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NETWORK CONTAGION AND INTERBANK AMPLIFICATION DURING THE GREAT DEPRESSION

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ABSTRACT

Interbank networks amplified the contraction in lending during the Great Depression. Banking panics induced banks in the hinterland to withdraw interbank deposits from Federal Reserve member banks located in reserve and central reserve cities. These correspondent banks responded by curtailing lending to businesses. Between the peak in the summer of 1929 and the banking holiday in the winter of 1933, interbank amplification reduced aggregate lending in the U.S. economy by an estimated 15 percent.

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1. Introduction

Understanding how financial networks propagate shocks, increase systemic risk, and potentially magnify economic downturns are questions of long-standing interest to policymakers and scholars. Economic theory suggests many channels through which networks may transmit shocks (e.g., Allen and Gale, 2000; Allen, Babus, and Carletti, 2010; Feixas, Parigi, and Rochet, 2000; Lagunoff and Schreft, 2001; Dasgupta, 2004; Cabellero and Simesek, 2013). Empirical research has provided some evidence of contagious failures flowing through interbank markets, particularly for the recent financial crisis in the United States and Europe (Cohen-Cole, Patacchini, and Zenou, 2011; Puhr, Seliger, and Sigmund, 2012; Fricke and Lux, 2012).[1] Yet, empirical analysis of how interbank connections amplified downturns is a surprisingly lightly studied aspect of past crises, even for well-researched episodes such as the Great Depression.

In this paper, we document how the interbank network transmitted deposit withdrawals through the nation's banking system and amplified the contraction in real economic activity during the Great Depression. Interbank balances exposed correspondent banks to shocks afflicting banks in the hinterland. Interbank deposits were a liquid source of funds that could be employed to meet sudden demands by depositors to convert claims to cash, and the removal of these deposits from correspondent banks peaked during periods that contemporary commentators described as, and that our analysis confirms were, banking panics. During these panics, withdrawals of interbank deposits forced correspondent banks to reduce lending to businesses. We estimate that these interbank outflows led to a substantial decline in aggregate lending, equal to approximately 15 percent of the total decline in commercial bank lending from the peak in 1929 to the trough in 1933.

[1] See Allen and Babus (2009) for a survey of the theoretical and empirical literature on bank networks.

Our paper contributes to the growing literature on financial networks and the real economy, illuminating both a mechanism for transmission (interbank deposits) as well as a source of amplification (balance-sheet effects). It also introduces an additional channel through which banking distress deepened the Great Depression and complements existing research on how bank distress during the Great Depression influenced the real economy. Friedman and Schwartz (1963) focused on how distress reduced money multipliers and monetary aggregates, triggering deflations, altering real interest rates, distorting consumers' and firms' choices, and fueling debt deflation (Fisher 1933). The key mechanism transmitting bank shocks to the aggregate economy was changes in the aggregate price level. In examining what they called "a contagion of fear," which altered the behavior of bank depositors and managers, they excluded interbank deposits from their analysis since at the aggregate level these net to zero (i.e., one bank's asset was another bank's liability). We show that interbank networks transfered shocks from one banks' balance sheet to their interbank partners, often in cities far away. These transmission chains could change the quantity and composition of credit, even if they did not change the money supply, the price level, or other aggregate variables at the heart of Friedman and Schwartz's analysis.

Bernanke (1983) focused on the liquidation of banks themselves, which raised the costs of acquiring credit and reduced the supply of loans from banks. The key mechanism transmitting this shock to the aggregate economy was the destruction of relationships and information that facilitated financial intermediation when banks failed. We find that the destruction of banks not only reduced credit available to their own customers, but also to customers of their correspondents, who had to alter the composition of their balance sheets to accommodate increased and increasingly volatile interbank outflows. We also find that bank failures were not necessary for banking panics and central-bank policies to have a substantial impact on aggregate lending. Runs on banks (i.e., periods when individuals and banks demanded prompt repayment of deposits) were sufficient to induce a cascade of interbank withdrawals that reduced aggregate lending. The Fed's tepid response to these interbank withdrawals during panic periods forced banks in reserve and central-reserve cities – particularly correspondent banks in major money centers – to reduce illiquid investments, such as loans to businesses, and hold more liquid assets, such as cash, reserves at the Fed, and government bonds. Our result extends Calomiris and Mason (2003b), who demonstrated that bank distress reduced loan supply and economic activity in the location in which a bank operated. Our research shows that these types of shocks had an additional effect, which was transmitted through the interbank network, from the hinterland where bank distress originated to the reservoirs of reserves in money centers such as New York and Chicago.

The next section of the paper describes the pyramid-like structure of interbank deposits that developed in the nineteenth century, how the founding of the Fed altered the holdings of these deposits, and the potential consequences of this structure during periods of severe distress, such as banking panics. Section 3 defines banking panics and identifies the panics that occurred during the early 1930s. In Section 4, event studies using high-frequency data show that banking panics triggered flows of interbank deposits. Panel estimates on call-report data identify a causal relationship between panics (as measured by the number, cause, and clustering of bank suspensions) and interbank outflows. Section 5 estimates how Fed member banks in financial centers altered the asset side of their balance sheets in response to interbank deposit flows. The penultimate section calculates the total decline in credit due to interbank amplification during the Great Depression. We conclude by discussing the implications of our findings for Federal Reserve policymaking in the 1930s and the effects of financial networks in banking crises in general.

2. The Interbank Deposit Network

The structure of the interbank network that existed on the eve of the Depression developed during the nineteenth century. Interior banks sought correspondent linkages with banks in larger cities. Regulations, particularly the national banking acts of the 1860s, cemented this pyramid structure, requiring country banks to meet legal reserve requirements by keeping a portion of their reserves as cash in their vaults and the remainder (originally up to three-fifths) in correspondent banks in reserve or central reserve cities. State laws reinforced the pyramid structure by requiring state-chartered banks to also split their reserves between vault cash and interbank balances. This reserve pyramid proved ineffective during large financial crises of the nineteenth century, when reserves became difficult, and at times impossible, to access. When faced with widespread demands for cash and credit, reserve city banks hoarded funds for their own defense and left country banks to fend for themselves. As a result, banking panics periodically shut down the payments system (Kemmerer, 1918; Sprague, 1910).

The authors of the Federal Reserve Act aimed to eliminate these crises by creating an elastic currency and a lender of last resort. They also sought to change the structure of reserves, which they saw as crucial for reducing the incidence of panics. If all commercial banks joined the Federal Reserve System, required reserves would be consolidated in one of the Fed's 12 regional reserve banks instead of being scattered among hundreds of commercial banks in scores of reserve cities. Reserves at the Fed could be shifted towards areas afflicted by local shocks or released *en masse* by relaxing reserve requirements to alleviate local shocks (Kemmerer 1918). A consequence of this consolidation would be a reduction in correspondent balances invested in the stock and call-loan markets, which were seen at the time as contributing to the banking panics of the nineteenth century (James 1978, Myers 1931, Sprague 1910).[2]

The Federal Reserve Act (as amended in 1917) required national and state-member banks to meet their reserve requirements entirely by holding deposits at their regional Federal Reserve Bank. By 1929, however, only 10% of state-chartered commercial banks had joined the Federal Reserve System. Since roughly 90% declined to join, much of the reserve pyramid remained in place. Non-member banks continued to meet their state-mandated reserve requirements by holding interbank deposits at banks in reserve and central reserve cities; they also held their excess reserves in these reserve-city banks, which they used to manage liquidity and offer a broader array of services to their clientele. Federal Reserve member banks also deposited excess reserves at correspondent banks in reserve and central reserve cities, since commercial correspondent accounts paid a higher interest rate (typically 2%) than Federal Reserve Banks (typically 0%). This was particularly true of reserve-city banks, which deposited their excess reserves in money-center banks in New York and Chicago. All major money-center banks belonged to the Federal Reserve System, as did almost all banks in the United States that conducted a correspondent banking business.[3] In June 1929, member banks held 93% of all interbank deposits in the United States. Non-member banks held only 7%.

[2] Withdrawals from non-central reserve city banks happened regularly, and if they were of sufficient magnitude, they could put pressure on call loan rates to rise and stock prices to fall, triggering panic selling of assets and inducing a financial panic that could reach well beyond New York City. The standard story for explaining why country banks and reserve city banks withdrew their interbank deposits in this era was due to the seasonal demand for money arising from planting and harvest cycles (Calomiris and Gorton, 1991). Indeed, all of the major panics of the pre-Federal Reserve era were marked by withdrawals of funds from country and reserve-city banks located in New York City (Bordo and Wheelock, 2011).

[3] In New York, for example, the 15 banks with largest number of correspondents belonged to the Federal Reserve. This group included nine national banks (Chase, Chatham-Phenix, Chemical, City, Commerce, First, Hanover, Park, and Seaboard), and six state member bank and trust companies (Bankers, Chemical, Guaranty, Irvine, Manhattan, and New York). In Chicago, the banks doing a substantial correspondent banking business either belonged to the Federal Reserve, were owned by a national bank that belonged to the Federal Reserve (e.g., all of the stock of First Union Trust and Savings was owned by First National Bank of Chicago), or were combined with a national bank in a holding company or similar corporate structure (e.g., Continental Illinois was a holding company that controlled the Continental National Bank and the Illinois Merchant and Trust Company).

Interbank deposits comprised a substantial share of the deposits of Federal Reserve member banks. On the eve of the Great Depression, in June 1929, the 8,707 member banks held \$35.9 billion in total deposits, \$18.7 billion in demand deposits, and \$3.7 billion in interbank deposits.[4] The share of interbank deposits was highest in reserve and central reserve cities, where member banks held \$1 of interbank deposits for every \$4 of demand deposits, and interbank deposits exceeded 60% of aggregate reserves. The June 1929 call report of the Federal Reserve shows that excess reserves held at the Fed, which could be used without triggering regulatory intervention, were low and interbank balances exceeded them by a substantial multiple. The implication is that money-center banks could satisfy unexpected declines in interbank balances only by liquidating investments or borrowing from the Fed.

Thus, although the Federal Reserve Act altered where national and state-member banks held almost all of their required reserves, an inverted pyramid of interbank balances remained in place on the eve of the Great Depression. The top layer of the pyramid consisted of member banks in central reserve cities. These banks held 46% of aggregate interbank balances, with 37.1% in New York and 8.8% in Chicago. These money-center banks held deposits from non-member banks as well as from member banks in reserve cities and country locales. The middle layer of the pyramid consisted of banks in the 59 reserve cities located throughout the United States. These banks held 37.6% of all interbank deposits, with each reserve city on average holding 0.6% of aggregate interbank balances. The base of the reserve pyramid consisted of country banks located in cities and towns throughout the United States. Most of these banks were state chartered, did not belong to the Federal Reserve System, and could not borrow directly from the Federal Reserve's discount window.

[4] For comparison, in June 1929, the 15,797 non-member banks held \$12.9 billion in time and demand deposits and \$291 million in interbank deposits.

Polk's *Bankers Encyclopedia* (1929), a compendium of all banks operating in the United States, documents the correspondent linkages between the foundation and pinnacle of the pyramid. Almost all country banks possessed correspondents within their own Federal Reserve district. The majority of country banks also possessed correspondents in either New York or Chicago, but few country banks possessed correspondents in reserve cities in other districts, and few reserve-city banks served as correspondents for more than a handful of banks from other districts. Almost every reserve-city bank deposited funds in a correspondent in New York or Chicago, and many worked with correspondents in both cities.[5]

These network linkages formed a channel through which country banks influenced the behavior of Fed members in financial centers. During banking panics, country non-member banks withdrew reserves from their correspondents, since these interbank balances were some of their most liquid assets. Country Fed member banks responded in similar manner since accessing excess reserves deposited at their correspondents was cheaper than going to the discount window or violating their legal reserve requirement and paying the penalties for doing so.[6] Interbank withdrawals from banks in reserve cities, in turn, induced further responses within the system that worked their way up to the Fed member banks at the top of the pyramid in Chicago and New York. Our analysis focuses on how this chain reaction induced reserve and central reserve-city banks to alter their balance sheets, reducing the quantity of credit available to commerce and industry.

In theory, the Federal Reserve System possessed tools that could be used to provide liquidity, even to non-member institutions, including rediscounting and open market

[5] This information comes from a stratified random sample of commercial banks drawn from Polk's *Bankers' Encyclopedia* for 1929. We randomly selected two pages per state from the encyclopedia. Those pages contained data on 1,393 banks, or about one of 20 banks operating at that time. In our sample, 58.3% of banks had correspondents in New York, 24.8% had correspondents in Chicago, 84.3% had correspondents in a reserve city in their own district, 15.8% had a correspondent in a reserve city in another districts.

