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Bank Networks and Systemic Risk: Evidence from the National Banking Acts

Mark Paddrik
Office of Financial Research
mark.paddrik@ofr.treasury.gov

Haelim Park
Office of Financial Research
haelim.anderson@ofr.treasury.gov

Jessie Jiaxu Wang
Arizona State University
jessie.jiaxu.wang@asu.edu

Bank Networks and Systemic Risk: Evidence from the National Banking Acts*

Mark Paddrik† Haelim Park‡ Jessie Jiaxu Wang§

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Abstract

The reserve requirements established by the National Banking Acts (NBAs) dictated the amounts and locations of interbank deposits, thereby reshaping the structure of U.S. bank networks. Using unique data on bank balance sheets, along with detailed interbank deposits in 1862 and 1867 in Pennsylvania, we study how the NBAs changed the bank network structure. Further, we quantify the effect on financial stability in a model of interbank networks with liquidity withdrawal. We find that the NBAs led to a concentration of interbank deposits at both the city and the bank level, creating systemically important banks in major financial centers. Our quantitative results show that the newly emerged system was "robust-yet-fragile" – while the concentration of linkages made the system more resilient in general, it increased the likelihood of contagion when financial center banks faced large shocks.

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†Office of Financial Research, U.S. Department of the Treasury, email: Mark.Paddrik@ofr.treasury.gov

‡Office of Financial Research, U.S. Department of the Treasury, email: Haelim.Park@ofr.treasury.gov

§W. P. Carey School of Business, Arizona State University, email: Jessie.Jiaxu.Wang@asu.edu

1 Introduction

The financial crisis of 2007-09 showed how the interconnectedness among financial institutions can pose systemic risk to the financial system. When a highly interconnected institution becomes distressed, as happened with Lehman Brothers, its counterparties may also experience losses and limited access to liquidity. An idiosyncratic shock to one institution can turn into a systemwide shock. In response, economists and policymakers have attempted to assess the relationship between network structure and systemic risk. While many theoretical models have been introduced (e.g., Allen and Gale (2000); Elliott, Golub, and Jackson (2014); Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015)), existing empirical work has been limited by several important challenges.

One notable challenge originates from the lack of detailed comprehensive data on the structure of financial networks. First, with limited information on the topology of financial networks, it is difficult to assess systemic susceptibility to contagion. Second, it is challenging to disentangle counterparty exposures arising from various instruments.

In this paper we examine how the National Banking Acts (NBAs) of 1863 and 1864 changed the structure of bank networks and affected the stability of the banking system. The NBAs allowed banks to meet requirements by maintaining a large portion of interbank deposits in designated cities. The resulting reserve hierarchy consolidated New York City's position as the nation's money center. We analyze how the NBAs reshaped the topology of interbank networks and banks' liquidity management. Then we build a model and quantitatively examine how the changes in interbank networks affect the transmission of liquidity shocks in the banking system.

The banking system at the time of the passage of the NBAs provides us a unique setting to examine how systemic risk arises from bank networks. First, to overcome the data challenges, we construct a dataset of banks in Pennsylvania and New York City that are listed in the annual report of state banks and examination reports of national banks for the years 1862 and 1867. The data provide information on individual correspondent relationships, giving us a fuller picture of the topology of the bank networks during that period. The state banking reports provide detailed information on the amounts "due from other banks" by individual debtor banks on the asset side of the balance sheet. Similarly, the examination reports list the amount of interbank deposits due from each individual legal correspondent. Such detailed information on bank balance sheets is significant as it allows us to identify the topology of the interbank networks and provides us a measure of the intensity of these relationships.[1]

Second, the simple structure of the U.S. banking industry during this period helps us to identify risk channels. While financial institutions today have various types of counterparty exposures due to a wide variety of financial instruments held by a number of parties, banks in the mid-to-late 1800s faced counterparty exposure solely because of interbank deposits. Moreover, the introduction of the NBAs legislation offers us an opportunity to observe the structural evolution of the interbank network. We compare different network structures and analyze the relationship between network structures and financial stability.

We document two key features of the interbank network before the NBAs. First, the interbank network already exhibited a core-periphery structure as rural banks dealt exclusively with banks in financial centers. In particular, many banks placed deposits in New York and Philadelphia. However, they also used banks in other regional financial centers such as Harrisburg and Scranton in Pennsylvania. Second, correspondent deposit markets in New York City and Philadelphia were of comparable size, indicating that Philadelphia was an important financial center that likely served as the ultimate repository destination of interbank deposits, much like New York City.

We find that the reserve pyramid with three distinct tiers emerged as new reserve requirements were enforced after the NBAs. This pattern arises because interbank deposits became heavily concentrated in cities designated as reserve and central reserve cities. New York City became the ultimate destination of interbank deposits. The size of correspondent deposits in New York City grew much larger than those in Philadelphia. Pittsburgh emerged as a new financial center after it was designated as a reserve city. At the same time, other regional centers experienced a reduction in the interbank deposits held by rural banks. Banks in financial centers increased their cash holdings to create larger liquidity buffers in the event of deposit withdrawals.

To examine how the concentration of interbank deposits at reserve and central reserve cities

[1] We refer to banks placing deposits in other banks as *respondents* and banks providing the services as *correspondents*. We use the terms "correspondent networks" and "interbank networks" interchangeably throughout the paper.

affects the stability of the banking system and the extent of contagion, we build a network model of interbank deposits. The model embeds liquidity withdrawals in the interbank payment system introduced by Eisenberg and Noe (2001). In this two-period model, banks may experience runs and asset liquidation due to a maturity mismatch between short-term liquid liabilities (demand deposits and interbank deposits) and long-term illiquid asset investments. Such a framework allows us to study the impact of banking panics due to deposit withdrawals, by both local and institutional depositors.

We then use the model to simulate two types of banking crises and compare systemic risk measures for the years before and after the NBAs. First, we investigate how investment losses of New York City banks affected the rest of the financial system. To simulate such crises, we reduce the expected investment returns of New York City banks. Second, we examine how liquidity shortages at banks outside financial centers affected the system: Rural banks withdrew deposits from their city correspondents, which in turn experienced liquidity shortages and liquidated their loans. For each simulated scenario, we measure the probability of joint liquidations among banks and compare the resilience of the banking system before and after the NBAs.

Our results show that the NBAs created a "*robust-yet-fragile*" system as interbank deposits became more concentrated. The banking system becomes more robust as long as the most connected institutions do not face large liquidity shocks. However, when expected losses are large enough to trigger massive withdrawals and liquidation at the most connected New York City banks, links start to serve as channels for contagion. Financial center banks fail to repay deposits in full to their respondents, thereby causing runs and systemic liquidation. We also find that the concentrated interbank network after the NBAs is more resilient to liquidity shocks originating from banks outside financial centers. Even though the interbank linkages pass contagious withdrawals upward along the pyramid, financial center banks are liquid enough to meet such demand.

Our findings suggest that financial stability depends crucially on the concentration of links, the composition of bank balance sheets, and the magnitude of shocks. The mechanism works as follows. A more concentrated network is more robust to mild shocks because risk diversification dominates contagion in such a system: Because a financial center bank has a greater number of depositors, each depositor bears only a small fraction of the shortfall. In contrast, such a system is more fragile when the financial center banks face large shocks: Large losses at the most connected institutions enable the transmission of liquidity shocks to a large number of counterparties simultaneously, increasing the likelihood of systemic liquidation events. In this case, concentrated links facilitate contagion. This "*robust-yet-fragile*" nature of the post-NBAs interbank network echoes the "knife-edge flipping" concept described in Haldane (2013) and the theoretical findings of Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015) and Gai and Kapadia (2010).

This study provides new insights into financial regulations related to the architecture of the financial system. One of the key proposals for regulatory reform following the financial crisis of 2007-09 is the mandatory clearing of standardized over-the-counter (OTC) derivatives through central counterparties (CCPs). This regulatory change has radically reshaped the interconnected structure among counterparties and cast CCPs as systemically critical under financial distress. While this regulatory reform is intended to mitigate counterparty risk and contagion, its equilibrium effect on financial resilience remains unclear. Our study contributes to the literature on network structure by analyzing a regulatory change to a historical banking system that is structurally similar to the effect of mandatory central clearing.

The theoretical literature on financial networks argues that certain network structures lead to contagion and systemic risk (Allen and Gale (2000); Eisenberg and Noe (2001)).[2] In particular, Eisenberg and Noe (2001) develop a framework in which banks have interconnected liability relationships. This payment equilibrium is the ideal tool for assessing default cascades. We contribute to this literature by adding contagious withdrawals to the Eisenberg and Noe (2001) payment framework. This new feature allows us to study not only default cascades triggered by asset losses, but also the propagation of funding risk due to sudden withdrawals of deposits.

This research also adds to the empirical and quantitative studies on financial network and stability (e.g. Furfine (2003); Nier, Yang, Yorulmazer, and Alentorn (2007); Gai and Kapadia (2010); Gai, Haldane, and Kapadia (2011); and Glasserman and Young (2015)). However, due to difficulties in identifying exact linkages and exposures among institutions, more studies are based on simulated networks rather than empirical networks. The few exceptions include

[2] An incomplete list includes Dasgupta (2004); Leitner (2005); Haldane and May (2011); Gai, Haldane, and Kapadia (2011); Caballero and Simsek (2013); Zawadowski (2013); Elliott, Golub, and Jackson (2014); Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015); Greenwood, Landier, and Thesmar (2015); and Wang (2015).

Gofman (2016), who studies the effect of restricting bank interconnectedness by estimating an interbank lending model to match statistics on the Fed funds market. Also, some empirical studies examine how historical bank networks transmitted panics (e.g. Richardson (2007); Carlson, Mitchener, and Richardson (2011); and James, McAndrews, and Weiman (2013)). Nonetheless, the arguments are limited to the extent that exact bilateral risk exposures are not readily observable in the banking system. One exception is that of Calomiris and Carlson (2016), who use detailed information on interbank networks to study the transmission of liquidity risks during the panic of 1893.[3] We fill this gap by using empirically observed interbank deposit relationships to construct bank networks before and after the National Banking Acts.

Last, our paper contributes to the literature on banking panics during the National Banking era (1863-1913) by empirically examining how the "pyramiding" of bank reserves contributed to systemic liquidity crises. While several studies have discussed how the structure of the interbank network was a major source of systemic risk during this period, they did not provide empirical evidence or quantitative analysis of how the liquidity crises became systemic (e.g., Calomiris and Gorton (1991); Sprague (1910); Kemmerer (1910); Gorton and Tallman (2014); Calomiris and Carlson (2016); Gorton and Muir (2016); and Wicker (1996).) Moreover, none of these studies compare the structure of the interbank network before and after the NBAs or assess how differences in interbank networks affected financial panics. We contribute to this literature by providing empirical evidence using micro-level data.

This paper proceeds as follows. Section 2 presents historical background on the National Banking Acts and the correspondent banking system. Section 3 provides data and summary statistics. Section 4 describes the model setup, and Section 5 analyzes the quantitative results. Section 6 concludes.

[3] Calomiris and Carlson (2016) use national banks' examination reports to obtain detailed information on interbank networks. This studies differs from theirs in three aspects. First, while they study the panic of 1893, we focus on the passage of the NBAs and their effect on the banking system. Second, while they look at national banks, we study both state and national banks. Third, they use reduced-form regressions to examine shocks from New York City; we adopt a structural approach to analyze the equilibrium effects of two types of shocks: those originating from New York City and those coming from rural banks.

2 Historical Background

The provisions of the National Banking Acts (NBAs) represented a major event in the development of the banking and financial infrastructure of the United States. The NBAs were passed with the intention to create a demand for U.S. Treasury bonds during the Civil War because, without an income tax, they were the only way to finance the North's war effort. The NBAs created a system of national banks and encouraged state banks to convert. This new class of banks was allowed to issue bank notes up to 90 percent of the lower of par or the market value of the U.S. Treasury securities they held. Because national bank notes were collateralized by U.S. Treasury bonds and traded at par, a uniform national currency was created.[4] In addition, the NBAs established a set of capital and reserve regulations. In this section, we examine the U.S. banking system during the National Banking era: (1) the reserve hierarchy under the NBAs, which was characterized by the concentration of interbank deposits in reserve and central reserve cities, and (2) the banking panics of the National Banking era.

2.1 Reserve Hierarchy under the National Banking Acts

Interbank networks developed in the early 1800s when advances in transportation and communication technologies led to rapid growth in interregional trade and increased the need for interregional capital transfer within the United States. However, banks could not accommodate interregional payments easily because most banks operated as unit banks under legal restrictions on branching. Interbank network relationships were an institutional response to circumvent branching restrictions. Small rural banks kept deposits with larger city banks, which cleared their checks through city clearinghouses. We refer to banks placing deposits in other banks as *respondents* and banks providing the services as *correspondents*.[5]

Prior to the passage of the NBAs, the adoption of reserve requirements was handled solely by state regulators. Reserve requirements were first implemented by the states of Virginia, Georgia, and New York following the panic of 1837. Although other states also introduced

[4] Prior to the NBAs, banks issued private bank notes that traded at discounts from face value when transactions took place at a distance from the issuing bank (Gorton (1999)).

[5] Correspondent banking offered other valuable services as well. Correspondent deposits placed in city correspondents provided rural banks an opportunity to invest in liquid assets that paid interest instead of using them for local lending, allowing them to diversify their asset portfolios. Also, these balances in major cities, especially New York, were traded among local banks outside financial centers. This helped them to adjust the level of their correspondent accounts at lower transactions costs.

Table 1. National Bank Reserve Requirements

Tier	Banks	Location	Reserve ratio	Max reserve deposit	Cash in vault
1	Central reserve city banks	New York City	25%	0	1
2	Reserve city banks	Philadelphia Pittsburgh	25%	1/2	1/2
3	Country banks	others	15%	3/5	2/5

Source: Carlson (2015)

reserve requirements in subsequent years, most states had no legal reserve requirements until the 1860s. Only 10 out of 33 states had such laws by then (Carlson (2015)). The state of Pennsylvania did not have legal reserve requirements.[6]

One of the most important regulations under the NBAs, and the focal event of this paper, was the creation of a reserve hierarchy (see Table 1). The top tier consisted of central reserve city banks. They were located in New York City when the NBAs were passed.[7] Central reserve city banks were required to hold reserves of at least 25 percent in lawful currency and notes, and they had to keep all their reserves in their vault. The middle tier comprised reserve city banks. They were located in Philadelphia and Pittsburgh for the state of Pennsylvania.[8] The reserve city banks were also required to hold a 25 percent reserve. However, they were allowed to hold half of the 25 percent as correspondent deposits in a central reserve city bank and the rest in lawful currency. The bottom tier consisted of the remaining banks, which were called country banks. They were rural banks located outside the central reserve and reserve cities. They were required to hold a 15 percent reserve on deposits, with up to three-fifths of the 15 percent as correspondent deposits in central reserve or reserve city banks and the rest in cash.

This tiered system is often said to have created a concentration of correspondent balances in New York City and was considered a source of instability in the U.S. banking system. Banks often held the maximum amount of reserves in reserve city and central reserve city banks in order to earn a 2 percent interest rate on their correspondent deposits. The reserves tended to be concentrated in New York City banks, which in turn lent extensively to investors to purchase

[6]See General Assembly of the State of Pennsylvania (1861) for bank regulatory requirements in Pennsylvania.
[7]Chicago and St. Louis became central reserve cities in 1887 Carlson (2015).
[8]There were 18 reserve cities in total at the time of the original act (Champ (2007)).

stocks on margin (call loans).

2.2 Banking Panics of the National Banking Era

Under the National Banking system, the United States experienced a series of serious banking panics. These panics occurred as holders of bank liabilities demanded the conversion of their debt claims into cash *en masse* (Calomiris and Gorton (1991)).[9] The pyramiding of reserves contributed to magnifying the extent of banking crises during the periods of stress.

While the NBAs included other regulations as well, the "reserve pyramiding" was viewed as one of the major factors in propagating shocks from rural areas to New York City and vice versa. Following the panic of 1907, regulators began to discuss the removal of the reserve pyramid to prevent future crises. The Federal Reserve Acts were passed in 1913 to reduce the concentration of correspondent balances held in financial center banks. Under the new regulation, Federal Reserve member banks were no longer allowed to use their interbank deposits as legal reserves. Instead, they were required to keep deposits in Federal Reserve Banks (Bordo and Wheelock (2013)).

On the one hand, contemporary policymakers and economists considered the pyramiding of reserves and the interbank systems' inability to accommodate seasonal flows of funds between New York and country banks to be sources of systemic risk, as shown in the National Monetary Commission reports. In this view, banking crises originated at the bottom of the pyramid and spread to the top of the pyramid. This occurred as rural banks withdrew their interbank balances from reserve city and central reserve city banks in times of "monetary stringency," causing a drain on the reserves at central reserve banks.[10] The withdrawal of funds by country banks resulted in financial strains on city correspondents, prompting a liquidity crisis among city banks and a suspension of cash payments in major cities. The panic of 1893 originated from country banks and spread to New York City banks.

