A Network Analysis of the National Banking Era (1863-1913)

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Introduction

- Goal: Determine a realistic model of the banking network across the United States during The National Banking Era (1863 1913) and apply modern network science tools to analyze it.
- Why the National Banking Era: There is no lender of last resort, exposure was straightforward compared to today, instruments and balance sheets are relatively clear compared to today, and regulation was both (relatively) simple and explicit.
- Main references: Champ B., Federal Reserve Bank of Cleveland, Working papers #19, #22, #23 (2007).
- Data for the period 1880 to 1909 available at http://minneapolisfed.org/research/economists/wewproj.html

Systemic Risk: various definitions

- "the likelihood of a sudden, usually unexpected, event that disrupts information in financial markets, making them unable to effectively channel funds to those parties with the most productive investment opportunities" (Mishkin 1995).
- "probability that cumulative losses will accrue from an event that sets in motion a series of successive losses along a chain of institutions or markets comprising a system" (Kaufman 1995).
- "the risk that the failure of a participant to meet its contractual obligations may in turn cause other participants to default with a chain reaction leading to broader financial difficulties" (Bank for International Settlements 1994).

- "In the payments system, systemic risk may occur if an institution participating on a private large- dollar payments network were unable or unwilling to settle its net debt position. If such a settlement failure occurred, the institutions creditors on the network might also be unable to settle their commitments. Serious repercussions could, as a result, spread to other participants in the private network, to other depository institutions not participating in the network, and to the nonfinancial economy generally." (Federal Reserve System 2001, 2)
- U.S. Commodity Futures Trading Commission: "[t]he risk that a default by one market participant will have repercussions on other participants due to the interlocking nature of financial markets.
- Cascades of shocks to banks plus general drop in liquidity

The network perspective

Andrew G Haldane's 2009 talk "Rethinking the Financial Network" is a brilliant summary of the nature of networks. He compares the 2002 SARS epidemic to the 2008 collapse of Lehman Bros. In both cases:

- an external event strikes;
- panic ensues and system seizes up;
- "collateral damage" is wide and deep;
- in hindsight, trigger event was modest;
- dynamics was chaotic.