[6] To access the reserves they were required to hold at one of the Federal Reserve System banks, member banks had to pay a fee, potentially be subject to an examination, and could not pay dividends as long as they were below the reserve requirement. Going to the discount window meant paying a penalty rate, potentially not being allowed to borrow, or posting double collateral.

operations, but leaders of the System disagreed on the extent to which the Fed could and should aid non-member banks (Richardson and Troost, 2009). These debates partly reflected concerns about the System's obligations to financial institutions that did not contribute to its upkeep or submit to its regulations as well as concerns about whether credit policies should be pro-cyclical as dictated by the doctrine of real bills. The leaders also disputed whether collateral originated by or passed through non-member banks was eligible at the Federal Reserve Banks' discount windows or for purchase on the open market. State non-member banks could borrow from their correspondents. These loans were secured by collateral, which typically took the form of short-term commercial loans originated by the borrowing bank. The correspondent could, in turn, use this collateral to borrow from the Federal Reserve. The legality of this practice was questionable. Some Federal Reserve Banks – particularly in Atlanta and New York – did on some occasions accept collateral originated by non-member institutions. Other Federal Reserve Banks and the Federal Reserve Board, however, refused to accept such collateral and pressured Atlanta and New York to cease doing so and to end efforts to pass liquidity through member banks to the banks at the base of the reserve pyramid.

3. Banking Panics and Abrupt Changes in Depositor Behavior

Because we seek to determine how interbank deposit withdrawals reduced lending, we begin by discussing the reasons for these withdrawals and their link to banking distress. During the Great Depression, there were periods when depositors abruptly changed behavior and rapidly withdrew deposits, perhaps in response to growing concerns over the safety of the financial system, increased uncertainty about the solvency of banks or government policy, or due to the "contagion of fear" that plays such a prominent role in the account by Friedman and Schwartz (Calomiris and Gorton, 1991; Calomiris and Mason, 1997; Calomiris and

Mason, 2003b; Friedman and Schwartz, 1963; Postel-Vinay, forthcoming). We therefore estimate interbank deposit withdrawals that occurred during banking panics versus those in other periods – when households and firms may have gradually drawn down their bank deposits to finance consumption and meet payrolls in response to the declining state of the economy. Estimating panic-period withdrawals helps to pin down the direction of causality in our argument. During panics, individuals' and firms' willingness to deposit funds in financial institutions shifted suddenly and sizably. Country banks accommodated these withdrawals in turn by withdrawing interbank balances. We can clearly measure the impact of changes in the supply of interbank balances on the quantity and composition of lending by correspondent banks. At other times, when supply and demand for deposits and loans moved gradually and in response to similar stimuli, endogeneity makes it difficult to infer the relationships that interest us from patterns in the data.

Economists have clearly defined banking panics in theory and practice (Calomiris and Gorton, 1991; Diamond and Dybvig, 1984; Freixas and Rochet, 1997; Gorton, 2012; Jorda et. al., 2013; Leavan and Valencia, 2013; Reinhart and Rogoff, 2009; Rochet, 2008). During panics, depositors (including consumers, firms, and financial institutions) abruptly change their behavior *en masse*, quickly seeking to convert debt claims to cash. Depositors, in other words, simultaneously run many banks. Banks respond by taking action to satisfy depositors' demands or mitigate the consequences of their failure to do so. Banks raise cash to repay depositors by calling loans, selling assets, drawing down interbank balances, or borrowing funds, either from financial institutions that remain on solid footing or from a lender of last resort. During the Great Depression, banks which failed to obtain sufficient liquidity resorted to enforcing the 30-day clause on savings deposits and suspending conversion of demand deposits.

Panics expand when depositors at additional institutions begin drawing down deposits. Banks that can neither repay depositors nor defray their demands must suspend operations. Those that do not re-open usually have their affairs resolved by regulatory authorities or in bankruptcy court. Sub-optimal outcomes can occur even for institutions that would have been solvent in calmer states of the world, but whose lack of liquidity forced them into liquidation.

Economists' definition of banking panics illuminates symptoms that can often be observed in historical records: a rush by depositors to convert claims to cash; efforts by banks to satisfy depositors' demands or mitigate the costs of their failure to do so; the consequences of failing to repay depositors, including bank suspensions and liquidations; the suspension of normal activities by healthy banks, which could have operated without interruption, in absence of panic; and the clustering of all of these events in both time and space. Scholars seeking to identify historical panics look for evidence of these symptoms using two methods. One method, often referred to as the narrative approach, draws inferences from aggregate time series and qualitative accounts. Aggregate data – such as time series of the number of bank suspensions, deposits trapped in suspended banks, changes in currency held by the public, or total deposit outflows from operating banks – reveal periods when the national financial system experienced substantial, sudden distress. Narrative sources – such as articles in newspapers and periodicals, memoirs of bankers, businessmen, and policymakers, and reports of regulatory agencies – provide confirmation as to whether informed observers believed that the bank distress observed in aggregate data was caused by sudden changes in depositors' behavior.

Scholars who have employed this narrative method have identified a consistent series of national and regional events in the United States during the Great Depression (Friedman and Schwartz, 1963; Jalil, 2015; Richardson, 2007; Wicker, 1996). The panics begin with the failure of Caldwell in November 1930, which triggered runs in Tennessee and surrounding states. A series of regional and national panics followed. These occurred in June 1931 (a regional panic emanating from Chicago), July 1931 (triggered by the banking crisis in Germany and troubles in Europe), September 1931 (a national panic induced by Britain's departure from gold), June 1932 (a second Chicago panic), and February 1933 (the nationwide panic preceding the bank holiday).[7] Wicker (1996) also discusses additional, smaller events, which he describes as local or mini-panics, such as events in Toledo in August 1931 and Philadelphia and Pittsburg in September 1931.

The second method uses micro data from examiners' reports of bank suspensions to identify patterns consistent with the symptoms of banking panics. This approach has been successfully employed (and cross-checked with the narrative method) to identify periods of bank distress during the 1930s (Richardson, 2008), to analyze banking panics on the eve of the Great Depression (Carlson, Mitchener, and Richardson, 2010), and to identify "local" panics during the 1920s (Davison and Ramirez, 2014).

We employ both methods to identify panics during the Great Depression. The first method – employing aggregate data on suspensions and narrative accounts – clearly identifies events that effected large numbers of banks in multiple, and in some cases, most Federal Reserve districts. These national and super-regional panics can be easily observed in data from weekly reporting banks, a national aggregate which comes from a sample drawn from large (and reportedly representative) institutions in about 100 sizeable cities (including all reserve and central reserve cities). The second method – which uses micro data and cluster analysis – shows that the national and super-regional events consisted of scores of runs clustered in time and space. Importantly, this method also identifies local panics that were

[7] For more information on the Chicago banking Panics, see Calomiris and Mason (1997) and Postel-Vinay (forthcoming).

confined to smaller geographical areas such as individual Federal Reserve district, counties, or cities, and that are difficult to detect in aggregate data.

For both methods, we use data from Federal Reserve Board's Division of Bank Operations ST 6386 data, described in detail in Richardson (2007, 2008) and in Appendix 1. This database indicates the date and location of all bank suspensions, liquidations, and mergers under duress. A suspension is defined as a bank closing its doors to depositors for at least one business day, whether temporarily or permanently. The database also indicates the reasons why banks suspended operations, based on examiners' conclusions at the time of suspension; whether banks reopened; and who decided to suspend operations, typically either regulatory authorities or a bank's own board of directors. For certain calculations, we merge this data with data on all banks in operation in the United States on July 1, 1929, as reported in Rand McNally Bankers Directory, with all observations given the latitude and longitude of the center of the town in which the bank operated.

Using these data, Figure 1 plots aggregate U.S. bank suspensions on a weekly basis, from July 1929 through February 1933. From July 1929 through October 1930, an average of 15 banks suspended each week, a figure slightly higher than during the 1920s (Davison and Ramirez, 2014). A Bai-Perron test identifies a structural break in the time-series of weekly suspensions in the middle of November 1930, just after the collapse of Caldwell and Company.[8] Weekly suspensions increased dramatically at that point in time. The weekly average rose from 15.1 to 39.1. The standard deviation increased from 6.6 to 29.4. This period of heightened banking distress lasted from November 1930 through the Banking Holiday of 1933.

[8] The break in November 1930 does not appear sensitive to the choice of the time interval or the minimum number of weeks for defining break length. Similar results arise when aggregating suspensions by day, week, month, quarter, or call-report interval, or when seeking to identify a single break or unknown number of breaks. Similar results are also found when examining subsets of banks, such as state and national, or member and non-member.

In this period, we search for periods when a panic's symptoms are clearly evident. We recognize panics as occurring in spans of consecutive weeks that cross four quantitative thresholds. First, suspensions in each week are above average for the period following the collapse of Caldwell and Company, when the Bai-Perron test indicated the shift to a regime of heighted bank suspensions. Second, for at least one week in the interval, weekly suspensions must be more than one standard deviation above weekly suspensions in the high-suspension regime and at least five standard deviations above weekly suspensions for the low-suspension regime. In most cases, this five-standard-deviation spike occurred during the initial weeks; in several cases, peak weekly suspensions exceeded average pre-Caldwell weekly suspensions by more than 10 standard deviations.[9] Third, for the entire interval, the proportion of banks closed by a decision of their board of directors, rather than by regulators, must exceed the proportion during the pre-Caldwell period. Fourth, for the entire interval, the proportion of suspensions that examiners attributed to runs, rather than other causes, must exceed the proportion during the pre-Caldwell period.

Using this data-driven definition, we identify seven panics. Table 1 lists these events and the tests of proportions described by criteria three and four above. Our list includes all of the regional and national panics typically identified by economic historians using the narrative method and aggregate data. Our method also identifies an additional interval that has received little attention in the literature. This unnamed event began in December 1931 and continued through the first week of February 1932.

Our second method uses geocoded data from examiners' reports of bank suspensions to identify geographic clusters of bank suspensions. Our approach extends the method of

[9] Intervals with peaks above five but below 10 standard deviations above the pre-Caldwell mean typically involved: (1) larger banks, especially in the two events centered in Chicago; (2) a new crisis beginning before its predecessor concluded, such as in the surge in suspensions that coincided with the financial crisis in Germany; or (3) the widespread suspension of payments imposed by state and/or county governments, such as the crisis in the winter of 1933, which are not recorded in our data set.

Davison and Ramirez (2014), who identified local banking panics during the 1920s. The Davison-Ramirez procedure involves identifying clusters of bank suspensions by calculating the number of banks that suspend within a limited distance (measured in miles) and a rolling window (measured in days since the last suspension of a bank within the potential cluster). Their algorithm also defines a minimum cluster size. Their analysis focuses on clusters with a minimum of four banks suspending within 10 miles of each other with no more than 30 days between failures. In the 1920s, they identify 35 "4-10-30" clusters, or roughly 3 per year. We apply their method to the contraction from 1929 through 1933 and find hundreds of clusters, with some spanning multiple call periods and multiple Federal Reserve districts. Many of these clusters occurred during the regional and national panics listed in Table 1, but scores of clusters occurred outside of these periods.

To determine whether clustering exceeded that which would normally be expected if bank suspensions were randomly distributed across all operating banks, we turn to the join-count statistic. The join count indicates the number of pairs of banks that suspended operations within a set distance (measured in miles) and a fixed time interval (such as a week).[10] Appendix 2 presents formulas for calculating the join-count, the count expected under the null hypothesis that bank suspensions were randomly distributed across operating banks, and the variance of the null. Figure 2 graphs the join count for banks suspending within 70 miles of each other during each week from July 1929 until the Banking Holiday in March 1933. The figure also plots the threshold at which we can reject the null hypothesis at the 5% significance level. In the majority of weeks during the Depression, the null hypothesis

[10] Our intervals begin each Sunday and end the following Saturday. Similar results arise for weeks spanning Thursday to Wednesday and Wednesday to Tuesday, which are consistent with the tabulation of weekly reporting data (usually based on Wednesday evening figures). Because a significant increase in withdrawals at nearby institutions may not occur instantaneously and nearby institutions may be able to satisfy depositor withdrawals for some time before suspending, we calculated joins over a variety of time horizons (including 7, 10, and 30 days; monthly, and quarterly) and distances (including 10, 30, 70, and 100 miles).

cannot be rejected. This result indicates that in the majority of weeks, the distribution of suspensions among operating banks across the landscape approaches that expected from random chance. In many weeks, however, the null can be rejected at the 5% level. In these weeks, bank suspensions were geographically correlated. Periods of geographic clustering coincide with all of the intervals that our data-driven definition identified as banking panics, which the figure indicates with gray horizontal bars. Each of these intervals began with a spike in the join count. For each initial spike (and for most other weeks in each of these intervals), the null hypothesis can be rejected at the 1% level. The large national and regional panics that we identify, in other words, began with and consisted of bank suspensions that were clustered in both time and space. Smaller statistically-significant upticks in the join count reveal local panics, often confined within a single Federal Reserve district. An example is the first spike apparent in Figure 2, in July 1929, which represents Florida's fruit-fly panic analyzed in Carlson, Mitchener, and Richardson (2010).