On the other hand, unexpected financial shocks in New York City were also an important

[9]There were five major financial panics during the National Banking era (Sprague (1910)). During the three most severe crises (in 1873, 1893, and 1907), specie was hoarded and circulated at a premium over checks drawn on banks and required the suspension of cash payment by the New York Clearing House (Calomiris and Gorton (1991)).

[10]Bank panics tended to occur in spring and fall: Country banks needed currency in spring because of costs related to the purchases of farming implements, and in late summer and early fall because of costs related to harvest.

source of systemic liquidity crises.[11] New York City banks were systemically important for their size and interconnectedness. Financial shocks in New York City accompanied sharp spikes in the call money market rate and a curtailment in credit availability. Four out of five major panics occurred after an initial financial shock in New York City. In particular, the suspension of cash payments, which was carried out during the panics of 1873 and 1907, restricted depositors' access to their funds, prevented nonfinancial businesses from meeting payrolls, and created a currency premium.

The consensus among financial historians has been that the pyramiding of reserves in New York increased the vulnerability of the U.S. banking system to banking crises because of unexpectedly large demands for currency arising from the countryside during harvest and planting seasons. Recently, however, this view has been challenged as scholars emphasize the importance of liquidity shocks from New York City (Wicker (1996)). One possibility is that reserve and central reserve city banks accumulated cash reserves to offset liquidity demands in anticipation of shocks from the interior, because they could not implement preventive measures to counteract unanticipated shocks in New York City. In Section 4, we examine how the banking system responded to these two types of liquidity shocks before and after the NBAs and discuss the implications for the stability of the system as a whole.

2.3 Reactions to Crises: New York Clearinghouse

Clearinghouses provided mechanisms for coordinating banks' responses to panics. Originally organized to provide an efficient way to clear checks, these coalitions of banks evolved into much more. More specifically, in response to banking panics, they acted as lenders of last resort, providing temporary liquidity to their members. Under branch banking restrictions, clearinghouses and their cooperative benefits were limited to citywide coalitions. Among them, the New York Clearinghouse played the most dominant role.

During banking panics, the New York Clearinghouse issued clearinghouse loan certificates as joint liabilities of the clearinghouse members. They accepted part of member banks' portfolios as collateral in exchange for clearinghouse loan certificates, thereby creating a market for the

[11] These crises were triggered by failures of large financial institutions, such as the closing of Jay Cooke Co. in 1873, Grant and Ward in 1884, Decker Howell and Co. in 1890, and Knickerbocker Trust Company in 1907.

illiquid assets.[12] In the absence of a formal lender of last resort, these loan certificates provided temporary liquidity to the banking system.

When panics could not be contained by the issuance of loan certificates, clearinghouses suspended the convertibility of deposits into cash. Such suspensions of convertibility were intended to limit the drain of cash reserves from the banking system by preventing runs.

During the National Banking era, there were five major panics that required the circulation of clearinghouse loan certificates. Three of the five panics (in 1873, 1893, and 1907) required the suspensions of convertibility. In Section 5.3, we examine quantitatively how the cash suspension and loan certificates affected the stability of the system as a whole.

3 Data and Summary Statistics

3.1 Data Sources

We use a combination of data sources to study how the introduction of the NBAs changed the structure of bank networks and affected the stability of the banking system. The first source is the *Reports of the Several Banks and Savings Institutions of Pennsylvania*, which provides quarterly balance sheets for that state's banks and savings institutions. The second source is the National Banks' Examination Reports, which were filed by the national bank examiners after their annual examinations. Appendix I provides a sample of our data.

Pennsylvania had a diverse economy with various types of banks, which makes it an ideal state to study how the establishment of reserve requirements reshaped interbank networks and affected financial stability. Banks in rural agricultural areas and smaller cities, in the middle of the state in particular, operated as unit banks and provided loans to local farmers. Banks in manufacturing areas around Pittsburgh served as correspondent banks for rural banks and issued industrial loans. And finally, banks in Philadelphia served as financial centers and lent to large industrial clients. Studying a state with a diverse economy is important because respondent banks chose their correspondent banks to accommodate their business models (Weber (2003);

[12] An individual clearinghouse member bank that needed loan certificates would have its loans and bonds examined by the clearinghouse loan committee to determine the quality of its collateral. Upon accepting it, the clearinghouse provided temporary loans up to 75 percent of the perceived collateral value. Banks with deficits could use loan certificates instead of regular currency to settle balances. Banks holding surpluses accepted these loan certificates as payment to earn the 6 percent interest. If a deficit bank failed and the collateral was insufficient to cover the loan certificates, the clearinghouse members jointly shared the loss.

Calomiris and Carlson (2016)). Pennsylvania banks represent a diverse set of correspondent relationships and therefore are a good starting point for understanding the U.S. banking system overall.

From these reports, we collect information on balance sheets and correspondent relationships for state and national banks.[13] For state banks, we have information on the amount that was due from each debtor bank and the name of each bank. For national banks, we collect information on the amount that was due from each agent and the name of each agent. Although state banking reports provided complete information about correspondents, national banks' examination reports recorded relationships only between national banks and their approved reserve agents because these amounts would later be verified at the correspondent banks to ensure that each national bank met its reserve requirements.[14]

State banks' annual reports provided quarterly balance sheets and the amounts due to each state-chartered Pennsylvania bank by individual debtors annually. Balance sheet information is available for March, June, September, and November, while correspondents' information is available for November of each year. We collect information on balance sheets and amounts due to each Pennsylvania state bank by individual debtor for November.

National banks did not report all of their correspondent banks because the primary purpose of examinations was to verify whether national banks met legal reserve requirements. Country banks selected the national banks in reserve cities with which they wished to keep a portion of their legal reserves, and sent the names of those banks to the comptroller. Once approved, they were known as *approved reserve agents*. Similarly, national banks in reserve cities selected national banks in central reserve cities. For both country banks and reserve city banks, only amounts due from approved reserve agents in reserve cities and the central reserve city were enumerated. Amounts due from other banks in reserve cities and the central reserve city were not reported. In addition, amounts due from other county banks did not need to be reported.

[13]The interbank deposit information recorded for Pennsylvania state banks offers a unique opportunity to study interbank relationships. Most states do not report "due-from" information on bank balance sheets or only report the aggregate amount without any details on banks' counterparties. Other states, such as New York, report the name of correspondent bank, but they do not report any information on the amount of deposits placed in this bank.

[14]A "due-to" account is a liability on a bank's balance sheet that indicates the amount of deposits payable to another bank. A "due-from" account is an asset on a bank's balance sheet that indicates the amount of deposits currently held at another bank.

For national banks in the central reserve city, no "due-from" information was reported since these banks had to hold all their reserves in cash.

Examiners' reports include three types of "due-from" payments from the banks with which they had relationships: (1) amounts due from approved redeeming agents, (2) amounts due from other national banks, and (3) amounts due from other banks. For approved redeeming agents, each agent's name is recorded with the corresponding amount. For other national banks and other banks, only aggregate due-from amounts were reported. During this period, most national banks had one reserve agent to keep their legal reserves. These reserve agents tended to be the major holder of national banks' correspondent deposits. On average, national banks kept 50 percent of total interbank deposits in one bank.[15] However, a few Philadelphia banks kept their reserves in multiple banks in New York City, with about 20 percent of total interbank deposits in each bank. To make the data on state banks' correspondents comparable to that of national banks with their approved reserve agents, we list only correspondent banks that held more than 20 percent of total interbank deposits for each bank.

We study the years 1862 and 1867 to capture the structure of bank networks before and after the enactment of the NBAs.[16] The data for 1862 are only from state banks and capture bank behavior before the unanticipated passage of the NBAs. In contrast, the data for 1867 contain both state and national banks and capture bank behavior after the passage of the NBAs. The year 1867 is informative for two reasons. First, in the absence of deposit insurance, finding reliable correspondent banks would have been time-consuming for both converted and newly established national banks, so these banks might have held cash at the start of their operations and taken longer to establish a correspondent relationship; we wanted a sample that includes national banks that were state banks in 1862. Second, national banks' examination reports do not provide information on national banks' reserve agents until 1867.[17]

[15] Calomiris and Carlson (2016) study the interbank network from the panic of 1893; they find similar values of 56 percent.

[16] Choosing the year 1862 may raise concerns about the representativeness of the data, since banks' behavior might have been affected by the Civil War. To alleviate these concerns, we compare the balance sheets and networks of Pennsylvania state banks for the periods 1859 and 1862 in Appendix IV.

[17] We have state bank balance sheets for the years of 1862 and 1867 and national bank balance sheets for 1867. Due to the difference in reported items between state bank balance sheets and national bank balance sheets, we create and standardize six asset categories and six liability categories. The asset categories are: cash; liquid securities; illiquid securities (U.S. bonds deposited with the U.S. Treasury to secure circulation and deposits); amounts due from other banks; loans; and other assets. The liability categories are: capital; surplus and profits; bank notes; deposits; amounts due to other banks; and other liabilities.

We divide the sample of banks into four classes according to their location: New York, Philadelphia, Pittsburgh, and country banks. As documented in Weber (2003), differences in the needs of the customers of each class of banks largely originated from location, shaping how they interacted with each other. The NBAs designated New York as the central reserve city and Philadelphia and Pittsburgh as reserve cities. Depending on their location, banks faced different regulations, which were reflected by balance sheets. Specifically, New York banks were large and served as depositories for other banks. Country banks were generally small and served as creditors to banks in major financial centers. Both Philadelphia and Pittsburgh banks served as intermediaries for other banks by taking deposits from country banks and placing them in New York City banks. However, some Philadelphia banks behaved more like central reserve city banks by maintaining large cash reserves and serving as ultimate depository institutions. In contrast, Pittsburgh banks behaved more like country banks by acting as creditor banks to financial center banks.

3.2 Balance Sheet Information

Table 2 shows the composition of balance sheets for New York, Philadelphia, Pittsburgh, and country banks in 1862 and 1867. Banks had a liquid balance sheet structure. Before the NBAs, banks held 13 percent of cash, 20 percent of liquid securities, and 13 percent of interbank deposits (not reported in the table). After the NBAs, banks held 12 percent of cash, 6 percent of liquid securities, and 8 percent of interbank deposits (not reported in the table). The amount of liquid assets other than cash decreased initially owing to the reduction in the amount of liquid securities. This is because the NBAs required banks to back their privately issued money in the form of bank-specific national bank notes with U.S. Treasury bonds. In turn, these bonds were no longer considered liquid.

In addition, Table 2 reveals that banks that served as depositories for country banks increased their cash holdings after the NBAs. New York banks increased their cash holdings significantly from 19 percent in 1862 to 38 percent in 1867. While higher cash holdings were required under the newly established reserve requirements, these banks were holding more than the amount required. Banks in Philadelphia, which also served as bankers' banks at the time, increased cash holdings as well. In contrast, Pittsburgh banks, which were not as important financial

Table 2. **Balance Sheet Summary Statistics**

	New York City			*Philadelphia*			*Pittsburgh*			*Country Banks*		
Year = 1862	Obs	Mean	SD	Obs	Mean	SD	Obs	Mean	SD	Obs	Mean	SD
Against Total Assets												
Cash	22	0.19	0.09	20	0.21	0.10	7	0.18	0.06	63	0.12	0.07
Liquid securities	22	0.16	0.14	20	0.30	0.14	7	0.32	0.13	63	0.18	0.14
Due from other banks	22	0.04	0.02	20	0.03	0.04	7	0.12	0.04	63	0.18	0.10
Loans	22	0.58	0.17	20	0.40	0.12	7	0.36	0.12	63	0.49	0.12
Against Total Liabilities												
Equity	22	0.35	0.07	20	0.24	0.06	7	0.36	0.07	63	0.28	0.09
Bank notes	22	0.04	0.03	20	0.13	0.10	7	0.39	0.17	63	0.40	0.21
Deposits	22	0.43	0.13	20	0.51	0.09	7	0.23	0.12	63	0.27	0.20
Due to other banks	22	0.13	0.10	20	0.09	0.09	7	0.01	0.01	63	0.01	0.02
Year = 1867	Obs	Mean	SD	Obs	Mean	SD	Obs	Mean	SD	Obs	Mean	SD
Against Total Assets												
Cash	19	0.38	0.15	24	0.31	0.08	15	0.12	0.07	132	0.14	0.06
Liquid securities	19	0.06	0.10	24	0.08	0.10	15	0.08	0.14	132	0.09	0.12
Due from other banks	19	0.04	0.04	24	0.07	0.05	15	0.09	0.05	132	0.15	0.09
Loans	19	0.39	0.13	24	0.50	0.08	15	0.66	0.09	132	0.58	0.14
Against Total Liabilities												
Equity	19	0.25	0.11	24	0.30	0.08	15	0.42	0.14	132	0.38	0.10
Bank notes	19	0.09	0.05	24	0.15	0.07	15	0.21	0.12	132	0.26	0.10
Deposits	19	0.46	0.17	24	0.48	0.12	15	0.35	0.21	132	0.34	0.16
Due to other banks	19	0.19	0.17	24	0.06	0.08	15	0.02	0.03	132	0.03	0.03

Note: This table is based on authors' calculations. Equity = Capital + surplus and profits.
Source: Authors' calculations using data from *Reports of the Several Banks and Savings Institutions of Pennsylvania* and *OCC National Banks' Examination Reports.*

center banks as those in Philadelphia at the time, actually decreased cash holdings. The level of their cash holdings was close to that of country banks.

3.3 Interbank Network

The reserve requirements of the NBAs reshaped the interbank network by shifting the destination of interbank deposits. The NBAs led to a concentration of interbank deposits at both the city level and the bank level: Interbank deposits became heavily concentrated in cities that were designated as reserve and central reserve cities. New York City became the ultimate destination of interbank deposits; before the NBAs, Philadelphia banks had played a more important role.

Figure 1 depicts the concentration of interbank deposits after the NBAs.[18] The inner, middle,

[18] Appendix III provides additional information on the interbank networks, including a depiction of the links on the map according to the banks' physical location.

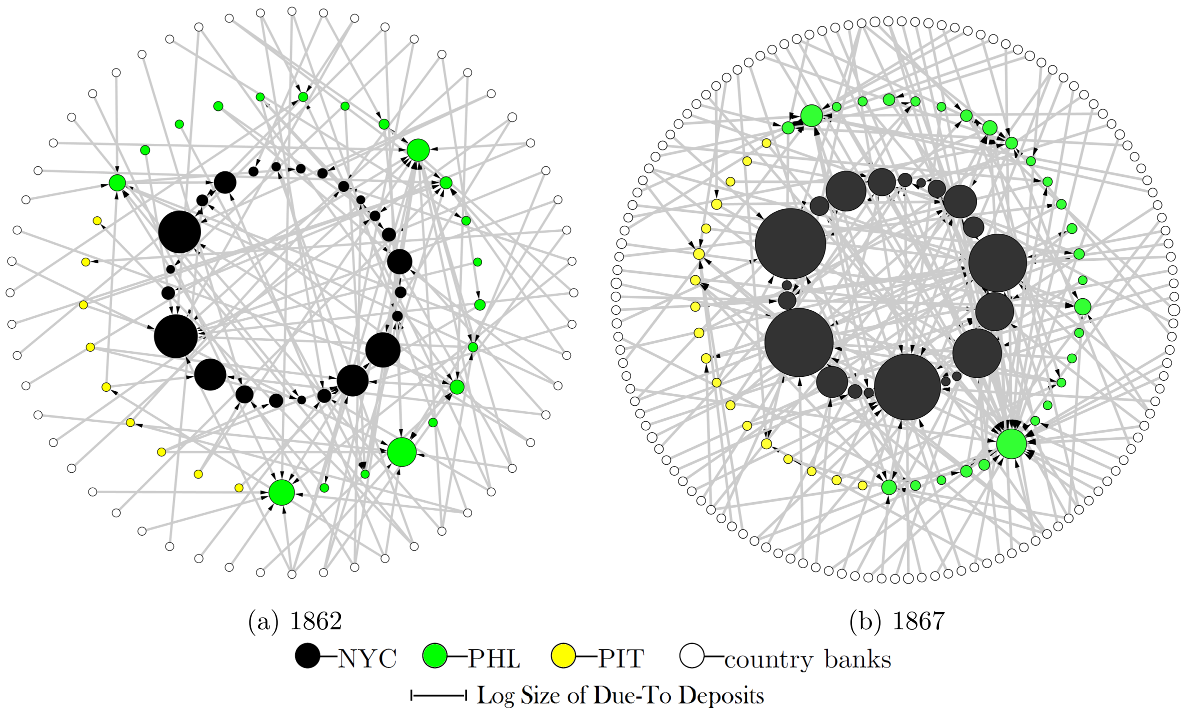
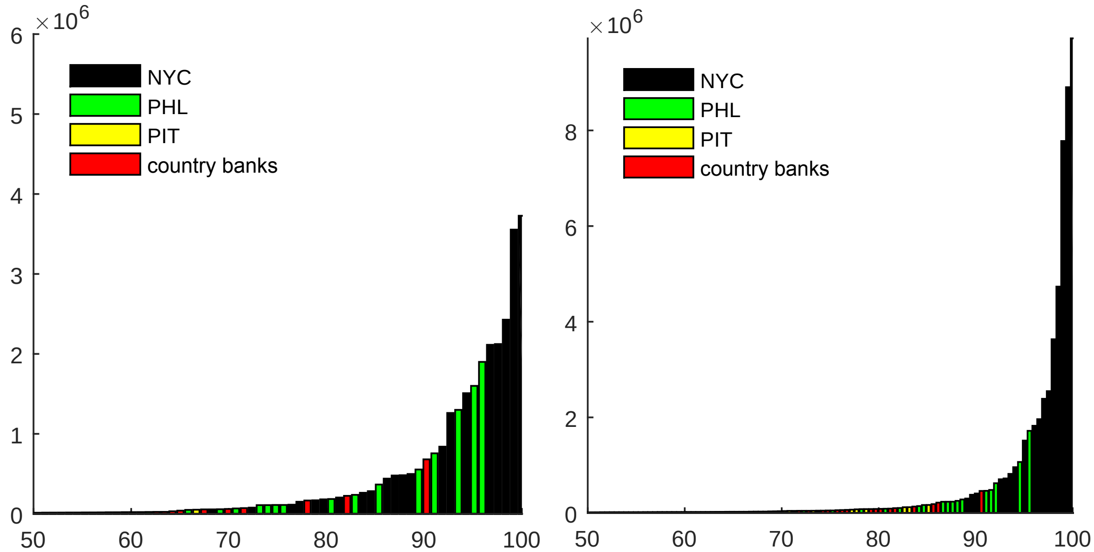


Figure 1. Interbank Network This figure depicts interbank networks in 1862 and 1867. The nodes colored in black, green, yellow, gray, and white indicate New York City banks, Philadelphia banks, Pittsburgh banks, and country banks, respectively. The diameter of each node is proportional to the bank's log size of interbank deposits due to other banks. A link with an arrow indicates a recorded deposit relationship where the arrow points to the correspondent. *Source*: Authors' diagrams using data from *Reports of the Several Banks and Savings Institutions of Pennsylvania* and *OCC National Banks' Examination Reports*.

and outer rings represent banks in the central reserve city, the reserve cities, and rural areas (also referred to as country banks). The size of the nodes reflects the relative rank of each bank in their respective correspondent markets according to the amount of interbank deposits held at each bank.