Manifestation of a complex adaptive system

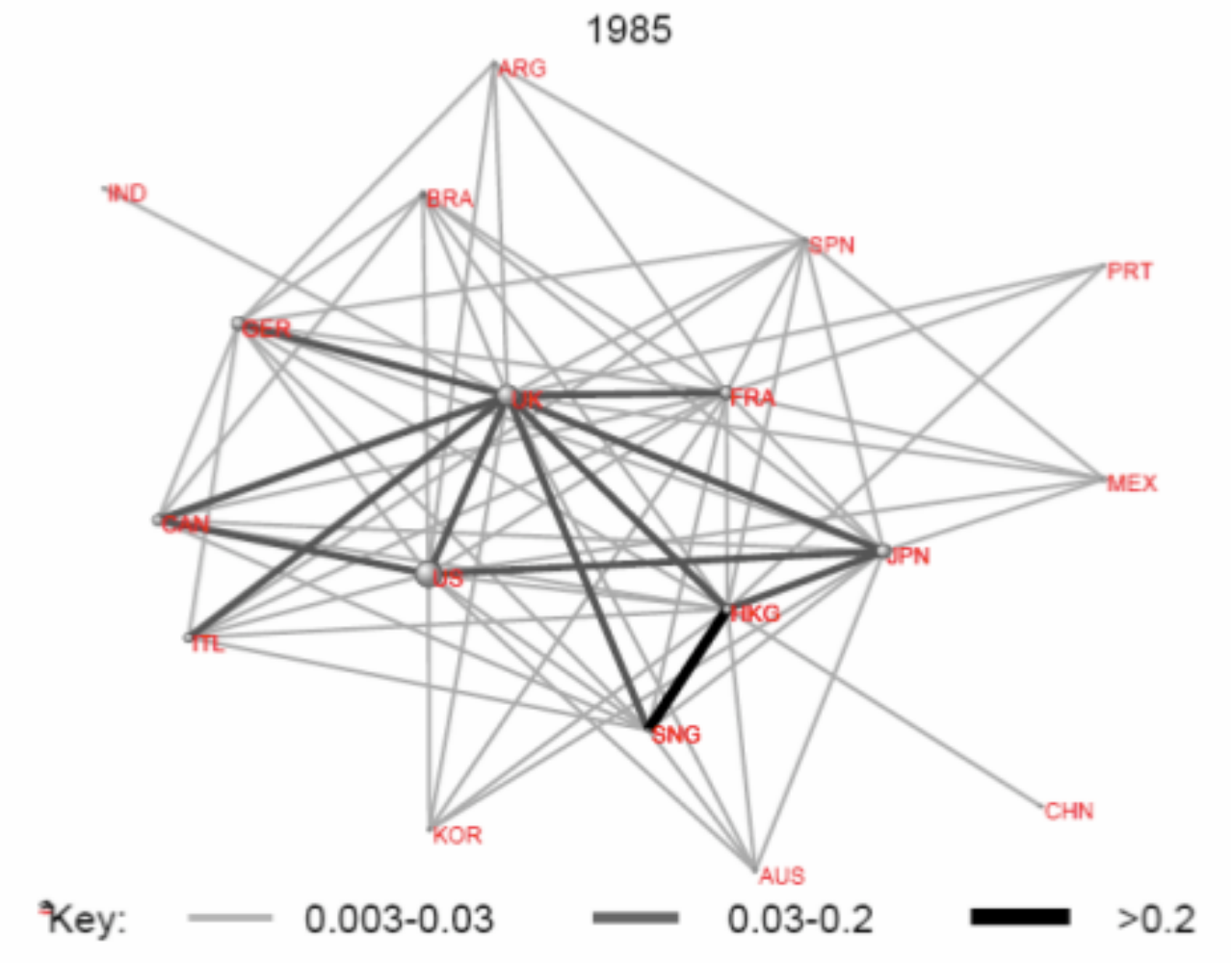
Complexity and Stability

What went wrong with the financial network?

- increasing complexity;
- decreasing diversity.

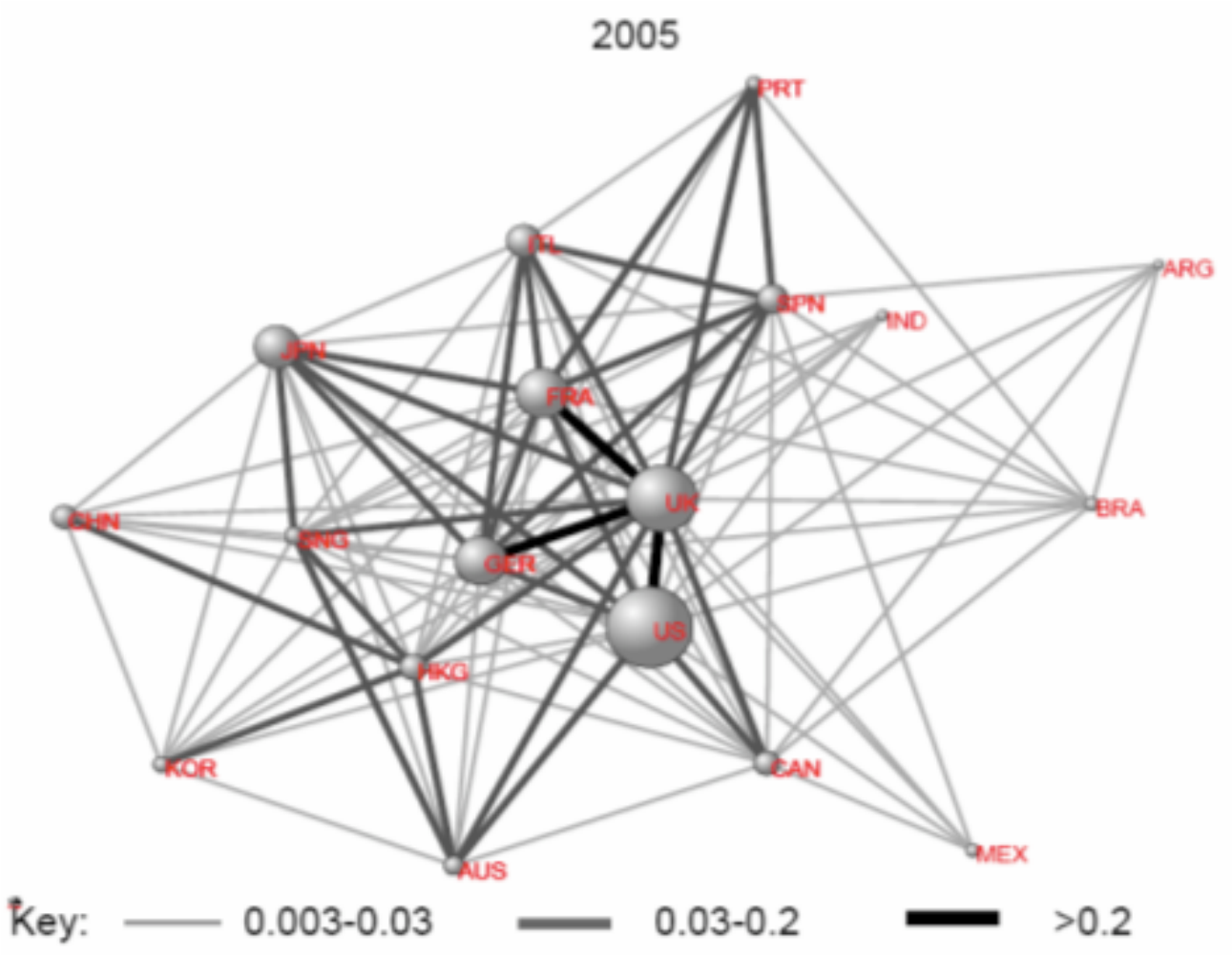
These two facts imply fragility and ring alarm bells for ecologists, engineers, geologists.