The time series and spatial data presented in this section establish that during the Great Depression, commercial banks experienced periods of national, regional, and local distress that were consistent with economists' definitions of banking panics. During these panics, bank suspensions differed in many ways from suspensions at other times. During panics, suspensions were more concentrated in time and space. Suspended banks were more likely to be run by their depositors. Suspensions were more frequently initiated by a bank's board of directors. In many of these events, the fraction of banks suspending temporarily increased. Temporary suspensions are clear indicators of illiquidity, since these institutions must have been solvent; they eventually repaid depositors, and in most cases, continued to pay dividends to stockholders. From related studies on the Great Depression, we know that in at least some of these incidents, suspended banks that were liquidated eventually had higher recoveries on assets (Richardson and Troost, 2009). All of this evidence is consistent with the observation that at some points during the Depression, depositors ran banks.

4. Interbank Deposits During Banking Panics

This section assesses whether bank runs triggered flows of interbank deposits. We begin by examining weekly aggregate data and using an event-study approach to determine how interbank balances behaved during the large regional and national panics identified in the previous section. Next, we examine a panel of quarterly call-report data and estimate the decline in interbank balances associated with suspensions of banks, during both large and local panics as well as both inside and outside panic periods.

A. Event Studies on Regional and National Panics

The previous section identified seven banking panics. For each, we define an event window based upon the criteria for determining a panic described in the previous section. From the date the panic began, t=0, we trace changes in deposits for eight weeks, until interbank balances began to rebound or until the beginning of the next event. Our data-driven definition, based upon spikes in the spatial and temporal clustering of bank suspensions relative to trend, makes it unlikely that the movements of interbank deposits during these periods, which included large outflows and followed by smaller return flows, arose from longer-run trends in the data, such as gradual declines in business activity.

To track how deposits behaved during these events, we examine data on the assets and liabilities of reporting member banks. The data report end-of-Wednesday balances each week for two groups: reporting member banks in New York City, and reporting other banks in 100 other cities, which includes Chicago, all reserve cities, and about 40 other cities, as described in our data appendix. Figure 3 plots changes in demand deposits for reporting cities outside of New York for the six major banking panics that occurred from 1930 to 1932. During each panic, demand deposits dropped substantially. Figure 4 plots changes in interbank deposits, which also dropped substantially during all of the panics. The regional crises following the collapse of Caldwell in 1930 and panics in Chicago in 1930 and 1931 witnessed smaller, shorter declines, as did the panic in December 1931, which followed the Fed's announcement that it would further raise discount rates. The banking panics following the financial crisis in Germany and Britain's departure from gold witnessed longer, larger declines in interbank deposits. The earliest inflection point in interbank balances occurred in the third week, with two more rebounding in the sixth week, and the two in the seventh week. Figure 5 shows banks in reporting cities reacted to outflows of interbank and demand deposit by reducing their deposits in domestic banks, primarily interbank deposits in central reserve cities. The magnitude of the reductions indicates that, during these panics, banks in reporting cities acquired from one-quarter to one-half of the deposits they paid out from their central-reserve-city correspondent accounts. For example, during the first four weeks of the post-Caldwell crisis, demand deposits fell by $159 million and interbank deposits fell by $176 million. Balances with domestic banks fell by $161 million or about one-half the total deposit outflow.[11]

The severity of the panic that occurred in the winter of 1933 is illustrated in Figures 6 through 9. Figure 6 shows the accelerating drain of interbank, demand, and time deposits from reporting banks outside of New York City. Demand deposits declined by $1,078 million, time deposits by $973 million, and interbank deposits by $887 million. Figure 7 reports how banks outside of New York gathered cash to satisfy depositors' demands. The

[11] Note that similar patterns appear in HP detrended data and when we limit the sample to events that occurred at least six months after the preceding panic. In the latter sample, we can determine that deposit outflows began four to eight weeks prior to the waves of bank suspensions that contemporary commentators described as full-blown banking panics. At that point (our t=0), interbank outflows accelerated rapidly. Federal Reserve officials at the time referred to the pre-panic withdrawals conducted largely by check and wire transfer as invisible runs (Richardson, 2008).

initial reaction was the withdrawal of bankers' balances from New York City. These withdrawals began in February, with $261 million withdrawn by February 15th. Withdrawals accelerated as the panic progressed, with $1,197 million withdrawn by March 8. In late February and early March, banks began calling loans and selling bonds in large volumes. $432 million out of the $531 million total decline in bonds came in the last week before the holiday. For loans to firms and individuals (not for the purpose of purchasing securities), $610 million of the total decline of $709 million occurred in the last week. It should be noted that after banks drew down their balances in New York, further response was muted by the state-banking holidays, which began in the second half of February and spread rapidly during the first week of March.

The crisis of 1933 affected banks in New York City to a greater extent than earlier events. Figure 8 plots weekly changes in deposits in New York City. From January 18 to March 8, demand deposits declined by $1,364 million, time deposits by $165 million, and interbank deposits by $919 million. Figure 9 shows how New York banks reacted to the drain from the interior as well as large foreign withdrawals. New York's money-center banks drew down their loans, called loans to firms and individuals, and borrowed from the Fed. Reserves fell first; between January 18 and February 15, they declined by $319 million. They fell by another $68 million by the end of the first week in March, and after the Fed suspended reserve requirements, fell another $90 million before rebounding. Lending contracted later. From February 15 to March 1, loans to firms and individuals (not for the purpose of purchasing securities) fell by $419 million. Borrowing from the Fed began in the last week of February when banks borrowed $183 million. In the first week of March, banks borrowed another $449 million. By that point, banks in New York City had discounted essentially all of their eligible paper, withdrawn almost all of their excess reserves, and were clamoring for additional liquidity support. The New York Federal Reserve Bank, however, could not provide that liquidity support as its stocks of free gold had fallen too low for it to distribute additional cash and credit to member banks. This constraint forced the New York Fed to seek a banking holiday in its state and for the nation as a whole.

B. Panel Estimates using Call Report Data

A new, panel database (described in Appendix 1) constructed from commercial bank call reports enables us to use an additional method for generating causal estimates of the effects of suspensions on interbank deposit flows during the Great Depression. The data come from call reports, which are roughly quarterly in frequency. No call took place in the first quarter of 1933, when the national banking holiday was declared, so these estimates do not include the effects of the national panic in the winter of 1933. The panel contains information aggregated by Federal Reserve district and for the three tiers of the banking system: country banks, reserve-city banks, and central-reserve-city banks. The panel's structure enables us to compare interbank deposit flows associated with banks that suspended operations due to bank runs or during panics with those of a control group – banks whose suspensions occurred outside of panics or banks that did not experience runs – from June 1929 through December 1932.

Our estimation strategy incorporates the structure of the reserve pyramid described in Section 2 via a series of assumptions. First, flows of interbank deposits to and from reserve cities within a district reflect distress among country banks in that district and not in other districts. Second, flows of interbank deposits to and from New York City reflect distress among all banks in the United States. Third, flows of interbank deposits to and from Chicago reflect distress among all banks in the Seventh, Ninth, and Tenth Federal Reserve Districts, which is the region from which Chicago derived the bulk of its interbank deposits.

Using the 15 calls spanning our sample period, we estimate the following equation:

(1) $$D_{it} = \alpha_i + \gamma_t + \sum_k \beta_k S_{kit} + \sum_k \beta_{kR}(S_{kit} * R) + \varphi X_{it} + \varepsilon_{it}.$$

D_{it} indicates the change in interbank deposits in district or central reserve city i from call t-1 to call t. The subscript $i = 1, 2, \ldots, 14$ corresponds to the 12 Federal Reserve districts plus the central reserve cities of New York (i=13) and Chicago (i=14).

S_{kit} measures bank suspensions in district i from call t-1 to call t.[12] The coefficient of interest, β, indicates the average flow of interbank deposits in response to the suspension of a bank in that district or in the region served by a central reserve city. To capture the identification strategies for panics discussed in section 3, in many specifications, we classify suspensions by type k, a dichotomous variable that splits the sample into suspensions during panics and all other suspensions. In these specifications there are thus two β coefficients – one for suspensions during panics and one for all other suspensions.

As also shown in equation (1), S_{kit} can be interacted with R, a variable indicating reserve cities, which we include in some of our specifications. In these specifications, β, indicates the flow of interbank deposits from a central reserve city associated with the suspension of a bank, and $\beta + \beta_R$, indicates the flow from the reserve cities associated with the suspension of a bank.

Equation (1) includes additional controls that are meant to capture other time and district influences on bank suspensions, including changes in economic conditions, Fed policies, and fundamentals, which previous scholarship has identified as potentially important (Calomiris and Mason, 2003b, Bernanke and James, 1991, Grossman, 1994). X_{it} includes the Federal Reserve's consumption index, derived from department store sales in each Federal Reserve district and measured by the change in the index between the month of call t-1 and t

[12] For New York, S is the sum of bank suspensions across the 12 reserve districts. For Chicago, S is the sum of bank suspensions in reserve districts 7, 9, and 10.

and the change in the discount rate in effect i each Federal Reserve district from date t-1 to t. For the central reserve city of New York, consumption is measured by the national index. For Chicago, consumption is measured by the average of the indices for the 7th, 9th, and 10th Districts. The discount rates for New York and Chicago are their respective district rates. Some specifications of Equation (1) also include intercept terms for each Federal Reserve district and each central reserve city, α_i, as well as time fixed effects, γ_t, or time trends, captured by a fourth order polynomial, $\sum_p t^p$, where p= 1, …, 4.

The first column of Table 2 provides a baseline OLS regression that includes only three explanatory variables: the number of bank suspensions, a constant, and an indicator for reserve cities. The estimated coefficients on our key variable of interest indicate that when a suspension forced a bank to shut its doors: (1) interbank deposits fell by $230,563 in reserve-city banks located in the suspended bank's district; (2) declined by the same amount in banks in the central reserve city of New York; and (3) fell by the same amount in the central reserve city of Chicago, if the bank belonged to the 7th, 9th, or 10th Federal Reserve Districts.

Columns 2-6 display "within," fixed-effects models using a variety of definitions of suspensions and approaches for controlling for unobserved influences. All specifications include time-varying, district-level control variables. The specifications control for time-varying factors common across the districts in one of two ways: a polynomial time trend (column 2) or time fixed effects (columns 3-6). The inclusion of these variables ensures that our findings are not driven by changes in Federal Reserve policies, changes in economic conditions in each district, and factors changing over time. Standard errors are Huber-White corrected and clustered at the level of Federal Reserve districts and central reserve cities.

Column 2 reports estimates for regressions that include an interaction between all bank suspensions and reserve cities This specification indicates that when a suspension forced a bank to shut its doors, interbank deposits in New York and Chicago fell by approximately \$294,683. Column 3 replaces the polynomial time trend with time-fixed effects. This reduces the influence of observations in periods when bank suspensions and interbank flows increased simultaneously in all districts, such as the fourth quarter of 1931 (after Britain abandoned gold). This specification indicates that when a suspension forced a bank to shut its doors, interbank deposits in New York and Chicago fell by \$287,594.

To pin that causality runs from banking panics to reductions in interbank deposits, using the definitions of panics discussed in Section 3, columns 4-6 separate suspensions into two classes: banks that suspended operations during panics and those that suspended operations during other periods,. We then compare the estimates for suspensions of these two types. Column 4 defines the panic group as banks in 10-day, 30-mile joins. Column 5 defines the panic group as banks using the Davison and Ramirez (2014) clustering algorithm. The non-panic group in these two specifications consists of suspensions not clustered in time and space. Column 6 defines the panic group as banks that suspended payments temporarily, resumed payments, and in most cases survived the Depression plus banks whose suspensions examiners attributed to runs. Suspensions in non-panic periods could have also triggered reductions in interbank balances because one of the first actions taken by the court-appointed receiver would be to withdraw the failed institutions' correspondent balances; these would typically be placed in a preferred custodial account under the receiver's control prior to disbursing funds to creditors. However, our regression estimates reveal that, on average, these suspensions were not consistently correlated with substantial flows of interbank balances. In most specifications, the null-hypothesis that the coefficient on non-panic suspension equals zero cannot be rejected.

In Columns 4-6, the coefficients indicate that when banks suspended operations during panics – as defined by joins, clusters, or temporary suspensions plus runs – interbank deposits in New York and Chicago fell by \$500,000 to \$2,000,000. Further, interbank deposits in the reserve cities located in the distressed bank's district fell by roughly $120,000 to $180,000. The largest estimates arise from definitions of panics that focus attention on periods when runs were widespread, even among banks that remained in operation. Column 6 reports the regression with the most appealing statistical properties in terms of credible identification. Panics are defined by examiners' reports of runs and by the fact that many banks that suspended operations during these events remained solvent and resumed operations. Causality clearly runs from sudden changes in depositors' behavior to outflows of interbank deposits. Other factors that might influence this relationship, both observed and unobserved, are controlled for with time and district fixed effects as well as data on the discount rate, consumption, and the number of banks suspending operations due to factors other than sudden changes in the public's demand for cash relative to deposits (all of which are time-varying, district-level control variables).

