Interbank Networks in the Shadows of the Federal Reserve Act*

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Abstract

Central banks provide public liquidity (through lending facilities and promises of bailouts) with the intent to stabilize the financial system. Even though this provision is restricted to member (regulated) banks, an interbank system can provide indirect access to nonmember (shadow) banks. We construct a model to understand how a banking network may change in the presence of central bank interventions and how those changes affect financial fragility. We provide evidence showing that the introduction of the Fed’s liquidity provision in 1913 increased systemic risk through three channels; it reduced aggregate liquidity, created a new source of financial contagion, and crowded out private insurance for smoothing cross-regional liquidity shocks (manifested through the geographic concentration of networks).

Keywords: Dual Banking System, Federal Reserve Act, Shadow Banking, Interbank Networks, Systemic Risk

JEL Classification: G20, E50, N22

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1 Introduction

Since the global financial crisis of 2007-2009, the inability of unregulated (shadow) banks to access the Federal Reserve Bank’s traditional lending facilities, and the impact of this restriction on financial stability, has been a recurrent theme for policy and academic discussion. Should the Fed have extended these facilities to nonmember banks before the crisis? Was it the right policy to use emergency lending programs to extend the provision of public liquidity to shadow banks upon the crisis? These questions are not new. They were also prominent during the initial years of the Federal Reserve Bank, which was founded in 1913 to provide liquidity to member banks, through a discount window, but with the cost of stricter regulations. The Federal Reserve Act made membership compulsory for national banks, but voluntary for state banks, most of which did not join the Federal Reserve System. Instead, state banks accessed public liquidity indirectly by borrowing from member correspondent banks (CQ Researcher (1923)).

The Federal Reserve Act created an antecedent of shadow banks that operated in the U.S. without direct access to central bank liquidity and faced less strict regulations. Having a large number of banks outside the realm of the Federal Reserve System constrained the Fed’s ability to implement monetary policy, prevent crises, and steer the system during a recovery. Indeed, several studies have shown that the inability of nonmember banks to access central bank liquidity magnified the severity of banking crises during the Great Depression, leading to the creation of new and more extensive lending facilities, such as the Reconstruction Finance Corporation (Wicker (2000), Anbil and Vossmeier (2017)).

While much can be learned from the initial years of the Federal Reserve System, few studies have investigated how the introduction of the Fed’s liquidity provision affected the stability of the interbank system. Some studies examine the effect of Federal Reserve liquidity provision on seasonal liquidity pressures on the banking system (See Miron (1986), Mankiw et al. (1987), Bernstein et al. (2010), Carlson and Wheelock (2018b)). Others focus on the structure of interbank networks and its effect on systemic risk many years later, during the Great Depression (see Mitchener and Richardson (2016); Carlson and Wheelock (2018b)). By exploiting this unique historical event, we study how the Fed’s liquidity provision changed the nature and the stability of the interbank system of the National Banking era.

We construct various datasets for this study. First, we obtain yearly state-level balance sheet

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Footnotes:

1Banks placing deposits in other banks and banks receiving deposits are called respondents and correspondents, respectively. We use the terms “correspondent networks," “interbank networks," and “interbank system" interchangeably throughout the paper.

2For more information on the anatomy of bank networks during the National Banking Era, see Anderson et al. (2019, forthcoming).
information for state and national banks from 1910 to 1929. We use this data to study how
the Fed’s liquidity provision affected the aggregate amount of private liquidity in the system,
the extent of Fed membership and the differences in balance sheets between members and
nonmembers. Then, we augment this data with bank-level interbank linkage information
from the state of Kansas. With this detailed linkage information, we document how the
passage of the Federal Reserve Act changed the structure of the interbank network.

With the first dataset on aggregate balance sheets, we find that the introduction of the Federal
Reserve System reduced the aggregate liquidity held by the banking system. For member
banks, the proportion of assets held as cash assets and correspondent deposits decreased
significantly after the creation of the Fed, which can be easily attributed to a reduction in
both the reserve requirement under the Federal Reserve Act and the explicit access to public
liquidity. More surprisingly, however, nonmember banks also reduced liquid assets (both cash
in vault and deposits held in other banks) even though they were unaffected by changes in
reserve requirements and were not allowed to access public liquidity. This result is consistent
with heavier reliance on interbank relations to secure access to public liquidity. Accordingly,
we find a substantial increase in short-term borrowing after the Federal Reserve Act, both
for member and nonmember banks. While member banks increased short-term borrowing
from the Fed, nonmember banks did the same from member banks.

With the second dataset on correspondent linkages, we find that correspondent relationships
became more local after the Fed was founded. First, both member and nonmember banks in
Kansas shifted correspondent relationships away from New York and towards Kansas City.
Second, nonmember banks increased their connectivity to other local financial centers, such
as Wichita and Topeka. Lastly, banks established new relationships with other country
banks. These changes reduced the importance of New York banks in the banking system.
The interbank network changed from a national New York City-based core-periphery structure
with New York banks at the core and the rest of banks in the periphery to a regional reserve
city-based core-periphery structure with banks in local financial centers at the core.

How did these changes affect the risk of contagion and systemic risk in the U.S. banking
system? To answer this question we build a model to (i) understand the effect of public
liquidity provision on the overall liquidity of the banking system (ii) capture the changes in
the structure of interbank network and the behavior of its participants in response to the
public liquidity provision and (iii) examine how these changes affected the possibility and
direction of contagion. In our model, we have reserve city banks and country banks. Banks
in a reserve city (as was the case of New York) have investment projects, collect deposits from
country banks, and pay interest in return. This captures the in-core nature of the national
New York City-based core-periphery structure of the pre-Federal Reserve monetary system, with banks in the core with projects and banks in the periphery with liquidity.

Our study suggests that the founding of the Fed may have created a new source of contagion for the banking system by combining two factors. The first factor is a decline in aggregate liquidity due to increased reliance on central bank liquidity assistance. This made the system vulnerable because nonmember banks heavily relied on their corresponds for indirect access to public liquidity and member banks reduced cash holdings despite the fact that they had faced deposit withdrawal risk by nonmember banks. The second factor is the increased interbank lending activity between member and nonmember banks, which in turn increased the complexity of the network and the extent of contagion.

Further, changes in the structure of the interbank system suggest that the introduction of central bank liquidity crowded out private insurance that was previously provided by the interbank network. While deemed as a source for financial instability, the concentration of reserves in New York City also allowed banks to smooth local liquidity shocks. As New York City banks pooled reserves of a large number of banks across different regions, the interbank network was able to diversify regional shocks that were not correlated (Gilbert (1983)). The Fed’s introduction of public liquidity induced banks to rely more on their local correspondents at lower costs, because of shorter distances, better information, stronger relations, etc. In short, the introduction of public liquidity provision changed the nature of interbank relations. More specifically, financial center banks transformed from being a provider of private liquidity insurance to a conduit for public liquidity insurance.

Our study has important implications for policy today. The presumption that providing public liquidity to (traditional) banking insulates members from potential risks that arise from banks that are not subject to the Fed’s oversight seems naive. Banks that are not subject to regulatory constraints can access public liquidity indirectly through interbank operations. Should the Fed provide liquidity more broadly and introduce restrictions on interbank operations? This could potentially solve the problem of contagion at the cost of implementing inefficient allocations and insurance. Should the Fed extend the provision of liquidity to other banks without regulating them? What is the social cost of such an extension of direct access to liquidity? Our empirical finding and theoretical framework offer new perspectives to tackle these questions.

Our paper makes contributions to several strands of literature. First, it adds to the literature on the founding of the Federal Reserve System. Previous studies have found that the introduction of the Fed reduced financial volatility by smoothing seasonal liquidity pressures on the banking system (See Miron (1986), Mankiw et al. (1987), Bernstein et al. (2010), Carlson
and Wheelock (2018b)). We contribute to this literature by showing that the introduction of the Fed also affected financial stability by reducing the liquidity of the banking system, increasing contagion risk and building up systemic pressures.

Our paper also adds to the literature on shadow banking and central bank liquidity provision. Some scholars have studied the effect on financial stability of public liquidity provision to non-banks, during the financial crisis of 2007-2009 (Fleming (2012), Duygan-Bump et al. (2013)). Others have studied the transmission channels of monetary policy in the presence of shadow banking (See Adrian and Shin (2009), Chen et al. (2018)). We contribute to this literature by showing that the provision of public liquidity affects the structure of the shadow banking system, and how this could have caused unanticipated effects on systemic risk.

On the theoretical front, we apply a network structure to understand how interlinkages (both intensively on the degree of borrowing and extensively on the existence and anatomy of links) react to government interventions. There is recent literature that endogenizes the effects of public interventions to the functioning of banking networks. Erol and Ordoñez (2017), for example, study the interbank network reactions to banking regulations. They show that after a certain threshold liquidity and capital requirements that were intended to provide stability to the system may have the unanticipated consequence of dismantling a network structure that insures against financial shocks, then reducing systemic stability. In this paper we study how lending facilities to certain banks may harm both network functionality and total stability.

The remainder of the paper is organized as follows. The next section presents a model that introduces an external agent (central bank) that provides liquidity into a banking setting and show how that affects the holding of liquidity among banks, their linkages and relations. Section 3 present empirical evidence of a reduction in aggregate liquidity (both for Fed members and nonmembers), an increase in short-term borrowing and the possibilities of contagion, and a change in the geographical properties of the core-periphery network. Finally, we conclude.

2 Model

Although the Federal Reserve was introduced to provide liquidity to the banking system, many state banks chose not to join the System. Even though nonmember banks were not allowed to access the Fed’s discount window directly, they did it indirectly through their relation with member banks in financial centers. The goal of our model is to illustrate how the nonmember banks’ indirect access to the central bank liquidity affects 1) the aggregate
liquidity of the banking system, 2) the nature of interbank exposures, and 3) the structure
of interbank network.