Global Financial Network 1985



(line denotes link strength as fraction of total GDP)

Global Financial Network 2005



Connectivity and Stability

Highly connected networks may be "robust yet fragile":

- In a network, connections may be either shock absorbers or shock amplifiers;
- There may be a "tipping point" that separates these two regimes.
- A fat-tailed "degree distribution" (the number of links per node) implies robustness to random shocks but vulnerability to shocks that target highly connected nodes.

Feedback and Stability

How do agents respond to a crisis?

- Epidemics: "hide" vs "flight";
- Finance: "hoard liquidity" vs "sell assets".

In finance, both responses are rational, but make the systemic problem worse.

Uncertainty and Stability

Networks generate chains of claims. At times of stress, these chains can amplify uncertainties about true counterparty exposures.

- In good times, counterparty risk is small, and thus "Knightian" uncertainty is small: stability improves with connectivity;
- In bad times, counterparty risk can be large and uncertain, due to the complicated web: stability declines with connectivity.

Diversity and Stability

- In ecosystems, biodiversity is known to improve stability;
- During the Great Moderation period, financial diversity was reduced;
- Pursuit of returns lead to many agents following similar strategies: portfolio correlations grew to $> 90\%$.
- Risk management regulation (a la Basel II) lead to similar risk management strategies for banks;
- As a result, bank balance sheet became increasingly homogeneous;

Finance became almost a "monoculture", and vulnerable to "viral infection".

Haldane: Summary

- Networks arising in ecology, engineering, the internet, finance, etc are complex and adaptive;
- They typically are "robust yet fragile";
- There is a role for intervention to create more stable networks;
- Key determinants for financial stability may be deduced by studying other types of networks.

What properties of the financial network most influence stability?

A Stylized Balance Sheet for a Bank

Assets	Liabilities
Long positions	Short positions
Reverse repos	Repos
Loans	Deposits
	Shareholder equity

Banks as nodes

Eisenberg-Noe 2001 identifies the stylized elements of a financial system consisting of N "banks":

1. The assets A_i of bank i
   - *external assets* A_i^M
   - *internal (Interbank) assets* A_i^{IB}
2. The liabilities of the bank i
   - *external debts* D_i
   - *internal (Interbank) debt* L_i^{IB}
3. w_ℓ, $\ell = (i, j)$ the amount bank i owes j.
4. The *equity* or *net worth*, defined by $K_i = A_i^M + A_i^{IB} - L_i^{IB} - D_i$
5. The solvency condition is $K_i \geq 0$.