The coefficients in Table 2 represent withdrawals of interbank balances by banks that suspended operations as well as withdrawals of interbank balances by banks that did not suspend but, during the panic, withdrew substantial quantities of interbank balances, either because they needed to pay depositors who withdrew funds or they wished to hold more cash in their vaults in case of future withdrawals. They also represent correspondent banks in reserve cities passing through the effect of interbank withdrawals as they withdrew their own excess reserves deposited in money-center banks in New York and Chicago. Interbank withdrawals for each group can be calculated with the following formulas.

(2) $I_{Total} = \beta_1 S_1 + \beta_1 S_{1,Chicago} + (\beta_1 + \beta_{1R}) S_1$

(3) $I_{Passthrough} = (\beta_1 + \beta_{1R}) S_1 * \delta_{5,2}$

(4) $I_{suspensions} = D_{1,nonmember} * f_{nonmember} + D_{1,member} * f_{member}$

Where I_{Total} equals total interbank withdrawals estimated by equation (1) for a particular specification in Table 2. β_1 is the coefficient on all suspensions (if all suspensions is the only type of suspension in the regression) or panic suspensions (if the specification subdivided suspensions into type 1 during panics and type 2 not during panics) in that specification for central reserve cities. $(\beta_1 + \beta_{1R})$ is the impact in reserve cities. S_1 is the total number of that type of suspensions in the United States. $S_{1,Chicago}$ is the total number of suspensions of that type in the 7th, 9th, and 10th Federal Reserve Districts. $I_{Passthrough}$ is the amount of interbank deposits withdrawn from reserve cities that banks in those cities in turn withdraw from central reserve cities. $\delta_{5,2}$, the coefficient indicating the share of interbank deposits passed through, which the next section estimates.

$I_{suspensions}$ equals withdrawals of interbank balances by banks of type 1 that suspended operations. This amount cannot be directly observed. We estimate it with a series of assumptions. We do not know the balance sheets of banks that suspend operations at the beginning of the event, such as a panic, which precipitated their closure. For the majority of banks, however, we know their deposits on the date of suspension, which is often noted on their St. 6386 form. When this information is missing, we can determine their deposits at the June call prior to their closure, which is listed either on their St. 6386 or in Rand McNally Bankers Directory.[13] D_1 is the sum of deposits measured near the date of suspension for all type 1 banks, member and non-member. $f_{nonmember}$ is the ratio of interbank balances to deposits on aggregate for all state commercial banks. f_{member} is the ratio of interbank balances to deposits on aggregate for all state commercial banks, excluding reserves with the Federal Reserve.[14]

[13] A series of robustness checks (available from the authors upon request) involves rerunning all of the regressions using deposits in suspended banks as the key independent variable. Those regressions yield signs and significance levels of coefficients almost identical to the regressions that we report using the number of bank suspensions and estimates of the interbank amplifier that differ by only a few percent. We report the latter because of the potential error in variables problem that this paragraph reports for data on deposits at the date of suspension.
[14] These values were measured by the OCC each year from the balance sheets of commercial and reported in their annual report.

These formulas allow us to calculate three important ratios. One is the fraction of interbank outflows caused by banks in reserve cities passing withdrawals of interbank balances through to central reserve cities, $I_{passthrough}/\, I_{Total}$. In our preferred specification from Table 2, that fraction is 9.9%. Two is the fraction of total interbank outflows due to withdrawals of banks that suspended operations, $I_{suspensions}/\, I_{Total}$. In our preferred specification from Table 2, that fraction is 8.6%. Three is the fraction of interbank withdrawals during panics by banks that survived the event $1 - I_{passthrough}/\, I_{Total} - I_{suspensions}/\, I_{Total}$. In our preferred specification from Table 2, that fraction is 80.7%. Note that we list the results of these calculations for all banks in Table 6, which summarizes the overall impact of the estimates presented in Tables 2 through 4.

To address uncertainty about which specifications in Table 2 best fit the data, we conduct two Bayesian-averaging exercises. Appendix 3 describes the details of our calculations. Table 3 presents the results. The left-hand columns report the results of Bayesian model averaging over all specifications reported in Table 2 and over all possible permutations of the control variables and fixed effects for those specifications. The results strongly favor the inclusion of district fixed effects, time fixed effects, and time varying controls. The results strongly favor the specification that divides suspensions into a panic group composed of suspensions that were temporary or attributed to runs and a non-panic group of all other suspensions. The posterior inclusion probability for that model exceeds 93%. The inclusion probability for the reserve city interaction receives moderate support: an inclusion probability of about 7%. The inclusion probabilities for all other specifications of suspensions are below 3%, and in most cases, less than 1%.[15] The coefficients from this Bayesian average exercise resemble those from our classical regression. Each bank

[15] The inclusion probability, coefficients, and other statistics for the variables and specifications that we do not report can be found in an online appendix, along with the data and code used to conduct this exercise.

suspension is associated with an outflow of about $472,000 from each central reserve city and about $442,000 from the relevant reserve cities. The Bayesian estimates provide a more precise estimate of the flows associated with suspensions outside of panics. As we saw in the aggregate data presented earlier, interbank balances tended to rebound when panics ended. The rebound is represented by the positive sign of the coefficient on non-panic suspensions in our Bayesian estimates.

The right-hand columns in Table 3 report the results of a Bayesian-averaging exercise over a broader set of models, including all specifications that we examined when analyzing the data, all specifications suggested by seminar audiences and reviewers, and all specifications that appeared in papers written by other authors using similar methodologies to quantify banking panics. The exercise strongly favors including district fixed effects, time fixed effects, and time varying controls, particularly the policy rate. The model with the highest inclusion probability, 99.9%, defines suspension during panics as suspensions that examiners attributed to runs and non-panic suspensions as all other suspensions. The inclusion probability for the reserve-city interaction is 43%. Both Bayesian models indicate that interbank deposits flowed back into reserve and central reserve cities during non-panic periods. The coefficients from this Bayesian exercise falls in the middle of those estimated in the comparable columns (4 through 6) in table 2. During panics, each bank suspension was associated with an outflow of about $1,049,000 from central reserve cities and an outflow of about $617,000 from reserve cities.

5. Asset Rebalancing and Interbank Amplification

We now examine how reserve and central-reserve-city banks, the two upper layers of the interbank network, altered their portfolios in response to deposit flows, particularly once the period of severe banking distress began. We analyze the same data panel described in the preceding section. Our econometric model differentiates deposit inflows from outflows because banks may not have responded symmetrically to reductions and increases in deposits.

We divide banks' assets into seven comprehensive and mutually exclusive categories:

(1) loans to the private sector
(2) government bonds
(3) corporate bonds
(4) cash and reserves held at the Federal Reserve
(5) interbank assets (a bank's deposits in other commercial banks)
(6) fixed assets such as the value of the bank building plus furniture and fixtures
(7) all other assets.

For each asset category, we regress the change in that asset type on inflows and outflows of interbank and public (demand plus time) deposits. Since the error terms for the seven equations corresponding to the seven asset categories may be correlated, we simultaneously estimate the seven equations using Zellner's (1962) method of seemingly unrelated regressions (SUR), which improves the efficiency of the estimates. We can summarize the set of regressions as:

$$(5)\ y_A = X_A\delta_A + \varepsilon_A,$$

where X is a matrix. y, δ, and ε are vectors, respectively indicating the dependent variables, coefficients, and error terms. The subscript, $A = \{1, \ldots, 7\}$, indexes these vectors, where the numbers indicate the category of assets from the list above. Each individual asset-category regression takes the following form:

$$(6)\ y_{it} = \propto + \textstyle\sum_z \delta_z X_{itz} + \sum_z \delta_z X_{itz}\,(X_{itz} * R) + \varepsilon_{it}$$

where y_{it} indicates the dependent variable (i.e. changes in dollar values of one of the asset classes listed above), measured from t-1 to t. The letter z indicates either inflows or outflows. X_{itz} indicates deposit flows of type z in district I from call t-1 to t. R is an indicator variable for central reserve cities. We interact the indicators for central reserve city and panic period so that we can obtain separate marginal effects for the two upper layers of the pyramid during the period of banking distress that began with the collapse of Caldwell and company.

The results reported in Table 4 show, on average, how the number of dollars invested in a type of asset changed when a dollar of interbank deposits flowed in (or out) of banks over our sample period, June 1929 to December 1932. To simplify the presentation, the table reports linear combinations of the underlying estimated coefficients and standard errors and hypothesis tests for those linear combinations. The table does not report asset categories (6) and (7), for which the coefficients were uniformly insignificant statistically and economically. Each row indicates the average response to a $1 flow of interbank deposits (either in or out) of the portfolio of a type of banks for a particular period. For example, the table's third row indicates how central reserve city banks responded to inflows of interbank deposits. On average, when $1 flowed in, loans increased by $0.56, government bonds increased by $0.48, and corporate bonds increased by $0.33, while reserves and interbank deposits fell by $0.37 and $0.14 respectively. These patterns probably reflect money-center banks' efforts to put to productive use cash and reserves that they had accumulated during periods of distress.

The second half of Table 4 focuses on outflows of interbank deposits. (Positive coefficients in this part of the table indicate that outflows were associated with reductions in assets, since in the underlying data, outflows are negative numbers). The estimates indicate that reserve-city banks acted as conduits, passing country-bank withdrawals up the pyramid to central-reserve-city banks. When country banks withdrew a dollar of interbank deposits from reserve-city banks, reserve-city banks in turn reduced deposits in central-reserve-city banks by $0.59. Central-reserve-city banks responded to interbank outflows by reducing holdings of loans and bonds and by increasing reserves held in their vaults or at the Fed. The size of the coefficients indicates that the buck stopped in central reserve cities. When a dollar of interbank deposits flowed out, money-center banks reduced lending by $0.54, holdings of corporate bonds by \$0.67, and holdings of government bonds by \$0.34. They also accumulated an additional \$0.47 in reserves.

By comparing coefficients on outflows and inflows, we can determine how banks changed the allocation of funds after a cycle in which interbank balances flowed out during a panic and returned when calm was restored. In reserve cities, the *net* effect of a \$1 outflow followed by a \$1 inflow was a \$0.32 reduction in loans, a \$0.03 decline in interbank balances held in central reserve cities, and a \$0.55 increase in holdings of government bonds. In central reserve cities, the increasing volatility of interbank balances principally altered the composition of the bond portfolio. A \$1 outflow followed by a \$1 inflow resulted in a net increase in holdings of government bonds by \$0.14, an increase in reserves of \$0.10, and a reduction in holdings of corporate bonds by \$0.34.

Overall, these results indicate that, as banking distress intensified and country banks faced runs, they pulled deposits out of reserve-city banks. These banks in the middle layer of the pyramid responded by drawing down their deposits at banks in central reserve cities. The buck stopped in New York and Chicago, where money-center banks accommodated interbank outflows by reducing lending and stockpiling cash.

6. Aggregate Interbank Amplifier

We can now quantify the aggregate reduction in lending associated with interbank deposit outflows during the Great Depression. We call this reduction interbank amplification. To calculate the gross amplifier, we multiply the number of bank suspensions by the estimated deposit outflows associated with suspensions during periods of panic and then multiply that product by the estimated decline in lending associated with interbank outflows. In other words, the gross interbank amplifier, A, is:

(7) $A = s_1 \, B_1 \, \delta_1.$

Here, s_1 is a 1 by 12 vector, indicating suspensions in Federal Reserve districts 1 through 12. B_1 is a 12 by 14 matrix whose elements indicate how suspensions during panics in district i influenced interbank outflows in district j. It is estimated in Tables 2 and 3. Using the notation from Equation (1), the elements of the matrix are: $B_{ij} = \beta_1 + \beta_{1R}$ if $i = j$ and $j \leq 12$. $B_{ij} = 0$ if $i \neq j$ and $j \leq 12$. $B_{i,13} = \beta_1$. And, $B_{i,14} = \beta_1$ if $i = 7, 9, 10$ and $\beta_{i,14} = 0$ otherwise. δ_1 is a 14 by 1 vector that indicates how interbank outflows influenced lending to businesses and purchases of corporate bonds in the 12 Federal Reserve districts and two central reserve cities, which we estimated in Table 4.

For all estimates of interbank amplification, we report bootstrapped standard errors, following the methodology of Cameron, Gelback and Miller (2008). For our models estimated using classical regression methods (columns 1 through 6), we resample with replacement by district 10,000 times, and for each sample containing at least one Fed district and one central reserve city (both are necessary to estimate the aggregate amplifier), we estimate Tables 2 and 4, calculate the gross and net amplifier, and then calculate the distribution of those estimates.

The first part of Table 5 first row shows gross amplification for each model estimated in Tables 2 and 3 for July 1929 through December 1932. Our estimate of the interbank amplifier in that period ranges from \$2.3 billion to \$4.9 billion. For example, in our preferred specification shown in column 6, the estimate is \$2.5 billion. In the specification selected by Bayesian model averaging over all potential models (column 8), the estimate is \$4.9 billion.