Our model helps to understand the behavior of unregulated financial intermediaries (such as
mutual funds, investment banks, etc.) that are not considered banks in the traditional sense
(so-called shadow banks). These institutions do not have direct access to lending facilities
and bailouts, but they can access liquidity indirectly using interbank connections.

We begin with an environment with two banks to study how the introduction of central bank
liquidity affects aggregate liquidity and interbank exposures by incorporating the incentives
of banks. Then, we add more banks to study the structure of the interbank network.

2.1 Environment

The economy is composed by two banks, \( x \) (nonmember bank) and \( y \) (member bank in a
reserve city). Bank \( x \) accepts \( D \) household deposits and has access to a project that pays a
net rate of return \( r_x > 0 \). Bank \( y \) does not have deposits and has a project that pays a net
rate of return \( r_y > 0 \). Projects can be liquidated in full at any point in time to recover the
original investment. We use this to capture bank \( x \) as a country bank in the periphery that
makes deposits at a reserve city bank \( y \) in the core.

Reserves and investments. After investing in the projects, some depositors may need the
funds and to withdraw from \( x \) before projects reach maturity (liquidity shocks). Accordingly,
\( x \) wants to keep reserves to fulfill those needs, and may do so by holding cash or by depositing
at bank \( y \), earning net interest \( r \) where \( r < r_x \) and \( r < r_y \). Denoting \( \Phi_x \) the cash reserves that
\( x \) keeps at its vault, and \( L \) the amount that \( x \) deposits at \( y \), bank \( x \) invests \( I_x = D - \Phi_x - L \).
Assuming bank \( y \) is subject to reserve requirements in the form of holding a fraction \( \phi \) of
liabilities in cash, denoting \( \Phi_y \) the cash reserves that \( y \) keeps at its vault, \( \Phi_y \geq \phi L \). This
implies that \( y \) invests \( I_y = L - \Phi_y \). We call \( I_x \) and \( I_y \) investments, \( \Phi_x \) and \( \Phi_y \) cash reserves,
and \( L \) the interbank deposits. The transactions and obligations described thus far, absent
liquidity shocks, are shown in Figure 1.

Liquidity shocks. We denote the early demand for deposits by \( \zeta \in [0, D] \), where \( \zeta \) is drawn
randomly from a distribution with CDF denoted by \( S \). We call \( \zeta \) the liquidity shock. There
are various scenarios, in terms of projects’ liquidations, that can materialize depending on
the size of the liquidity shock. These are the possible cases:

\[^{3}\text{State regulators allowed state banks to keep reserves at reserve cities to meet reserve requirements. Reserve city banks paid 2\% (and no more than 2\%) interest on these deposits, which justify our assumption that } r \text{ is exogenous (See James (1978)).}\]
Figure 1 shows the flow of funds in the system absent a liquidity shock. Household depositors lend \( D \) to \( x \). \( x \) invests \( I_x \), makes interbank deposits \( L \) at \( y \), and keeps the rest of \( D \) as cash reserves. \( y \) invests \( I_y \) and keeps the rest of \( L \) as cash reserves. After projects mature, \( y \)'s project returns \( I_y(1+r_y) \). \( y \) pays \( L(1+r) \) of this to \( x \). \( x \)'s project returns \( I_x(1+r_x) \). Finally, \( x \) returns \( D \) to households. Liquidity shocks can disrupt this flow of funds by demanding early withdrawals by depositors. We have assumed that liquidation of projects covers the original investments so to focus on liquidity crises, as households can always be repaid \( D \) regardless of the shock.

1. If \( \zeta \leq \Phi_x + \Phi_y \), the combined cash reserves from \( x \) and \( y \) are sufficient to meet the liquidity shock.
   (a) If \( \zeta \leq \Phi_x \), withdrawals are met by \( x \)'s cash in vault.
   (b) If \( \Phi_x < \zeta \leq \Phi_x + \Phi_y \), \( x \)'s cash reserves are not enough and \( x \) borrows \( \Phi_y \) short-term from \( y \) to cover the withdrawals.\(^4\)

2. If \( \zeta > \Phi_x + \Phi_y \), the combined cash reserves from \( x \) and \( y \) are not enough to cover the liquidity shocks, in which case \( x \) must either liquidate its own project or withdraw its deposits from \( y \) to an extent that exceeds \( y \)'s cash reserves. The latter requires \( y \) into liquidating its project. These are the possibilities:
   (a) If \( \Phi_x + \Phi_y < \zeta \leq \Phi_x + L \), the deposits of \( x \) at \( y \) are enough to cover the liquidity needs, together with \( x \)'s cash, then \( x \) withdraws \( L \) from \( y \), who has to liquidate its project.\(^5\) Regardless of the fact that \( y \) must liquidate its project, \( x \) can recover \( L \) from \( y \) on demand.\(^6\)
   (b) If \( \Phi_x + L < \zeta \leq \Phi_x + \Phi_y + I_x \), \( x \) must also liquidate its own project as deposits at \( y \) are insufficient. The liquidation recovers \( I_x \), which, together with cash reserves \( \Phi_x \) and \( \Phi_y \), suffices to ride the shock. In this case, \( x \) can keep its deposits at \( y \).

\(^4\)Such lending is risk-free so we assume that \( y \) does not charge an interest for simplicity. Given this, whether \( x \) borrows \( \Phi_x + \Phi_y - \zeta \) or \( \Phi_y \) is inconsequential.

\(^5\)In principle, \( x \) could liquidate its own project before withdrawing its deposits from \( y \). This never happens in equilibrium because \( r_x > r \). Also, it is inconsequential whether \( x \) withdraws \( L \) or \( \Phi_x + L - \zeta \).

\(^6\)We assume that \( r \) is promised by \( y \) only if \( x \) keeps its deposits at \( y \) until the maturity of the project. Accordingly, if \( x \) needs to withdraw some of its deposits, it loses the claim to \( r \).
i. If $\Phi_x + L < \zeta \leq \Phi_x + I_x$, $x$ does not borrow from $y$.

ii. $\Phi_x + I_x < \zeta \leq \Phi_x + \Phi_y + I_x$, then $x$ borrows $\Phi_y$ short-term from $y$.

(c) If $\Phi_x + \Phi_y + I_x < \zeta$, neither $I_x$ from the liquidation of the project, nor deposits $L$ at $y$ suffice by themselves, hence $x$ liquidates its project and withdraws its deposits from $y$. In this case, $x$ makes no profit.

**Profits.** Summarizing these cases, the ex-post profit of bank $x$ is

$$
\pi_x = \begin{cases} 
I_x r_x + Lr & \text{if } \zeta \leq \Phi_x + \Phi_y \\
I_x r_x & \text{if } \Phi_x + \Phi_y < \zeta \leq \Phi_x + L \\
Lr & \text{if } \Phi_x + L < \zeta \leq \Phi_x + \Phi_y + I_x \\
0 & \text{o.w.}
\end{cases}
$$

From an ex-ante perspective, $\Gamma \equiv S[\Phi_x + L]$ is the probability that $x$’s project is not liquidated and $\Delta \equiv S[\Phi_x + \Phi_y] + (S[\Phi_x + \Phi_y + I_x] - S[\Phi_x + L])^+$ is the probability that $y$’s project is not liquidated, where $z^+ = \max \{0, z\}$. Then the expected profits of bank $x$ can be in general expressed by,

$$
\mathbb{E}[\pi_x] = \Pi_x = \Gamma I_x r_x + \Delta Lr
$$

Following similar arguments, the ex-ante profit of bank $y$ is

$$
\Pi_y = \Delta (I_y r_y - Lr).
$$

**Short term borrowing.** The amount of short-term borrowing by $x$ from $y$, is given by

$$
b = \begin{cases} 
\Phi_y & \text{if } \Phi_x < \zeta \leq \Phi_x + \Phi_y \\
\Phi_y & \text{if } \Phi_x + I_x < \zeta \leq \Phi_x + \Phi_y + I_x \\
0 & \text{o.w.}
\end{cases}
$$

The expected short term borrowing is then

$$
B \equiv \mathbb{E}(b) = (S[\Phi_x + \Phi_y + I_x] - S[\Phi_x + I_x] + S[\Phi_x + \Phi_y] - S[\Phi_x]) \Phi_y.
$$

**Timing and optimality.** Given the expected profits, bank $x$ chooses $L$ to lend to $y$, its cash
reserves $\Phi_x$ and investment $I_x$. Then $y$ chooses its cash reserves $\Phi_y \geq \phi L$ and investment $I_y$. Finally, liquidity shocks materialize. This timeline is summarized in Figure 2.

![Figure 2: Timeline of events](image)

**Upstream contagion.** Consider a realized shock $\zeta$. If $\zeta \leq \Phi_x + \Phi_y$, there is no spillover from $x$ to $y$. If $\Phi_x + L < \zeta \leq \Phi_x + I_x + \Phi_y$, $x$ liquidates its own project. In these two cases, there is no contagion from $x$ to $y$ in terms of forcing $y$’s project liquidation.

If $\Phi_x + \Phi_y < \zeta \leq L + \Phi_x$, then $x$ withdraws its deposits $L$. $x$’s project matures but $y$’s project gets liquidated. If $\Phi_x + \Phi_y + I_x < \zeta$, then both projects get liquidated. In both of these cases, $y$’s project gets liquidated. We call this situation *upstream contagion from $x$ to $y$*. The probability of upstream contagion is then $1 - \Delta$.