We find that the NBAs accelerated a concentration of interbank linkages among banks in financial centers partly because of a rapid expansion in the number of country banks relative to that of city correspondents. The total number of banks and interbank deposit linkages grew from 1862 to 1867. While the number of country banks expanded sharply, the number of banks serving as correspondents in reserve cities and the central reserve city did not increase. Consequently, a small number of city correspondents received a large share of due-to deposits, contributing to a concentration of interbank linkages in financial center banks. In addition, Figure 1 shows



(a) 1862

(b) 1867

Figure 2. Cross-Sectional Distribution of Interbank Deposits Due to Other Banks This figure illustrates the distribution of interbank deposits due to other banks held at banks sorted by the size of due-to deposits in 1862 and 1867. Because only a small set of banks had positive due-to deposits, we show only the top 50 percent of the sample, corresponding to the horizontal axis of 50 to 100. The vertical axis indicates the amounts of due-to deposits in millions of dollars. The bars colored in black, green, yellow, and red indicate New York City banks, Philadelphia banks, Pittsburgh banks, and country banks, respectively.
Source: Authors' diagrams using data from *Reports of the Several Banks and Savings Institutions of Pennsylvania* and *OCC National Banks' Examination Reports*.

that the NBAs consolidated New York's position as the nation's financial center. Before the NBAs, the size of interbank due-to deposits received by the largest New York City banks and Philadelphia banks was comparable, suggesting that both cities were equally important financial centers. After the NBAs, the size of interbank due-to deposits received by the largest New York City banks was much larger than that of Philadelphia banks, indicating that New York City banks had become the ultimate reserve depositories.

To further highlight the concentration of interbank deposits, we compare the cross-sectional distribution of due-to deposits before and after the NBAs (see Figure 2). Given that only a small set of banks had positive due-to deposits, we sort banks by the size of due-to deposits and only show the top 50 percent of banks in each year.[19] Different colors differentiate banks by location. We conclude that, in comparison with 1862, interbank deposits in 1867 were heavily

[19]Banks in central reserve city and reserve cities tended to have positive due-to deposits whereas rural banks mostly had zero due-tos.

Table 3. Distribution of Interbank Deposits

	Total		Philadelphia		Pittsburgh		Country banks	
Year = 1862	$ amount	# links	% amount	% links	% amount	% links	% amount	% links
New York City	3,863,434	62	0.64	0.29	0.77	0.56	0.30	0.27
Philadelphia	4,401,210	80	0.11	0.09	0.19	0.31	0.63	0.52
Pittsburgh	64,551	4	0.00	0.00	0.00	0.00	0.01	0.03
Other PA	287,582	30	0.10	0.25	0.03	0.06	0.02	0.11
Other U.S.	413,821	31	0.14	0.38	0.01	0.06	0.04	0.07
Year = 1867	$ amount	# links	% amount	% links	% amount	% links	% amount	% links
New York City	3,186,785	92	1.00	1.00	0.89	0.80	0.30	0.31
Philadelphia	2,075,679	90	0.00	0.00	0.09	0.15	0.60	0.53
Pittsburgh	269,740	16	0.00	0.00	0.03	0.05	0.07	0.09
Other PA	28,760	4	0.00	0.00	0.00	0.00	0.01	0.02
Other U.S.	62,702	6	0.00	0.00	0.00	0.00	0.02	0.04

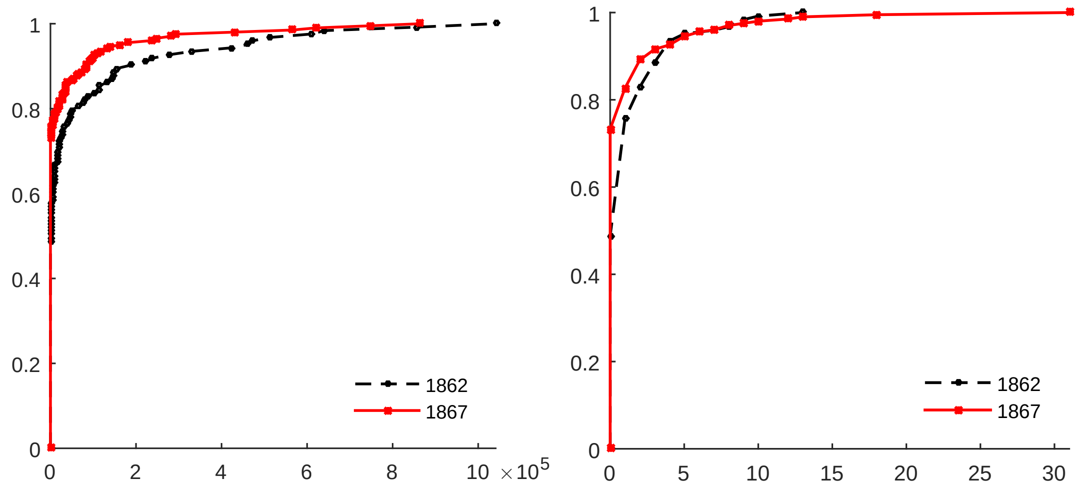
Notes: This table shows the distribution of correspondent deposits for the years 1862 and 1867 grouped by the origins and the destinations of interbank deposits. The columns indicate the location of respondent banks and the rows indicate the location of correspondent banks. We classify respondent banks into three groups: Philadelphia, Pittsburgh, and country banks. In addition, we classify correspondent banks that receive interbank deposits from respondent banks into five classes. The first two columns show the absolute amount of interbank deposits and the total number of correspondent relationships. The rest of the columns show the fraction of deposits held at different locations against total major due-from deposits in Philadelphia, Pittsburgh, and country banks in Pennsylvania.
Source: Authors' calculations using data from *Reports of the Several Banks and Savings Institutions of Pennsylvania* and *OCC National Banks' Examination Reports*.

concentrated in a much smaller number of banks, mainly in New York.

To measure the concentration of due-to deposits at financial center banks, we compute the Herfindahl-Hirschman Index (HHI) of due-to deposits aggregated up to the city level based on where deposits were held. From 1862 to 1867, the HHI of Pennsylvania banks decreased from 100 to 15. In comparison, the HHI of New York City banks increased from 524 to 823, a multiple of 5 times that of Philadelphia banks in 1862 to a multiple of 50 times in 1867.[20] These numbers suggest that New York City and Philadelphia banks served as important correspondents before the NBAs, but that New York City banks became the dominant repository after the NBAs.

Similar patterns are visible when we focus on the micro-level linkage data, recorded as the due-from deposits of Pennsylvania banks on the asset side of the balance sheets. Table 3 shows the distribution of correspondent deposits for the years 1862 and 1867 grouped by the origin

[20]The HHI of Pittsburgh banks and other Pennsylvania banks were close to zero in both years.



(a) Empirical CDF of interbank deposits (b) Empirical CDF of number of respondents

Figure 3. Empirical Cumulative Distribution of Bank-level Interbank Due-to Deposits and Number of Respondents This figure shows the empirical CDF of bank-level interbank due-to deposits and the number of respondent relationships in 1862 and 1867. We calculate the total deposits amount and the number of respondent relationships at each correspondent bank and estimate the empirical CDF non-parametrically. The distribution in black corresponds to 1862 and red in 1867. Horizontal axis denotes the amount of interbank deposits and the number of respondents respectively in panel (a) and (b).
Source: Authors' diagrams using data from *Reports of the Several Banks and Savings Institutions of Pennsylvania* and *OCC National Banks' Examination Reports*.

and destination of interbank deposits. The columns indicate the locations of respondent banks and the rows indicate the locations of correspondent banks. The first two columns show the dollar amount of interbank deposits and the total number of correspondent relationships for all Pennsylvania banks. Both the deposit size and the number of correspondent relationships highlight the relative importance of New York as the destination of deposits increased relative to Philadelphia, confirming the earlier findings using due-to deposits. In particular, the number of correspondent relationships with New York banks increased from 62 to 92.[21] The rest of the columns show the fraction of deposits held at different locations against total major due-from deposits in Philadelphia, Pittsburgh, and country banks in Pennsylvania. Philadelphia and Pittsburgh banks shifted a larger portion of their deposits in New York City rather than locally. Finally, there is a shift in deposits to Pittsburgh by country banks during this period. This suggests that Pittsburgh banks began to function as a major correspondent city as a result

[21] This increase is a lower-bound estimate due to the nature of the data on interbank deposit coverage explained at the beginning of Section 3.

Table 4. Longest Shortest Path and Degree by Location

	Longest Shortest Path			*In-Degree*			*Out-Degree*		
Year = 1862	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
NYC	-	-	-	2.7	10	1	-	-	-
Philadelphia	2.4	5	1	3.4	13	0	2.1	5	1
Pittsburgh	1.9	4	1	0.3	1	0	2	3	1
Country banks	3	6	0	0.2	2	0	1.7	5	0
Year = 1867	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
NYC	-	-	-	5.4	18	1	-	-	-
Philadelphia	1	1	1	3.1	31	0	1	2	1
Pittsburgh	1.3	3	1	0.8	5	0	1.2	2	1
Country banks	1.8	3	1	0	1	0	1.2	4	1

Notes: This table provides summary statistics for the longest shortest path, in-degree, and out-degree of interbank networks by location and year. We use the Floyd-Warshall algorithm (for directed graphs) to compute the shortest path starting from each bank with positive due-froms. The in-degree of a node in a network is the number of incoming edges. The out-degree of a node in a network is the number of outgoing edges.
Source: Authors' calculations using data from *Reports of the Several Banks and Savings Institutions of Pennsylvania* and *OCC National Banks' Examination Reports*.

of the NBAs, though the nominal amounts of interbank deposits were smaller that those in Philadelphia and New York City.

Using the micro-level linkage data on due-froms, we also find strong evidence of a concentrated interbank network in both the amount of deposits and the number of correspondent relationships. Based on the due-from data, we calculate the total deposit amounts and the number of correspondent relationships at each correspondent bank. The number of correspondent relationships corresponds to the in-degrees of the interbank network.[22] Then we estimate the empirical cumulative distribution function (CDF) non-parametrically for each year. Figure 3 shows the empirical CDF of interbank deposits and in-degrees in 1862 and 1867. The distribution in black corresponds to 1862 and in red to 1867. The interbank deposit CDF for 1867 lies on top of that of 1862, which is direct evidence of the concentration. For the distribution of in-degrees, the 1867 CDF mostly lies on top of the 1862 CDF, except when the domain of the 1867 network in-degrees surpasses that of 1867; very few banks in 1867 had a much larger number of in-degrees.

[22] The in-degree of a node in a network is the number of incoming edges. The out-degree of a node in a network is the number of outgoing edges.

Table 4 provides summary statistics for the distance and degrees of the interbank network in 1862 and 1867, grouped by location. We compute the shortest path starting from each bank with positive due-froms using the Floyd-Warshall algorithm. The in-degree of a node in a network is the number of incoming edges (number of respondents). The out-degree of a node in a network is the number of outgoing edges (number of correspondents). The interbank network statistics further show that the banking sector in 1867 became more exposed to risks in New York City banks. The distance to New York City banks decreased,[23] and the number of banks that had a direct correspondent relationship with a New York City bank increased. First, from 1862 to 1867, the length of the shortest path decreased, indicating that the NBAs increased the banking system's exposure to New York City banks. Second, the in-degree count of New York City banks significantly increased,[24] despite Philadelphia and Pittsburgh having a decrease in out-degree relationships.[25] This evidence shows that, on average, banks in New York City had a much larger number of respondents in 1867, indicating that bank linkages became more concentrated in New York City. Furthermore, the in-degrees of Pittsburgh banks had also increased, demonstrating that by designating Pittsburgh as a reserve city the NBAs reshaped the interbank network and established Pittsburgh banks as important hubs.

4 Model

In this section, we set up a model of a correspondent bank network. Banks place deposits at other banks, thereby creating a network of interbank liability relationships. We extend the interbank clearing system introduced by Eisenberg and Noe (2001) and Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015) to a two-period setting that allows for liquidity withdrawals. In the model, banks may experience withdrawals and liquidation due to a maturity mismatch between short-term liquid liabilities (demand deposits and interbank deposits) and long-term illiquid asset investments. Such a framework allows us to simulate liquidity crises in the banking system during the National Banking era.

[23]The distance between two nodes is the number of edges in the shortest path connecting them.

[24]These numbers are conservative measures. Although we remove linkages for less than 20 percent of the total "due-froms" for each bank, most of these removed linkages are deposits placed in small country banks.

[25]Banks' major correspondents shifted as the NBAs were enacted, as many state banks were slow to convert to national banks, causing new and converting banks to find new banking relationships in major cities that could act as reserve agents.

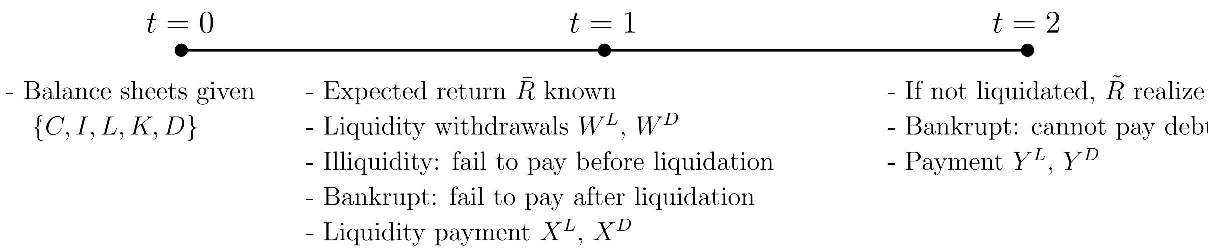


Figure 4. The Model Timeline

4.1 Environment

Consider an economy populated by N risk neutral banks, $i = \{1, 2, ..., N\}$. The economy lasts for two periods ($t = 0, 1, 2$) and there is no discounting. Figure 4 illustrates the model's timeline.

At $t = 0$, bank i is endowed with equity capital K_i and deposits from local depositors D_i. It can also hold interbank deposits due to other banks. Denote L_{ji} as the interbank deposits at bank i due to bank j: here bank i is the correspondent and bank j is the respondent. The interbank liability relationships are characterized by a weighted directed network $L = [L_{ji}]$. The total liability of bank i amounts to $D_i + \sum_j L_{ji}$. The liability is in the form of demand deposits with a maturity of two periods but can be withdrawn early at $t = 1$.

The total assets are allocated as vault cash C_i, investment in loans and securities I_i, as well as interbank deposits due from other banks $\sum_k L_{ik}$. The bank balance sheet items at the initial date are summarized in Table 5.