We also calculate the *net* interbank amplifier, which accounts for both the reduction in lending due to interbank outflows during panics and the rebound in lending when interbank funds returned after each panic subsided. The net amplifier, A_{net}, is:

(8) $A_{net} = s_1 B_1 \delta_1 + s_2 B_2 \delta_2$

Here, s_2 is a 1 by 12 vector, indicating suspensions in Federal Reserve districts 1 through 12. B_2 is a 12 by 14 matrix, whose elements indicate how suspensions during panics in district i influenced interbank outflows in district j, which we estimate in Tables 2 and 3. Using the notation from Equation (1), the elements of the matrix are: $B_{ij} = \beta_2 + \beta_{2R}$ if $i = j$ and $j \leq 12$. $B_{ij} = 0$ if $i \neq j$ and $j \leq 12$. $B_{i,13} = \beta_2$. $B_{i,14} = \beta_2$ if $i = 7, 9, 10$ and $\beta_{i,14} = 0$ otherwise. δ_2 is a 14 by 1 vector that indicates how interbank inflows influenced lending to businesses and purchases of corporate bonds in the 12 Federal Reserve districts and two central reserve cities, which we estimated in the top portion of Table 4. Estimates of the net amplifier range from $1.3 in our preferred specification to $3.3 billion in the specification based upon Davison and Ramirez (2014).

Table 5 shows that our estimates of interbank amplification amounted to a substantial fraction of the decline in all commercial bank lending. From June 1929 through December 1932, the total fall in commercial bank lending amounted to $14.055 billion. Of this, $3.335 billion consisted of loans and investments trapped in failed commercial banks, and $10.4 billion was the decline of credit by banks still in operation. Given these figures, the net interbank amplifier amounted to 13.2% of the total decline in commercial bank credit outstanding and 55.7% of the loans and investment trapped in failed commercial banks, in our preferred classical estimate, and about the same percentage in the Bayesian specification with the highest posterior inclusion probability.[16]

The second part of Table 5 expands our estimate to include the impact of the banking panic of winter 1933. As noted earlier, the effects of the final panic during the contraction cannot be calculated using call report data, since the comptroller of the currency and state authorities did not call for reports of condition between December 1932 and June 1933. So,

[16] Data on total loans and investments trapped in suspended banks are from the Federal Reserve' compilation of examiners' reports for suspended banks as described in Richardson (2008). Data on total credit extended by commercial banks from Federal Reserve Board of Governors (1943).

for this period, we compute the interbank amplifier from weekly reporting data. We assume that, during this period, the share of the decline in an asset category due to interbank withdrawals was equal to the share of total withdrawals made by interbank depositors. We scale up the amount withdrawn to account for the fact weekly reporting banks represented only a fraction of all banks in New York and around the nation.[17] Based upon these assumptions, we calculate that during the panic in January, February, and March of 1933, interbank withdrawals resulted in a $268 million reduction in lending by banks in New York City and a $646 million reduction in lending by banks outside of New York City. Incorporating this information yields our estimate of gross and net interbank amplification from the peak of the business cycle in the summer of 1929 through the trough in the winter of 1933. In our preferred specification shown in column 6, the net amplifier is $2.773 billion. The standard error is $1,277, indicating that we can reject the null hypothesis that our estimate equals zero at the 1% level.

To restate our estimate in terms of the total decline in commercial bank credit from peak to trough, we need to make another calculation, which is complicated because the precise figure for the total credit decline during the banking panic of the winter of 1933 is unknown. Little data exists since, as noted above, most states and the federal government suspended the collection of call reports during the crisis. We therefore estimate the contraction of credit by assuming that loans and investments for *non-member* and *country-member* banks declined at the same rate as reporting member banks for which data exists.[18]

[17] The Federal Reserve does not indicate the identities of the reporting banks or the exact proportion of all assets represented by these banks. For the nation as a whole, the Federal Reserve reports that they attempted to keep that proportion around 70 percent. When we compare the weekly reporting data for New York City for the last week of 1932 to the call report data from the same week (though from a different day of the week), we find that the interbank balances for the weekly reporting banks represented 82 percent of all interbank balances in the city. The fraction of other components of the balance sheet represented by weekly reporting banks ranges from 74 percent (net demand deposits) to 96 percent (reserves with the Fed). Since the fraction of interbank balances falls near the median of this range, we use this figure as our scaling factor.

[18] Note that this may be an overestimate of their rate of loss for several reasons. First, reserve city banks typically lost funds at higher rates than country banks during panics. Second, during the winter of 1933, more

That rate was 13.2%. At the December 1932 call, member banks in reserve and central reserve cities possessed $17.862 billion in loans and investments. Country member banks held $9.607 billion in loans and investments and non-member banks held $7.924 billion in loans and investments. Using these figures, we estimate that, during the 1933 panic, total loans and investments declined by $4.603 billion ($2.365 billion among member banks reserve and central reserves cities and $2.238 billion in country member and all-nonmember banks). The total decline in credit from commercial banks during the contraction from summer 1929 to winter 1933 therefore equaled $18.658 billion. Net interbank amplification, therefore, accounted for 12.6% to 29.9% of the total decline in credit during the contraction from summer 1929 through winter 1933. The decline was 14.9% in our preferred estimate and 12.6% in the Bayesian estimate with the highest inclusion probability over all specifications.[19]

Table 6 estimates the sources of withdrawals during panic periods, using the methods outlined in equations 2 through 4 and coefficients reported in tables 2 through 4. The majority of interbank withdrawals came from banks that remained open during panics and survived the contraction. Estimates of the survivors' share range from 66.2% to 94.7%, with 80.7% in our preferred classical specification and 70.6% in the Bayesian estimate with the highest inclusion probability over all models. The share due to banks that suspended operations was smaller, ranging from 3.0% to 14.6%, with 8.6% in our preferred specification. Estimates of interbank withdrawals passed through reserve to central reserve cities range up to 23.6%, with 10.7% in our preferred classical estimate and 16.8% in the in

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than two dozen states declared banking holidays in the latter half of February and first week of March, and moratoria effecting country banks occurred in most cases before moratoria effecting reserve and central reserve cities. This may be an underestimate, however, because country bank's post-Banking-Holiday reopening rate was substantially lower than that of large banks operating as correspondents in reserve and central-reserve cities; early banking holidays may mask, therefore, the date and impact of their demise.

[19] Data limitations prevent us from stating this as a fraction of failed banks from peak to trough of the contraction, because we lack information on the contraction of credit due to banks forced to suspend operations by local and state moratoria in February and March of 1933 and which then subsequently ceased operations.

the Bayesian estimate with the highest inclusion probability over all models. These estimates indicate that the reserve pyramid operated, in important ways, as intended. It enabled respondent banks to access interbank funds during periods of distress, and when regional demands for funds exceeded regional capacities, it enabled regional reserve cities to drawn on central reserve cities for additional funds. This result explains a key finding in Calomiris and Mason (2003b), which showed that member banks' interbank balances decreased their risk of failure to the same extent as holding cash. We show that when the reserve pyramid operated effectively prior to the banking holiday, interbank bank balances were liquid. Surviving banks used them as a source of funds whenever they needed to satisfy depositors' demands. Their effectiveness in reducing respondents' risk of failure, however, depended upon correspondent banks' ability to convert assets – such as loans and bonds – into cash. Our result also reconciles Calomiris and Wilson (2003a), who examined failure risk of Fed member banks during the early 1930s; Calomiris and Wilson (2004), who showed that banks in New York City reduced lending in response to increases in solvency risk; and Van Horn and Richardson (2011), who showed that New York's money-center banks maintained lending as usual in response to shocks to likely repayment of international loans in central Europe, particularly Germany. We show that money-center banks experiencing liquidity drains (whether or not related to the quality of their own loan portfolios) remained in operation by reducing lending and selling corporate bonds. Country member banks, according to Calomiris and Mason (2003a), could not do this. Differential liquidity of loans made by country and reserve-city banks, therefore, explains the different trajectories of bank distress and credit contraction across the reserve pyramid.

7. Conclusion

Theory suggests that network linkages can transmit shocks and exacerbate financial crises. We demonstrate that network linkages played an important role in amplifying the contraction of lending during the Great Depression.[20] In the 1930s, commercial banks responding to sudden, large depositor withdrawals – those typically associated with bank runs and panics – and rapidly removed interbank balances from correspondent banks in reserve and central-reserve cities in order to meet depositors' demands for cash. Reserve-city banks, almost all of which were Fed members, responded by re-balancing their portfolios, passing the buck up the reserve pyramid, and reducing lending to businesses. The aggregate contraction in bank credit from this "interbank amplifier" caused overall lending during the Great Depression to decline by approximately 15 percent up to the Banking Holiday of 1933.

Ironically, the Federal Reserve System had been created with the purpose of preventing crises, such as those that had regularly plagued the banking system in the 19th century, but the Fed's failure to convince roughly half of all commercial banks to join the system allowed a pyramided-structure of reserves to persist into the third decade of the 20th century and created a channel through which the interbank deposit could influence real economic activity. In theory, pyramided reserves could be deployed to help troubled banks, but during the banking panics of the 1930s, just as in the panics of the late nineteenth century, the total size of these withdrawals overwhelmed correspondent banks, leaving those banks with the choice of either contracting on the asset side of their balance sheets or borrowing from the Fed. With the Fed unable or unwilling to provide sufficiently liquidity to support distressed correspondent banks, they were forced to react to interbank outflows by reducing lending, thus amplifying the decline in investment spending. Although the mechanism is new,

[20] By contrast, during the recent financial crisis, the interbank market evaporated in August 2007, with many banks unable to borrow at a range of short-term maturities; however, central banks responded to the collapse in interbank lending by injecting massive amounts of liquidity (Allen and Babus, 2009). As most countries experiencing troubles had floating exchange rates, governments were not constrained in ways that may have prevented them from injecting liquidity into the banking system in the 1930s (Eichengreen, 1992); moreover, central banks more actively coordinated their response to the crisis through agreements such as swap facilities for foreign exchange (Moessner and Allen, 2011). This event was preceded by lax credit conditions that fueled the rise in house prices in several countries and the subsequent collapse in mortgage-backed securities prices in the U.S. that particularly affected commercial and investment banks.

our results corroborate other studies on the Depression, which emphasize how banking distress reduced loan supply (Bernanke, 1983; Calomiris and Mason, 2003b).

What might have alleviated this problem? One solution would have been for the Federal Reserve to extend sufficient liquidity to the entire financial system. The Fed could have done this by lending funds to banks in reserve centers. In turn, those banks could have loaned funds to their interbank clients. To do this, banks in reserve centers would have had to accept as collateral loans originated by non-member banks. Banks in reserve centers would, in turn, need to use those assets as collateral at the Federal Reserve's discount window.

Why didn't the Fed do this? At the beginning of the Depression, the leaders of the Federal Reserve disagreed about the efficacy and legality of such action. During the stock market crash in the fall of 1929 and the initial banking panics in the fall of 1930, the Federal Reserve Banks of New York and Atlanta aggressively extended credit to member banks, which in turn extended loans to their financial counterparties. The Fed Banks did this by accepting as collateral eligible paper held but not originated by their member banks. Other Federal Reserve banks and some members of the Federal Reserve Board criticized these actions, which they deemed to be unwise and potentially illegal. The debate continued until legislation in 1932 broadened the Fed's lending authority, clearly authorizing New York and Atlanta's earlier actions (Chandler, 1971). Then, however, the Fed lacked the will and may have lacked the resources to alleviate the situation.

Another potential solution would have been to compel all commercial banks to join the Federal Reserve System and require all commercial banks to hold their reserves at a Federal Reserve Bank. Due to powerful political lobbies representing state and local bankers, however, Congress was unwilling to contemplate legislation that would have effected such changes. Had they done so, the pyramid structure of required reserves would have ceased to exist, and the interbank amplifier, as defined here, would have been dramatically diminished.

That said, given the inaction of some Federal Reserve Banks during the 1930s, had such changes taken place, they may have magnified banking distress as more banks would have depended on obtaining funds through Federal Reserve Banks that adhered to the real bills doctrine. As we show, the costs of the pyramid in terms of a contraction in lending were substantial, but banks still met some of their short-term needs through this structure during the turbulent periods of banking distress.

The notion that linkages of Federal Reserve member banks to financial institutions outside the Federal Reserve System were an important source of contagion in the 1930s echoes recent commentary on the role of shadow banks in the financial crisis of 2007-08.[21] The parallels include the susceptibility of shadow banks and non-member banks to runs, the lack of access of non-member banks and shadow banks to the discount window, the flight to liquidity and quality during periods of acute uncertainty and financial distress (Moessner and Allen, 2012), and intercontinental contagion (the last of which remains a clear avenue for future research).[22] That said, the timing of the two financial crises in relation to the business cycle, the precise mechanisms for propagating network distress, and the network structures appear somewhat different.

