Systemic Risk:
The Great Recession vs.
The Great Depression

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Motivation

• Financial crises can have severe consequences, depressing living standards and lengthening the time of recovery from recessions (Reinhart and Rogoff, 2014)

• Crisis of 2007-8 suggests linkages among financial institutions may have played a role in propagating financial distress

• Recent work on the Great Depression (Mitchener and Richardson 2013, 2015) shows how network linkages transmit distress and amplify the decline in credit during a crisis
Systemic Risk (SR) materializes from:

1. Heightened default probabilities of financial institutions (FI) or the belief they will occur
2. Connections between FIs (credit quality, interbank deposits, etc.)

• Systemic risk matters if the risks and perceived or actual negative externalities are large
  - e.g., large-scale credit disintermediation and/or amplification of business cycles when systemically important FIs suspend or fail
Dodd-Frank Act (2010)

• Defined a systemically important financial institution (SIFI) as any FI that is:

1. Large
2. Complex
3. Connected to other FIs
4. “Critical” -- provides hard to substitute services to the financial system

• Assumption – The suspension or failure of particular FIs matters for the financial system’s health

• Implication – Measuring institution i’s contribution to systemic risk important for understanding potential for negative externalities
Our Research Agenda

• Examine *ex ante* systemic risk prior to the two largest American financial crises in (at least) the last 110 years
  – How prone was each system to failure?
  – How do the networks compare in structure?
  – Where were the vulnerabilities?

• Consider counterfactual stressors and outcomes
Disclaimer: comparisons across the two crises are interesting but challenging

• Changes in financial firms and reporting of them raise issues of comparability
• Measurement of networks
  – Market-based measures yield less data historically
  – More “banks” historically then presently
  – More shadow banks presently
• Reasons for linkages may have changed over 75 years
  – e.g., formal correspondent linkages more important in the past?
Economic History research on banking networks grown in last 5 years

- Heitfield, Richardson & Wang (2013) correspondent relationships of all banks operating in Tennessee, Mississippi and Alabama in 1930 to study the first banking panic.
- Mitchener and Richardson (2013, 2015) measure how interbank flows amplified credit downturn during Great Depression
- Carlson and Wheelock (2016) explore how founding of Fed influenced interbank network’s ability to cope with solvency vs. liquidity shocks
- Paddrik, Park, Wang (2016) introduction of national banks, network concentration, and stability
- Lots of work still to be done, including links to the present ...
Methodology

• Use a common, flexible approach based on Das (2016) and Das et. al. (2017) to quantify risk for each era’s financial network

• Allows us to consider empirically estimate “exposure” despite not knowing everything we might want about each network

  – Unlike 1929, formal networks are unobservable today — regulators (e.g., Fed & FDIC) do not collect information

  – Data on balance-sheet linkages between FIs is often opaque or incomplete, both historically and today
Generalized Systemic Risk Measure

Our overall systemic risk measure takes the following functional form:

\[ S = (C' \; EC)^{1/2} \]

where \( C \) is an \( n \times 1 \) vector of credit risk measures and \( E \) is a network adjacency matrix.

Risk to the system from institution \( i \) has two components:

1) Internal Risk (“Compromise Risk”)
   - The likelihood institution \( i \) fails or suspends and the impact that event has on the system
   - e.g., could be defined as credit risk

2) External Risk (“Connectivity Risk”)
   - The chance that a collapse of institution \( i \) increases the likelihood that other institutions then suspend or fail
Example of a directed network with 18 nodes

One-way arrows mean that risk flows in the direction of the arrow. Two-way arrows mean risk flows in both directions. The network is summarized in the adjacency matrix.
1929 Data

• Hand collected from Rand McNally Bankers’ Directory
  • Balance sheet information, location, correspondents
• All banks in the United States operating in 1929
  ▪ 28,522 institutions
  ▪ 4,040 correspondents
  ▪ 72,991 linkages
In honor of the RAs
1929 Bank-level Analysis

- Average number of correspondents = 2.6
- Median number of correspondents = Mode = 2

Histograms

Right tail truncated
1929 Bank-level statistics

- For the 4,040 banks listed as correspondents
  - Average number of banks corresponding to = 18.1
  - Median number of banks corresponding to = 2, (Mode = 1)
  - Minimum = 1 and Maximum = 4,673 (guesses?)

