable equal to one for balances above the deposit insurance limit, 90 days prior to the run.
Age of account in years at run	Time an account has been open in years on the day before the shock.
Depositor or family has loan	A depositor or a member of the depositor's family has a current or past loan from the bank on the date of the run, excluding overdraft accounts against fixed deposits.
Depositor or family is staff	A depositor or a member of the depositor's family is a staff member.
Daily transactions, year prior to run	Mean number of transactions per day over the year prior to the run, but excluding the 90 days immediately prior.
Daily withdrawal, year prior to run	Mean withdrawal amount per day over the year prior to the run, but excluding the 90 days immediately prior.
Daily deposit, year prior to run	Mean deposit amount per day over the year prior to the run, but excluding the 90 days immediately prior.

The table gives definitions for variables shown in Table I.