By the mid-2000s, shadow banks had accumulated assets that were at least as large as those in the commercial banking system. Some scholars have argued that the initial distress in financial markets originated from transactions in which shadow banks were intimately involved, such as in the asset-backed commercial paper and repurchase agreement ("repo") markets (Gorton, 2010 and Gorton and Metrick, 2012). The run on the shadow banking system began in 2007, prior to the economic downturn in early 2008, and distress was spread

[21] Shadow banks of the early twenty-first century carry out credit and maturity-transformation activities that are similar to those of commercial banks, but they are not subject to the regulation and supervision traditional banks face.
[22] In the earlier crisis, many scholars have pointed to the collapse of Creditanstalt in May 1931 as the pivotal event that spread contagion across Europe (Eichengreen, 1992; Schubert, 1991; Accominotti, 2012)

from these markets to other parts of the financial system partly through shadow-bank linkages with traditionally regulated banking and insurance firms.[23] By contrast, in the United States. Great Depression, output fell prior to severe financial institution distress.[24] Industrial production in the United States peaked in the summer of 1929, with the first banking panic coming more than a year later, in October 1930.

Further, the precise way in which network linkages led to disintermediation differs in the two crises. In the 1930s, the decline in interbank balances was sufficient to reduce aggregate lending; the effect was sizeable, even when compared to the loss of lending due to the failure of commercial banks. On the other hand, in the recent crisis, Acharya (2013) argues that the destruction of shadow banks has been the source of overall disintermediation, suggesting that commercial banks have been unable to fill the void in credit resulting from their disappearance.

Given the widespread use of deposit insurance today, the behavior of commercial bank deposits also differed during the two crises: they fell during the Great Depression whereas they rose during the recent financial crisis (Moessner and Allen, 2011). It is possible that the presence of deposit insurance during the 1930s could have mitigated runs on banks and thus reduced the large strain on the reserve pyramid. The reduction in interbank deposit outflows, in turn, might have then alleviated the need for the Fed to act as a lender of last resort.

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[23] Adrian and Ashcroft (2012, p.3) state that these network linkages include "back up lines of credit, implicit guarantees to special purpose vehicles and asset management subsidiaries, the outright ownership of securitized assets on bank balance sheets, and the provision of credit puts by insurance companies."

[24] The precise timing of banking distress and economic distress, however, varied across countries (Grossman, 1994, Grossman and Meissner, 2010).

Appendix 1: Data

Our principal source for constructing information on the reserve pyramid is *Banking and Monetary Statistics of the United States, 1914 to 1941* (Federal Reserve Board of Governors, 1943). It presents information from the call reports of Federal Reserve member banks aggregated by Federal Reserve district, including counts of banks in each district as well as detailed summaries of assets (15 categories) and liabilities (17 categories) for member banks located in reserve cities and for banks located outside of reserve cities (called country banks). Book values of loans and investments are reported, making the interpretation of regression coefficients straightforward. It also contains detailed classifications of the loans, investments, and deposits of banks from 1928 through 1941. For the Second and Seventh Federal Reserve Districts, we calculate the balance sheets of banks in the central reserve cities of New York and Chicago by subtracting reserve and country banks from all banks.

For our analysis, we then aggregate bank asset information into three categories: (1) lending to businesses (the sum of loans, acceptances, and corporate bonds); (2) lending to the U.S. government (the sum of government securities of varying maturity); and (3) reserves (the sum of cash in the vault and deposits at Federal Reserve banks). We calculate reserves in this manner to conform to the approach used by Friedman and Schwartz, who excluded from their calculations balances at domestic banks (which counted as part of a bank's legally required reserves if deposited in a bank in a reserve or central reserve city) and balances at foreign banks. We also excluded cash items in the process of collection from banks' reserves, because the slow pace of intercity check clearing left these items simultaneously on the balance sheets of multiple banks, leading to a double counting of reserves presumed reserves. During periods of distress, banks found items in the process of collection generally illiquid and uncollectible (see Richardson, 2007, for details).

Data are for each call date. The nature of the calls raises statistical issues. Many modern time series tests assume observations arise from stable data generating processes with consistent spacing, which is not characteristic of these data. The spacing of the calls was long and variable. Calls occurred in 1929 on March 27, June 29, October 4, and December 31; in 1930, on March 27, June 30, September 24, and December 31; in 1931, on March 25, June 30, September 29, and December 31; in 1932, on June 30, September 30, and December 31; and in 1933, not until June 30. Because the comptroller did not call for reports of condition during the Banking Holiday in March 1933, call report data reveal little about the collapse of the commercial banking system in the winter of 1933. Overall, calls occurred on average every 96 days, but the standard deviation of that average, 35, was high. Restricting the analysis to regularly spaced calls, December and June, eliminates more than half the observations from the data set, leaving six during the Great Contraction – far too few to employ statistical tests based upon asymptotic arguments. Moreover, the December and June calls almost always occurred on the last day of the month. Banks' balance sheets on these dates may have differed systematically from balance sheets on other dates, when the calls were intentionally unpredictable. We overcome these complications with the methods typical in the literature. We present results assuming the calls were equally spaced, but we check this assumption, by re-estimating our results with daily rates of change between calls rather than change between calls, and recovering similar results.

Bank data covering the events in the first quarter of 1933 and periods between call reports can be obtained using weekly data on a subset of reporting member banks. The information appears in *Banking and Monetary Statistics of the United States, 1914 to 1941* (Federal Reserve Board of Governors, 1943), Tables 49 and 50. Table 49 presents information for weekly reporting banks in New York City. Table 50 presents information for weekly reporting banks in 100 other cities, including Chicago, all other reserve cities, and approximately 40 other municipalities. The advantages of these data are that they are reported consistently over time and at a higher frequency. The disadvantages are that the tables do not present complete balance sheets – only figures for selected assets and liabilities. Moreover, the data come from a non-random set of banks. The chosen banks were meant to create a representative sample, but the sample changes in size over time, as banks merge, fail, or, for some other reason, depart the data set. Changes in the sample occasionally represent changes in the sample composition or sampling methodology. It is impossible to know the size of this problem because the Federal Reserve does not indicate the identities of the reporting banks or the exact proportion of all assets represented by these banks. For the nation as a whole, the Federal Reserve reports that they attempted to keep that proportion around 70%. When we compare the weekly reporting data for New York City for the last week of 1932 to the call report data from the same week (although on a different day), we find that the interbank balances for the weekly reporting banks represented 82 percent of all interbank balances in the city. The fraction of other components of the balance sheet represented by weekly reporting banks ranges from 74 percent (net demand deposits) to 96 percent (reserves with the Fed).

The most accurate source for information about bank failures during this period is the micro-level data from the Board of Governors' bank suspension study. These are described in Richardson (2007, 2008). The Board's Division of Bank Operations completed a form ST 6386b for each bank that suspended operations. From these forms, we extract an array of information: a bank's location, whether it was a Fed member or non-member, whether it possessed a state or national charter, the date of its suspension, the date of its reopening (if any), the deposits it possessed on the date of suspension, whether it was suspended by a decision of its board of directors or under the authority of a state or national bank examiner, and whether its suspension was triggered by a run. The latter piece of information was elicited by asking opinions of examiners and other authorities and according to the assessment procedures used by the division of bank operations. Documents describing these procedures indicate that while depositors lining up outside a bank pleading to withdraw funds was one symptom of a run, the determination of whether a run occurred should be based upon the volume of withdrawals and their impact on the bank as well as evidence of significant withdrawals via check or wire transfer, which usually occurred before ordinary individuals panicked over the safety of their funds. Researchers at the Federal Reserve called these events "invisible runs." For 1929-32, we tabulate the ST 6386 micro data by call date and Federal Reserve district, creating an accurate analog for our panel of bank balance sheets by call date.

Appendix 2: Join-Count Statistic

We use the Join-count statistic as a measure of spatial autocorrelation to assess whether bank failures are geographically clustered together, and to examine how this clustering varies over time. For the sample of all banks in the United States, we calculate a separate join-count statistic for every week in the sample between July 1st, 1929 and February 27th, 1932 based on whether the bank failed or remained open in that week. We represent the spatial relationship between banks using a spatial weights matrix W_{ij}, where the ijth element of the matrix contains one if bank i is within an L mile radius of bank j and zero otherwise. We examined join counts for L equals 10, 20, 30, 70, and 100 miles and find that 70 miles best fits the data. We represent the status of each bank as being either failed or open with vector y, where an element of the vector equals one if a bank has failed in that week and zero if a bank remains open in that week. We use W_{ij} and y to count the number of joins as the number of cases where two banks that are both within L miles of one another both fail in the same week. The number of observed joins, FF, equals

$$FF = \frac{1}{2}\sum_i \sum_j w_{ij} y_i y_j$$

We can test for whether bank failures are clustered near one another by comparing the observed number of joins with the expected number of joins under the null hypothesis that bank failures are randomly dispersed. Define N_F as the total number of failed banks in that week, and N as the total number of banks. The expected number of joins under the null hypothesis is:

$$\mathbb{E}[FF] = \frac{1}{2}\left(\sum_i \sum_j w_{ij}\right)\left(\frac{N_F}{N}\right)$$

The variance of the expected join-counts is:

$$\sigma_{FF}^2 = \frac{1}{4}\left(\frac{2s_2 N_F(N_F-1)}{N(N-1)} + \frac{(s_3 - s_1)N_F(N_F-1)(N_F-2)}{N(N-1)(N-2)} + \frac{4(s_1^2 + s_2 - s_3)N_F(N_F-1)(N_F-2)(N_F-3)}{N(N-1)(N-2)(N-3)}\right) - \mathbb{E}[FF]^2$$

where

$$s_1 = \sum_i \sum_l w_{ij}$$

$$s_2 = \sum_i \sum_l \left(w_{ij} + w_{ji}\right)^2$$

$$s_3 = \sum_i \left(\sum_j w_{ij} + \sum_j w_{ji}\right)^2$$

This can be used to calculate the test statistic, Z_{FF}, which will be asymptotically normally distributed and can be used to conduct a one-sided test for geographical clustering of bank failures.

$$Z_{FF} = \frac{FF - \mathbb{E}[FF]}{\sqrt{\sigma_{FF}^2}}$$

Appendix 3: Bayesian Model Averaging

We address uncertainty over the specification of equation (1) with a Bayesian Model Averaging (BMA) approach, which enables us to determine the specification that best fits the data. Our BMA analysis considers all models that potentially illuminate the causal link between interbank-deposit flows and banks suspensions. This class of models includes, on the right-hand side, a series of variables that divide all bank suspensions into those that occurred during panics, as defined by the methods in Section 3, and those that occurred outside of panics. We consider all time varying controls, and allow our averaging procedure to choose between including them in levels, changes, or seasonally adjusted. We consider specifications including either none or a full set of unit fixed effects and specifications including time trends, a full set of time fixed effects, both, or neither. With this set of models, we estimate the posterior probability for every model under consideration.

