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INTERBANK EXPOSURES: QUANTIFYING THE RISK OF CONTAGION

by

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Abstract

This paper examines the likelihood that failure of one bank would cause the subsequent collapse of a large number of other banks. Using unique data on interbank payment flows, the magnitude of bilateral federal funds exposures is quantified. These exposures are used to simulate the impact of various failure scenarios, and the risk of contagion is found to be economically small.

Contents

1. Introduction

Preventing the troubles of an individual or small number of financial institutions from causing widespread disruption in financial markets or significant difficulty at otherwise viable institutions is a crucial element of a central bank's mission. It was primarily this concern that led the Federal Reserve Bank of New York to facilitate the private sector acquisition of a large stake in the hedge fund Long Term Capital Management when the latter experienced financial difficulty last fall. Although LTCM was not a bank or otherwise supervised by the Federal Reserve, the US central bank decided to proactively encourage an orderly process by which private sector firms would largely take control of the troubled hedge fund in an attempt to restore the smooth functioning of financial markets.

In testimony before Congress, both Federal Reserve Board Chairman Alan Greenspan (1998) and Federal Reserve Bank of New York President William McDonough (1998) argued that the Fed's intervention was designed with at least two purposes. First, by preventing a forced liquidation of LTCM, the Federal Reserve hoped to maintain the viability and smooth functioning of important financial markets in which LTCM played a significant role. A sudden failure of a large financial institution may have frozen some financial markets, thereby drying up liquidity needed by other market participants. Second, the Fed's action aimed to eliminate the potential knock-on effects that were feared should LTCM have been liquidated immediately. That is, other institutions such as commercial and investment banks were feared to have large exposures to LTCM and may have failed or come close to failure. Moreover, other institutions with possibly no direct exposure to LTCM could have been affected in the event that those with direct exposure to LTCM would have failed.

The LTCM episode illustrates a useful distinction between two different, albeit potentially correlated types of systemic risk. The first type is the risk that some financial shock causes a set of markets or institutions to simultaneously fail to function efficiently. The second type of systemic risk is the risk that failure of one or a small number of institutions will be transmitted to others due to explicit financial linkages across institutions.[1]

Academic research originally focused on the first type of systemic risk. Specifically, such research was motivated by the attempt to derive a theoretical understanding of bank runs. Diamond and Dybvig (1983) were the first to formally model the liquidity transformation role of a bank and derive how this role leads to the possibility of an equilibrium characterised by a run. This research has since been extended by Jacklin and Bhattacharya (1988), who formally distinguish between panics and more

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[1] The FDIC emphasised this second scenario following the failure of Continental Illinois. For example, shortly before Continental Illinois failed in 1984, 65 institutions held deposits worth more than 100% of their equity as uninsured deposits in Continental (Kaufman (1985)).

rational, information-based runs, Donaldson (1992), who theoretically analyses the role of interbank trade in determining the likelihood of runs, and Loretan (1995), who simulates a simple model of a banking system and quantifies the extent to which the probability of a run depends on the level of interbank lending.

Some research has shed light on the first type of systemic risk by extrapolating lessons from history. For example, Calomiris and Kahn (1996) and Cowen and Kroszner (1989) each explore historical interbank clearing arrangements to investigate how banks protected themselves from panics prior to modern bank regulation. Park (1991), studying actual historical experience with bank runs in the United States, discovers that bank-specific information is crucial to determining which banks were run as part of a crisis. Calomiris and Mason (1997), finding that solvent banks generally did not fail during the 1932 Chicago banking panic, argue that this first type of systemic risk may indeed be lower than what has commonly been perceived.

Most empirical examinations of systemic risk that concentrate on more recent episodes have also focused on the first view of systemic risk. In particular, research has explored how investors react to failures of important institutions or major shocks to financial markets. Aharony and Swary (1983) study the market reaction to the three biggest US bank failures prior to Continental Illinois, Swary (1986) (for US banks) and Jayanti and Whyte (1996) (for Canadian and British banks) examine the market effect of the failure of Continental, and Musumeci and Sinkey Jr. (1990) review the aftermath of the Brazilian debt crisis. These papers find that surviving banks were hardest hit depending on the extent to which they had portfolio characteristics similar to the failing institution or direct exposures to the troubled markets. These empirical results support the notion that modern bank runs can be interpreted as a rational market response to new information rather than a contagion effect caused by either direct interbank linkages or irrational panic.