Boss, Elsinger, Summers, Thurner 2004

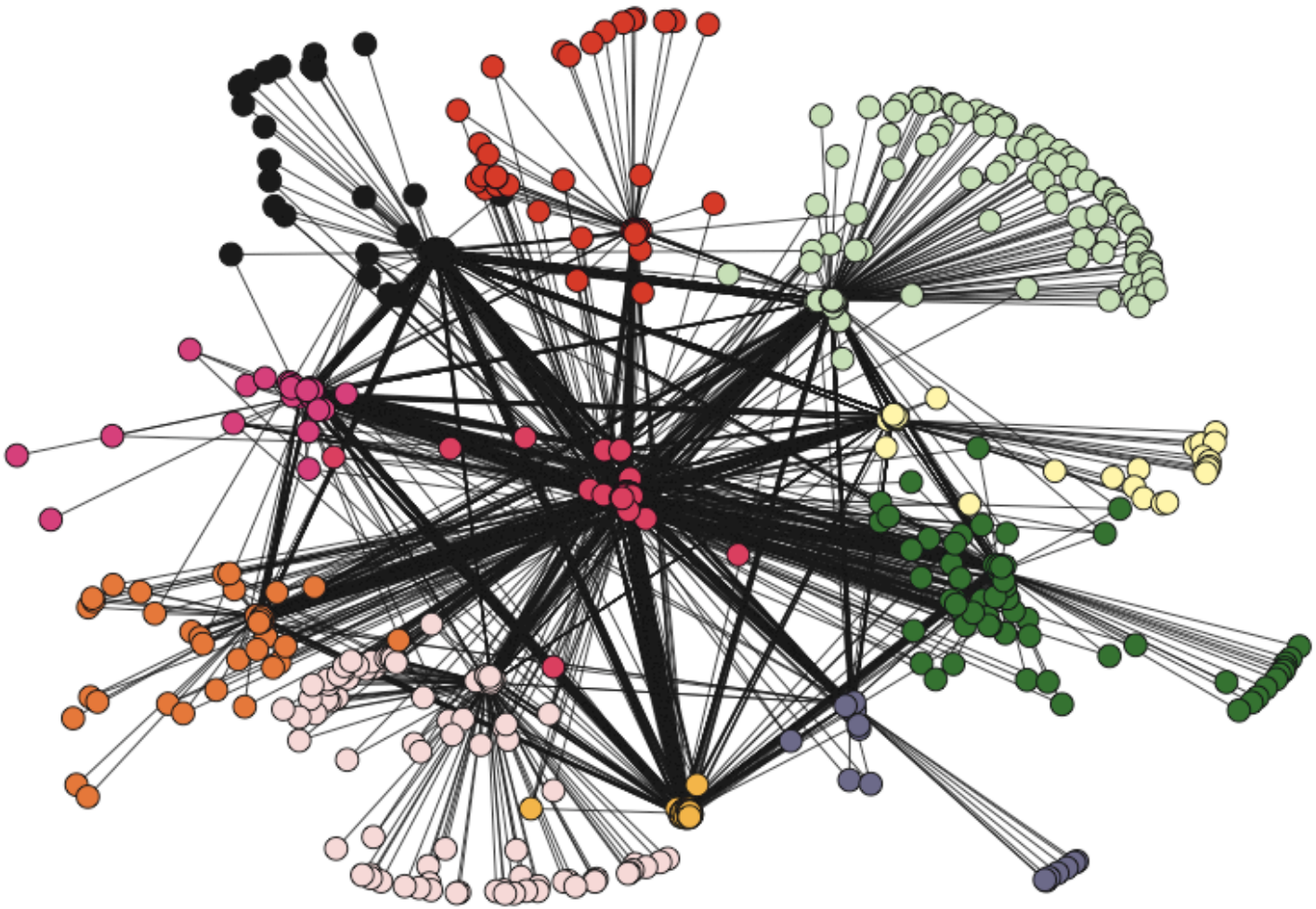
This early network study of the Austrian banking system, estimating the matrix L for about 900 Austrian banks. They were able to use a rather complete dataset on interbank links. They found:

- Out-degree has Pareto tail with exponent ~ 3.1;
- In-degree has Pareto tail with exponent ~ 1.7;
- Contract size distribution degree has Pareto tail with exponent ~ 1.87;
- Relatively small Clustering coefficient

$$C = 3 \times \frac{\text{number of triangles}}{\text{number of connected triples}} \sim 0.12$$