We consider Q models across the model space $M = [M_1, M_2, \dots, M_Q]$. Every model has a linear form:

(A.1) $D = \theta_q Z_q + \varepsilon_q$ with $\varepsilon_q \sim N(0, \sigma_q^2 I)$ for q = 1, 2,…,Q

where D is interbank deposit flow. For model q, θ_q is vector of coefficients for all variables included in the model. Z_q is the data matrix. ε_q is an error term, and σ_q^2 is the error variance. For each model, both θ_q and Z_q are a subset of the full set of possible regressors. We use a Normal-Inverse-Gamma prior distribution for our models and parameters, which enables us to estimate posterior distributions. We place an equal prior probability on every model, so $\pi(M_q) = 1/Q$. For each θ_q, we assign a prior probability $\pi(\theta_q | \sigma_q^2) = N(0, \sigma_q^2 I)$. Thus, the prior for θ is centered around zero. We select σ_q^2 depending on our anticipated scale of the parameters. We select σ_q^2 = 100,000. For σ_q^2, we assign a prior probability $\pi(\sigma^2 | \gamma) =$

$IG(\alpha, \beta)$, where *IG* denotes the Inverse Gamma distribution. For all models we set $\alpha = \beta = 0.5$. By combining this prior distribution with our set of data, *D*, we can obtain an estimate of the posterior probability of each model as:

(A.2) $p(M_q|D) = \frac{p(D|M_q)\pi(M_q)}{\sum_{q=1}^{Q} p(D|M_q)\pi(M_q)},\ q = 1,2,\dots,Q.$

A higher posterior model probability indicates a model that better fits the data. We calculate a particular coefficient's probability of inclusion as:

(A.3) $p(\beta_j \neq 0|D) = \sum_{\beta_j \epsilon M} p(M_q|D).$

The posterior expected value and variance of each regression coefficient is an average of β_j weighted by the model probabilities:

(A.4) $E(\beta_j|D) = \sum_{q=1}^{Q} p(M_q|D) E(\beta_q|D, M_q)$

and

(A.5) $Var(\beta_j|D) = \sum_{q=1}^{Q} p(M_q|D)[Var(\beta_j|D, M_q) + E(\beta_j|D, M_q)^2] + [E(\beta_j|D)]^2.$

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Table 1: National and Regional Banking Panics in the United States during the Great Depression

		Number of Suspensions		Closed by Bank Directors			Banks Experiencing Runs		
Name of Period	Weeks	All	Non-member	#	Difference (Pct Pt)	Z	#	Difference (Pct Pt)	Z
Pre-panic baseline	7/1/1929 - 11/1/1930	1037	904	770			422		
Caldwell crisis	11/16/1930 - 1/31/1931	756	645	698	0.18	9.5	402	0.12	5.2
First Chicago panic	6/7/1931 - 6/27/1931	133	104	115	0.12	3.1	99	0.34	7.4
Crisis after German panic	7/26/1931- 9/12/1931	270	206	229	0.10	3.5	125	0.06	1.7
After England departs gold	9/13/1931 - 11/7/1931	771	597	662	0.11	5.9	511	0.26	10.8
Winter '32 crisis	12/13/1931 - 2/6/1932	662	512	557	0.10	4.8	425	0.24	9.4
Second Chicago panic	6/19/1932 - 8/20/1932	271	203	252	0.19	6.6	143	0.12	3.6
Winter '33 crisis	12/18/1932 - 3/4/1933	491	396	439	0.15	6.6	265	0.13	4.9

Sources and notes: See the text and Appendix 1 for definitions and data sources. Closed by directors and banks experiencing runs are tabulations based on examiners' reports of all suspended banks. Difference (Pct Pt) is the percentage of banks closed by directors or banks experiencing runs in that period minus the percentage in the pre-panic baseline value shown in the tables' initial row. The Z-statistic for the two sample test for equality of proportion of means indicates that in each case, we can reject the null hypothesis that the percentage in that period equaled the percentage in the pre-panic period.

Table 2: Bank Suspensions and Interbank Deposit Flows, June 1929- December 1932

	Definition of Panic-Period Suspensions and Estimation Method					
	All: OLS	All: Panel FE	All: Panel FE	10-30 Joins: Panel FE	10-30 Clusters: Panel FE	Temp + Runs: Panel FE
Panic Suspensions	-230,563***	-294,683***	-287,594***	-816,996**	-1,996,247**	-501,302**
	(53,759)	(25,003)	(30,750)	(283,229)	(747,782)	(166,766)
Panic Suspensions * Reserve City		318,213***	316,286***	632,626	1,875,112*	338,567
		(82,851)	(84,894)	(480,682)	(970,537)	(252,280)
Other Suspensions				40,955	80,477	143,697
				(186,777)	(123,000)	(359,695)
Other Suspensions * Reserve City				168,340	5,513	242,766
				(430,397)	(215,389)	(587,973)
Observations	196	196	196	196	196	196
R-squared	0.114	0.250	0.307	0.307	0.310	0.320
District TVC	No	Yes	Yes	Yes	Yes	Yes
Time FE	No	No	Yes	Yes	Yes	Yes
Time Trend	No	Yes	No	No	No	No
SE Robust & Clustered	No	Yes	Yes	Yes	Yes	Yes
# Fed Districts	14	14	14	14	14	14

Notes: In Columns 1 to 3, all suspensions are treated as panic suspensions. In columns 4 through 6, 10-30 joins indicates banks suspending within 10 miles of another suspending bank in 30-day windows. 10-30 clusters indicates banks suspending in Davison-Ramirez clusters with parameters 10 days, 30 miles, and 4 banks, as described in text. Temp + Runs is the sum of temporary suspensions plus permanent suspensions that examiners attributed to runs. Other suspensions are all suspensions minus panic suspensions Standard errors in parentheses calculated using Huber-White method and are clustered on Federal Reserve districts and central reserve cities. *** indicates $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 3: Bayesian Model Averaging

Over Specifications shown in Table 2			Over All Regression Specifications		
Suspension Specification	Inclusion Probability	Coefficient	Suspension Specification	Inclusion Probability	Coefficient
Panic			Panic		
Temporary + Runs	0.935	-472,036	Runs	0.999	-1,049,586
(Temporary + Runs) * Reserve City	0.067	29,579	Runs * Reserve City	0.430	432,637
Non-Panic			Non-Panic		
Other Suspensions	0.935	206,607	Other Suspensions	0.999	935,146
Other * Reserve City	0.067	-14,338	Other * Reserve. City	0.430	-462,209

Note: Suspension specification reports pairs of panic and non-panic suspensions considered across model specifications. Calculations of inclusion probabilities and coefficients are described in detail in Appendix 3.

Table 4: Estimated Interbank Deposit Flows and Asset Allocations, June 1929- December 1932

	Asset Category				
	Loans	Government Bonds	Corporate Bonds	Reserves	Interbank Deposits
Interbank Deposit Inflows					
Reserve City, 1929-1933	-0.137	0.612 *	0.143 *	-0.081	0.557 ***
	(0.387)	(0.319)	(0.076)	(0.203)	(0.096)
Central Reserve City, 1929-1933	0.557 ***	0.479 ***	0.325 ***	-0.370 ***	-0.138 ***
	(0.180)	(0.148)	(0.035)	(0.093)	(0.045)
Interbank Deposit Outflows					
Reserve City, 1929-1933	0.178	0.067	0.142 *	0.038	0.590 ***
	(0.429)	(0.354)	(0.084)	(0.224)	(0.106)
Central Reserve City, 1929-1933	0.542 ***	0.341 **	0.665 ***	-0.468 ***	0.091 *
	(0.198)	(0.16)	(0.039)	(0.104)	(0.049)

Notes: Regressions are based on equation (6) as described in the text. P-values indicated with asterisks: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table 5: Estimates of the Interbank Amplifier during the Great Depression

	Definition of Panic-Period Suspensions and Estimation Method							
	All: OLS	All: Panel FE	All: Panel FE	10-30 Joins: Panel FE	10-30 Clusters: Panel FE	Temp + Runs: Panel FE	Temp + Runs: BMA	Runs: BMA
				July 1929 to December 1932				
Gross Amplifier ($millions)	2,287	2,365	2,298	2,676	4,842	2,453	2,603	4,906
Standard Error (Bootstrapped)	1,149	943	1,061	913	2,964	992		
% Decline Bank Lending	16.3	16.8	16.4	19.0	34.5	17.5	18.5	34.9
% Lending Failed Banks	68.6	70.9	68.9	80.2	145.2	73.6	78.1	147.1
Net Amplifier ($millions)				2,560	4,670	1,859	1,755	1,440
Standard Error (Bootstrapped)				1,449	3,257	1,277		
% Decline Bank Lending				18.2	33.2	13.2	12.5	10.2
% Lending Failed Banks				76.8	140.0	55.7	52.6	43.2
				July 1929 to Banking Holiday				
Gross Amplifier ($millions)	3,201	3,279	3,212	3,590	5,756	3,367	3,517	5,820
Standard Error (Bootstrapped)	1,149	943	1,061	913	2,964	992		
% Decline Bank Lending	17.2	17.6	17.2	19.2	30.9	18.0	18.9	31.2
Net Amplifier ($millions)				3,474	5,584	2,773	2,669	2,354
Standard Error (Bootstrapped)				1,449	3,257	1,277		
% Decline Bank Lending				18.6	29.9	14.9	14.3	12.6

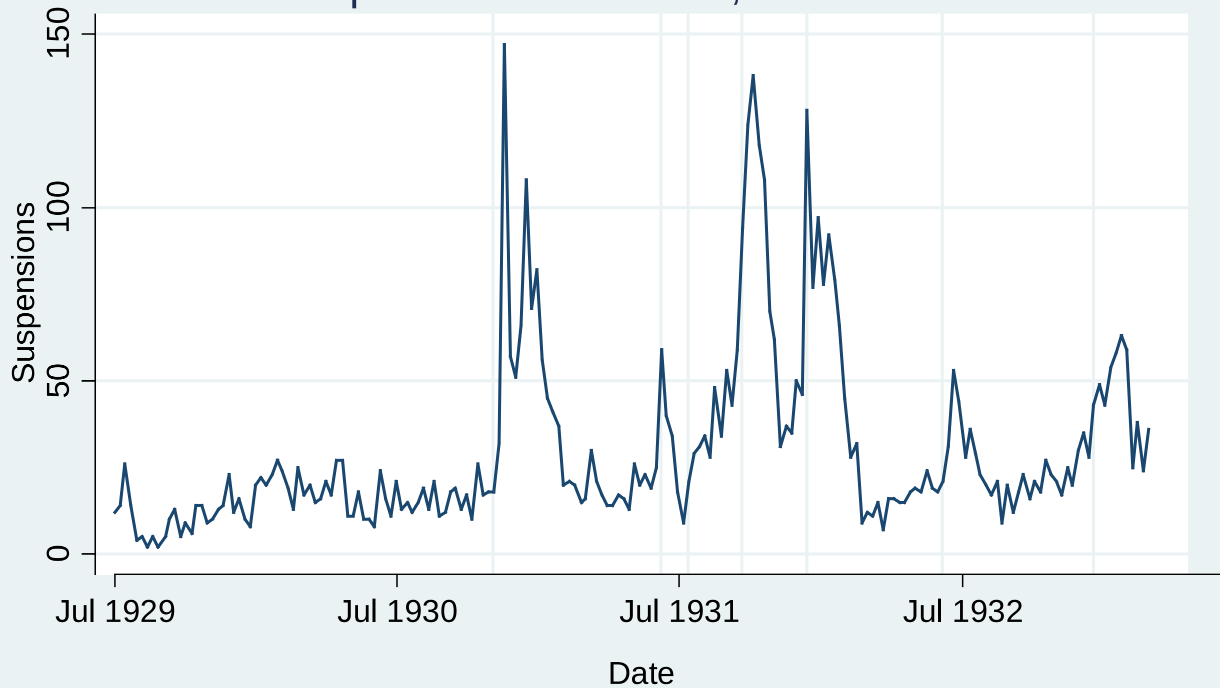
Notes: Columns 1-6 are based using estimates from Table 2. Columns 7 and 8 are based on models shown in Table 3. The method for bootstrapping standard errors is described in the text. Due to missing data, % Lending Failed Banks cannot be calculated for January, February, and March of 1933.

Table 6: Decomposing Withdrawals During Panics, June 1929 - December 1932

	Estimation Method and Definition of Panic-Period Suspensions Employed							
Sample Period and Estimated Effect	All: OLS	All: FE	All: Panel FE	10-30 Joins: Panel FE	10-30 Clusters: Panel FE	Temp + Runs: Panel FE	Temp + Runs: BMA	Runs: BMA
Survivors	66.2	89.3	89.6	86.0	94.7	80.7	70.2	79.6
Suspensions	10.2	14.0	14.6	6.2	3.0	8.6	6.8	3.6
Pass-through	23.6	-3.3	-4.2	7.8	2.3	10.7	23.0	16.8