Investigation into the second type of systemic risk, namely the risk that a failure of one or a small number of significant institutions will cause severe knock-on effects due to high interbank exposures, has been more limited. Recent work on this type of systemic risk, however, has been stimulated by the perception that the dramatic increase in the use of fairly complicated financial instruments has increased the possibility of this type of systemic event.[2] Rochet and Tirole (1996) develop a model of interbank lending whereby the existence of interbank exposures generates incentives for interbank monitoring. These authors examine the trade-off between the positive influence on bank risk caused by peer monitoring and the negative influence on bank risk resulting from the increase in systemic risk due to increased linkages between banks. By explicitly modelling the benefits deriving from peer review, Rochet and Tirole provide theoretical justification for why a central bank's optimal approach

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[2] For example, the notional principal amount of exchange-traded derivatives outstanding increased from $618 billion in 1986 to $9.2 trillion in 1995 (Bank for International Settlements (1997)).

to systemic risk would not simply be centralising all markets in which banks generate bilateral credit exposures.

The remaining theoretical work on the second type of systemic risk has focused more narrowly on systemic risk in payment systems, that is, the risk that the failure of one or a number of system participants to settle their payment obligations will cause others to fail to settle as well.[3] Schoenmaker (1995) develops a model of interbank settlement which, with certain parameter values, argues that the costs of creating settlement arrangements that lower systemic risk may outweigh the benefits of doing so. Cohen and Roberds (1993) develop a model of a payment system with various operating procedures and describe the relationship between settlement rules and guarantees and the level of systemic risk, here defined as the risk of a costly intervention by the system guarantor.

Empirical work exploring the second type of systemic risk relies on the ability to bilaterally measure interbank credit exposures. Unfortunately, as pointed out by Todd and Thomson (1990), the lack of suitable data has historically made this impossible. For example, bank call reports have information regarding certain types of interbank exposures, e.g. the total amount of federal funds and repurchase agreements that a bank conducts with other financial institutions. Unfortunately, the data neither separates the collateralised transactions (repos) from those that are uncollateralised (federal funds) nor provides any information on the number or identity of the bank's counterparties.

With these data limitations, the few empirical papers exploring the second view of systemic risk focus only on systemic risk within a particular payment system. For example, Humphrey (1986) uses data from the Clearinghouse Interbank Payments System (CHIPS) to simulate the impact of a settlement failure of a major participant in the payment system and demonstrates that this could lead to a significant level of further settlement failures. Angelini, Maresca, and Russo (1996), applying a similar method for the Italian netting system, find that interbank settlement exposures of Italian banks are much smaller than those in the United States, thereby providing evidence that systemic risk in payment systems will vary, in part, according to market characteristics. Taken together, these two studies suggest that the number of participants and the magnitude of the payment flows may influence the amount of systemic risk in a payment system. McAndrews and Wasilyew (1995), using simulated bilateral payment flow data, expand on this idea and quantify the relationship between the likelihood of systemic risk in a payment system and the number of banks, the size of payments, and the nature of linkages across banks within a payment system.

The conclusions reached in these papers regarding systemic risk in payment systems, while useful for the optimal design of such systems, cannot easily be generalised into lessons concerning the second type of systemic risk more broadly. That is, even if the potential for knock-on effects in a payment

[3] For an introduction to the issues of payment system risk, see Borio and Van den Bergh (1993).

system is reduced to zero, financial institutions still have exposures with one another that can lead to a systemic crisis. For instance, since the time of Humphrey's study, extensive investments in risk management at CHIPS have dramatically reduced the possibility of a systemic failure of that system.[4] In Canada, systemic risk in the payment system has been eliminated because the central bank has guaranteed final settlement of the country's private sector, net-settling, large-value clearing system (LVTS) (Dingle (1998)). Nevertheless, despite the reduction in payment system risk, interbank lending and other interbank exposures in Canada and the United States can create a situation where the failure of an important institution causes problems at other, highly exposed institutions. Thus, to understand the likely magnitude of systemic bank failures, one must measure interbank exposures beyond what may arise in a payment system.

In contrast to previous empirical work on the second type of systemic risk, this paper looks beyond payment system risk and quantifies the degree of contagion that results from interbank federal funds exposures. Section 2 describes the data used in the paper and the assumptions regarding the translation of this data into measures of potential interbank credit losses. Section 3 provides the results of various failure simulations. Section 4 suggests some implications of the results and concludes.