Table 5. Balance Sheet of Bank i at $t = 0$

Assets	**Liabilities**
Vault cash C_i	Equity capital K_i
Investment in loans and securities I_i	Local deposits D_i
Deposits due from other banks $\sum_k L_{ik}$	Deposits due to other banks $\sum_j L_{ji}$

Balance Sheet Equation: $C_i + I_i + \sum_k L_{ik} = K_i + D_i + \sum_j L_{ji}$

Bank i's investment in loans and securities are long-term and illiquid. It matures at the final date $t = 2$ with return rate $\tilde{R}_i$. If held to maturity, the total proceeds from investment amount to $I_i\tilde{R}_i$. The investment is risky: the return rate $\tilde{R}_i$ is given by

$$\log \tilde{R}_i = \log \bar{R}_i + \varepsilon_i, \tag{1}$$

where $\log \bar{R}_i$ is the log expected return rate at $t = 1$ and ε_i is the idiosyncratic shock. The vector ε is drawn from a mean-zero multivariate normal distribution with standard deviation σ and correlation matrix ϱ. Here, the investment return rates have a lower bound of zero: in the worst-case scenario banks can lose up to their initial investment I. The investment returns can be correlated among banks. This allows us to account for the case of correlated investments, such as the common pool of securities held by banks in New York City.

4.2 Liquidity Withdrawal Payment Equilibrium

A defining characteristic of banking and a common theme across several banking crises during the National Banking era are episodes of elevated redemption requests. Massive withdrawals by local depositors and respondent banks could create liquidity shortages at city correspondents and trigger costly liquidations, defaults, and potentially suspensions of cash payments.[26] In the model, whether a bank is able to meet the withdrawal requests depends on how the amount of withdrawals compares with the bank's liquid assets, namely cash assets and interbank deposits that are due from banks. In particular, the liquidation risk of a bank is closely tied to whether it can successfully redeem its own deposits held at city correspondents.

A network model of an interbank clearing system allows us to identify the spillover effects. In this subsection, we build on the Eisenberg and Noe (2001) clearing system and formalize the payment equilibrium for liquidity withdrawals at $t = 1$.

Let the indicators W^L and W^D denote the liquidity withdrawal events. If $W^L_{ik} = 1$, bank i withdraws at $t = 1$ the interbank deposits it has placed at bank k. $W^D_i = 1$ means local depositors withdraw from bank i. Let the clearing payment matrix at $t = 1$ be X^L, where X^L_{ik} denotes the payment by bank k upon bank i's withdrawal, $X^L_{ik} \in [0, L_{ik}]$. Similarly, let X^D be the payment vector upon local depositors' withdrawals, $X^D \in [0, D]$.

Costly liquidation occurs when a bank's liquid assets fail to meet its total liquidity withdrawal

[26] We discuss the implication of suspensions of convertibility at New York City banks in Section 5.3.1. In this context, when cash suspensions are triggered, liquidations and defaults are avoided.

requests. The total liquidity withdrawal obligations bank i faces is

$$O_i^1 = \sum_j W_{ji}^L L_{ji} + W_i^D D_i. \tag{2}$$

The bank's total liquid assets include vault cash C_i and the withdrawal of deposits due from other banks $\sum_k W_{ik}^L X_{ik}^L$. Based on whether a bank can meet the liquidity withdrawals before and after liquidating the long-term investments, we next define respectively the events of a bank being *illiquid* and *bankrupt* at $t = 1$. The definitions are similar to those in Allen and Gale (2000).

Definition 1 *Bank i is illiquid at $t = 1$ if it fails to meet liquidity withdrawals with all liquid assets. Let $\mathbb{I}_i^l$ be the indicator of such event,*

$$\mathbb{I}_i^l = 1 := C_i + \sum_k W_{ik}^L X_{ik}^L < O_i^1, \tag{3}$$

and bank i liquidates the investment at a proportional cost, yielding $\xi_l I_i$, $\xi_l \in (0, 1)$.

The salvage value comes at a cost caused, for example, by the disruption of service or the sale of loans at a discount, as in Shleifer and Vishny (1992). The costs also imply that bank runs have real economic consequences by causing the recall of loans and the termination of productive investment.

Accounting for potential liquidation, the maximum liquidity bank i could obtain equals the sum of vault cash, total withdrawal of deposits due from correspondents, and proceeds from asset liquidation. Denote the *maximum liquidity* by H_i^1

$$H_i^1 = C_i + \sum_k W_{ik}^L X_{ik}^L + \mathbb{I}_i^l \xi_l I_i. \tag{4}$$

If the maximum liquidity can cover the total liquidity withdrawals, bank i pays withdrawal requests in full and keeps the remaining assets (if investment liquidation is not triggered then bank i holds the investment to maturity). Otherwise, if bank i cannot meet the liquidity demands even after liquidation, it is *bankrupt*.

Definition 2 *Bank i is bankrupt at $t = 1$, denoted by indicator $\mathbb{I}_i^{d1}$, when the maximum liquidity* *after liquidation is smaller than total liquidity withdrawals, i.e.*

$$\mathbb{I}_i^{d1} = 1 := H_i^1 < O_i^1. \tag{5}$$

Upon bankruptcy, an additional social cost is incurred proportional to the liquidity shortfall, expressed by $\mathbb{I}_i^{d1} \xi_d \left(O_i^1 - H_i^1 \right)$.[27] The social cost does not affect the payment equilibrium and is modeled to provide a measure for systemic risk in our quantitative analysis.

The bankrupt bank pays all depositors on a *pro rata* basis, resulting in zero equity value. While local depositors have seniority in payment priority today, local depositors had the same seniority as respondent banks during the National Banking era. Essentially, local depositors and all respondent banks would have been paid by the defaulting bank in proportion to the size of their nominal claims. The liquidity payment matrix X^L and the payment vector to local depositors X^D at $t = 1$ are

$$X_{ji}^L = \frac{W_{ji}^L L_{ji}}{O_i^1} \min \left\{ O_i^1, H_i^1 \right\} \quad X_i^D = \frac{W_i^D D_i}{O_i^1} \min \left\{ O_i^1, H_i^1 \right\}. \tag{6}$$

Next we describe conditions that can trigger liquidity withdrawals at $t = 1$. A bank experiences a liquidity shortage when its vault cash cannot cover the liquidity withdrawals by its own depositors. Similar to the impatient type 1 depositors in Diamond and Dybvig (1983), this type of bank withdraws interbank deposits held at correspondents. As such, a bank's liquidity shortage triggers withdrawals at its correspondents. Formally, $\forall L_{ik} > 0$

$$C_i < \sum_j W_{ji}^L L_{ji} + W_i^D D_i \Rightarrow W_{ik}^L = 1. \tag{7}$$

Alternatively, as noted in the literature on bank runs, a patient depositor has an incentive to withdraw if she is likely to receive less by waiting. This outcome can arise from two scenarios. First, it is always a dominating strategy for depositors to withdraw when a correspondent liquidates the investment.[28] From (3) in definition 1, the correspondent is likely to liquidate

[27] This approach follows Glasserman and Young (2015) and reflects the feature that large shortfalls are more costly than small shortfalls. The bankruptcy cost can result from loss of bank franchise value and disruption of credit and payment services to local customers and businesses, see, for example White and Yorulmazer (2014). During the National Banking era, the bankruptcy cost of failing banks was partly financed by the bank shareholders under the double liability rule – a form of contingent liability requirement imposed by the National Banking Acts. Under double liability, shareholders of the failing banks could lose not only the market value of the equity, but also the par value. For details on double liability see Esty (1998) and Grossman (2001).

[28] This is because there are no more cash flows generated in $t = 2$. If the correspondent defaults at $t = 1$, a depositor redeems a positive fraction of her nominal claims if she withdraws and zero otherwise. If the

when O_i^1 is large or when $\sum_k W_{ik}^L X_{ik}^L$ is small. In other words, respondent banks and depositors withdraw when a correspondent receives a significant fraction of withdrawal requests or when it fails to redeem in full its own due-froms.[29] Formally,

$$\left(\frac{\sum_j W_{ji}^L + W_i^D}{\sum_j L_{ji} + 1} > \bar{f}\right) \vee \left(\sum_k W_{ik}^L X_{ik}^L < \sum_k W_{ik}^L L_{ik}\right) \Rightarrow W_{ji}^L = 1, \forall L_{ji}^L > 0;\ W_i^D = 1. \quad (8)$$

In a second scenario, when the correspondent remains liquid, a patient depositor withdraws when the probability of not being able to redeem fully in $t = 2$ exceeds a certain threshold. Formally, conditional on $\bar{R}_i$, we have

$$\Pr\left(\frac{C_i + I_i\tilde{R}_i + \sum_k \left(W_{ik}^L X_{ik}^L + (1 - W_{ik}^L)L_{ik}\right) - O_i^1}{O_i^2} < 1\right) > \bar{p} \Rightarrow W_{ji}^L = 1, \forall L_{ji} > 0;\ W_i^D = 1. \quad (9)$$

Next we formally define the payment equilibrium of liquidity withdrawals at $t = 1$.

Definition 3 *For given initial balance sheets $\{C, I, K, D, L\}$ and expected investment returns $\bar{R}$, the collection of illiquidity and bankruptcy indicators $\mathbb{I}^l$ and $\mathbb{I}^{d1}$ defined by (2) - (5), the liquidity payments X^L and X^D defined by (6), and the withdrawal indicators W^L and W^D defined by (7) - (9) form a liquidity withdrawal payment equilibrium.*

A liquidity withdrawal payment equilibrium is a collection of mutually consistent withdrawals, interbank payments, and liquidations at $t = 1$. This notion of payment equilibrium is a generalization of a clearing equilibrium in Eisenberg and Noe (2001) and Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015). In contrast to these papers, withdrawals are also part of the equilibrium, determining the liquidity needs of banks. This innovation is critical to modeling financial contagion due to liquidity withdrawals and panic-based runs, a key feature of crises observed during the National Banking era. In the data, the interbank liability relationships were directed along the deposit hierarchy from country banks toward the central reserve city. A large enough negative financial shock to a central reserve city bank would not only lead to this bank's default, but also cause a cascade of failures, spreading to its respondents in the reserve cities and in the countryside. On the other hand, a significant withdrawal shock at country banks would

correspondent does not default at $t = 1$, a depositor redeems fully her nominal claims if she withdraws and possibly less than fully otherwise.

[29] To match the data structure, we do not model a continuum of depositors who decide whether to withdraw based on their private signals à la Goldstein and Pauzner (2005). Rather, these "reduced-form" withdrawal decisions serve the purpose while maintaining the microfoundations.

force these banks to withdraw interbank deposits with their city correspondents (due-froms), and likely lead to a cascade of liquidations at their correspondents in the reserve cities and the central reserve city. As such, our framework is capable of modeling banking panics starting from the seasonal liquidity withdrawals at country banks described in Section 2.2.

As is typical in bank run models, self-fulfilling runs can potentially cause multiple equilibria for the payment equilibrium at $t = 1$.[30] Similar to the treatment by Elliott, Golub, and Jackson (2014) and Stanton, Walden, and Wallace (2016), we focus on the outcome with the minimal number of withdrawals. Specifically, we initially assume that (2) - (6) can be satisfied with no withdrawals. If the resulting liquidation and payments are not consistent with zero withdrawals from (7) - (9), we recalculate the cash flows given these identified withdrawals. We continue updating the set of withdrawals and computing the implied liquidation and payments until no more withdrawals occur.

4.3 Final Date Payment Equilibrium

We next formalize the final date payment equilibrium for the remaining obligations. The final date payment system consists of all banks that remain liquid (those with $\mathbb{I}_i^l = 0$).[31] Let the clearing payment matrix at $t = 2$ be Y^L where Y_{ik}^L denotes the payment by bank k to bank i, $Y_{ik}^L \in [0, L_{ik}]$. Similarly, let Y^D be the payment vector to local depositors at maturity, $Y^D \in [0, D]$.

The total matured obligations of bank i are

$$O_i^2 = \sum_j (1 - W_{ji}) L_{ji} + \left(1 - W_i^D\right) D_i. \tag{10}$$

The ability of bank i to fulfill its matured obligations depends on the value of its total assets, which include not only the vault cash and total redemption of deposits due from correspondents, but also the realized investment proceeds. The value of bank i's total assets is

$$H_i^2 = I_i \tilde{R}_i + C_i + \sum_k W_{ik}^L X_{ik}^L + \sum_k (1 - W_{ik}^L) Y_{ik}^L. \tag{11}$$

[30] For example, all depositors withdrawing is likely an equilibrium. Essentially, depositors face strategic complementarity.

[31] Some of the banks might have experienced liquidity withdrawals but are able to meet the demand without liquidating investments or redeeming all deposits at correspondent banks. The final date payment system also include those who have withdrawn deposits from certain correspondents while keeping other links intact.

The final date bankruptcy event is defined based on whether a bank is able to fulfill total matured obligations using all assets.

Definition 4 *Bank i is bankrupt at $t = 2$, denoted by indicator $\mathbb{I}_i^{d2}$, when the value of its total assets is smaller than the total matured obligation,*

$$\mathbb{I}_i^{d2} = 1 := H_i^2 < O_i^2. \tag{12}$$

Upon bankruptcy, a social cost is incurred proportional to the shortfall.

The bankrupt bank pays all depositors on a *pro rata* basis, resulting in zero equity value. The payment matrix to respondent banks and the payment vector to local depositors at $t = 2$ are respectively

$$Y_{ji}^L = \frac{(1 - W_{ji}^L)L_{ji}}{O_i^2} \min\left\{O_i^2, H_i^2\right\}, \quad Y_i^D = \frac{(1 - W_i^D)D_i}{O_i^2} \min\left\{O_i^2, H_i^2\right\}. \tag{13}$$

Definition 5 *Given initial balance sheets $\{C, I, K, D, L\}$, the realized investment returns $\tilde{R}$, and the $t = 1$ liquidity withdrawal payment equilibrium $\{W^L, W^D, \mathbb{I}^l, \mathbb{I}^{d1}, X^L, X^D\}$ given by (2) - (9), the collection $\{Y^L, Y^D, \mathbb{I}^{d2}\}$ of payments and bankruptcy form a final date payment equilibrium if (10) - (13) are satisfied for all banks simultaneously.*

Following Eisenberg and Noe (2001) and Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015), the final date payment equilibrium characterized by $\{Y^L, Y^D, \mathbb{I}^{d2}\}$ always exists and is generically unique.

5 Quantitative Analysis

In this section, we quantitatively assess the impact of the NBAs on financial stability by feeding the micro-level data of interbank liability relationships and balance sheets into the model. We first examine the impact of the changes in the interbank network on systemic risk measures by simulating two types of liquidity crises. Then we extend the model to assess the impact of banks' actions, such as clearinghouse loan certificates and suspension of cash payments, in addressing liquidity crises.

To quantify the impact of changes in interbank networks, we calculate various indicators of financial stability following the literature.[32] The first set of measures focus on the systemic risk of bank liquidation and bankruptcy. We compute $\mathbb{P}_l^{joint}$, the probability of joint liquidation when at least θ_l fraction of banks simultaneously liquidate. Similarly, we compute $\mathbb{P}_d^{joint}$ the probability of joint bankruptcy when at least θ_d fraction of banks simultaneously default.

$$\mathbb{P}_l^{joint} = \mathbb{P}\left(\frac{\sum_i \mathbb{I}_i^l}{N} \geq \theta_l\right), \quad \mathbb{P}_d^{joint} = \mathbb{P}\left(\frac{\sum_i (\mathbb{I}_i^{d1} + \mathbb{I}_i^{d2})}{N} \geq \theta_d\right). \tag{14}$$

We also compute the expected percentage of banks liquidating and defaulting

$$P_l = \mathbb{E}\left(\frac{\sum_i \mathbb{I}_i^l}{N}\right), \quad P_d = \mathbb{E}\left(\frac{\sum_i (\mathbb{I}_i^{d1} + \mathbb{I}_i^{d2})}{N}\right). \tag{15}$$

The second set of measures concern the magnitude of dollar costs due to liquidation or bankruptcy. V_l and V_d denote, respectively, the expected dollar value of total liquidation and bankruptcy costs, both normalized by the total value of bank balance sheets of that year. The formulas are as follows:

$$V_l = \frac{\mathbb{E}\left[\sum_i \mathbb{I}_i^l (1-\xi_1) I_i\right]}{\sum_i \left(K_i + D_i + \sum_j L_{ji}\right)}; \quad V_d = \frac{\mathbb{E}\left[\sum_i \sum_{t=1}^2 (1-\xi_d)\mathbb{I}_i^{d_t}(O_i^t - H_i^t)\right]}{\sum_i \left(K_i + D_i + \sum_j L_{ji}\right)}. \tag{16}$$

Differences in network structures before and after the NBAs could have contributed to how contagion spread; hence, measuring contagion risk through linkages is of central interest to our study. The third set of measures look at the percentage of liquidations and bankruptcies caused by the illiquidity at a neighboring bank that is directly hit by negative shocks. In particular, we compute the fraction of liquidations and bankruptcies minus the fraction of banks negatively shocked. For example, if a New York City bank were to be hit by a significant negative shock in its investment return, this bank's failure might initiate a cascade of liquidations. We then sum up the liquidations at all other banks caused by this initial shock.