**Parametric specifications.** In order to have closed form results, we assume that $\zeta$ is drawn from a truncated uniform distribution. For some $\alpha \in [0,1]$, there is $1 - \alpha$ probability that there is no liquidity withdrawal and $\zeta = 0$. There is $\alpha$ probability that $\zeta$ is drawn from $U[0,D]$. Denote $z^\pm = \max\{0, \min\{1, z\}\}$. Then the expected profits of $x$ and $y$ are

$$\Pi_x = \left(1 - \alpha \frac{I_x}{D}\right)^\pm I_x r_x + \left(1 - \alpha \frac{2L - 2\Phi_y}{D}\right)^\pm L r$$

$$\Pi_y = \left(1 - \alpha \frac{2L - 2\Phi_y}{D}\right)^\pm (L (r_y - r) - \Phi_y r_y).$$

Expected short-term borrowing is

$$B = \frac{2\alpha \Phi_y^2}{D}.$$ 

Bank $y$ maximizes $\Pi_y$ by choosing $\Phi_y \geq \phi L$. Bank $x$ maximizes $\Pi_x$ subject to $I_x + L \leq D$ and the optimal continuation strategy of $y$. We assume $\phi < 1 - \frac{r}{r_y}$, because otherwise reserve requirements do not allow profit margins for $y$. In order to simplify the algebra and the exposition, we assume that $r_y < 2r$ throughout the paper, which ensures that reserve requirements bind for $y$, this is $\Phi_y = \phi L$.

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7We assume that $x$ makes a take offer $L$ to $y$, which is always accepted because $y$’s outside option is 0.
Proposition 1. If \( \alpha \geq \frac{3-2\phi}{4(1-\phi)} \), the equilibrium quantities are given by

\[
L = \frac{D}{4\alpha (1 - \phi)} \quad I_x = \frac{D}{2\alpha} \quad \Phi_x = D - I_x - L \quad \Phi_y = \phi L.
\]

If \( \frac{3-2\phi}{4(1-\phi)} \geq \alpha \geq \frac{r_x-r}{2r_x} \), the equilibrium quantities are given by

\[
L = \frac{D (2\alpha r_x - r_x + r)}{2\alpha (r_x + 2 (1 - \phi) r)} \quad I_x = D - L \quad \Phi_x = 0 \quad \Phi_y = \phi L.
\]

These cases are instructive about the pecking order to obtain funds. While \( y \)'s investment \( L \) is protected only by \( x \)'s cash reserves \( \Phi_x \), \( x \)'s investment \( I_x \) is protected by both cash reserves and interbank reserves \( \Phi_x + L \). Even though \( y \)'s investments generate higher returns, the fact that there are more reserves protecting \( I_x \) induces more investment in \( I_x \).

In Figure 3 we show that, as \( \alpha \) increases (this is, liquidity shocks become more likely), all instruments to deal with those shocks increase (more cash reserve, more expected borrowing, and more interbank deposits). This reaction comes at the expense of reducing illiquid investments.

Figure 3: Investments, interbank deposits, short term borrowing, and cash reserves

Figure 3 plots the equilibrium quantities as a function of the probability of a liquidity shock \( \alpha \) in line with Proposition 1. Illiquid investments are decreasing in risk. Since reserves protect the illiquid investment, reserves go up. Before risk becomes too high, interbank deposits are the preferred form of reserves compared idle cash reserves. At high risk, the returns promised on interbank deposits also need protection, and cash reserve substitute interbank deposits. Interbank deposits start falling yet the total total reserves keep increasing.
2.2 Introducing Central Bank Liquidity Provision

In this section we show that the public liquidity provision reduces aggregate liquidity in the banking system, including that of banks that do not have direct access to such liquidity. In addition, the public liquidity provision can make the banking system more vulnerable to regional shocks because banks reduce their connectivity to core banks that otherwise provides a private market to smooth out cross-regional liquidity shocks.

Suppose that there is now a central bank that provides short term liquidity to $y$, for a maximum amount $m$, which we refer to as the public liquidity provision ($m = 0$ is the baseline case of no liquidity provision in the previous analysis). Although bank $x$ is not a member of the Federal Reserve System, it can indirectly access the Fed’s liquidity facilities through its interbank relation with $y$. We are interested in how the ability of $x$ to indirectly access central liquidity affects $x$’ reserve holdings, and in turn affects contagion and systemic risk.

Notice that, regardless of the maximum size of the intervention $m$, bank $y$ does not want to keep any reserves and $\Phi_y = \phi L$. For bank $x$, using idle reserves $\Phi_x$ or borrowing at most $m$ from the central bank via $y$ are substitutes. Therefore, any shock $\zeta$ below $m$ can be met at no cost by banks. In contrast, a shock above $m$ will require banks to use their own reserves or a liquidation of projects. Therefore, from the viewpoint of the bank $x$ at the time of deciding its reserves, future shocks effectively are $\zeta' = (\zeta - m)^+$ in so far as liquidation is necessary. $\zeta'$ is 0 with probability $1 - \alpha + \alpha m D$ and it is drawn from $U[0,D-m]$ with probability $\alpha D - m D$. Then,

$$\Pi_{x,m} = \left(1 - \frac{I_x - m}{D}\right)^{\pm} I_x r_x + \left(1 - \frac{2L - 2\Phi_y - m}{D}\right)^{\pm} Lr$$

Define $\gamma = \frac{4 - 4\phi}{3 - 2\phi} - 1$, and $\beta = \frac{(2\alpha r_x - r_x + r)(1 - \phi)}{\alpha(3 - \phi)r_x + 3(1 - \phi)r}$. 

**Proposition 2.** If $\frac{m}{D} \leq \gamma$ the equilibrium quantities are given by

$$L = \frac{D + \alpha m}{4\alpha (1 - \phi)}, \quad I_x = \frac{D + \alpha m}{2\alpha}, \quad \Phi_x = D - I_x - L, \quad \Phi_y = \phi L.$$

If $\gamma \leq \frac{m}{D} \leq \beta$ the equilibrium quantities are given by

$$L = \frac{D (2\alpha r_x - r_x + r) - m\alpha (r_x - r)}{2\alpha (r_x + 2(1 - \phi)r)}, \quad I_x = D - L, \quad \Phi_x = 0, \quad \Phi_y = \phi L.$$

There are several effects of $m$ to highlight. First, the combined reserves of bank $x$, $\Phi_x + L$,
decrease in \( m \) in both cases. This is because central bank liquidity reduces the need for reserves. Second, interbank deposits \( L \) become an investment for \( x \). For low levels of \( m \) (first case), \( I_x \) and \( L \) increase with \( m \) because both are treated as investments. This leads to a steep reduction in cash reserves. When \( m \) becomes large enough (second case), \( x \) will not keep any cash reserves and only keeps interbank deposits. Then, as \( m \) goes up, \( x \) starts reducing interbank deposits \( L \) as it shifts its asset portfolio from low paying investment \( L \) to high paying investment \( I_x \).

The next proposition describes how short-term borrowing reacts to \( m \).

**Proposition 3.** Expected short term borrowing is

\[
B = \frac{2\alpha (\Phi_y + m)^2 + \alpha m^2}{D}
\]

which is strictly increasing in \( m \).

Figure 4 summarize the previous results for different levels of the public liquidity provision, \( m \). Bank \( x \) increases both its own investments \( I_x \) and the indirect investments through interbank deposits \( L \), reducing its cash reserves more elastically than its investments. Compared to the baseline, for medium \( m \), idle cash reserves \( \Phi_x \) are not necessary to protect the investment \( L \) as there are enough public funds to do so. Given this enhanced flexibility, bank \( x \) then increases its holdings of the high return investment \( I_x \) and reduces its interbank deposits \( L \) since they do not need these reserves to protect their investments.

Figure 4: Investments, interbank deposits, short term borrowing, and cash reserves

Figure 4 plots the equilibrium quantities as a function of central bank liquidity \( m \) in line with Propositions 2 and 3. Illiquid investments of \( x \) are increasing in \( m \). Interbank deposits \( L \) first increase, then decrease. Expectation of the short-term borrowing by \( x \) from \( y \) is increasing in \( m \). Cash reserves of \( x \) are decreasing. Note that \( y \)'s illiquid investments and cash reserves mimic \( L \) since \( I_x = (1 - \phi)L \) in equilibrium.
This simple analysis highlights the effect of public liquidity provision on investments and private reserves of shadow banks. Compared to the case without public provision of liquidity \((m = 0)\), shadow banks always invest more in illiquid assets and hold less cash reserves.

### 2.3 Systemic risk

To capture systemic risk, we consider two related concepts. One is financial fragility, which considers how frequently projects are (or expected to be) liquidated, even in the presence of public liquidity. The other is vulnerability, which considers how the system endogenously becomes dependent on public liquidity to avoid projects’ liquidation, this is how frequently projects are in need of liquidity, regardless of whether they end up being liquidated or not.

**Financial Fragility:** There are different facets of financial fragility. First, the *failure of a project* is the situation in which a project is liquidated, even though the project is funded with public liquidity. Second, the *expected failure of a project* is the probability that the project gets liquidated because public and private liquidity are not sufficient. Formally, for \(x\)'s and \(y\)'s projects separately, expected failure of \(y\)'s project is \(1 - \Delta_m\) and that of \(x\)'s project is \(1 - \Gamma_m\).

These concepts can be aggregated, given rise to two systemic concepts. First, the *expected systemic failure* is the probability that both projects get liquidated. This is \(1 - S[\Phi_x + \Phi_y + I_x + m]\). Second, the *expected idiosyncratic failure* is the probability that at least one project gets liquidated. This is \(1 - S[\Phi_x + \Phi_y + m]\).

**Proposition 4.** Expected failures are decreasing in \(m\) and decreasing in \(\phi\).

This result shows that more public liquidity prevents projects’ liquidation (naturally at the potential cost of public liquidity distortions), and then reduces financial fragility.