2. Forming estimates of interbank exposure and amount at risk

This study exploits payment flow data from the Federal Reserve's large-value transfer system, Fedwire, during February and March 1998. This data is used to uncover federal funds transactions on a bilateral basis. Most federal funds transactions are settled over Fedwire. That is, suppose Bank A agrees to lend \$10 million to Bank B on a Tuesday at an interest rate of 5.50%. The Fedwire transaction data will contain a payment from Bank A to Bank B for \$10 million on Tuesday and also a payment from Bank B to Bank A for \$10,001,527.78 on Wednesday.[5] Using the search algorithm described in Furfine (1999a,b), all federal funds transactions between financial institutions that were conducted over Fedwire were identified. Because such transactions are uncollateralised interbank loans, they represent a measure, calculable bilaterally, of interbank credit exposures.

The set of federal funds transactions described above provides a conservative measure of interbank credit exposure. That is, interbank exposures arise from many other sources besides federal funds loans. Generally, these other exposures will be reported on bank call report forms in an aggregate

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[4] These changes have been brought about both by internal recognition of the risks by the clearinghouse and by external direction by the Federal Reserve, which has a stated policy regarding the tolerable level of risks in large-value settlement systems (Board of Governors (1998)).

[5] Federal funds interest rates are quoted on a discount yield basis.

amount. That is, the call report reveals a bank's aggregate cash and balances due from other institutions, but does not report this exposure bilaterally.

To get a sense of how important these other exposures may be, Table 1 reports aggregate interbank exposures of US commercial banks to other US financial institutions as of 31 December 1997.[6] These totals are taken from the bank call reports with the exception of the federal funds sold figure, which was calculated from Fedwire data on 31 December 1997 and January 2, 1998. On this date, the $103.4 billion of federal funds sold by US commercial banks to US depository institutions represented approximately 14% of the total exposure reported in Table 1. This percentage, however, probably underestimates the relative importance of federal funds loans if one is interested in potential credit losses. First, the data available from call reports does not identify the use of collateral. In particular, it includes repurchase agreements, which by construction are collateralised transactions, and it is further likely that many interbank loans and derivatives exposures are also collateralised.[7] Second, the figures for cash items in the process of collection and credit exposures related to derivatives are not reported by type of counterparty, and thus overstate US commercial bank exposure to other US depository institutions.

Table 1: Exposures of US commercial banks to US depository institutions

At 31 December 1997 ($ billions from bank call reports except where otherwise specified)

Cash items in the process of collection[1]	Balances due from depository institutions in the US	Federal funds sold and securities purchased under agreements to resell[1] (Federal funds sold to depository institutions in the US[2])	Loans to depository institutions in the US	Credit exposure of all off-balance sheet derivative contracts covered by the risk-based capital standards[1]
157.9	68.2	261.6 (103.4)	55.1	188.9
		Total: 731.7		

[1] Total exposure to all counterparties. [2] Calculated from Fedwire transaction data on 12/31/97 and 01/02/98.

This discussion emphasises the difficulty that generally available data poses to a researcher interested in the second type of systemic risk and highlights the attractiveness of the data source used in this paper. In particular, the data is available bilaterally and also represent uncollateralised lending. Thus, the results that follow may be viewed as reliable, yet potentially conservative estimates of the risk of contagion.

[6] This table looks only at exposures to US depository institutions in order to be somewhat consistent with the simulations in this paper. Due to required data on bank capital levels, only federal funds exposures between US commercial banks will be examined.

[7] The degree to which collateral mitigates interbank credit risk depends crucially on its quality (e.g. ability to hold its value when it is needed). One fear mentioned in the LTCM case was that collateral taken by LTCM counterparties could not be liquidated at pre-crisis prices, leaving counterparties with larger credit exposures than were evident ex ante.