- Average Shortest Path Length ~ 2.59

Austrian Network September 2002

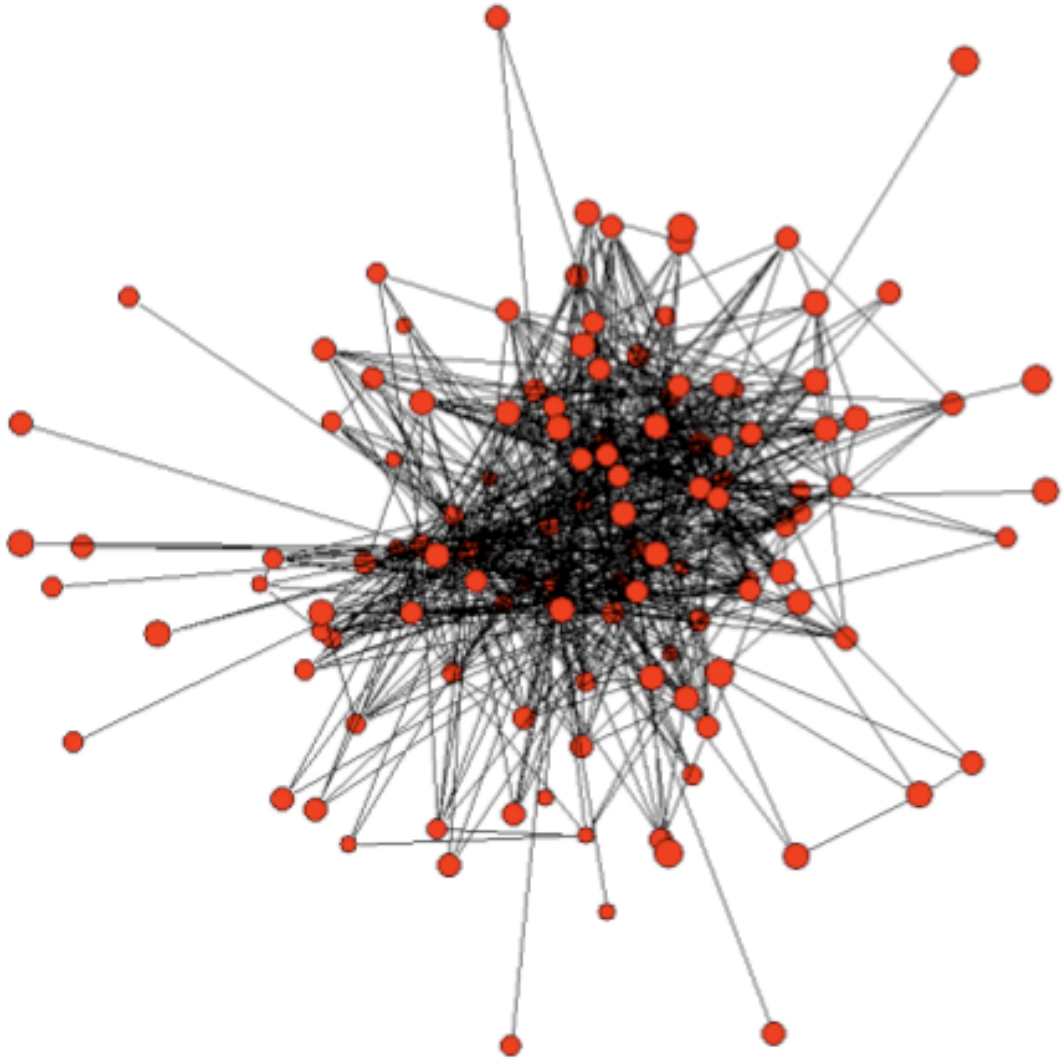


Cont-Moussa-Bastos 2011

This paper includes a detailed study of the Brazilian Interbank network. Their dataset included over 2400 financial institutions. It contained full interbank exposures, reported on six dates (June 2007, December 2007, March 2008, June 2008, September 2008 and November 2008) as follows:

- fixed-income instruments (certicate of deposits and debentures);
- borrowing and lending (credit risk);
- derivatives (including OTC instruments such as swaps);
- foreign exchange and,
- instruments linked to exchange-traded equity risk.

Brazil Network Dec 2007



Summary Statistics of Brazilian Network

Their findings about the network on December 2007:

- In and Out-degree distributions have Pareto tails;
- Contract size distribution has Pareto tail;
- Average in-link exposure is dependent on in-degree;
- Average out-link exposure is dependent on out-degree;
- Local clustering coefficient negatively related to node degree.