Histograms
## Banks with most relationships, 1929

<table>
<thead>
<tr>
<th>Bank Name and Location</th>
<th># corresponding to</th>
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</thead>
<tbody>
<tr>
<td>1) Continental Illinois Bank and Trust Co. Chicago (in Chicago, IL)</td>
<td>4673</td>
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<tr>
<td>2) Chase National Bank (in New York City, NY)</td>
<td>3107</td>
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<tr>
<td>3) Central Hanover Bank and Trust Company (in New York City, NY)</td>
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<td>4) National City Bank (in New York City, NY)</td>
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<td>5) First National Bank Of Chicago (in Chicago, IL)</td>
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<td>6) Guaranty Trust Company of New York (in New York City, NY)</td>
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<td>7) National Park Bank (in New York City, NY)</td>
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<td>8) Irving Trust Company (in New York City, NY)</td>
<td>1133</td>
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<tr>
<td>10) First National Bank (in Minneapolis, MN)</td>
<td>1081</td>
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</table>
1929 Analysis at the city level
Credit Risk in 1929

• Our measure of $C$ is defined as

$\frac{\text{Undivided profits} + \text{Surplus}}{\text{net worth}}$

Where net worth = paid-in capital + Undivided profits + Surplus

Intuition: leverage ratio
Basic Network Statistics for 1929

• We begin by defining a link as a connection between banks with HQs in two distinct cities
  – Not at the bank level - gives a better depiction of network than single one-off transaction for each bank.

• Number of nodes (cities) = 15,697
• Number of links between cities = 43,237
• Largest connected cluster size = 15,617 (almost all cities are connected)
• Diameter is the longest shortest path between any two connected nodes
  – For our largest cluster (i.e., all cities) = 17
  – Implications for contagion
Minimum of 5 City Connections (connections defined at city level)
Minimum of 10 City connections (connections defined at city level)
Minimum of 100 city connections
(High Correspondence with Reserve Cities)
1929 Network
(Nodes with at least 10 connections)

Notice the clustering of connections around Chicago and New York – indicative of the reserve pyramid structure still in existence.
1929 Network
(Nodes with at least 5 connections)
# Interacting with the data

## 1929 Bank Risk Networks: DMV (2017)

<table>
<thead>
<tr>
<th>Bank Data</th>
<th>Network Links Data</th>
<th>Network Nodes Data</th>
<th>Network</th>
<th>Nodes Map</th>
<th>Degree Distribution</th>
<th>Notes</th>
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<th>TownName</th>
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<th>CountyName</th>
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**Outputs:**
- Number of Nodes = 529
- Number of Links = 3788
- Diameter = 14
- Largest Cluster Size = 490
- Fragility/Concentration = 1976.6462/3374318
Network Structure

• Random network theory predicts most nodes will have roughly the same number of links
  – Nodes typically follow a Poisson distribution with a bell shape

• Social & economic networks tend to follow power laws (Barabasi and Bonabeau, 2003; Gabaix, 2003)
  – The probability that any node was connected to j other nodes was proportional to $1/j^\alpha$
  – So, if $\alpha \sim 2$, any node was roughly four times as likely to have just half the number of incoming links as another node.
  – Characterized by continuously decreasing function
Distribution of Linkages

Probability (%)

Degree (Last bar shows degree > 100)

0.2530105
Right tail of linkage distribution
Power Law Coefficient

\[ \alpha = -0.4372 \]
Centrality of Nodes

- The node that is most important in terms of connectivity
- Influence of any node, $x_i$, in a network comes from connections to other nodes $j$. These nodes are impacted by the nodes they are connected to and so on, such that

$$x_i = \sum_{j=1}^{n} E_{ij}x_j$$

- LHS of system of equations is a n-vector $x$ which provides a score for the influence or centrality of each node in the network.
Centrality in 1929
Criticality in 1929

- Ordering depends on credit quality of banks as well as centrality
- Criticality = Centrality \times \text{Leverage} \text{ (proxy for credit risk)}
Systemic Risk

We implement the simple systemic risk measure

\[ S = (C' EC)^{1/2} \]

Where \( C \) is the risk vector, i.e., leverage, and \( E \) is the network (0,1) adjacency matrix (linkages).

\[ S = 826.13 \quad -- \quad \text{hard to interpret as there is no time series of these values} \]
Risk Decomposition: Impact of each institution on S

Decompose $S$ into the sum of $n$ components by differentiating with respect to $C$

Using Euler’s theorem, the decomposition is:

$$
S = \sum_{i=1}^{n} \frac{\partial S}{\partial C_i} C_i = \frac{C}{2S} (E'C + EC) \in R^n
$$

Therefore, each component, $\frac{\partial S}{\partial C_i} C_i$, defines the corresponding institution risk measure of institution $i$. 
Cities with greatest partial risk are also those that were designated central reserve or reserve cities.
Risk Increment

The effect of a one-unit worsening in risk score for the city’s average bank leverage on systemic risk

\[
\frac{\partial S}{\partial C} = \frac{1}{2S} (E'C + EC)
\]
**Fragility**

- Networks with focal points are ones that are highly concentrated.
- Implication: A highly concentrated network tends to spread distress more quickly.