The sample of federal funds transactions contains the 719 commercial banks that traded funds using Fedwire at least once during the February–March 1998 period. These banks account for over 70% of total commercial banking assets.[8] Summary statistics for the bilateral exposure data are shown in Table 2. As illustrated, mean exposure increases with a bank's ability to absorb losses, measured here by tier 1 capital. For example, banks with less than $10 million in tier 1 capital have an average bilateral funds exposure of $13 million. Banks with over $1 billion in tier 1 capital have average bilateral funds exposures of $163 million. The last column provides some further evidence that smaller banks generally have larger funds exposures relative to their capital level. For example, the median estimated interbank federal funds exposure of a bank with less than $10 million in tier 1 capital is roughly 2.28 times its capital. For banks with tier 1 capital greater than $1 billion, the median exposure falls to only 0.01 of capital.[9]

Table 2: Summary statistics for bilateral federal funds exposures

Tier 1 capital of exposed bank	Number of observations (banks)	Mean (median) exposure ($ millions)	Mean (median) ratio of exposure to tier 1 capital
< $10 million	11,461 (131)	13 (10)	2.46 (2.28)
$10–$100 million	21,534 (397)	18 (10)	0.76 (0.26)
$100 million–$1 billion	14,612 (151)	35 (20)	0.13 (0.09)
> $1 billion	11,741 (40)	163 (50)	0.05 (0.01)

The figures in Table 2 report the magnitude of interbank federal funds exposures. To consider how exposures relate to likely losses, one must also consider the likely recovery rate of an institution with an exposure to a failing bank. Here, two possibilities are considered. First, James (1991) estimates that typical losses on assets of a failing bank including the cost of resolution are around 40%. However, the bank failures that James studies were not systemic events. As a second approximation, therefore, it is assumed that creditor banks will recover 95% of their exposure, which is consistent with the ex post realisation of the losses incurred by Continental Illinois as reported by Kaufman (1994).[10]

With the actual federal funds credit exposures and the two assumptions regarding expected losses, one can translate the data into expected losses of creditor banks following the failure of one of their

8 The largest bank not included in the sample was ranked 51st by size with assets of $12.4 billion.

9 Regulation F limits a bank's exposure to any correspondent institution to 25% of total (tier 1 and tier 2) capital. This limit, however, does not apply whenever the correspondent is at least adequately capitalised or has become inadequately capitalised within the previous 120 days. Virtually all US commercial banks were at least adequately capitalised during the sample period of February–March 1998.

10 Actual losses on a failing bank's portfolio may take months or years to calculate. These simulations may be thought of as reflecting the level of the immediate support given by the central bank in anticipation of recovery rates similar to those of the past.

counterparties. For example, suppose that Bank A lends Bank B $100 in the funds market. If Bank B fails, the simulations will assume that Bank A will lose either $40 or $5. If Bank A's capital level is 100, then Bank A will not fail, regardless of the assumed loss rate. If Bank A has only 15 in capital, Bank A will fail in one of the two calculations. This simple illustration demonstrates that the degree of contagion for a given failure scenario depends crucially on the nature of banking relationships. In particular, the number and the capitalisation of the counterparties to significant debtor banks are crucial determinants to the degree of contagion.

3. Simulation results

This section considers the outcome of four different failure scenarios: the failure of the most significant bank, the failure of the second most significant bank, the failure of the 10th most significant bank, and the joint failure of the two most significant banks. The most significant bank was defined as the one with the most federal funds borrowed from all other banks in the system. The other banks were ranked analogously. Using the two estimates for expected loss, it was determined whether a given failure scenario would cause a credit loss to a bank greater than its tier 1 capital.[11] If others fail as a result of the initial failure, the knock-on effects that these subsequent failures may cause were also calculated. Figures 1 and 2 present the results corresponding to a 40% and 5% loss rate, respectively.

As shown in Figure 1, assuming a 40% loss rate, the failure of the most significant debtor bank in the funds market would cause the subsequent failure of between two and six other banks. Failure of a less important bank translates into a slightly lower number of failures, typically less than four. It is worth noting, however, that the impact of the failure of the second most significant bank is not unlike the impact of the 10th most significant. This indicates that there is little decline in the magnitude of the linkages among the top 10 banks participating in the federal funds market. Dotted lines indicate additional failures caused by the initial set of failures. Such a second-round effect rarely occurs, with only one additional bank affected. Even when both the top two banks are assumed to have failed, second-round failures are virtually non-existent.