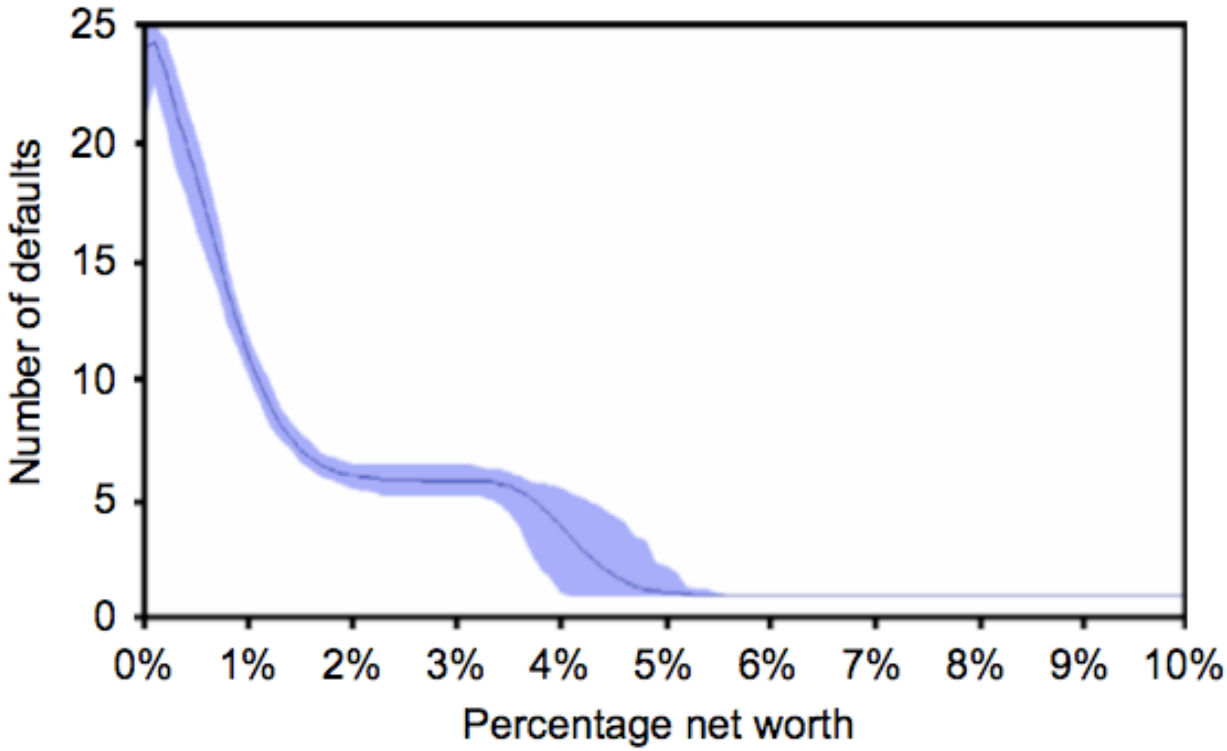
NYYA 2007: General Setup

The 2007 paper "Network models and financial stability" by Nier-Yang-Yorulmazer-Alentorn was influential in beginning "network" theoretical studies of systemic risk.

- Random network of $N = 25$ banks with Poisson degree distribution, parameter $P = 0.2$;
- Balance sheets on each bank:
  - Assets a_v;
  - Constant capital buffers $\gamma = 0.05a$;
  - Interbank assets $\theta = 0.20a$
  - Constant interbank link weights w;
- Assume partial recovery after default.

They run Monte Carlo simulations of the resulting cascade, varying one parameter at a time away from their benchmark values.