[32] Prior literature provides a broad set of systemic risk measures as indicators of stability. Eisenberg and Noe (2001) propose measuring the chances of waves of default (joint default events) that a given shock induces in a network. Acharya, Pedersen, Philippon, and Richardson (2009) define it as "the risk of a crisis in the financial sector and its spillover to the economy at large." De Bandt and Hartmann (2000) consider systemic risk as "a systemic event that affects a considerable number of financial institutions or markets in a strong sense, thereby severely impairing the general well-functioning of the financial system." Glasserman and Young (2015) calculate the total loss in value summing over all nodes in the system. Other research has used market-based measures such as marginal expected shortfall (Acharya, Engle, and Richardson (2012)), liquidity mismatch index (Brunnermeier, Gorton, and Krishnamurthy (2014)), CoVaR (Adrian and Brunnermeier (2016)).

5.1 Constructing the Banking System

We begin by constructing the banking system by obtaining the values of balance sheet items (C, I, K, D, L) from our empirical data. We compute cash, the vector C, using the sum of the balance sheet items *cash* and *liquid securities*.[33] Equity capital K equals *bank capital* plus *profits and earnings*. Deposit D is constructed by adding *deposits* and *bank notes*. Interbank network L is constructed from the micro-level due-from data where L_{ij} is the dollar value of interbank deposits of bank i due from bank j. Finally, we back out the level of investments I from the balance sheet equation: *Loans* = *Equity* + *Deposits* + *Amount due to banks* − *Cash* − *Amount due from banks*.[34] Here *"Amount due to banks"* is the total interbank deposits due to other banks and *"Amount due from banks"* is the total interbank deposits due from other banks.

The benchmark model is parameterized as follows. We draw $\log \bar{R}$ from an i.i.d. normal distribution $N(0.1, 0.1)$. This implies that, on average, banks expect to receive a 10 percent return from asset investments when held to maturity, and the cross-sectional difference of expected returns is 0.1. The risky returns $\log \tilde{R}$ are then drawn from distribution $N(\log \bar{R}, \sigma = 0.1, \varrho = 0.1)$. The values are chosen similar to those used by Georg (2013).[35] For the costs of liquidation and bankruptcy, we set as a benchmark $\xi_l = \xi_d = 0.55$. This means that upon liquidation banks can recover a salvage value of 55 percent of their initial investment. When a bank goes bankrupt, each dollar of payment shortfall creates an additional 0.55 dollars of bankruptcy costs above and on top of the shortfall itself.[36] Without loss of generality, we consider the threshold for a systemic liquidation event to be $\theta_l = 15$ percent, and the threshold for a systemic bankruptcy event to be $\theta_d = 5$ percent.[37] Finally, we parameterize the conditions to trigger liquidity withdrawals. The threshold fraction of withdrawal requests that a correspondent receives $\bar{f}$ is set

[33] More detailed descriptions of balance sheet items are in Section 3. In 1862, securities were not required to be put up as collateral to issue bank notes, so we categorize all securities as liquid. Appendix II contains detailed information on regular and standardized balance sheets for state and national banks.

[34] While we observe loan investment from the balance sheet data directly, the raw data do not necessarily satisfy the balance sheet equation. The reason is that for regulatory purposes, certain assets on the state banks balance sheets, such as "due from brokers" and "due from directors," were not counted toward total assets.

[35] Our results are robust to the parameterization of σ and ϱ.

[36] These values are set in line with Glasserman and Young (2015). The liquidation and bankruptcy cost ξ_l and ξ_d are scalers; for our purpose of comparing across years, the specific magnitudes of the scalers do not affect our results.

[37] The parameterization of the systemic liquidation and bankruptcy threshold is without loss of generality. The reported probabilities of systemic crises will be higher if we set a lower fraction. The θ_l value is set so that the systemic risk in different crises simulations is not too low and not too high. In Gai and Kapadia (2010) for example, the value is set at 5 percent.

to 5 percent. We also set the threshold probability of not being able to redeem fully when not withdrawing $\bar{p}$ to 20 percent. Table 6 lists the parameter calibration for our baseline simulation.

Table 6. Benchmark Parameter Values

Parameter	**Notation**	**Value**
Expected investment return rate	$\log \bar{R}$	N(0.1, 0.1)
Conditional volatility of investment return rate	σ	0.1
Correlation of investment return rate	ϱ	0.1
Liquidation cost proportional to loan size	ξ_l	0.55
Bankruptcy cost proportional to shortfall	ξ_d	0.55
Threshold fraction of a systemic liquidation event	θ_l	15%
Threshold fraction of a systemic bankruptcy event	θ_d	5%
Threshold fraction of withdrawals to trigger more withdrawals	$\bar{f}$	5%
Threshold probability of not able to redeem fully upon waiting	$\bar{p}$	20%

5.2 Simulating Liquidity Crises

Liquidity crises during the National Banking era can be divided into two types based on the origin of liquidity shocks, as discussed in subsection 2.2. The first class of crises began with correlated investment losses in New York City banks. In turn, liquidity crises started from there and spread to the rest of the country, from the top toward the bottom of the reserve deposit hierarchy. We refer to this type as the *top-to-bottom crises*. A second class of liquidity crises occurred due to seasonal fluctuations in local demand for liquidity outside of New York City. Heavy withdrawals of interbank deposits by country banks overwhelmed the ability of city correspondents to meet the demand. In this type of crises, liquidity shortages originated from the bottom of the deposits hierarchy and spread to the top; we refer to this as the *bottom-to-top crises*. In this section, we study how bank networks contributed to liquidity crises in the National Banking era by simulating the two types of crises.

5.2.1 Top-to-Bottom Crises

To assess the impact of the top-to-bottom crises, we simulate the scenario when New York City banks expected to have correlated losses in loan and security investments, which in turn triggered massive withdrawals at those banks. Specifically, we draw $\log \bar{R}$ of all New York

City banks from a multivariate normal distribution $N(0.1 - \Delta \log \bar{R}_1, 0.1)$. Here $\Delta \log \bar{R}_1$ is the reduction in expected investment rates for all New York City banks. The expected return $\log \bar{R}$ for all other banks and $\log \tilde{R}$ are drawn as in the benchmark. Then, we plug in the empirical data on balance sheets and interbank deposits. For each value of $\Delta \log \bar{R}_1$, we simulate 5,000 random draws of the investment returns. For each draw, we solve for the two-period payment equilibrium using an iterative algorithm. Based on the solved equilibrium of payment equilibrium and liquidation/bankruptcy indicators, we compare the financial stability measures in 1862 and 1867.

Figure 5 presents the main results. Each of the six panels plots $\mathbb{P}_l^{joint}, \mathbb{P}_d^{joint}, P_l, P_d, V_l, V_d$ with 1862 in black and 1867 in red. All measures are expressed as percentages. The horizontal axis indicates the level of expected return reduction $\Delta \log \bar{R}_1$ for all New York City banks. When the shock size is small, say the expected investment return is reduced by 5 percent (i.e., the expected return rates $\log \bar{R}$ for New York City banks are between 5 percent and 10 percent), all systemic risk measures for 1867 lie below those of 1862. However, with a shock size as large as 0.3, all measures of 1867 exceed those of 1862. The exact threshold shock sizes where the 1867 values exceed the 1862 values depend on the specific measures.

Our results show that the resilience of bank networks depends crucially on the magnitude of negative shocks for top-to-bottom crises. As long as the magnitude of the negative shocks to New York City banks is within a threshold, the post-NBAs network outperforms in resilience. However, when the losses are large enough to trigger liquidation at financial center banks, concentrated linkages start to serve as channels for systemic contagion; consequently, systemic risk measures in 1867 increase exponentially whereas those for 1862 are less responsive.

In particular, the post-NBAs network is more robust to mild negative liquidity shocks to New York City banks, and the underlying mechanism is due to a drop in interbank contagion. The contagion measures, provided in Panels (c)-(d) in Figure 5 illustrate the expected percentage of illiquid and bankrupt banks that are not located in New York City. These banks are not directly shocked; hence, the liquidation and bankruptcy are likely caused by their direct or indirect liability relationships with the shocked New York City banks. When the expected return of New York City banks is reduced slightly, say 5 percent, a more concentrated network reduces contagion. This comes from two effects. First, as the length of counterparty chains gets shorter

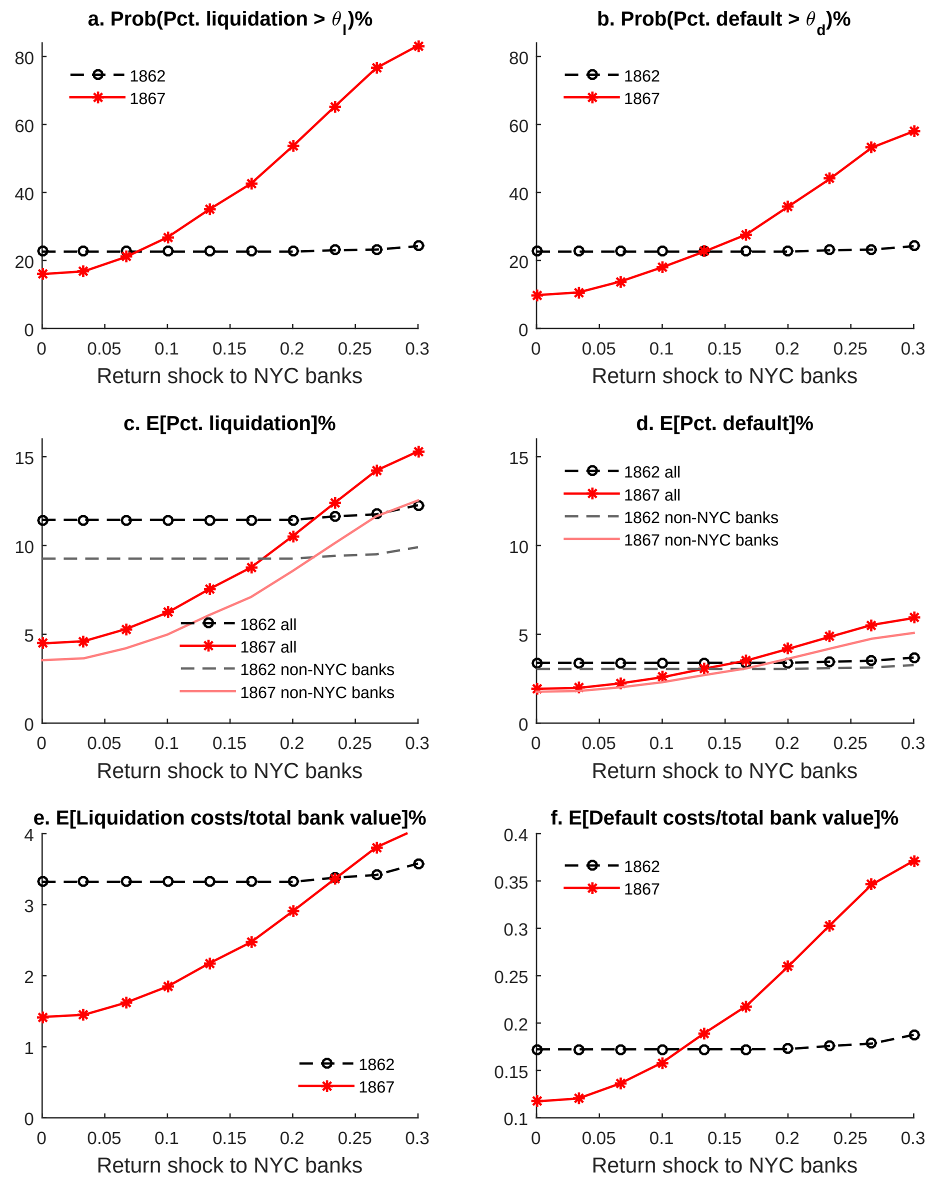


Figure 5. Top-to-Bottom Crises: systemic risk measures This figure shows the financial stability measures when we reduce the expected investment return rate $\log \bar{R}$ of all New York City banks. The horizontal axis indicates the level of return reduction $\Delta \log \bar{R}_1$ for all New York City banks. Panels (a)-(f) show respectively the probability of a systemic liquidation event $\mathbb{P}_l^{joint}$, the probability of a systemic default event $\mathbb{P}_d^{joint}$, the expected percentages of liquidations and bankruptcy P_l and P_d, and the expected liquidation and bankruptcy costs normalized by total value of the banking sector V_l and V_d. All measures are in percentages. Dashed black curves plot the measures before the Acts (1862) and solid red curves after the Acts (1867). In particular, in Panels (c)-(d), the gray and light red curves show the expected percentage of liquidation and bankruptcy that are not located in New York City and thus are not directly shocked with lower expected returns.
Source: Authors' calculations.

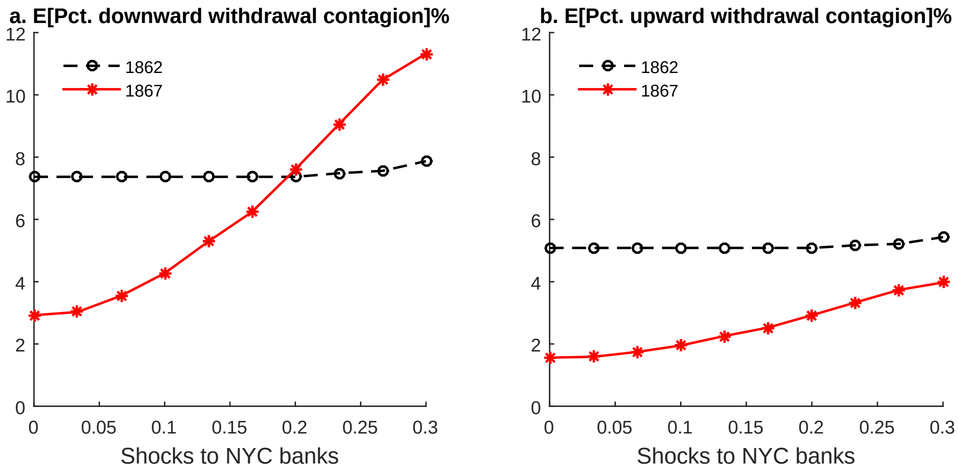


Figure 6. Top-to-Bottom Crises: contagion channels This figure shows the channels of contagious withdrawals when we reduce the expected investment return rate $\log \bar{R}$ of all New York City banks. The horizontal axis indicates the level of return reduction $\Delta \log \bar{R}_1$ for all New York City banks. Panels (a)-(b) show the expected percentage of banks suffering from depositors' withdrawals because their correspondents default and because their respondents have a liquidity shortage. All values are in percentages. All dashed black curves plot the measures before the Acts (1862) and all solid red curves after the Acts (1867).
Source: Authors' calculations.

(from an average of 3 in 1862 to 1.8 in 1867), the chances of contagion from indirect counterparties are lower. Second, the concentration increases the number of respondents each New York City correspondent has. This facilitates risk diversification because only a small fraction of loss at the correspondent is passed on to individual respondents per the *pro rata* payment rule. In contrast, contagious liquidation is more pronounced once the negative shocks are sizable. Under large investment loss, New York City banks default on their respondents, causing withdrawals and illiquidity at respondents in a systemic fashion. As such, the concentrated interbank linkage acts as a mechanism for contagion.

We classify contagion channels based on whether liquidation propagates upward or downward along the hierarchy of interbank deposits. A downward withdrawal contagion occurs when a bank suffers from liquidity withdrawals because its correspondent defaults on its deposits. Similarly, upward withdrawal contagion occurs when a respondent experiences a liquidity shortage and has to withdraw from its correspondents. Figure 6 decomposes the contagion measures into downward in panel (a) and upward in panel (b). Consistent with the above mechanism, top-to-bottom crises under large-sized liquidity shocks are mainly caused by downward withdrawal contagion from New York City banks at the top of the pyramid to their respondents.

This phase transition of financial stability confirms the "robust-yet-fragile" nature of the interbank network in Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015), and further confirms that the "knife-edge dynamics" highlighted in Haldane (2013) also manifest in the historical bank networks.

5.2.2 Bottom-to-Top Crises

We simulate the *bottom-to-top* crises by randomly drawing a given fraction of country banks and setting exogenously their $W^D = 1$ such that their local depositors withdraw. Specifically, we simulate the vector of W^D for country banks from a multivariate correlated binary distribution with given "success probability" and then vary this probability as an aggregate shock. For each value of "success probability," we simulate 5,000 random draws of the vector W^D. For each draw, we solve for the two-period payment equilibrium using an iterative algorithm while minimizing withdrawal outcomes. Then, based on the solved payment equilibrium and liquidation/bankruptcy indicators, we compare the financial stability measures in 1862 and 1867.