The bottom half of Figure 1 reports the assets held by the failing banks. Following the failure of the most significant bank, the largest total combined assets of banks that fail as a direct result is $33 billion, or approximately 0.8% of total commercial banking assets. The secondary failure is of a small bank that adds little to the total assets of failed banks. When a bank other than the most significant is assumed to fail, the assets of banks that subsequently fail are reduced noticeably. The failure of the

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[11] The results are quantitatively unchanged if the unit of measurement is the bank holding company rather than the bank. Essentially, the benefit of additional creditor capitalisation is offset by the implicitly larger shock needed to fail an entire debtor holding company.

second most significant bank causes failures of banks holding assets of no more than $1.6 billion. Further, there are noticeable differences across days. The failure of the two most significant banks would cause subsequent failures of banks holding total assets ranging from $375 million to $34 billion.

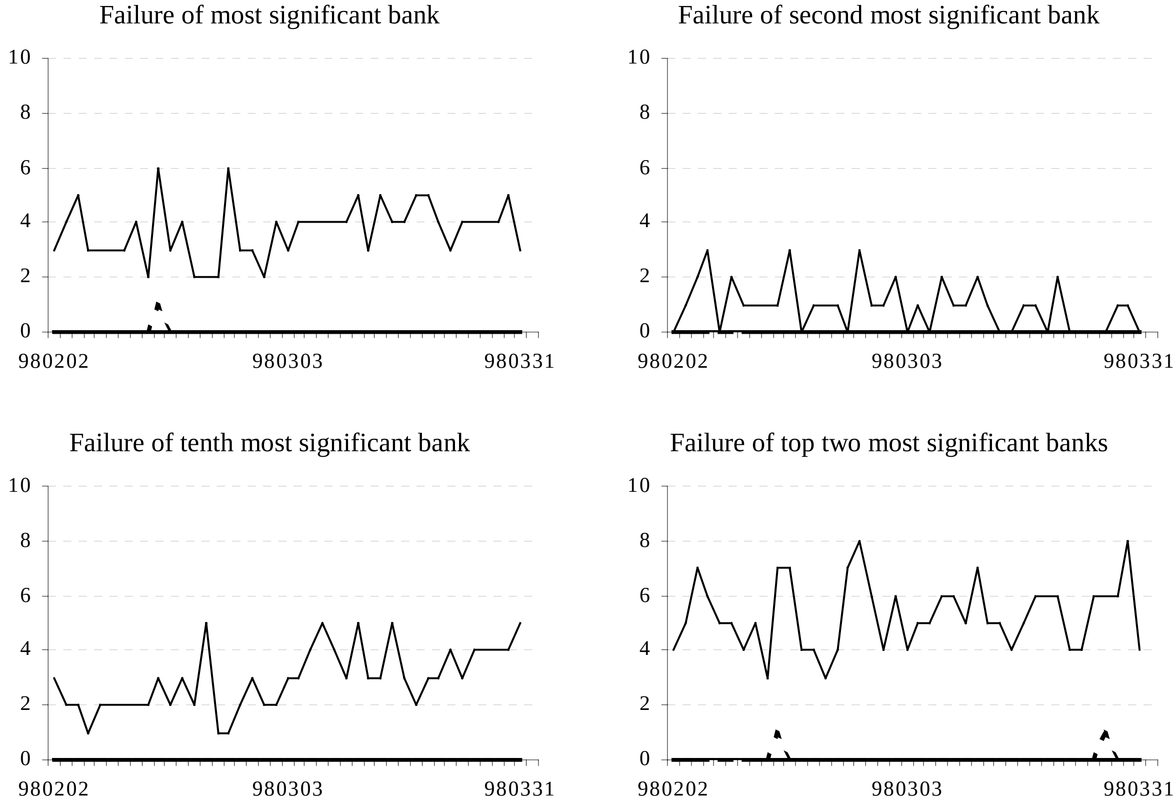
The results are strikingly different if we assume a 95% recovery rate on interbank exposures, as shown in Figure 2. With this assumption, contagion is virtually non-existent. In fact, the failure of the most significant bank causes no further failure. Under any of the failure scenarios, no more than one other bank, with assets of less than $250 million, fails.

The above simulation results highlight the relationship between expected loss rates and the extent of contagion. Figure 3 illustrates this relationship more generally. The top panel of Figure 3 graphs the sample-period maximum number of banks and assets that fail following the failure of the most significant bank. The data points related to 5% and 40% loss rates can be read from Figures 1 and 2. Only when loss rates exceed 60% do the assets of failed banks exceed 2% of the industry. At the maximum loss rate of 100%, corresponding to a credit loss equal to the full amount of the federal funds loans, the failure of the most significant bank causes at most the failure of 21 other banks that total $147 billion in assets, or just under 3.5% of the industry. The bottom panel of Figure 3 shows the same results following the failure of the top two banks. At a 45% loss rate, the failure of the top two banks would cause the subsequent failure of at most 11 additional banks amounting to $127 billion, or approximately 3% of total banking assets. At a 100% loss rate, maximum failures reach 31 banks holding 4% of commercial banking assets.