**Vulnerability:** There are also different facets of vulnerability. The *expected vulnerability of a project* is the probability that the project gets liquidated, regardless of whether public liquidity was used to avoid liquidation. The expected vulnerability of \(y\)'s project is \(1 - \Delta\), and of \(x\)'s project is \(1 - \Gamma\), which are evaluated at quantities given in Proposition 2 that are adjusted to \(m > 0\). Similar terms can be defined for the broader system. The *expected systemic vulnerability* is the probability that both projects need public liquidity and the *expected idiosyncratic vulnerability* is the probability that at least one project needs public liquidity. The former is \(1 - S[\Phi_x + \Phi_y + I_x]\) whereas the latter is \(1 - S[\Phi_x + \Phi_y + I_x + m]\) for quantities given in Proposition 2.
Proposition 5. For \( \frac{m}{D} \leq \gamma \), expected vulnerability is increasing in \( m \). For \( \gamma \leq \frac{m}{D} \leq \gamma \), expected vulnerability of \( x \) and expected idiosyncratic vulnerability are increasing in \( m \), whereas expected vulnerability of \( y \) and expected systemic vulnerability are decreasing in \( m \).

Vulnerability takes into account the reliance on central bank liquidity and provides a way to think about consequences of contractionary policies in terms of lower provision of public liquidity. For small \( m \), vulnerability of \( y \)'s project goes up because \( L \) goes up while for large \( m \) vulnerability of \( y \)'s project goes down because \( L \) goes down. On the other hand, vulnerability of \( x \)'s project goes up regardless, because the total reserves of \( x \), \( \Phi_x + L \), goes down. The main implication is that the public liquidity provision increases the vulnerability of the system to liquidation. A decline in the liquidity of the banking system makes nonmember banks highly reliant on public liquidity. In response, they endogenously exposed themselves to require such liquidity more frequently. Naturally, in the presence of distortions in providing liquidity the use of the public guarantee becomes more likely in equilibrium.

2.4 Networks

In this section, we extend our framework to study how the structure of the interbank network changes in response to central bank liquidity provision. We show that banks move their interbank relations towards counterparts that provide less insurance but are less costly to maintain. We take this to mean that banks reduce their connectivity to central reserve cities and increase their connections to regional reserve cities, with the consequence of public insurance crowding out private insurance against cross-regional liquidity shocks.

We extend our analysis to several banks. As a first step we focus on four banks in two pairs. More specifically, banks \( x_1 \) and \( y_1 \) are linked as described in the baseline, and the same is true for banks \( x_2 \) and \( y_2 \). We assume that banks \( x_1 \) and \( x_2 \) have household deposits and projects. In contrast, banks \( y_1 \) and \( y_2 \) have interbank deposits received from \( x_1 \) and \( x_2 \) and projects. We call \( \{x_1, x_2\} \) the periphery and \( \{y_1, y_2\} \) the core. As a next step we generalize the functioning of banks in the core.

We introduce these generalizations in Section 2.4.1. In Section 2.4.2 we study how core banks can coinsure each other through forming a sort of clearinghouse, and take this to capture New York banks. Finally, in Section 2.4.3, we allow periphery banks located in different regions to choose their correspondents from those that have greater coinsurance possibilities but may be far (say banks in New York) and those that have less coinsurance possibilities but may be closer (say banks located in regional reserve cities). This allows us to study the impact of the central bank’s liquidity provision \( m \) on the network structure. We show that central
bank liquidity induces a shift of links from the far-core (New York City) to the close-core (regional reserve cities), thereby crowding out private insurance that the system is able to provide.

### 2.4.1 Extended setting with two pairs of two banks

We assume that core banks, \( y_1 \) and \( y_2 \) each have access to central bank liquidity, capped at \( m \) in total. We also assume that the shocks \( x_1 \) and \( x_2 \) face are negatively correlated, so we rule out competition over central bank liquidity.

Denote \( \theta = \frac{\alpha}{2} \leq 0.5 \) the probability that the shock \( \zeta_1 \) is drawn from \( U[0, D] \) and that the shock \( \zeta_2 = 0 \). The parameter \( \theta \) is also the symmetric probability that the shock \( \zeta_2 \) is drawn from \( U[0, D] \) and that the shock \( \zeta_1 = 0 \). There is, then a probability \( 1 - 2\theta = 1 - \alpha \) that there is no shock, and \( \zeta_1 = \zeta_2 = 0 \). This specification implies that only one bank needs liquidity at a time and we do not need to model the priorities of the central bank over which bank to provide liquidity to, and how much. In other words, we abstract form aggregate liquidity shocks in the system, meaning all shocks are purely endogenous and induced by contagion.

Given these shock structure, the ex-ante profit of \( x_i \) is

\[
\Pi_{x_i} = \left( 1 - \theta \frac{I_{x_i} - m}{D} \right)^\pm I_{x_i} r_x + \left( 1 - \theta \frac{2L_i - 2\Phi_{y_i} - m}{D} \right)^\pm L_i r.
\]

As in the previous analysis, we will focus on a relatively low public liquidity provision. Defining \( \chi \equiv \frac{(2\theta r_x - (r_x - r))(1 - \phi)}{\theta (3 - \phi) r_x + 3(1 - \phi) r} \), we can show that,

**Proposition 6.** For \( 0 \leq m \leq D\chi \), equilibrium quantities are given by

\[
L_i = \frac{D (2\theta r_x - (r_x - r) - m\theta (r_x - r))}{2\theta (r_x + 2(1 - \phi) r)}, \quad I_{x_i} = D - L_i, \quad \Phi_{x_i} = 0, \quad \Phi_{y_i} = \phi L_i.
\]

### 2.4.2 Liquidity Coinsurance in the Network

Now we allow core banks \( y_1 \) and \( y_2 \) to insure each other against liquidity shocks coming from banks \( x \) by reallocating liquidity between the two. When \( x_i \) faces a liquidity shock, it can borrow from \( y_i \), who can also borrow from \( y_j \). Now ex-ante profits are giving by

\[
\Pi_{x_i} = \left( 1 - \theta \frac{I_{x_i} - m}{D} \right)^\pm I_{x_i} r_x + \left( 1 - \theta \frac{2L_i - 2\Phi_{y_i} - m}{D} \right)^\pm L_i r.
\]
Liquidity coinsurance, captured in the term $2\Phi_{y_i}$, reduces the liquidation risk of the interbank deposits of $x_i$.

**Proposition 7.** For $0 \leq m \leq D\chi$, equilibrium quantities are given by

$$L_i = \frac{D(2\theta r_x - r_x + r) - \theta m (r_x - r)}{2\theta (r_x + 2(1 - \phi)r - \phi r)}$$

$$I_{x_i} = D - L_i, \quad \Phi_{x_i} = 0, \quad \Phi_{y_i} = \phi L_i.$$

### 2.4.3 Endogenous network

In this section, we extend the framework to show that the provision of public liquidity insurance crowds out the provision of private liquidity insurance. This happens when the periphery banks’ choice of correspondents changes under the central bank liquidity provision and leads to the formation of a new network structure.

Let $x_i$ represent a bank in region $i$, which can place deposits in a local reserve city bank $y^C_i$ or a New York City bank $y^N_i$. Similarly, let $x_j$ represent a bank in region $j$, which can place deposits in a local reserve city bank $y^C_j$ or a New York City bank $y^N_j$. For both banks $x_i$ and $x_j$, placing deposits in New York City banks incurs a higher cost than placing deposits in regional reserve cities because of the geographical distance between respondents and correspondents. As discussed earlier, two New York City banks $y^N_i$ and $y^N_j$ insure each other against liquidity shocks by reallocating liquidity in the system. In the absence of the central bank, this framework, $x_i$ and $x_j$ will choose $y^N_i$ and $y^N_j$ in order to reduce their exposure to local liquidity shocks. Since liquidity shocks are not perfectly correlated between regions $i$ and $j$, $x_i$ and $x_j$ can smooth local liquidity shocks by adjusting their interbank deposits in New York City.

Now, assume that central bank liquidity $m$ is introduced. Since $x_i$ can mitigate local liquidity shocks by borrowing from a regional correspondent $y^C_i$ directly, we study conditions under which it will choose to connect to $y^C_i$ rather than $y^N_i$ because it is cheaper. Similarly, $x_j$ will choose to connect to $y^C_j$ rather than $y^N_j$. There are two options for equilibria. Banks can either connect to New York City banks for private insurance but pay higher costs, or they can connect to regional reserve city banks.

From the earlier analysis in Section 2.4.1, we know that if both banks connect to their regional correspondents, in equilibrium,

$$\Pi^C_{x_i} = \left(1 - \theta \left(\frac{D - L_C}{D} - m\right)\right) (D - L_C) r_x + \left(1 - \theta \frac{2(1 - \phi) L_C - m}{D}\right) Lr$$
where
\[ L_C = \frac{D (2\theta x - r_x + r) - m\theta (r_x - r)}{2\theta (r_x + 2 (1 - \phi) r)} \]

From the earlier analysis in Section 2.4.2, if both regions connect to NY, in equilibrium,

\[ \Pi_{x_i}^N = \left(1 - \theta \frac{D - L_N - m}{D}\right) (D - L_N) r_x + \left(1 - \theta \frac{2 (1 - 2\phi) L_N - m}{D}\right) L_N r - c \]

where
\[ L_N = \frac{D (2\theta x - r_x + r) - \theta m (r_x - r)}{2\theta (r_x + 2 (1 - \phi) r - \phi r)} \]

Define \( \eta \equiv \frac{\phi r ((4 - 5\phi) r + 2 r_x) (r_x - r)}{2 (2 (1 - \phi) r + r_x) ((2 - 3\phi) r + r_x)} \).

**Lemma 1.** Suppose that \( 0 \leq m \leq D\chi \).

\[ \frac{d (\Pi_{x_i}^{CL} - \Pi_{x_i}^N)}{dm} = -\eta (D (2\theta x - r_x + r) - \theta m (r_x - r)) < 0. \]

This means that even after accounting for endogenous deposit levels, the marginal benefit from cross-regional private insurance is reduced by the introduction of central bank liquidity. The marginal benefit decreases as the amount of central bank liquidity increases.