Figure 7 shows the financial stability measures for bottom-to-top crises. The horizontal axis indicates the percentage of country banks experiencing withdrawals from local depositors. Each of the six panels illustrates $\mathbb{P}_l^{joint}, \mathbb{P}_d^{joint}, P_l, P_d, V_l, V_d$ for 1862 in black and for 1867 in red. All the measures are expressed as percentages. Our results show that the 1867 banking system is more robust to liquidity shocks originating from country banks. All systemic risk measures for 1867 lie below those for 1862. The interbank links can pass on contagious withdrawals upward along the pyramid. Nonetheless, the financial center banks have enough liquid assets and are diversified among depositors such that they are more capable of withstanding large liquidations.

The bottom-to-top crises are mainly due to upward withdrawal contagions from country banks to their correspondents. Figure 6 decomposes the contagion measures into downward in panel (a) and upward in panel (b).[38] The upward contagion measures in 1867 are much lower than in 1862, confirming the above result that the post-NBAs network becomes more robust to liquidity shocks originating from country banks.

[38] A downward withdrawal contagion occurs when a bank suffers from liquidity withdrawals because its correspondent defaults on its deposits. Similarly, upward withdrawal contagion occurs when a respondent experiences a liquidity shortage and has to withdraw from its correspondents.

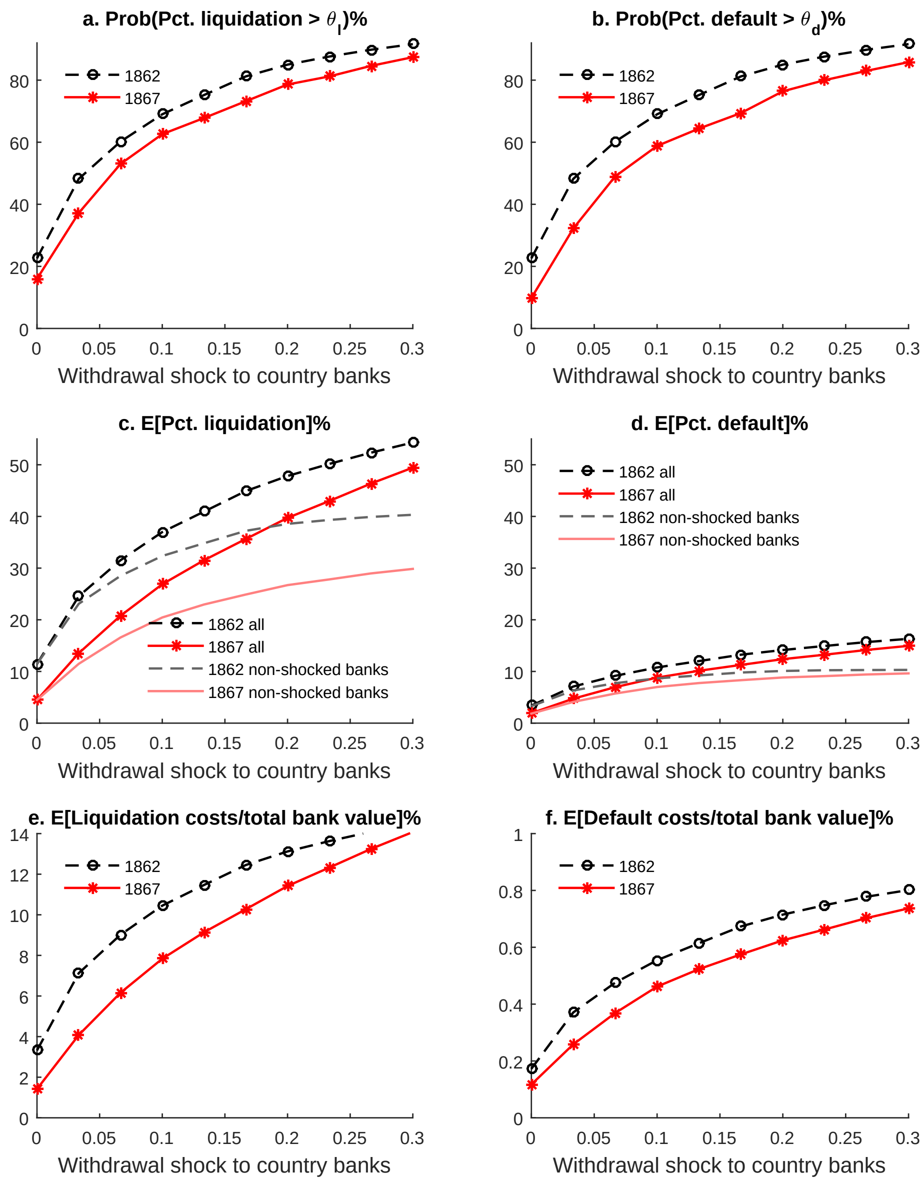


Figure 7. Bottom-to-Top Crises: systemic risk measures This figure shows the financial stability measures when we shock all country banks with a correlated probability of withdrawals from local depositors. The horizontal axis indicates the exogenous probability of withdrawal shocks at country banks. Panels (a)-(f) show, respectively, the probability of a systemic liquidation event $\mathbb{P}_l^{joint}$, the probability of a systemic default event $\mathbb{P}_d^{joint}$, the expected percentages of liquidations and bankruptcy P_l and P_d, and the expected liquidation and bankruptcy costs normalized by total value of the banking sector V_l and V_d. All values are in percentages. Dashed black curves plot the measures before the NBAs (1862) and solid red curves after the NBAs (1867). In particular, in Panels (c)-(d), the gray and light red curves show, respectively, the expected percentages of liquidation and bankruptcy that are not directly shocked with exogenous withdrawals.
Source: Authors' calculations.

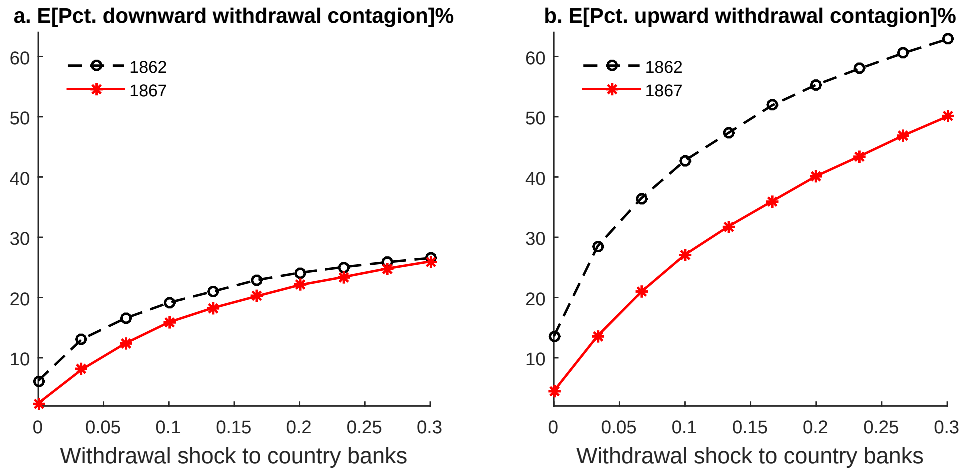


Figure 8. Bottom-to-Top Crises: contagion channels This figure shows the channels of contagious withdrawals when we shock all country banks with a correlated probability of withdrawals from local depositors. The horizontal axis indicates the exogenous probability of withdrawal shocks at country banks. Panels (a)-(b) show, respectively, the expected percentages of banks suffering from depositors' withdrawals because their correspondents default and because their respondents have liquidity shortages. All values are in percentages. Dashed black curves plot the measures before the Acts (1862) and solid red curves after the Acts (1867).
Source: Authors' calculations.

Summing up the lessons learned from simulating liquidity crises, the impact of the NBAs on systemic risk seems to have increased the systemic nature of top-to-bottom crises but not the bottom-to-top crises. These results not only confirm the theoretical finding of Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015) and Gai and Kapadia (2010), but also add to the discussion of key sources of bank panics during the National Banking era. Many have long believed that bank panics originated with banks outside financial centers, and recent studies have shown that significant financial shocks in New York City may have been a more important source of crises. Our findings show that financial center banks were resilient to financial distress coming from country banks, but that the same was not true for country banks when the financial centers were suffering liquidity shortages, suggesting that liquidity shocks to financial center banks might have been a greater threat to financial stability. This result is consistent with the fact that major panics after the NBAs originated in New York City.

5.3 Extension: New York City banks' reaction to crises

In the absence of a formal lender of last resort, banks responded to panics by transforming themselves into a single institution called a clearinghouse and acted collectively. The clearinghouse then issued loan certificates to create private money and alleviate problems due to liquidity shortages. When the issuance of loan certificates could not contain the panic, banks jointly suspended the convertibility of deposits into currency. In this section, we discuss how the actions taken by the New York Clearinghouse affected financial stability.

5.3.1 Suspension of Convertibility at New York City Banks

When receiving massive withdrawals, a bank can temporarily suspend payments to stop a potential run; this is referred to as the *suspension of convertibility.* The potential impact of cash suspensions on systemic risk is mixed. On the one hand, if banks can suspend convertibility when liquidity withdrawals are massive, liquidations at these New York City banks can be avoided. Furthermore, anticipation of this policy reduces the incentive of patient depositors and respondents to withdraw early, thereby preventing systemic runs (Diamond and Dybvig (1983)). On the other hand, during the National Banking era, New York City banks held the majority of interbank deposits (especially after the NBAs): when the withdrawal requests of their respondents were not fulfilled, liquidity shortages spread to their respondent banks in other cities, generating contagion.

We extend the benchmark model to incorporate cash suspensions as follows. A New York City bank invokes the suspension of convertibility when: (1) its liquid assets (vault cash plus the redemption of deposits due from other banks) fail to meet its total liquidity withdrawal requests, and (2) its asset investment is among the top 50 percent in size among all New York City banks.[39] The motivation for these conditions is that banks invoke cash suspension when liquidations are about to be triggered, and especially when the liquidation costs are anticipated to be significant. The suspension events have the following impact on the two-period payment

[39]The suspension event is identified at the individual bank level. If we were to model suspension as a collective action so that all New York City banks suspend payments whenever one of the banks has a liquidity shortage, the systemic risk measures in simulation would be close to zero. This occurs since in absence of frictions such as information asymmetry and fire sales, bank runs can be effectively prevented in the model just by suspension, which is unrealistic in practice. We choose the "50th percentile" so that suspensions at New York City banks have a non-negligible probability to occur.

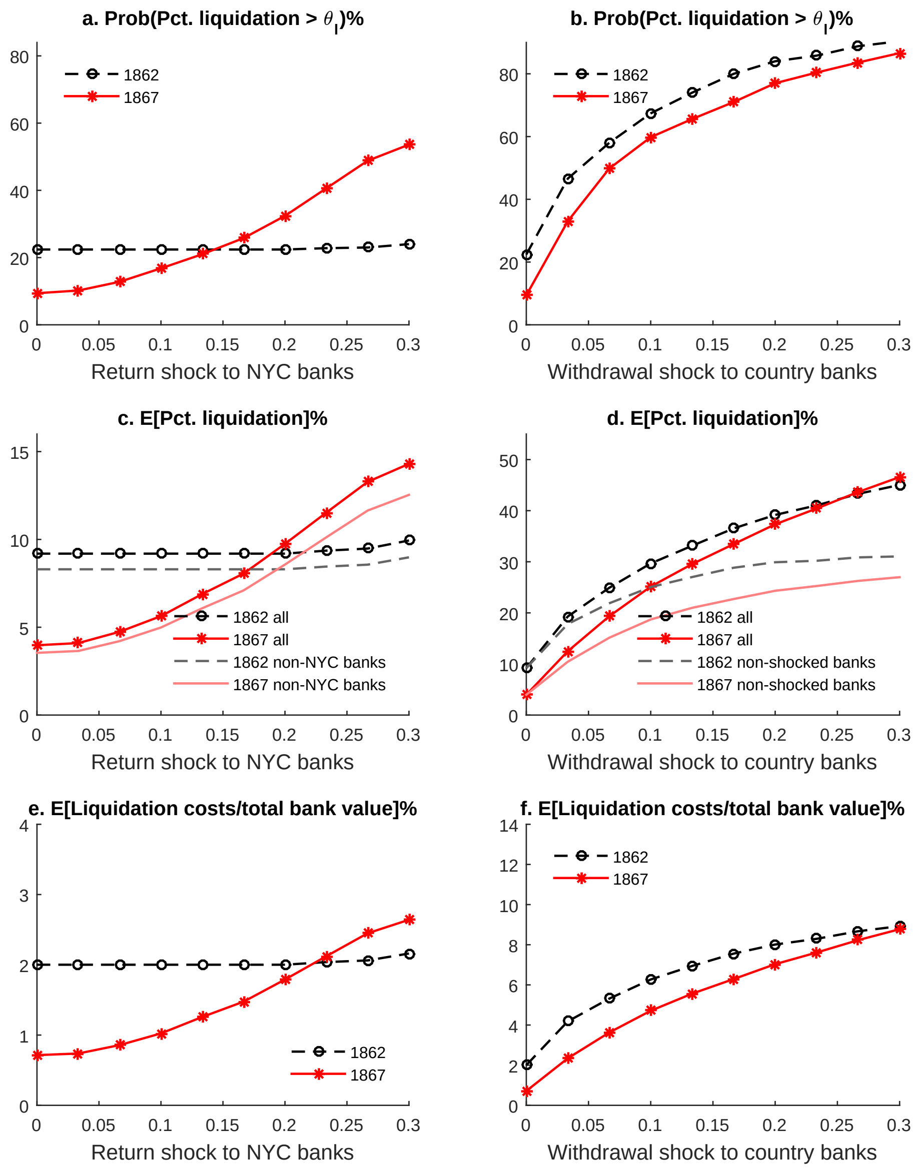


Figure 9. Cash Suspensions in Top-to-Bottom and Bottom-to-Top Crises This figure shows the financial stability measures when we allow New York City banks to suspend cash payment in the simulations of the top-to-bottom (panels on the left) and bottom-to-top crises (panels on the right). The horizontal axis indicates the size of the shocks, the level of return reduction $\Delta \log \bar{R}_1$ for all New York City banks (left panels), and the exogenous probability of withdrawal shocks at country banks (right panels). Panels (a)-(b) show the probability of a systemic liquidation event $\mathbb{P}_l^{joint}$; panels c-d the expected percentages of liquidations P_l, and Panels (e)-(f) the expected liquidation costs V_l normalized by total value of the banking sector. In Panels (c)-(d), the gray and light red curves are the expected percentage of liquidations at banks that are not directly shocked. All values are in percentages. Dashed black curves plot the measures before the NBAs (1862) and solid red curves after the NBAs (1867).
Source: Authors' calculations.

equilibrium. Suspensions guarantee that liquidations will not happen at these New York City banks; hence the withdrawal conditions (8) are not effective anymore at suspending banks because the conditions are based on a positive liquidation likelihood. We keep the rest of the model and the parameterization the same as the benchmark and simulate the two types of crises: the top-to-bottom and the bottom-to-top crises.

Figure 9 plots the systemic risk measures of liquidation in the top-to-bottom (panels on the left) and bottom-to-top (panels on the right) crises. The main patterns observed in Figure 5 and Figure 7 persist.[40] Interestingly, all measures are in general lower than in the benchmark model. This implies that the benefit of suspension in reducing liquidations at New York City banks and preventing runs dominates the contagion downside. Our findings on the systemic risk impact of the more concentrated bank networks remain robust when allowing for cash suspensions.

We next illustrate the mechanism of contagion using a specific simulated scenario for the top-to-bottom crises. We set the level of return reduction $\Delta \log \bar{R}_1$ for all New York City banks to 0.3 (the highest level of shock in our simulation). The panels in Figure 10 illustrate the dynamics of a top-to-bottom contagion in the interbank network. The red, yellow, and blue nodes indicate banks experiencing bankruptcy, liquidation, and suspension. In this simulated state, one New York bank (American Exchange Bank) has an expected return loss of 17.2 percent, which triggers the withdrawal condition (9). Liquidation and default at this bank causes the liquidity shortage of its two respondents in Philadelphia. This is stage 1 of the interbank contagion. The red node in the most inner ring indicates the initially shocked New York City bank; the red and yellow nodes in the middle ring represent the two respondents in Philadelphia. Stage 2 of the contagion causes the liquidity shortage at a majority of the respondents of the two Philadelphia banks. In stage 3, liquidity shortage is transmitted from a respondent to its correspondent via withdrawals (see the red node on the left). In stage 4, a liquidating country bank withdraws from its correspondent in New York City: a run on the New York City bank eventually leads to a suspension (blue node). This suspension causes illiquidity at all its respondents, which have to withdraw from other correspondents also in New York City (the yellow node in the most inner

[40] When the withdrawal shocks to country banks are close to 0.3, the 1867 measures are higher than the 1862 measures for bottom-to-top crises. This is because the fraction of New York City banks in 1867 is smaller. Increasing the shock size further above 0.3 is not meaningful because the probability of systemic liquidation event has already reached close to 90 percent.