Figure 1: Simulation results for 40% loss rate

Direct effect ------ Second round Third round

Number of banks failing per round



Assets in $ millions of banks failing per round

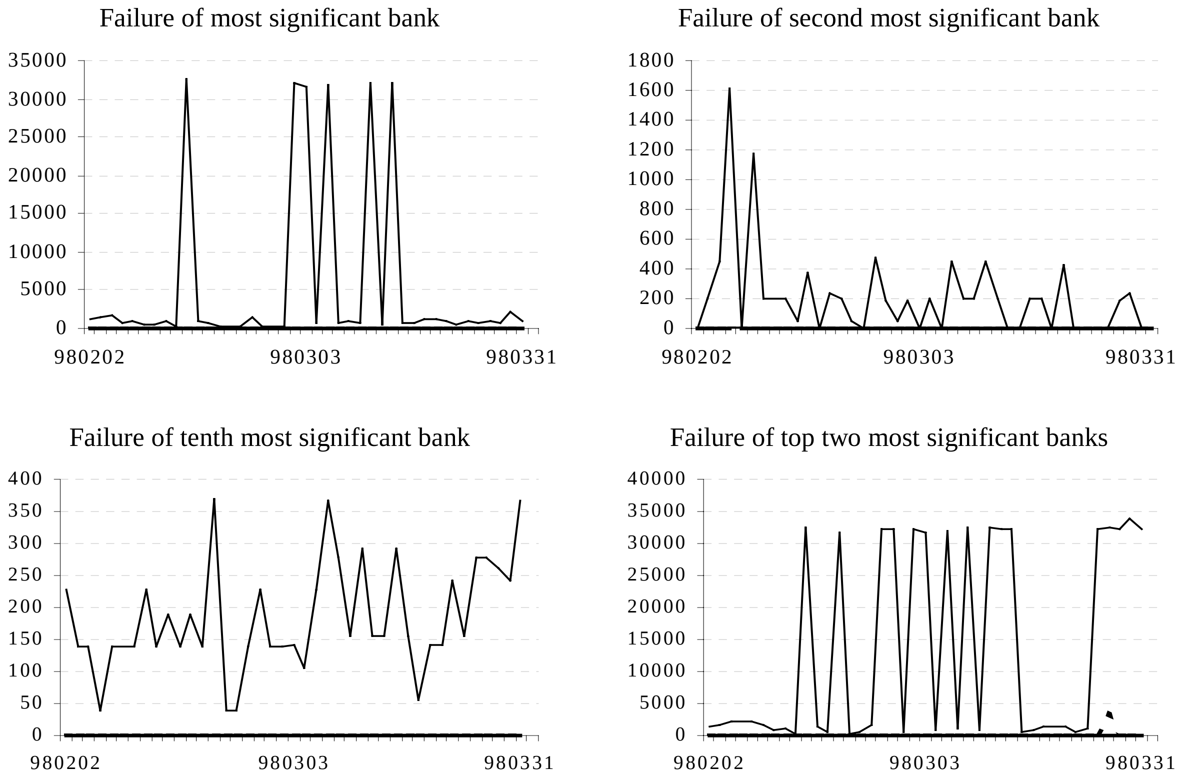


Figure 2: Simulation results for 5% loss rate

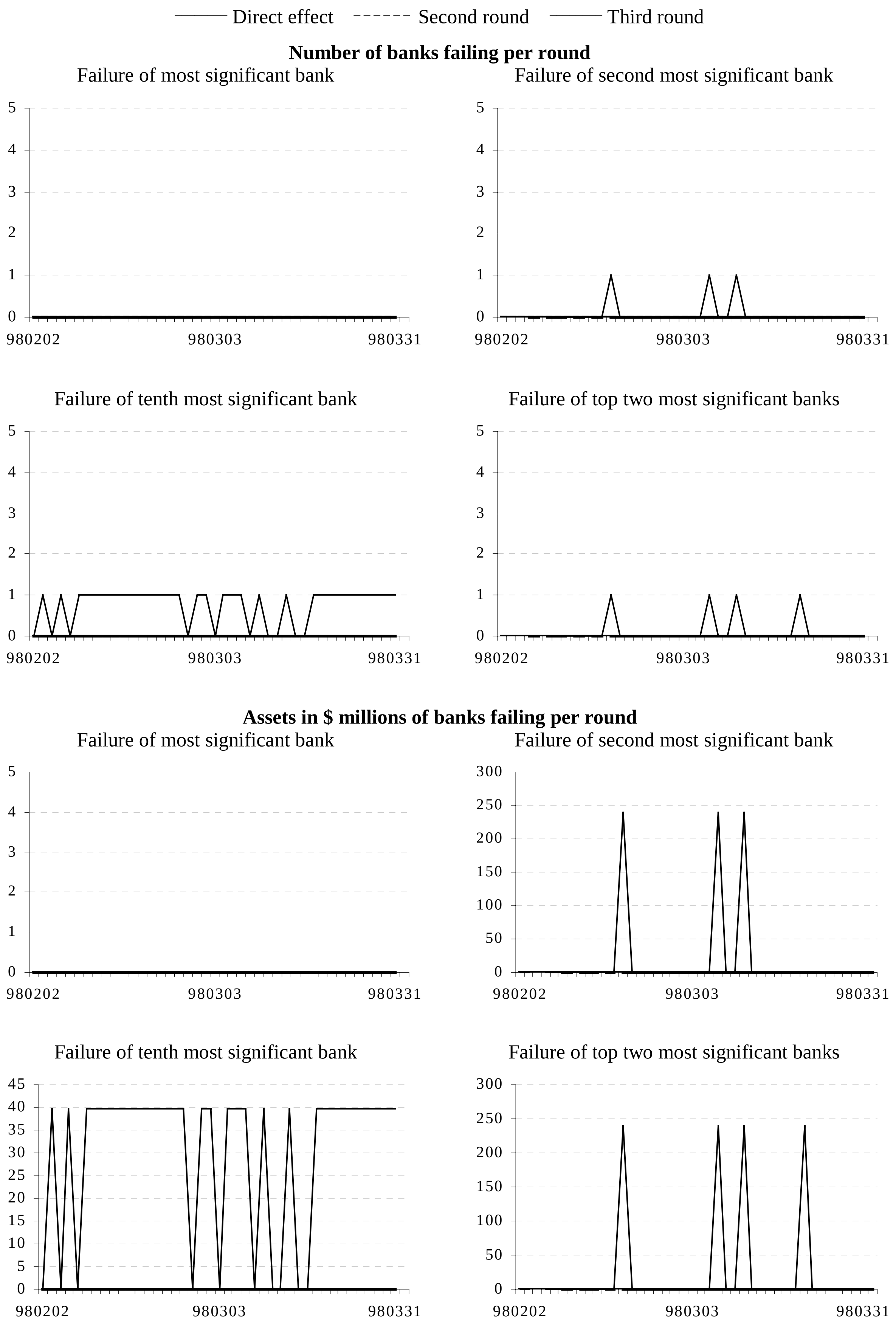
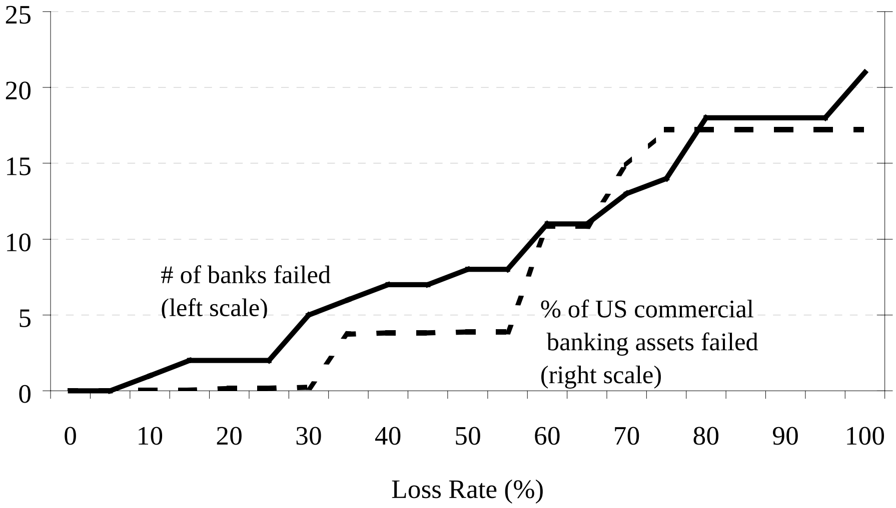
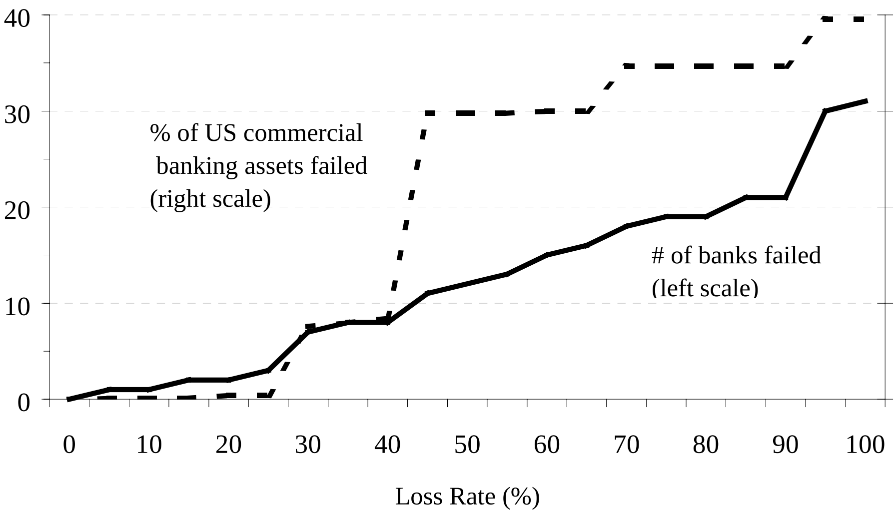