NYYA Results



NYYA Results

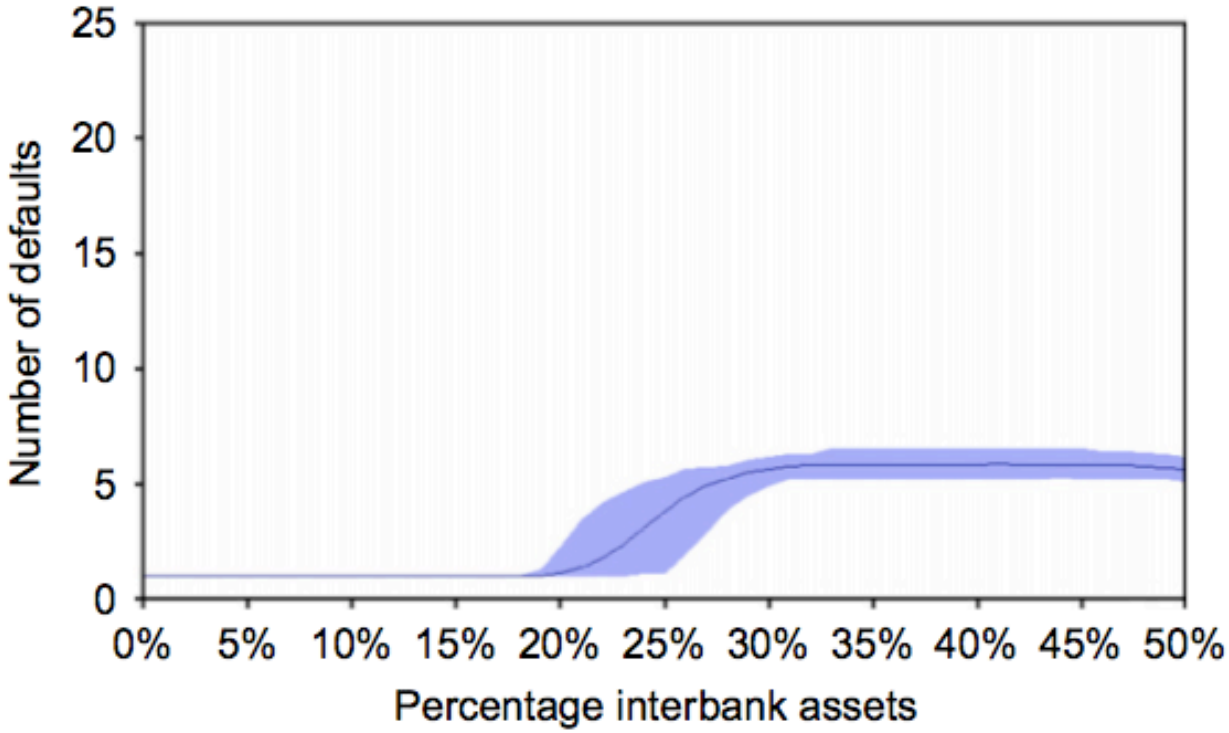


Fig. 2. Number of defaults as a function of the percentage of interbank assets in total assets (θ) 100 runs for each parameter constellation $(\gamma, \theta, p, N, E)$. Parameter values as in Table 1 (excep