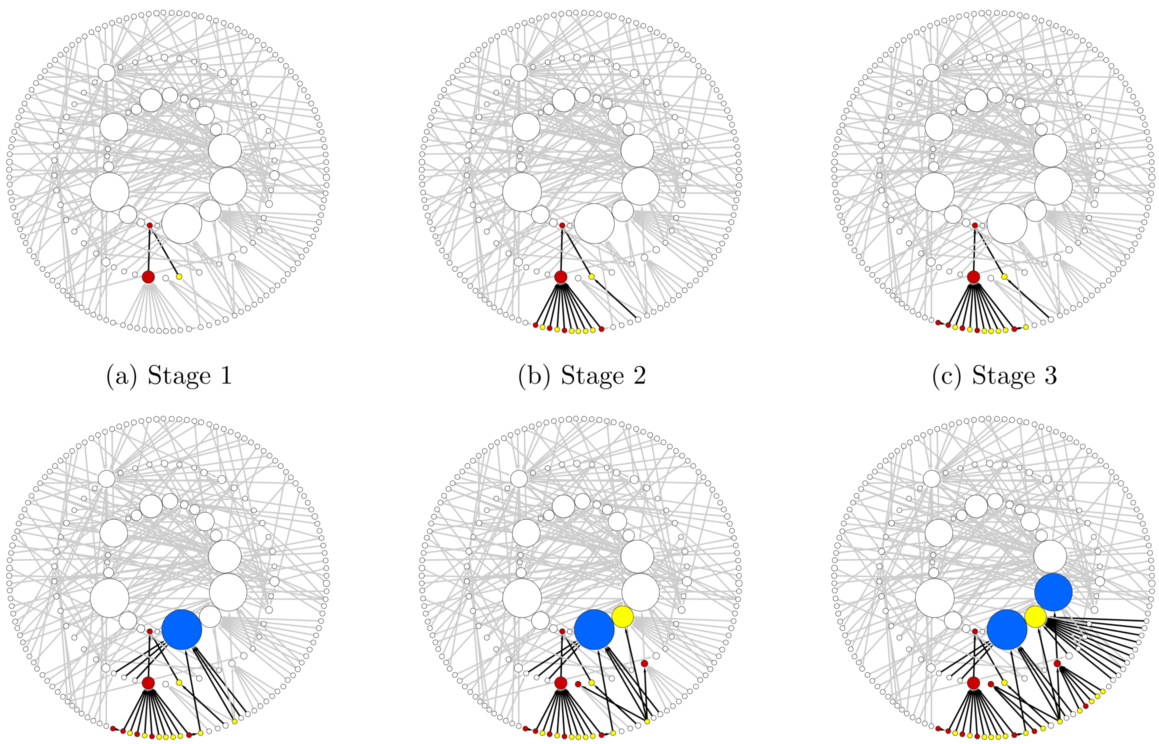

(a) Stage 1 (b) Stage 2 (c) Stage 3
(d) Stage 4 (e) Stage 5 (f) Stage 6

Figure 10. Dynamics of Contagion in the Interbank Network This panel of figures illustrate the dynamics of a top-to-bottom contagion in the interbank network. The instance is simulated based on the 1867 network. The diameter of each node is proportional to the bank's log size of interbank due-to deposits. A link with an arrow indicates a recorded deposit relationship. The red, yellow, and blue nodes indicate banks experiencing bankruptcy, liquidation, and suspension, respectively.
Source: Authors' calculations.

ring), causing further illiquidity (stages 5-6).

5.3.2 New York City Clearinghouse Loan Certificates

We further extend the benchmark model to allow New York City banks to issue clearinghouse loan certificates among member banks in order to share liquidity risk. If the total liquidity surplus of New York City banks that do not experience a liquidity shortage exceeds a certain multiple of the total liquidity shortage of those New York City banks that do, then loan certificates are issued among members. As a result, liquidation at all New York City banks can be avoided. Furthermore, the extent that contagion spreads to other parts of the system can also be limited. We keep the rest of the model and the parameterization the same as the benchmark and simulate the two types of crises.

Figure 11 shows that the systemic risk measures in the post-NBAs network tend to be much lower compared to the benchmark, especially for top-to-bottom crises when New York City banks are directly shocked. The clearinghouse loan certificates among New York City banks greatly facilitated risk sharing. Such risk-sharing relationships differed from liability links that can create contagion because they unambiguously reduced liquidation risk among New York City banks. Essentially, they allowed liquidity-rich bank to reallocate their excess liquidity to those that were close to liquidation. Although New York City banks did not have direct links among themselves, they might have shared common respondents; hence one New York City bank's liquidation could eventually spread to another New York City bank. By sharing excess liquidity, the liquidity-rich banks would regain the liquidity payback when all investments matured, while preventing potential contagion caused by indirect linkages. Our results confirm the value of risk sharing at the financial center banks where interbank deposits are concentrated.

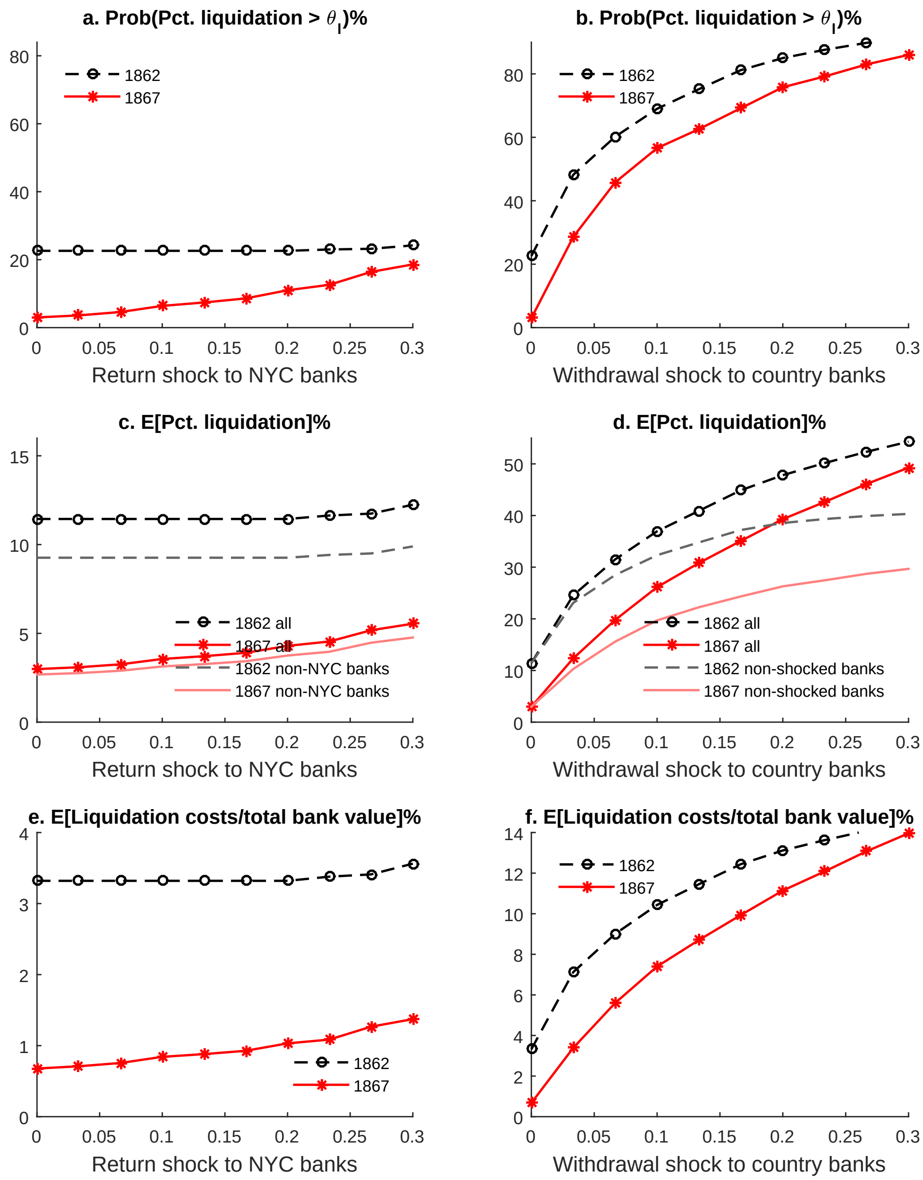


Figure 11. Clearinghouse Loan Certificates in Top-to-Bottom and Bottom-to-Top Crises This figure shows financial stability measures when we allow New York City banks to issue clearinghouse loan certificates among member banks in the simulations of the top-to-bottom (panels on the left) and bottom-to-top crises (panels on the right). The horizontal axis indicates the size of shocks, the level of return reduction $\Delta \log \bar{R}_1$ for all New York City banks (left panels), and the exogenous probability of withdrawal shocks at country banks (right panels). Panels (a)-(b) show the probability of a systemic liquidation event $\mathbb{P}_l^{joint}$; panels (c)-(d) the expected percentages of liquidations P_l; and panels (e)-(f) the expected liquidation costs V_l normalized by total value of the banking sector. In Panels (c)-(d), the gray and light red curves are the expected percentage of liquidations at banks that are not directly shocked. All values are in percentages. Dashed black curves plot the measures before the Acts (1862) and solid red curves after the Acts (1867).
Source: Authors' calculations.

6 Conclusion

The financial crisis of 2007-09 sparked growing recognition of the role that an interconnected financial architecture plays in global financial stability. However, despite the importance of developing a structural framework to address systemic risk concerns, the ability to analyze such policies is limited. In particular, the lack of detailed data on the precise linkages among financial institutions makes empirical analysis challenging.

This paper instead takes a historical approach, by examining how the National Banking Acts (NBAs) of 1863 and 1864 changed the structure of bank networks and affected the stability of the banking system. The reserve requirements established by the NBAs dictated the amounts and locations of interbank deposits, thereby reshaping the structure of bank networks. We first analyze the impact of the NBAs on the topology of interbank networks using unique data on bank balance sheets and detailed interbank deposits in 1862 and 1867 in Pennsylvania. We find that a reserve pyramid with three distinct tiers emerged after the NBAs, and that the interbank linkages became more concentrated in a small number of financial center banks, creating financial institutions with greater systemic importance.

We then build a model of interbank networks and examine how such changes in the interbank network affect the transmission of liquidity shocks in the banking system. Quantitative results show that the bank networks became "*robust-yet-fragile*." A greater concentration of links leads to a less fragile interbank network in general; however, systemwide contagion can occur when highly interconnected financial center banks face large shocks.

Our findings shed new light on financial regulation that mandates the central clearing of OTC derivatives. Despite the intention to mitigate bilateral counterparty risk, this regulatory change also radically reshaped the interconnected structure and raised risk concerns about the systemically important CCPs. Economic history provides a laboratory to study important policies like this. By analyzing a regulatory change to a historical banking system that is structurally similar to the effect of mandatory central clearing, our study highlights the persistence of the too-connected-to-fail problem.

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Appendix I: Sample Data

This study relies on the balance sheets of state and national banks in Pennsylvania. The following two figures provide sample data from the two sources.

Due to the Allentown Bank, from the following named solvent banks respectively, on the third day of November, 1862:

Manufacturers' and Mechanics' Bank, Philadelphia	$29,710 52
Union Bank, New York	88,413 33
Easton Bank	9,209 69
Farmers' and Mechanics' Bank, Philadelphia	6,453 44
Northern Liberties Bank	3,328 20
Penn Township Bank	2,765 62
Corn Exchange Bank, Philadelphia	4,225 01
Mauch Chunk Bank	2,412 79
Union Bank, Philadelphia	649 90
Union Bank of Reading	1,133 91
Farmers' and Mechanics' Bank of Easton	606,17
Farmers' Bank of Reading	8 33
Bank of Catasauqua	885 13
Philipsburg Bank, New Jersey	713 21
Pottstown Bank	72 00
E. W. Clark & Co., Philadelphia	5,780 58
	156,367 83

Figure I.1. Pennsylvania State Bank Report: Allentown Bank This table lists all the correspondent banks which Allentown Bank had positive deposits due from.
Source: *Reports of the Several Banks and Savings Institutions of Pennsylvania.*

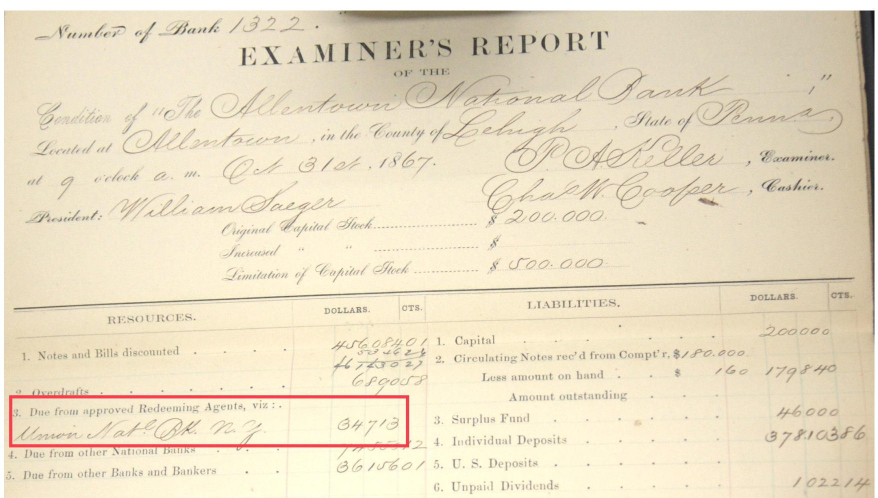


Figure I.2. OCC National Banks' Examination Report: Allentown National Bank This figure shows a handwritten examiners report that was filed annually. The red box highlights the major correspondent banks which Allentown National Bank had positive deposits due from.
Source: *OCC National Banks' Examination Reports.*

Appendix II: Balance Sheet Standardization

Because state and national bank balance sheets report different items, we combined them to create a standardized list of six asset categories and six liability categories. The asset categories are: cash; liquid securities; illiquid securities (U.S. Treasury bonds deposited with the U.S. Treasury to secure circulation and deposits); amounts due from other banks; loans; and other assets. The liability categories are: capital; surplus and profits; bank notes; deposits; amounts due to other banks; and other liabilities. In the following tables, we report both the original and the standardized categories.

Table II.1. State Bank Balance Sheet Structure

Assets	Standardized
Gold and silver in the vault of the bank	Cash
Current notes, checks, and bills of other banks	Cash
Uncurrent notes, checks, and bills of other banks	Cash
Other obligations of other banks	Due from
Bills and notes discounted, (not under protest)	Loans
Bills and notes discounted, (under protest)	Loans
Mortgages held and owned by the bank	Loans
Assessed value for 1862 of the real estate bound by said mortgages	Loans
Judgments held and owned by the bank	Loans
Real estate held and owned by the bank	Loans
Due from solvent banks	Due from
Due from insolvent banks	Due from
Public and corporate stocks and loans	Liquid securities
Bonds held by the bank	Liquid securities
Treasury notes	Liquid securities
Claims against individuals or corporations, disputed or in controversy	Loans
All other debts and claims either due or to become due	Loans
Expenses	Other
Value of any other property of the bank, as the same stands charged on the books, or otherwise	Other
Liabilities	**Standardized**
Capital stock actually paid in	Capital
Deposits	Deposits
Certificates of deposit	Deposits
Due to the Commonwealth	Other
Due to banks	Due to
Due to individuals	Deposits
Claims against the bank in controversy	Other
Surplus, contingent, or sinking fund	Surplus
Earnings	Surplus
All other items of indebtedness not embraced in foregoing specifications	Other

Notes: This table lists the original and standardized balance sheet items for state banks.
Source: Authors' compilation based on the *Reports of Several Banks and Savings Institutions of Pennsylvania.*

Table II.2. National Bank Balance Sheet Structure

Assets	Standardized
Loans and discounts	Loans
Overdrafts	Loans
U.S. bonds deposited to secure circulation	Illiquid securities
U.S. bonds deposited to secure deposits	Illiquid securities
U.S. bonds and securities on hand	Liquid securities
Other stocks, bonds, and mortgages	Liquid securities
Due from approved redeeming agents	Due from
Due from other national banks	Due from
Due from other banks and bankers	Due from
Real estate, furniture, etc.	Other
Current expenses	Other
Premiums	Other
Checks and other cash items	Cash
Bills of national banks	Cash
Bills of other banks	Cash
Specie	Cash
Fractional currency	Cash
Legal tender notes	Cash
Compound interest notes	Cash
Liabilities	**Standardized**
Capital stock	Capital
Surplus fund	Surplus
Undivided profits	Surplus
National bank notes outstanding	Notes
State bank notes outstanding	Notes
Individual deposits	Deposits
United States deposits	Deposits
Deposits of U.S. disbursing officers	Deposits
Due to national banks	Due to
Due to other banks and bankers	Due to
Amount due, not included under either of the above headings	Other

Notes: This table lists the original and standardized balance sheet items for national banks. Due from approved redeeming agents, checks and other cash items, specie, fractional money, legal tender notes, and compound interest notes counted toward legal reserves (The National Bank Acts, Banker's Magazine, 1875)

Source: Authors' compilation based on the *OCC National Banks' Examination Reports* and *Report of the Comptroller of the Currency.*

Appendix III: Additional information about the interbank network

This appendix provides additional information about the interbank network of major correspondents discussed in Section 3.3. The National Banking era saw the concentration of interbank deposits in central reserve cities. As a result the interbank network of major correspondents had a more concentrated structure in 1867 than in 1862. Figure III.1 depicts the networks in 1862 and 1867 at the bank level using a force-directed layout. The 1862 network had a core-periphery structure, with a small number of highly connected core banks mainly receiving deposits and a large number of country banks making up the periphery, mainly acting as depositors. Although the network remained a core-periphery structure in 1867, some key transitions in the network structure are notable: the tiered hierarchical structure of banks became more pronounced and deposits grew more concentrated.