**Proposition 8.** There exists \( m^* \) such that, in equilibrium, for \( m < m^* \), both regions deposit their reserves at New York, and for \( m > m^* \) both regions deposit their reserves in their corresponding reserve cities.

Because central bank liquidity increases the ability of banks to absorb local liquidity shocks, this means \( x_i \) and \( x_j \) can reduce their reliance on New York City banks. The introduction of central bank liquidity enables banks to reduce their connectivity to New York and increase their connectivity to regional reserve cities, leading to a decline in the concentration of links in New York City and the emergence of a new network structure. These changes are illustrated in Figure 5.

### 2.5 Summary

Our simple model has highlighted three testable predictions of the potential implications of public liquidity provision, \( m \). We summarize these results here

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\^8\ We use stability as our solution concept which allows for \( x_1 \) and \( x_2 \) to deviate together.
Figure 5: Network reactions to public liquidity provision

Figure 5 illustrates the change in the structure of the regional interbank network. After a certain threshold of central bank liquidity $m$, the benefits of cross regional private insurance are offset by the geographical costs since public liquidity covers a large fraction of liquidity shocks.

1. **An increase in $m$ reduces aggregate liquidity.** Private liquidity holdings (cash and interbank deposits) reduce in both member and non-member banks.

2. **An increase in $m$ intensifies interbank relations.** More interconnections (in terms of short-term borrowing) increases the possibility of contagion, which increases the vulnerability of the system to regional liquidity shocks.

3. **An increase in $m$ dissipates the interbank network.** The network structure changes from a geographically concentrated core to a dissipated core, crowding out private insurance for cross-regional shocks.

3 Empirical Evidence

In this section we discuss empirically how the introduction of the Fed’s discount window changed aggregate liquidity in the banking system, the intensity of interbank relations and the structure of interbank networks.

3.1 The Interbank System Under the Federal Reserve System

In the 19th century, the U.S. banking system was fragmented due to restrictions on branching, which gave rise to an interbank system as an institutional response to coordinate interregional payments of goods and services. The interconnected nature of the U.S. banking system was solidified after the passage of the National Banking Act in 1863, which allowed national banks
to meet their reserve requirements by keeping interbank deposits in financial center banks.\textsuperscript{9} State bank regulators passed similar laws afterwards.

In addition to their use in meeting reserve requirements and allow for cross-state transactions, banks also maintained interconnections to manage seasonal swings in money and credit demands. Banks in agricultural regions, for instance, faced seasonal demands for cash and credit due to crop planting and harvesting in spring and fall. These agricultural banks withdrew their interbank deposits from financial centers in peak seasons, with those funds coming from other banks in areas where seasonal demands were less pressing. These regional differences in demand produced somewhat offsetting flows of interbank deposits in central Reserve City banks, which effectively provided private insurance across regions (see, for instance, Kemmerer (1910)).

While the interbank system helped banks to manage seasonal demands during agricultural cycles, it did not create additional liquidity. As a result, cash demands of country banks drained cash balances held in New York City banks and led to seasonal spikes in interest rates. Contemporaries thought these seasonal swings contributed to bank panics, which prompted calls for reform to create an \textit{an elastic currency} that would reduce the dependence on interbank relationships to reallocate funds across regions (Sprague (1910)).

In response to this financial landscape, the Federal Reserve System was created in 1913 with three primary objectives: to eliminate the concentration of bank reserves in New York City banks and replace it with 12 regional Reserve banks, to create an \textit{an elastic currency} to reduce seasonal volatility, and to prevent panics (Calomiris (1994)). The Fed offered a discount window to its member banks, but required banks to meet the new reserve requirement by placing deposits in 12 regional Federal Reserve Banks instead of reserve and central reserve city banks.\textsuperscript{10}

Under the Federal Reserve Act, member banks were classified into three groups: \textit{central reserve city banks} (those located in New York City, Chicago, or St. Louis), \textit{reserve city banks}

\textsuperscript{9}The National Banking Act classified national banks into three groups: \textit{central reserve city banks} (those located in New York City, Chicago, or St. Louis), \textit{reserve city banks} (banks in other selected large cities), and \textit{country banks} (banks in all other locations). Central reserve city banks were required to hold cash reserves equal to 25\% of their deposits. Reserve city banks were also required to hold reserves equal to 25\% of their deposits, of which one-half could be deposits with a correspondent bank in a Central reserve city. Lastly, Country banks were required to hold reserves equal to 15\% of their deposits, but they could keep three-fifths of the 15\% as deposits with a correspondent bank in reserve and/or central reserve cities.

\textsuperscript{10}Even though only member banks were given access to Fed services, including the discount window, the Act made it possible for the Fed to extend the discount window to nonmember banks in special circumstances with the approval of the Federal Reserve Board. Prior to 1923, for instance, the Board allowed member banks to discount eligible paper acquired from nonmember banks (See Hackley (1973), p. 119). Thereafter, the Board approved the extension of credit to nonmember banks only in exceptional circumstances (See Carlson and Wheelock (2013)).
(banks in other selected large cities), and country banks (banks in all other locations).\textsuperscript{11} Central reserve city member banks were required to hold 13% of demand deposits and 3% of time deposits as deposits with Federal Reserve Banks. Reserve city member banks were required to hold 10% of demand deposits and 3% of time deposits as deposits with Federal Reserve Banks. Lastly, country member banks were required to hold 7% of demand deposits and 3% of time deposits as deposits with Federal Reserve Banks. The Federal Reserve Banks did not pay interest on these deposits.

By requiring member banks to hold the reserve deposits of their local member banks and to furnish them with currency and additional reserves as needed to accommodate local demands, reformers wanted banks to obtain funds from the discount window of its local Reserve Bank instead of withdrawing deposits or borrowing funds from New York City banks. While the Federal Reserve Act succeeded in reducing the size of the interbank deposits, it could not eliminate the interbank network entirely. Deposits with the Federal Reserve Banks did not pay any interest, whereas deposits at city correspondents paid 2% interest. Hence, member banks continued to hold some deposits with correspondents to earn interest and diversify their asset portfolios (CQ Researcher (1923), Carlson and Wheelock (2018b)). In addition, a large fraction of state banks chose not to become members because they wanted to earn interest on their interbank deposits. Also, the Federal Reserve Act prohibited member banks from using interbank deposits to meet reserve requirements, while state regulators allowed state banks to do so (CQ Researcher (1923)).

The Act made it compulsory for national banks to join but voluntary for state banks. The founders of the Federal Reserve System hoped to bring state banks under a more unified system of regulation and supervision, but only a small fraction of state banks become members: by June 1915, only 17 state banks had become Fed members. More banks joined after a 1917 revision that lowered capital and reserve requirements. The lack of participation by state banks resulted in the creation of a parallel banking system which operated outside of the Federal Reserve System.

Figure 6 shows state bank membership rate per state in 1920. Membership grew slowly, eventually reaching a peak of 1,648 state banks (compared with 19,141 nonmember banks) in 1922 (Committee on Branch and Banking (1935)). Yet, a large fraction of state banks remained to operate outside the Federal Reserve System.\textsuperscript{12} Figure 7 shows the proportion of nonmember banks against total commercial banks from 1914 to 1929. By December 1929,

\textsuperscript{11}The reserve requirements were first introduced in 1913 and went into effect in 1914. They were amended in 1917.

\textsuperscript{12}In terms of relative size, member banks tended to be larger than nonmembers but nonmembers still held a sizable fraction of total deposits. In 1923, for instance, nonmember banks held more than a third of total U.S. commercial bank deposits ($10.6 billion of a total of $37.7 in the whole system).
nonmember banks comprised 65% of all commercial banks (only 10% of state banks were members) and a 25% of total deposit holdings.

Figure 6: State Bank Federal Reserve System Participation Rate by State

Figure 6 shows state bank Federal Reserve System participation rate by state in 1920. 

Having a large fraction of state banks outside the realm of the Federal Reserve System had major implications for the nature of the interbank system. In what follows we will show that this led to a large number of banks accessing the Fed’s discount indirectly through their correspondents. Before the Fed was established, country banks borrowed short-term funds from their correspondents. After the Fed was established, they started relying more intensively on their correspondents to borrow for short periods with the understanding that when city correspondents ran out of funds, they would go to the Fed and rediscount their own eligible paper to replenish liquidity positions.

3.2 Data Sources

We use various datasets to examine how the introduction of the Federal Reserve’s liquidity provision changed the structure of the interbank network and affected the stability of the banking system (both ex-ante, this is vulnerability and ex-post, this is fragility).

First, we construct aggregated balance-sheet data. We use state-level yearly balance sheet information for national and state banks from 1910 to 1929 using the Annual report of the
Figure 7: Share of Federal Reserve Member Banks, 1914-1929

Figure 7 shows the proportion of national, state member, and state nonmember banks from 1914-1929. National and state member banks were members of the Federal Reserve System, whereas state nonmember banks were not.

Source: Committee on Branch, Group, and Chain Banking, 1932.

Comptroller of the Currency. We use information reported the last day of each June.\textsuperscript{13} The OCC report provides national bank data divided into three classes based on where they resided, \textit{central reserve cities}, \textit{reserve cities} and \textit{counties}.\textsuperscript{14} The report does not provide state-bank data classified according to their location. Because all national banks were members of the Federal Reserve System and few state banks became members of the Federal Reserve System (Figure 7), in what follows we will treat generically national banks as a proxy for member banks and state banks as a proxy for nonmember banks.