![Network A](NETWORK A)

- Hub-and-spoke

![Network B](NETWORK B)

- Less Fragile
Fragility

• A measure that increases as the concentration in the network increases.
• Concentration results in a greater likelihood that bank-specific risk will lead to systemic risk.
• Fragility, $R$, is computed as
  \[ R = \frac{E(d^2)}{E(d)} \]
  where $d$ is the number of connections to other nodes and $E(.)$ is the expectations operator.
• Fragility in the 1929 network was $= 1031$
  – This is very high: the network is super concentrated
  – Herfindahl=0.0119
The 2007 Network
Construction of the network

• We begin by defining a link between banks using a Granger causality regression between two banks to build a directed network.
• A directed link in the network is projected from node i to node j if a regression of stock returns $r(j, t)$ on $r(i, t-1)$ and $r(j, t-1)$ evidences a significant coefficient on $r(i, t-1)$.
• Methodology based on:
2007 Data

• We use 581 publicly traded financial institutions
• Data obtained from CRISP
• Listed under the following major Standard Industrial Classification Codes (SIC):
  – Group 60: Depository institutions
  – Group 61: Non-depository credit institutions
  – Group 62: Security and commodity brokers, dealers, exchanges, and services
Building 2007 Network

• Using Merton (1974), we calculate daily asset values and their volatilities to derive daily asset returns where the former are generated from measures of:
  – Market capitalization
  – Annualized equity return volatilities
  – Total face value of debt
  – Annualized risk free rate of return (based on constant maturity US Treasuries)

• Using the daily asset returns, we then compute Granger causality regressions that examine whether the returns between institutions $i$ and $j$ are “causally” linked which gives us the adjacency matrix $E$
2007 Credit Risk

• From the daily asset returns, we compute asset betas on a rolling basis and then calculate expected asset returns using CAPM.

• The expected asset returns are used to determine the annualized probability of \( \text{default} \) \((c_i)\) for a given institution \(i\)
  
  – i.e., the probability of the market value of the FI’s assets > FI’s debt
Basic Network Stats for 2007

- Number of nodes = 581
- We run 336,980 regressions to create the network.
- Number of Links = 32,979
- Largest connected cluster size = 581 (all banks are connected)
- Diameter (maximal shortest path between any two connected nodes) of large cluster = 3
  - Implications for contagion
This is a representation of the directed network, i.e., every black dot represents a connection between the node in the row to a column node.
Distribution of Linkages: 2007

Recall: the right-hand tail in 1929 has mass at degree 7000.
Fragility of System: 2007

• Fragility in the 2007 network = 134
• This is still very high, but less than 1929 = 1031
  – Herfindahl (2007)=0.002
  – Herfindahl (1929)=0.0119
Preliminary Findings

• 1929 is a dense network
  – Perhaps related to geography/technology and institutions
• Ex ante system fragility was higher in 1929
• Pyramid reserve system concentrates risk in the city centers -- fatter tail
  – Hub and spoke
Future Directions

• What features explain the higher ex ante risk of 1929 network?
  – Pyramid system
  – Branch and group banking
  – Size of banks

• Examine how bank suspensions and failures changed systemic risk

• Examine counterfactuals to key known entities
  – Lehman in 2007
  – Bank of U.S. vs. Caldwell in 1930

• More data
  – All banks in U.S., not just publicly traded
  – Formal linkages for 2007?
Caldwell and Company features prominently in the First Banking Panic of the Great Depression

Consider just 5 of the Affiliates

- National Bank of Kentucky (Louisville, KY)
- Holston-Union National Bank (Knoxville, TN)
- Holston Trust Company (Knoxville, TN)
- Central Bank and Trust Co. (Asheville, NC)
- Louisville Trust Company (Louisville, KY)
Caldwell and Company: linkages to sample of affiliates

Affiliates

- National Bank of Kentucky (Louisville, KY)
  - 30 institutions in Indiana

- Holston-Union National Bank (Knoxville, TN)
  - 201 institutions in Kentucky

- Holston Trust Company (Knoxville, TN)
  - 9 institutions in Tennessee

- Central Bank and Trust Co. (Asheville, NC)

- Louisville Trust Company (Louisville, KY)
  - 1 institution in Illinois

Continental Illinois (Chicago)

Guaranty Trust Company (NYC)

The Philadelphia National Bank (PA)
Caldwell and Company

Affiliates

- National Bank of Kentucky (Louisville, KY)
- Holston-Union National Bank (Knoxville, TN)
- Holston Trust Company (Knoxville, TN)
- Central Bank and Trust Co. (Asheville, NC)
- Louisville Trust Company (Louisville, KY)

Atlanta and Lowery National Bank (Atlanta)
Continental Illinois (Chicago)
American Trust (Charlotte)
National Park Bank (NYC)
Fifth Third Union (Cincinnati)
Forth and First Bank (Nashville)