Figure 3: Maximum expected failures by assumed loss rate

Failure of most significant bank



Failure of two most significant banks



4. Implications and conclusions

This paper has exploited a unique data source that details the bilateral credit exposures arising from overnight federal funds transactions to explore the likely contagious impact of a significant bank failure. It was found that multiple rounds of failures are unlikely, and that aggregate assets at subsequently failing banks would never be expected to exceed 1% of total commercial banking assets when loss rates are kept to historically observed levels.[12] It should also be noted, however, that although the system-wide impact of certain failures may be small when measured by total assets of failing banks, additional failures will generally occur.

An important caveat to these results is that only federal funds exposures were used. As data on other interbank exposures is not available bilaterally, these findings should be viewed as a reliable lower bound on the risk of contagion. Because the magnitude of interbank exposures may be noticeably higher, policymakers may still wish to further decrease the risk of widespread bank failures resulting from the failure of an important institution. The results reported here suggest that both the magnitude of exposures and the expected losses given default are both important determinants of the degree of contagion, and therefore policymakers may wish to address both of these issues. To lower exposures among banks, for example, more widespread use of netting arrangements might be encouraged (Bank for International Settlements (1998, 1990)). Also important, however, are the banking regulations that increase the likelihood of small loss rates, such as prompt and early closure of troubled institutions. The prompt corrective action and least costly resolution aspects of the FDIC improvement act (FDICIA) of 1991 are helpful steps in this direction (Kaufman (1996)). Lower losses given default may also be more likely when there is early warning of financial trouble. With large institutions becoming increasingly complex, such a warning may come from market signals, such as observable higher interest rates on an institution's subordinated debt (Calomiris (1998)).

Having taken steps to minimise the extent of multiple bank failures arising from interbank exposures, policymakers would still be concerned with the first type of systemic risk, that financial markets or large sets of institutions simultaneously fail to operate efficiently either for rational or for irrational reasons. As argued earlier, this risk is not entirely separable from the risk of the contagious failures analysed in this paper. In fact, the risk of markets seizing up may be higher given uncertainty about the magnitude and potential threat of interbank exposures. Although this paper attempts to reduce the uncertainty related to these exposures, the inevitable limitations of available data leave room for further analysis.

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[12] The lack of significant bank failures does not simply result from the size distribution of creditor banks in the funds market. While common perception is that the funds market channels reserves from small banks to large banks, Furfine (1999b) reports that banks over $10 billion in assets are responsible for 89.6% of funds bought and 72.5% of funds sold in the funds market on average.

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