Second, we construct a micro-level \textit{interbank linkage data}. We collect linkage information for all banks in Kansas banks for 1910 and 1920 using the \textit{Biannual Report of the Bank Commissioner of the State of Kansas} and the \textit{Polk Bankers’ Directory}. The \textit{Biannual Report} provides complete correspondent information for state banks, which is collected by state supervisors for regulatory purposes. The \textit{Directory} provides self-reported principal correspondents for all banks in the United States.\textsuperscript{15} As a result, these correspondents tended to be major national banks in reserve and central reserve cities. We use the \textit{Directory} to collect correspondent information for national banks. We then use these sources to examine the differences in the structure of the interbank network between member and nonmember banks over time.

\textsuperscript{13}While the report provided national bank balance sheet information at the quarterly frequency, it only provided state bank balance sheet information for the last day of June.

\textsuperscript{14}Data for central-reserve cities is constructed at the city level for three cities: New York City, Chicago, and St. Louis. Data for reserve cities is constructed at the city level for 17 cities: Albany, NY; Baltimore, MD; Boston, MA; Cincinnati, OH; Cleveland, OH; Detroit, MI; Kansas City, MO; Louisville, KY; Milwaukee, WI; Minneapolis, MN; New Orleans, LA; Omaha, NE; Philadelphia, PA; Pittsburgh, PA; Saint Joseph, MO; Saint Paul, MN; and San Francisco, CA. Finally, data for country national banks is constructed at the state-level.

\textsuperscript{15}Other studies have used bankers’ directories to study the interbank system. For instance, Carlson et al. (2011) used the \textit{Rand McNally Bankers’ Directory} and the \textit{Polk Bankers’ Directory} to examine how the Fed’s intervention mitigated the severity of banking crises in Florida in 1929.
3.3 Balance Sheet Analysis

As discussed above, we use national banks as a proxy for member banks and state banks as a proxy for nonmember banks. The decision of whether to become a member or not affected banks’ liquidity demand because it determined reserve requirements and affected the ability of banks to borrow from the Fed. While member banks were subject to reserve requirements under the Federal Reserve Act, nonmember banks were subject to state-specific reserve requirements. The Federal Reserve Act made two important modifications on reserve requirements. It lowered reserve requirements for member banks, while it left state banks unaffected. In addition, it prohibited member banks to use interbank deposits to meet reserve requirements, whereas state regulators allowed nonmember banks to use interbank deposits to satisfy reserve requirements. Member banks could access the Fed’s discount window whereas nonmember banks could not.

Table 1 provides summary statistics on balance sheet ratios for national and state banks from 1910 to 1929, with a gap between 1918 and 1920. We do not show data from 1918 to 1920 for two reasons. First, during this gap there is no separate information of interbank deposits due from other banks and due from the Federal Reserve Bank. Secondly, during World War I, the Fed offered a preferential discount rate on loans secured by government debt to support the War. The Fed removed this preferential rate and raised its discount rate in 1920-1921. More generally, the period between 1915-1920 is transitory. After its founding, the Fed provided a three-year phase-in period for member banks to adjust to new reserve requirements. In addition, the amendment was passed in 1917 to lower reserve requirements to attract more state banks.

We begin by examining the volume of short-term borrowing by banks.\textsuperscript{16} Panel (a) of Figure 8 plots the ratio of short-term borrowing to total liabilities for banks, distinguishing between national (member) banks in the first panel and state (mostly nonmember) banks in the second. Before the introduction of the Fed, short-term borrowing was not large. In addition, national banks borrowed less than state banks (roughly 1\% versus 2\%).\textsuperscript{17} After the introduction of the Fed, both types of banks increased their borrowing, but national banks increased borrowing more than state banks; while state banks almost duplicated their relative borrowing, national banks more than triplicated it. These patterns suggest that national banks were borrowing more to fund short-term borrowing by state banks.

\textsuperscript{16}Short-term borrowing consisted of "bills rediscounted" and "bills payable." "Bills rediscounted" were loans sold with recourse. "Bills payable" were composed of promissory notes of the borrowing bank and borrowing from Federal Reserve Banks in the 1920s.

\textsuperscript{17}These patterns are driven by the fact that reserve city and central reserve city banks generally borrowed less frequently than country banks (See Carlson and Wheelock (2018b)).
Table 1: Summary Statistics, 1910-1917 and 1921-1929

<table>
<thead>
<tr>
<th></th>
<th>National Banks</th>
<th>State Banks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1910-1917</td>
<td>1921-1929</td>
</tr>
<tr>
<td>cash to assets</td>
<td>6.056</td>
<td>1.769</td>
</tr>
<tr>
<td></td>
<td>(2.887)</td>
<td>(0.705)</td>
</tr>
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<td>duefroms to assets</td>
<td>14.36</td>
<td>7.615</td>
</tr>
<tr>
<td></td>
<td>(6.167)</td>
<td>(3.487)</td>
</tr>
<tr>
<td>equity to liabilities</td>
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<td>13.2</td>
</tr>
<tr>
<td></td>
<td>(9.467)</td>
<td>(2.92)</td>
</tr>
<tr>
<td>deposits to liabilities</td>
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<td>69.94</td>
</tr>
<tr>
<td></td>
<td>(24.16)</td>
<td>(9.05)</td>
</tr>
<tr>
<td>duetos to liabilities</td>
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<td>8.39</td>
</tr>
<tr>
<td></td>
<td>(13.91)</td>
<td>(5.545)</td>
</tr>
<tr>
<td>borrowing to liabilities</td>
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</tr>
<tr>
<td></td>
<td>(2.359)</td>
<td>(3.544)</td>
</tr>
<tr>
<td>obs.</td>
<td>567</td>
<td>630</td>
</tr>
</tbody>
</table>

Table 1 displays summary statistics for national and state banks during the period 1910-1929. Cash is composed of specie and legal tender notes. Duefroms are interbank deposits due from other banks. Equity is composed of paid in capital and surplus. Duetos are interbank deposits due to other banks. Borrowing is short-term borrowing from other banks or the Federal Reserve Bank. 

Source: *Annual report of the Comptroller of the Currency.*
Now we turn attention into the most liquid asset on the balance sheet. Panel (b) of Figure 8 plots the share of bank assets held in the form of vault cash for both national and state banks from 1910 to 1929. While all banks held less cash after the Fed was introduced, the reduction was larger for national banks (from 6.1% to 1.8%) than for state banks (from 4.3% to 2.4%). While the reduction for national banks resulted directly from access to central bank liquidity and lower reserve requirements, the reduction for state banks is largely explained by indirect access to central bank liquidity.

Next, we examine the movement of interbank deposits. Panel (c) of Figure 8 shows the evolution of deposits due from other banks. Both for national and state banks the relative deposits in other banks declined roughly by 50% (from around 14% to around 8% in both cases). Panel (d) of Figure 8 shows the evolution of deposits due to other banks. In this case, the large decline was mostly experienced by national banks that used to be correspondents and received most of the interbank deposits in the system. For national banks, a reduction in the volume of interbank deposits due from and due to other banks was likely a direct consequence of the National Banking Act, which prohibited them from using interbank deposits to meet reserve requirements. In contrast, for state banks, a decline in the volume of due from deposits was less mechanical as they were still able to meet reserve requirements by holding interbank deposits.

In Figure 9, we replicate the previous two figures for national banks in each geographical classification group and examine their relationships with national versus state banks separately. In Panel (a) of Figure 9, we examine national banks’ deposits due from other national banks and their deposits due from other state banks. National banks held most of their deposits in other national banks and very little in state banks. After the founding of the Fed, the share of bank assets held in the form of deposits due from other national banks declined significantly for all three groups of national banks. This suggests that there was a reduction of private insurance after the introduction of the Fed among national banks.

In Panel (b) of Figure 9, we look at national banks’ deposits due to other national banks and their deposits due to other state banks. After the founding of the Fed, national banks in both reserve and central reserve cities saw a large reduction in the volume of their deposits due to other national banks. However, they did not see a significant decline in the volume

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18Vault Cash was composed of specie and legal tender notes.
19Deposits due from other banks are deposits held in correspondents and are thus assets of that bank. In contrast, deposits due to other banks are deposits that other banks hold with a correspondent national bank and are thus liabilities of the correspondent bank.
20Note that the gap is larger in these two figures when compared to the rest because the OCC did not separate "deposits due from other banks" into "deposits due from other national banks" and "deposits due from other state banks" between 1915 and 1917. Similarly, it did not report "deposits due to other national banks" and "deposits due to other state banks" separately.
of their deposits due to other state banks. In other words, despite the reduction of private cross-insurance, national banks in financial centers were still vulnerable to runs by state banks.

**Robustness:** We check the robustness of our findings by restricting the data in two dimensions. First, we restrict our sample using state bank participation rate. As shown in Figure 6, states with financial and manufacturing sectors displayed a higher proportion of state bank membership than agricultural states. Given the irregular geographic distribution of membership, one might be concerned that the described changes were generated by state member banks, and as such, our classification of all state banks as nonmembers clutter the analysis. To alleviate this concern, we restrict our sample and compare the asset composition of member and nonmember banks in states where the Fed membership ratio of state banks was under 10 percent in 1920.

Second, we restrict our sample using state-level reserve requirements. Changes in the liquidity of the state banking system might be driven by changes in reserve requirements by state regulators rather than voluntary liquidity changes. In order to rule out this possibility, we divided states into three groups: (1) states that decreased reserve requirements, (2) states that increased reserve requirements, and (3) states that did not change reserve requirements. Between 1910 and 1929, 22 states reduced reserve requirements, while 10 states increased reserve requirements. The remaining states kept reserve requirements unchanged.\(^{21}\)

Figure 10 plots the fraction of total assets that state banks in states where state bank participation rate was below 10 percent held in borrowing, cash and interbank deposits. In all cases, and regardless of the change in reserve requirements, nonmember banks reduced cash and interbank deposits and increased borrowing after the Fed’s founding in 1914.