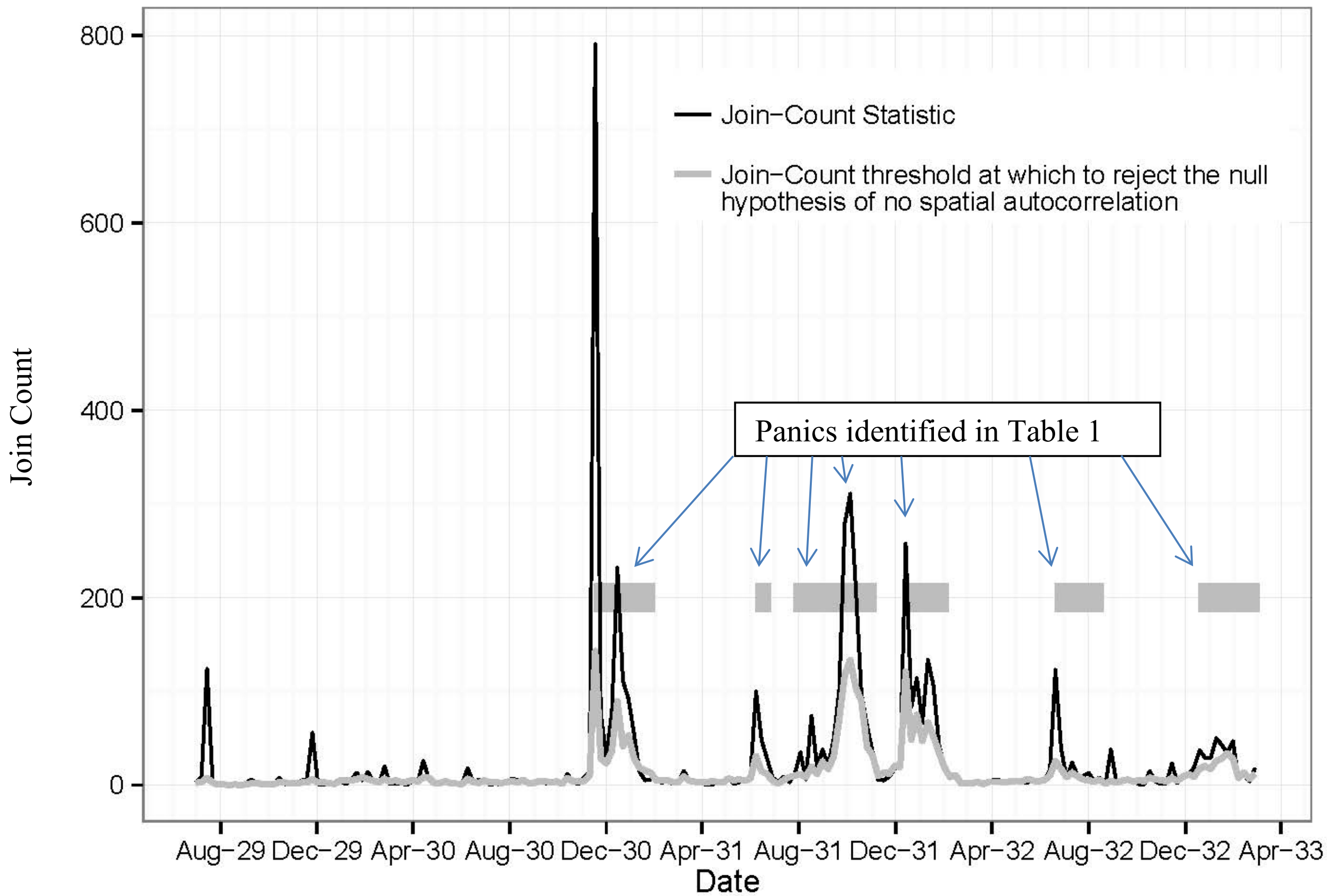
Notes: Columns 1-6 are based using estimates from Table 2. Columns 7 and 8 are based on models shown in Table 3.

Figure 1
Suspensions Per Week, 1929 to 1933



Vertical lines indicate Caldwell crisis, first Chicago panic, German crisis, Britain's departure from gold, second Chicago panic, winter '32 crisis, and winter '33 crisis.

Figure 2: Spatial Autocorrelation of Bank Suspension, Weekly July 1929 through February 1933



Note: The solid horizontal bars at level 200 indicate the intervals identified as regional or national banking panics in Table 1.

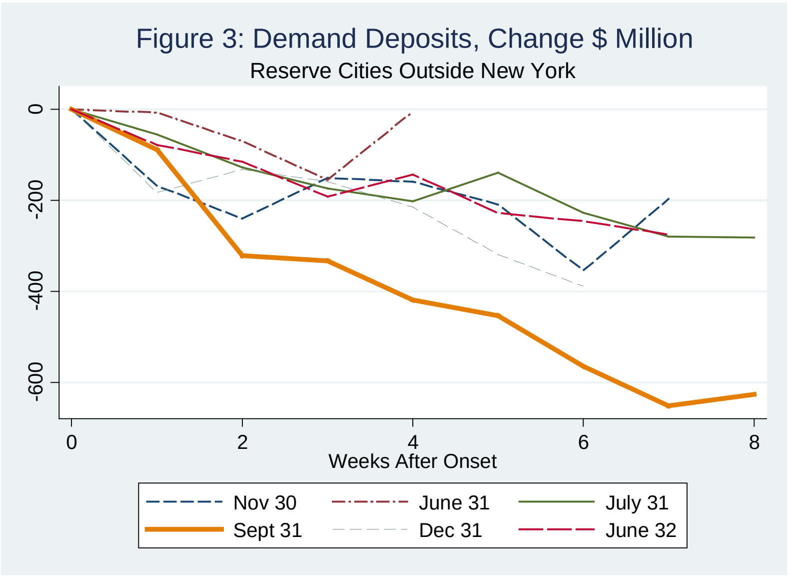


Figure 3: Demand Deposits, Change $ Million
Reserve Cities Outside New York
0
-200
-400
-600
0
2
4
6
8
Weeks After Onset
Nov 30
June 31
July 31
Sept 31
Dec 31
June 32

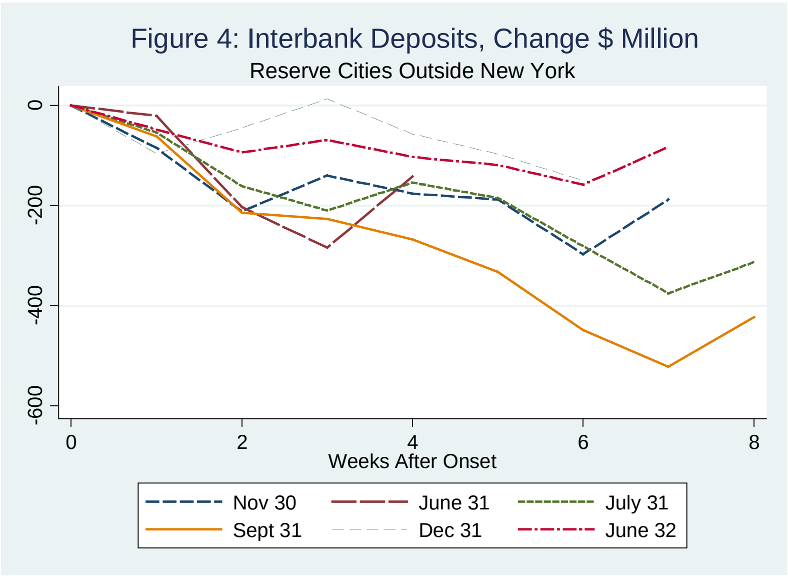


Figure 4: Interbank Deposits, Change $ Million
Reserve Cities Outside New York
0
-200
-400
-600
0
2
4
6
8
Weeks After Onset
Nov 30
June 31
July 31
Sept 31
Dec 31
June 32

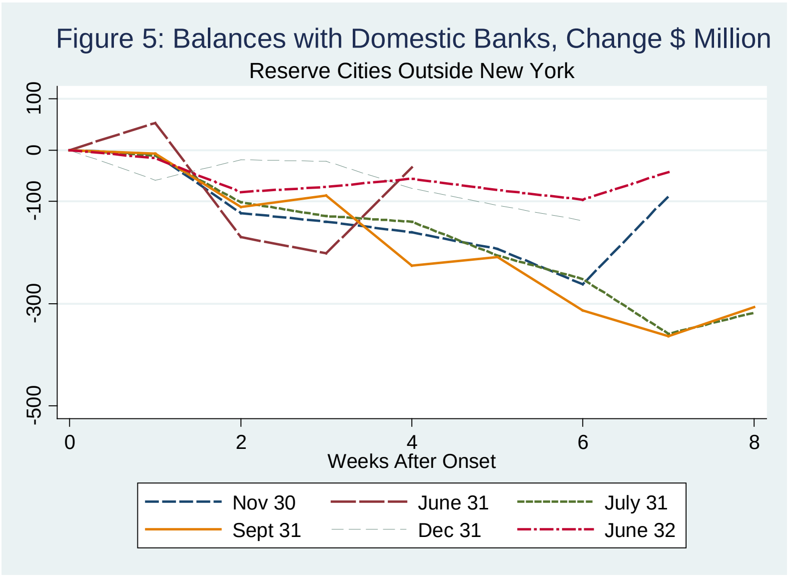
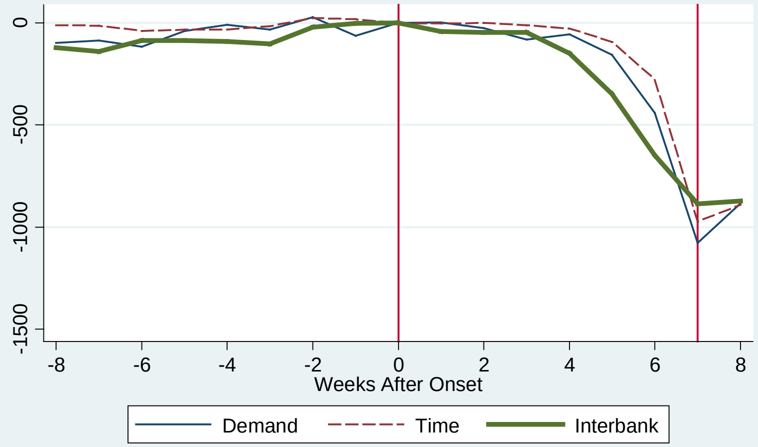


Figure 5: Balances with Domestic Banks, Change $ Million
Reserve Cities Outside New York
100
0
-100
-300
-500
0
2
4
6
8
Weeks After Onset
Nov 30
June 31
July 31
Sept 31
Dec 31
June 32

Figure 6: Outside New York, Change in Deposits $ Million

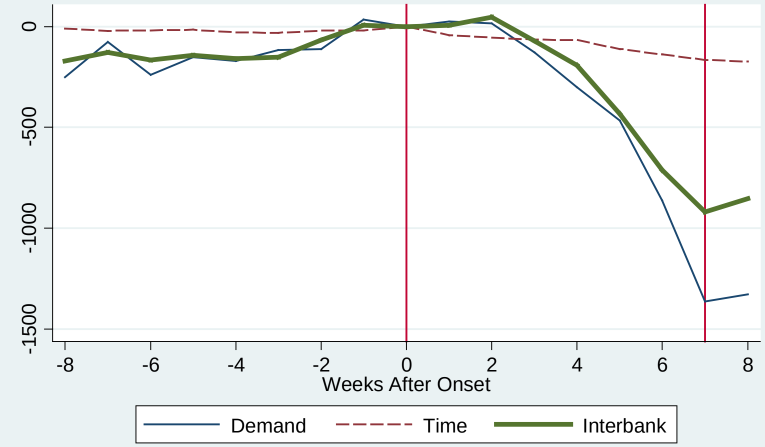
Weeks Before and After Onset of Panic



Vertical lines: 18 January 1933 and 8 March 1933.

Figure 8: New York City, Change in Deposits $ Million

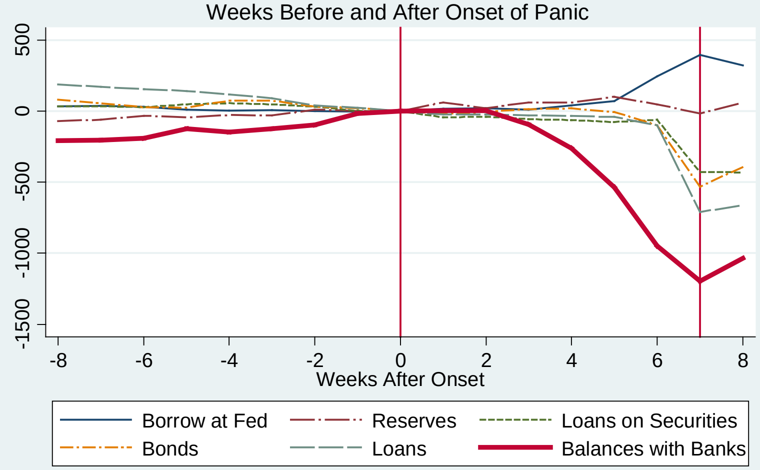
Weeks Before and After Onset of Panic



Vertical lines: 18 January 1933 and 8 March 1933.

Figure 7: Outside New York, Change in Assets $ Million

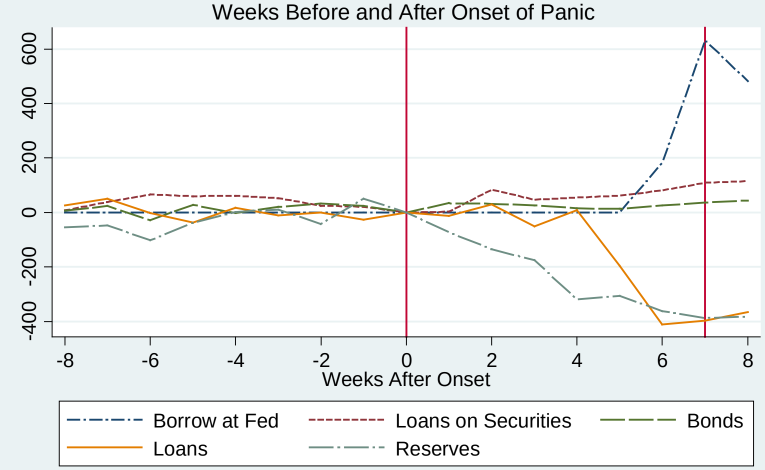
Weeks Before and After Onset of Panic



Vertical lines: 18 January 1933 and 8 March 1933. Reserves = vault cash + Fed deposits

Figure 9: New York City, Change in Assets $ Million

Weeks Before and After Onset of Panic



Vertical lines: 18 January 1933 and 8 March 1933. Reserves = vault cash + Fed deposits