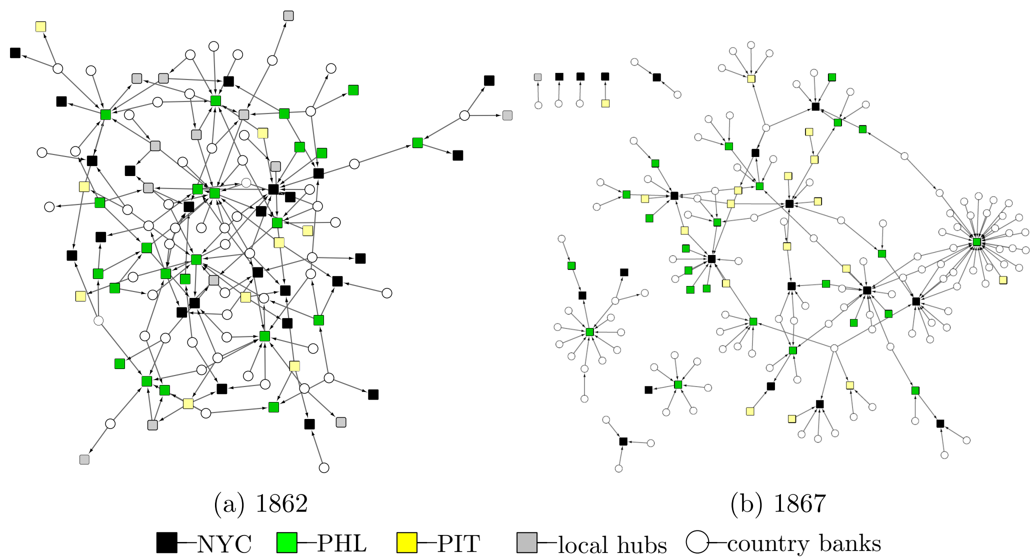
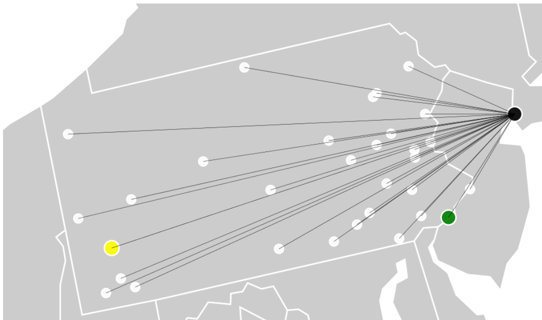
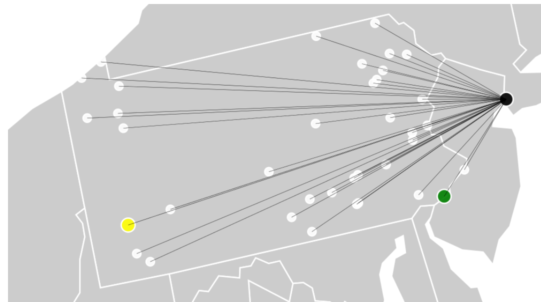


Figure III.1. Banks' Major Correspondent Network This figure depicts banks' major correspondent networks in 1862 and 1867 using a force-directed layout. The black, green, yellow, gray, and white nodes denote banks located in New York City, Philadelphia, Pittsburgh, other local hubs, and rural areas, respectively. A link with an arrow indicates a recorded deposit relationship where the arrow points to the correspondent.
Source: Authors' diagrams using data from the *Reports of Several Banks and Savings Institutions of Pennsylvania* and *OCC National Bank Examination Reports*

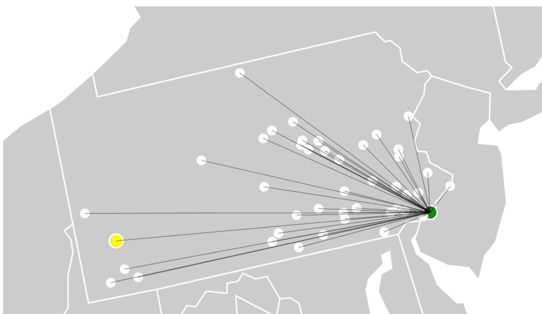
We can also visualize the changes in city-level interbank deposits (see Table 3) by graphing the interbank networks according to banks' physical location. Figure III.2 shows the networks on a map of the United States and compares the interbank relationships by location. The bank-level relationships are aggregated up to the town/city level, represented by a circle on the map. For example, Figure III.2.a shows the interbank deposits held in New York City; each linked location represents a correspondent relationship between a New York City bank and at least one bank at that location. Consistent with Table 3, correspondent relationships became more concentrated in major cities in 1867.



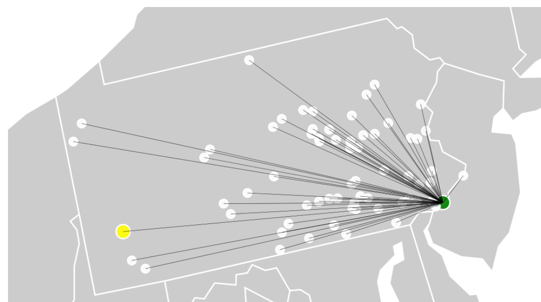
(a) 1862 New York City



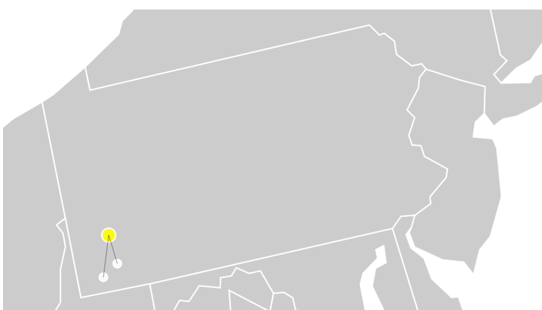
(b) 1867 New York City



(c) 1862 Philadelphia

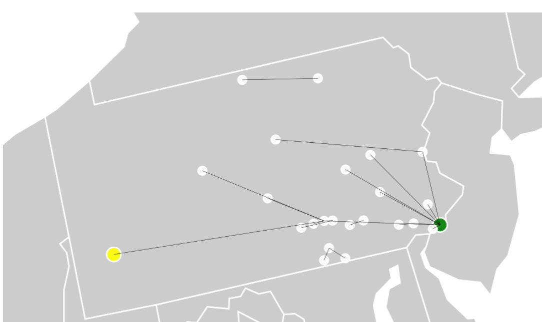


(d) 1867 Philadelphia

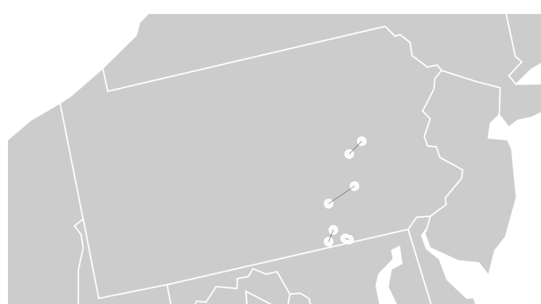


(e) 1862 Pittsburgh

(f) 1867 Pittsburgh



(g) 1862 Other Locations



(h) 1867 Other Locations

Figure III.2. Compare Bank Networks by Location This panel of figures plots the interbank relationships by aggregating bank-level relationships up to the town/city level, represented by a circle. Circle colors correspond to the country bank locations (gray), Pittsburgh (yellow), Philadelphia (green), and New York City (black). Each right and left figure plots the "due from" relationships of New York City (a)-(b), Philadelphia (c)-(d), Pittsburgh (e)-(f), and other locations (g)-(h) in 1862 (right) and 1867 (left).

Source: Authors' diagrams using data from the *Reports of Several Banks and Savings Institutions of Pennsylvania* and the *OCC National Bank Examination Reports*.

Appendix IV: The Civil War's Impact on Bank Balance Sheets and Interbank Deposits

Analyzing the year 1862 may raise concerns about the representativeness of our study since the country was engaged in the Civil War. The national circumstances could have affected bank balance sheets and network structures. In this appendix we describe and compare the topology of interbank networks in detail: (1) bank balance sheets, (2) correspondent relationships, and (3) the structure of the interbank deposit network. This analysis is meant to provide a vehicle for differentiating the impact of the Civil War from that of the NBAs. We find that there were some changes in the networks between 1859 and 1862. In particular, we find an increase in the amount of interbank deposits and a shift of the deposits in New York.

We begin by examining the balance sheets of state banks and savings institutions in Pennsylvania for the years of 1859 and 1862. While the state banking department at that time did not impose any reserve requirement regulations, banks still maintained liquid balance sheet structures. Table IV.1 shows that the Pennsylvania state banks held on average somewhere between 20 and 30 percent of their assets in the form of liquid assets. We do not see a significant difference in the level of cash assets. However, we do see an increase in the amount of interbank deposits from 1859 to 1862. A higher level of interbank deposits would overestimate the effect of shocks. While interbank deposits worked as liquidity buffers in normal times, they magnified the extent of liquidity shocks during crises.

Table IV.2 summarizes the disaggregated correspondent information of the banks. Rows 3-11 of the Table IV.2 show that Pennsylvania banks had relationships with a large number of banks, on average holding amounts due with 14 other banks.[41] These numbers are relatively constant over the two periods, and this holds for both all and major deposits, suggesting that the number of relationships was not particularly affected.

Given that we do not see a change in the number of relationships, we next examine if there was a change in the distribution of interbank deposits by location (see Table IV.3). In 1859, Philadelphia banks maintained a large portion of their deposits in Pennsylvania, holding half of them in Philadelphia and the other half in country banks in Pennsylvania. Philadelphia banks also maintained a large portion of their deposits outside Pennsylvania. Pittsburgh banks held their interbank deposits across New York (almost 20 percent), Philadelphia (about 25 percent), but maintained most of their deposits in local business hubs outside Pennsylvania (around 50 percent). Country banks spread their interbank deposits across New York, Philadelphia, and Pittsburgh, but maintained a large portion of their interbank deposits in other local business hubs and elsewhere (37 percent).

By 1862, we do see some major changes in the distribution of interbank deposits. All three types of banks began holding large portions of their interbank deposits in New York City

[41] The median number was approximately 11, and the range was between 1 and 54.

Table IV.1. Balance Sheet Summary Statistics: 1859 and 1862

	New York City			*Philadelphia*			*Pittsburgh*			*Country Banks*		
Year = 1859	Obs	Mean	SD	Obs	Mean	SD	Obs	Mean	SD	Obs	Mean	SD
Against Total Assets												
Cash	8	0.22	0.05	20	0.14	0.04	7	0.13	0.04	52	0.10	0.06
Liquid securities	8	0.06	0.05	20	0.10	0.07	7	0.04	0.03	52	0.03	0.023
Due from other banks	8	0.04	0.02	20	0.04	0.02	7	0.02	0.01	52	0.09	0.07
Loans	8	0.69	0.05	20	0.67	0.07	7	0.78	0.07	52	0.73	0.11
Against Total Liabilities												
Equity	8	0.38	0.13	20	0.34	0.07	7	0.57	0.06	52	0.41	0.10
Bank notes	8	0.01	0.01	20	0.12	0.05	7	0.21	0.06	52	0.37	0.12
Deposits	8	0.42	0.17	20	0.47	0.07	7	0.18	0.05	52	0.17	0.08
Due to other banks	8	0.20	0.09	20	0.06	0.04	7	0.02	0.01	52	0.03	0.02
Year = 1862	Obs	Mean	SD	Obs	Mean	SD	Obs	Mean	SD	Obs	Mean	SD
Against Total Assets												
Cash	22	0.19	0.09	20	0.21	0.10	7	0.18	0.06	63	0.12	0.07
Liquid securities	22	0.16	0.14	20	0.30	0.14	7	0.32	0.13	63	0.18	0.14
Due from other banks	22	0.04	0.02	20	0.03	0.04	7	0.12	0.04	63	0.18	0.10
Loans	22	0.58	0.17	20	0.40	0.12	7	0.36	0.12	63	0.49	0.12
Against Total Liabilities												
Equity	22	0.35	0.07	20	0.24	0.06	7	0.36	0.07	63	0.28	0.09
Bank notes	22	0.04	0.03	20	0.13	0.10	7	0.39	0.17	63	0.40	0.21
Deposits	22	0.43	0.13	20	0.51	0.09	7	0.23	0.12	63	0.27	0.20
Due to other banks	22	0.13	0.10	20	0.09	0.09	7	0.01	0.01	63	0.01	0.02

Note: This table is based on authors' calculations. Equity = Capital + surplus and profits.
Source: Authors' calculations using data from the *Reports of Several Banks and Savings Institutions of Pennsylvania.*

and reduced holdings of their interbank deposits in other local business hubs and elsewhere. The desire of Pennsylvania banks to hold more deposits in New York City banks might have originated from New York banks' ability to collectively act to prevent large crises through the clearinghouse.

The shift in the distribution of interbank deposits might have caused us to overestimate the systemic risk measures coming from New York City, as the 1859 data shows less connectivity to New York City. This means that the use of the 1862 network might inflate the probability of liquidation and default under the simulated shocks. As a result, by using 1862, we provide conservative estimates of the degree the degree of concentration at New York City and the resulting fragility of the 1867 system.

Table IV.2. Interbank Correspondent Relationships

	All Deposits		*Major Deposits*	
	1859	1862	1859	1862
PA banks in sample	78	89	78	89
Correspondent relationships per PA bank				
Mean	14.1	13.2	1.2	1.4
Max	54	43	3	3
Min	1	1	0	0
Number of correspondent banks of PA banks				
Pennsylvania	152	188	34	25
Non-Pennsylvania	223	129	21	29
- Union States	127	97	20	29
- Confederate States	96	32	1	0

Note: The table shows summary statistics of the correspondent relationships of Pennsylvania bank in 1859 and 1862. We show the average, maximum, and minimum number of relationships based on all the deposits and on the major deposit relationship. On average, the number of correspondent relationships increased from 1859 to 1862. In addition, we present the number of correspondent banks between the two years by location. The number of correspondents decreased overall, and the number of major correspondents increased because of the separation of Union and Confederate state bank relationships during the Civil War. Though we observe a shift in correspondents selection, the major correspondents of Pennsylvania banks were not affected, as all but one major correspondent were in the Union prior to the Civil War.
Source: Authors' calculations using data from the *Reports of Several Banks and Savings Institutions of Pennsylvania*.

Table IV.3. Distribution of Interbank Deposits: 1859 and 1862

	Total		Philadelphia		Pittsburgh		Country banks	
Year = 1859	$ amount	# links	% amount	% links	% amount	% links	% amount	% links
New York City	291,447	15	0.00	0.00	0.41	0.37	0.19	0.17
Philadelphia	1,017,777	43	0.78	0.56	0.23	0.25	0.59	0.45
Pittsburgh	105,736	7	0.00	0.00	0.06	0.13	0.08	0.08
Other PA	123,728	15	0.13	0.13	0.00	0.00	0.07	0.18
Other U.S.	143,987	15	0.08	0.31	0.30	0.25	0.07	0.11
Year = 1862	$ amount	# links	% amount	% links	% amount	% links	% amount	% links
New York City	3,863,434	62	0.64	0.29	0.77	0.56	0.30	0.27
Philadelphia	4,401,210	80	0.11	0.09	0.19	0.31	0.63	0.52
Pittsburgh	64,551	4	0.00	0.00	0.00	0.00	0.01	0.03
Other PA	287,582	30	0.10	0.25	0.03	0.06	0.02	0.11
Other U.S.	413,821	31	0.14	0.38	0.01	0.06	0.04	0.07

Notes: This table shows the distribution of correspondent deposits for the years 1859 and 1862 grouped by the origins and the destinations of interbank deposits. We classify respondent banks into three groups: Philadelphia, Pittsburgh, and country banks. In addition, we classify correspondent banks that receive interbank deposits from respondent banks into five classes. The first two columns show the absolute amount of interbank deposits and the total number of correspondent relationships. The rest of the columns show the fraction of deposits held at different locations against total major due-from deposits in Philadelphia, Pittsburgh, and country banks in Pennsylvania.
Source: Authors' diagrams using data from the *Reports of Several Banks and Savings Institutions of Pennsylvania.*