To summarize, we find that the presence of the Fed reduced liquidity (in the form of cash and interbank deposit) and intensified interbank relations (in the form of higher short-term borrowing) for both member and nonmember banks. Furthermore, member banks significantly reduced their relations with other member banks, but not their relation with nonmember banks. These factors suggest less private cross-insurance but still exposure to withdrawals, which contributed to the possibility of more contagion and vulnerability of the financial system.

\(^{21}\)See White (2014) for information on state reserve requirements. We classify DE, CA, DE, GA, IN, KS, KY, LA, MI, MN, MT, NM, NY, OK, OR, PA, SD, TX, VA, WA, WV, WI as states with decreasing reserve requirements. In addition, we classify AR, CO, IA, MD, MS, NH, SC, TN, VT, WY as states with increasing reserve requirements. Lastly, we classify AL, CT, FL, ID, IL, ME, MA, MO, NE, NV, NJ, NC, ND, OH, OK, UT as states that did not change reserve requirements.
3.4 Network Analysis

In this section we study how the introduction of the Federal Reserve System affected the structure of the interbank system in Kansas, where only 9 out of 1096 state banks became Fed members. We compare the network structure of national (member) banks to that of state (nonmember) banks. Recall that there were two major differences between these two types of banks. First, nonmember banks relied on their city correspondents to access the Federal Reserve liquidity, whereas member banks could access the Fed’s discount window directly. Second, nonmember banks continued to hold large deposits in financial centers whereas member banks reduced interbank deposits. This was partly because state banks could meet reserve requirements by holding interbank deposits in reserve and central reserve cities, whereas member banks were not allowed to do so under the Federal Reserve Act.

Table 2 shows the number of national and state banks in 1910 and 1920, by location (banks in Kansas City, Topeka, and Wichita were reserve city banks and banks outside these cities were classified as country banks). The banking system was dominated by state nonmember banks (80 percent of all banks were state banks). There were a relatively small number of national banks in the three Kansas reserve cities because all major national banks were located on the Missouri side of Kansas City.

<table>
<thead>
<tr>
<th></th>
<th>Reserve City Banks</th>
<th>Country Banks</th>
<th>Reserve City Banks</th>
<th>Country Banks</th>
</tr>
</thead>
<tbody>
<tr>
<td>National</td>
<td>9</td>
<td>198</td>
<td>11</td>
<td>241</td>
</tr>
<tr>
<td>State</td>
<td>28</td>
<td>826</td>
<td>46</td>
<td>1044</td>
</tr>
</tbody>
</table>

Table 2 shows the number of banks for indicated groups in 1910 and 1920.


Of these banks, we have complete correspondent linkages for state banks, but only partial information for national banks. The self-reported nature of national bank data means that national banks’ correspondent linkages represented relationships between respondent banks in Kansas and correspondents in reserve and central reserve cities. Due to this difference, we restrict our state bank data and focus on the interbank relationships between respondent banks in Kansas and correspondent banks in reserve and central reserve cities. In addition, we consolidate correspondent links to Kansas City, KS and Kansas City, MO and call it Kansas City. Lastly, because we want to focus on the effect of central bank liquidity on existing relationships, we analyses banks that were present in both 1910 and 1920.
Table 3 shows that both national and state banks had a high proportion of correspondent relationships with banks in Kansas City. While both types of banks relied on other financial centers (New York in particular) as well, state banks tended to rely more heavily on correspondents in Kansas City. After the introduction of the Fed, both types of banks moved their correspondent relationships away from New York and other central reserve and reserve cities located outside Kansas into Kansas City and other reserve cities in Kansas. In other words, the presence of the Fed encouraged banks to rely on local correspondents more heavily.

To have a more complete picture, we now re-examine how the introduction of the Fed affected the interbank system by focusing only on state banks and using their complete correspondent information (not only those to central reserve and reserve cities). Table 4 confirms that there was a shift from New York and other reserve cities outside Kansas to Kansas City and other reserve cities in Kansas. In addition, country banks in Kansas increased the proportion of country bank correspondents within Kansas. This was driven by both an increase in the proportion of links in important local towns (such as Atchison, Hutchinson, and Salina) and an increase in the number of towns with banks that began to serve as correspondents. In other words, the presence of the Fed made correspondent relationships more local in the sense that the core resided in the state.

To identify more clearly the change in the geographical concentration of the interbank system, we compute the distances between respondent and correspondent banks in kilometers. Table 5 reports the result. It shows that the presence of the Fed led banks to choose correspondents located in close geographic proximity. Only the longest distance of reserve city banks remained unchanged, most likely because those particular banks continued to maintain their relationships with New York City banks.

Unlike national banks, state banks could meet their reserve requirements by holding interbank deposits in any approved reserve and/or central reserve city banks. Even though this rule remained unchanged, Kansas state banks chose to reduce their connectivity to New York City. Their decision to hold interbank deposits locally reflects a reduction in their need to rely on New York banks to diversity interbank deposits and reduce their exposures to local shocks. This shift in the network structure suggests that the presence of the Fed enabled these banks to rely on public liquidity provision at the expense of the previous private liquidity provision.

The importance of New York banks to provide the private insurance arrangement for regional liquidity shocks was well documented. First, the flows of withdrawals and deposits were not perfectly correlated across different regions, so outflows of funds in some regions were partly offset by inflows of funds in other regions through the adjustment of interbank balances in New York (Carlson and Wheelock (2018a)). Second, by pooling bank reserves from banks in
Table 3: Interbank Network, Kansas State Banks, 1910 and 1920.

<table>
<thead>
<tr>
<th></th>
<th>Reserve City Banks</th>
<th>Country Banks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percentage</td>
</tr>
<tr>
<td>New York</td>
<td>24</td>
<td>22.64</td>
</tr>
<tr>
<td>Chicago</td>
<td>9</td>
<td>8.49</td>
</tr>
<tr>
<td>St. Louis</td>
<td>6</td>
<td>5.66</td>
</tr>
<tr>
<td>Kansas City</td>
<td>42</td>
<td>39.62</td>
</tr>
<tr>
<td>Topeka</td>
<td>4</td>
<td>3.77</td>
</tr>
<tr>
<td>Wichita</td>
<td>15</td>
<td>14.15</td>
</tr>
<tr>
<td>Other reserve cities</td>
<td>2</td>
<td>1.89</td>
</tr>
<tr>
<td>Country banks in Kansas</td>
<td>3</td>
<td>2.83</td>
</tr>
<tr>
<td>Country banks in other states</td>
<td>1</td>
<td>0.94</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Reserve City Banks</th>
<th>Country Banks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percentage</td>
</tr>
<tr>
<td>New York</td>
<td>27</td>
<td>20.61</td>
</tr>
<tr>
<td>Chicago</td>
<td>8</td>
<td>6.11</td>
</tr>
<tr>
<td>St. Louis</td>
<td>7</td>
<td>5.34</td>
</tr>
<tr>
<td>Kansas City</td>
<td>63</td>
<td>48.09</td>
</tr>
<tr>
<td>Topeka</td>
<td>7</td>
<td>5.34</td>
</tr>
<tr>
<td>Wichita</td>
<td>11</td>
<td>8.4</td>
</tr>
<tr>
<td>Other reserve cities</td>
<td>4</td>
<td>3.05</td>
</tr>
<tr>
<td>Country banks in Kansas</td>
<td>1</td>
<td>0.76</td>
</tr>
<tr>
<td>Country banks in other states</td>
<td>3</td>
<td>2.29</td>
</tr>
</tbody>
</table>

Table 4 provides information on the number of links each city received from reserve city and country banks in Kansas. New York, Chicago, and St. Louis were central reserve cities. Kansas City, Topeka and Wichita were reserve cities in Kansas. Kansas city data is aggregated across Kansas City, KS and Kansas City, MO. The linkage data is aggregated across these cities and used to calculate the proportion of links in each city. 

Figure 8: Aggregate Balance Sheet Ratios, 1910-1929

<table>
<thead>
<tr>
<th>National Banks</th>
<th>State Banks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a): Short-Term Borrowing as Share of Total Liabilities</td>
<td></td>
</tr>
<tr>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
</tr>
<tr>
<td>(b): Vault Cash as Share of Total Bank Assets</td>
<td></td>
</tr>
<tr>
<td><img src="image3" alt="Graph" /></td>
<td><img src="image4" alt="Graph" /></td>
</tr>
<tr>
<td>(c): Deposits due from other banks as Share of Total Bank Assets</td>
<td></td>
</tr>
<tr>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
</tr>
<tr>
<td>(d): Deposits due to other Banks as Share of Total Bank Liabilities</td>
<td></td>
</tr>
<tr>
<td><img src="image7" alt="Graph" /></td>
<td><img src="image8" alt="Graph" /></td>
</tr>
</tbody>
</table>

Figure 8 plots the ratio of short-term borrowing to total liabilities for national and state banks. Data for national banks are aggregated across all U.S. states, 17 reserve cities, and three central reserve cities. Data for state banks are aggregated across all U.S. states, all reserve cities, and reserve cities by the OCC. Source: Annual report of the Comptroller of the Currency.
Figure 9: Interbank Deposits, National Banks in Tier Groups, 1910-1929

(a): Deposits due from other Banks

<table>
<thead>
<tr>
<th>Year</th>
<th>Central Reserve City Banks</th>
<th>Reserve City Banks</th>
<th>Country Banks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1910</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>1911</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>1912</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>1913</td>
<td>0.09</td>
<td>0.09</td>
<td>0.09</td>
</tr>
<tr>
<td>1914</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>1921</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>1922</td>
<td>0.18</td>
<td>0.18</td>
<td>0.18</td>
</tr>
</tbody>
</table>

(b): Deposits due to other Banks

<table>
<thead>
<tr>
<th>Year</th>
<th>Central Reserve City Banks</th>
<th>Reserve City Banks</th>
<th>Country Banks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1910</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>1911</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>1912</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>1913</td>
<td>0.09</td>
<td>0.09</td>
<td>0.09</td>
</tr>
<tr>
<td>1914</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>1921</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>1922</td>
<td>0.18</td>
<td>0.18</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Figure 9 plots the ratio of deposits to other banks against total liabilities for national banks in each tier group. The table examines national banks’ deposits due to other national banks and their deposits due to other state banks separately. Data for country banks are aggregated across all U.S. states; data for reserve city banks are aggregated across 17 reserve cities; and data for central reserve cities are aggregated across the three central reserve cities.

Source: *Annual report of the Comptroller of the Currency.*
Figure 10: Bank Liquidity and Changes in State-Level Reserve Requirements, 1910-1929

Figure 10 plots the share of short-term borrowing against total liabilities, the share of vault cash against total assets, and the share of deposits due from other banks against total assets for states with different reserve requirements. Data is further restricted for states where the Fed membership ratio of state banks was under 10 percent in 1920. Data for national banks are aggregated across all U.S. states, 17 reserve cities, and three central reserve cities. Data for state banks are aggregated across all U.S. states, all reserve cities, and reserve cities by the OCC.

Source: Annual report of the Comptroller of the Currency.
Table 4: Distance between Respondent and Correspondent Banks

<table>
<thead>
<tr>
<th></th>
<th>1910 Reserve City Banks</th>
<th>1910 Country Banks</th>
<th>1920 Reserve City Banks</th>
<th>1920 Country Banks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longest distance</td>
<td>1895.9</td>
<td>1543.6</td>
<td>1883.8</td>
<td>1303.6</td>
</tr>
<tr>
<td></td>
<td>(221.7)</td>
<td>(747.6)</td>
<td>(279.1)</td>
<td>(845.0)</td>
</tr>
<tr>
<td>Shortest distance</td>
<td>44.17</td>
<td>113.3</td>
<td>27.33</td>
<td>91.31</td>
</tr>
<tr>
<td></td>
<td>(76.13)</td>
<td>(124.3)</td>
<td>(69.54)</td>
<td>(110.7)</td>
</tr>
<tr>
<td>Mean distance</td>
<td>592.4</td>
<td>561.4</td>
<td>551.7</td>
<td>433.1</td>
</tr>
<tr>
<td></td>
<td>(171.4)</td>
<td>(286.8)</td>
<td>(215.1)</td>
<td>(260.9)</td>
</tr>
<tr>
<td>Median distance</td>
<td>214.2</td>
<td>310.2</td>
<td>234.8</td>
<td>245.0</td>
</tr>
<tr>
<td></td>
<td>(268.6)</td>
<td>(261.0)</td>
<td>(258.4)</td>
<td>(189.5)</td>
</tr>
<tr>
<td>Total distance</td>
<td>3015.4</td>
<td>2322.4</td>
<td>3265.1</td>
<td>2191.8</td>
</tr>
<tr>
<td></td>
<td>(1552.2)</td>
<td>(1300.9)</td>
<td>(1503.8)</td>
<td>(1553.3)</td>
</tr>
<tr>
<td>Obs.</td>
<td>106</td>
<td>2730</td>
<td>131</td>
<td>3166</td>
</tr>
</tbody>
</table>

Table 5 provides information on geographical distances between respondent and correspondent banks in kilometers. It shows that the presence of the Fed led banks to choose correspondents located in close geographic proximity.

Table 5: Interbank Network, Kansas Banks, 1910 and 1920.

<table>
<thead>
<tr>
<th></th>
<th>National Banks</th>
<th></th>
<th>State Banks</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reserve City Banks</td>
<td>Country Banks</td>
<td>Reserve City Banks</td>
<td>Country Banks</td>
</tr>
<tr>
<td></td>
<td>Number</td>
<td>Percentage</td>
<td>Number</td>
<td>Percentage</td>
</tr>
<tr>
<td>New York</td>
<td>7</td>
<td>25.93</td>
<td>184</td>
<td>36.44</td>
</tr>
<tr>
<td>Chicago</td>
<td>10</td>
<td>37.04</td>
<td>60</td>
<td>11.88</td>
</tr>
<tr>
<td>St. Louis</td>
<td>5</td>
<td>18.52</td>
<td>38</td>
<td>7.52</td>
</tr>
<tr>
<td>Kansas City</td>
<td>4</td>
<td>14.81</td>
<td>209</td>
<td>41.39</td>
</tr>
<tr>
<td>Topeka</td>
<td>2</td>
<td>0.40</td>
<td>4</td>
<td>3.92</td>
</tr>
<tr>
<td>Wichita</td>
<td>8</td>
<td>1.58</td>
<td>15</td>
<td>14.71</td>
</tr>
<tr>
<td>Other Reserve Cities</td>
<td>1</td>
<td>3.70</td>
<td>4</td>
<td>0.79</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>National Banks</th>
<th></th>
<th>State Banks</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reserve City Banks</td>
<td>Country Banks</td>
<td>Reserve City Banks</td>
<td>Country Banks</td>
</tr>
<tr>
<td></td>
<td>Number</td>
<td>Percentage</td>
<td>Number</td>
<td>Percentage</td>
</tr>
<tr>
<td>New York</td>
<td>12</td>
<td>30</td>
<td>191</td>
<td>32.54</td>
</tr>
<tr>
<td>Chicago</td>
<td>10</td>
<td>25</td>
<td>52</td>
<td>8.86</td>
</tr>
<tr>
<td>St. Louis</td>
<td>6</td>
<td>15</td>
<td>21</td>
<td>3.58</td>
</tr>
<tr>
<td>Kansas City</td>
<td>8</td>
<td>20</td>
<td>283</td>
<td>48.21</td>
</tr>
<tr>
<td>Topeka</td>
<td>11</td>
<td>1.87</td>
<td>7</td>
<td>5.51</td>
</tr>
<tr>
<td>Wichita</td>
<td>28</td>
<td>4.77</td>
<td>11</td>
<td>8.66</td>
</tr>
<tr>
<td>Other Reserve Cities</td>
<td>4</td>
<td>10</td>
<td>1</td>
<td>0.17</td>
</tr>
</tbody>
</table>

Table 3 provides information on the number of links each city received from national and state banks in Kansas. This table focuses on the interbank relationships between respondent banks in Kansas and correspondent banks in reserve and central reserve cities. New York, Chicago, and St. Louis were central reserve cities. Kansas City, Topeka and Wichita were reserve cities in Kansas. Kansas city data are aggregated across Kansas City, KS and Kansas City, MO. The linkage data is aggregated across these cities and used to calculate the proportion of links in each city.

different regions, New York City banks were able to accommodate liquidity transfers between regions, thereby smoothing interregional flows (Gilbert (1983), James and Weiman (2010)). By reducing the relevance of New York banks in the U.S. interbank network, the central bank liquidity provision crowded out previous private liquidity insurance, plausibly at the cost of using public funds to cover such public insurance.

To summarize, the introduction of liquidity provision by the Fed changed the structure of the interbank system for nonmember banks as well as for member banks. By injecting public liquidity into the banking system, it reduced the necessity of nonmember banks to maintain correspondent relationships across multiple cities and outside the state. In addition, it eliminated the role of New York City national banks as the ultimate liquidity provider and allowed country banks to rely on local financial centers to access liquidity. This shift of correspondent relationships away from New York and toward local financial centers transformed interbank relation from the *national New York City-based core-periphery* structure to the *regional reserve city-based core-periphery* structure.

4 Conclusion

The extent of central bank liquidity provision by the Federal Reserve Bank has been the subject of heated debate among academics and policymakers, particularly due to the inability of shadow banks to access the Fed’s liquidity support and the implementation of emergency lending facilities during the financial crisis of 2007-2009. How much liquidity should the Fed provide? To whom? Under what conditions?

As the answers to these recent questions may be “contaminated” by the closeness to the events and by the complexity and variety of modern banking, in this paper we study a unique historical event. How did the founding of the Federal Reserve affected the structure, functioning and stability of the banking system?

In 1914 the Federal Reserve Act was passed to provide liquidity to member banks that satisfied reserve requirements. By doing so, it created “public” liquidity insurance for the banking system, which incurred the social cost of taxation but came with the benefit of regulating and supervising its members. We show that this intervention changed the functioning of the banking system in three relevant ways. First, it reduced the banks’ incentives to hold liquid assets. Member banks reduced liquid assets in the anticipation of borrowing from the Fed. At the same time, nonmember banks obtained access to central bank liquidity by connecting to members, so they reduced liquid assets as well. As a result the whole banking system became less liquid. Second, it created a new source of contagion within the network,
inducing instability by making it more vulnerable to shocks. There was an increase in the intesity of interbank relations through short-term borrowing, which make the system more exposed to contagion. Third, it reduced private cross-regional insurance provision of the interbank system with New York at its center. Public liquidity provision crowded out private insurance at the cost of taxation distortions.

All these changes – a decline in aggregate liquidity, a more intense network associated with higher contagion risk and vulnerability, and the disappearance of a concentrated network that helped the banking system to manage privately cross-regional liquidity shocks – suggest that the public provision of liquidity may have hindered the functioning of interbank relations at the cost of taxpayer funds. It addition, it created a system of shadow banks because nonmember banks operated outside federal regulation and supervision. These results have natural implications for the current policy discussion and for assessing post-reforms attempts to prevent non-banks from accessing central bank liquidity. A comprehensive reform should acknowledge that restricting "official" access to public liquidity does not prevent "real" access to public liquidity. Such an attempt may indeed backfire by creating a favorable landscape for the rise of a shadow banking system that may operate with illiquid assets and greater systemic risk.
References


CARLSON, M. AND D. C. WHEELOCK (2018a): “Did the founding of the Federal Reserve affect the vulnerability of the interbank system to contagion risk?” Journal of Money, Credit and Banking, 50, 1711–1750.


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