NYYA Results

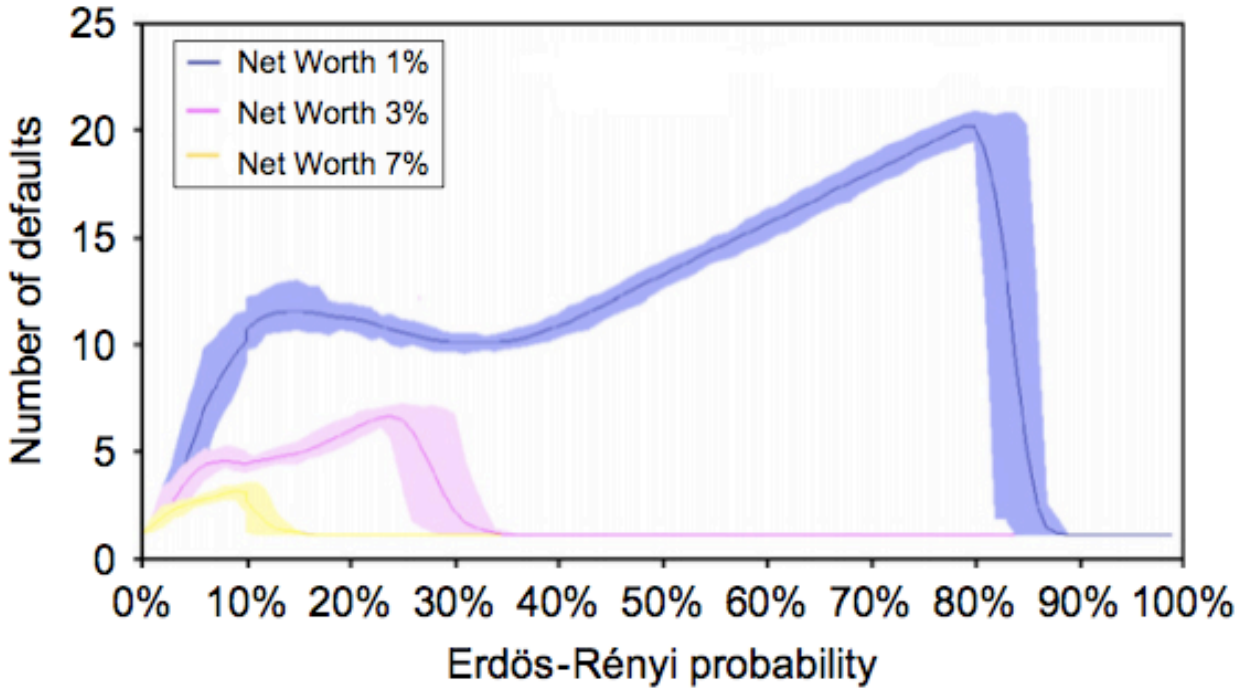


Fig. 3. Number of defaults as a function of the probability of connectedness (p) for different percent of net worth (γ). Based on 100 runs for each parameter constellation $(\gamma, \theta, p, N, E)$. values as in Table 1 (except for p and γ).

NYYA Results

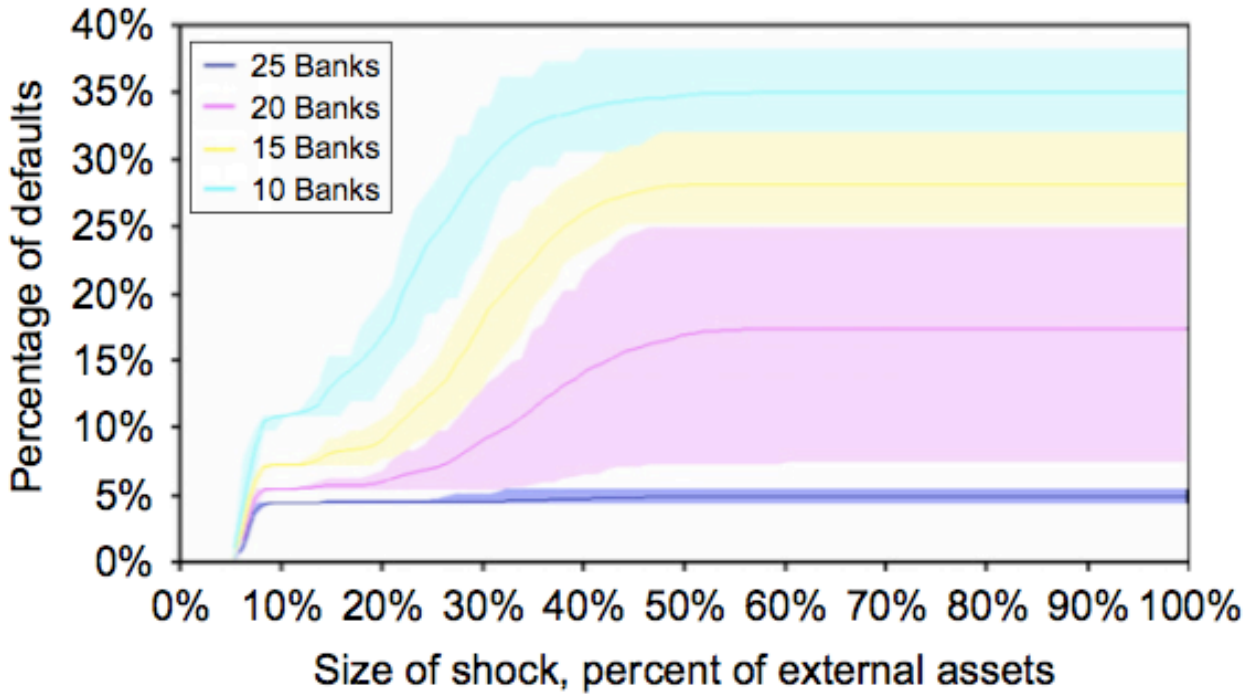


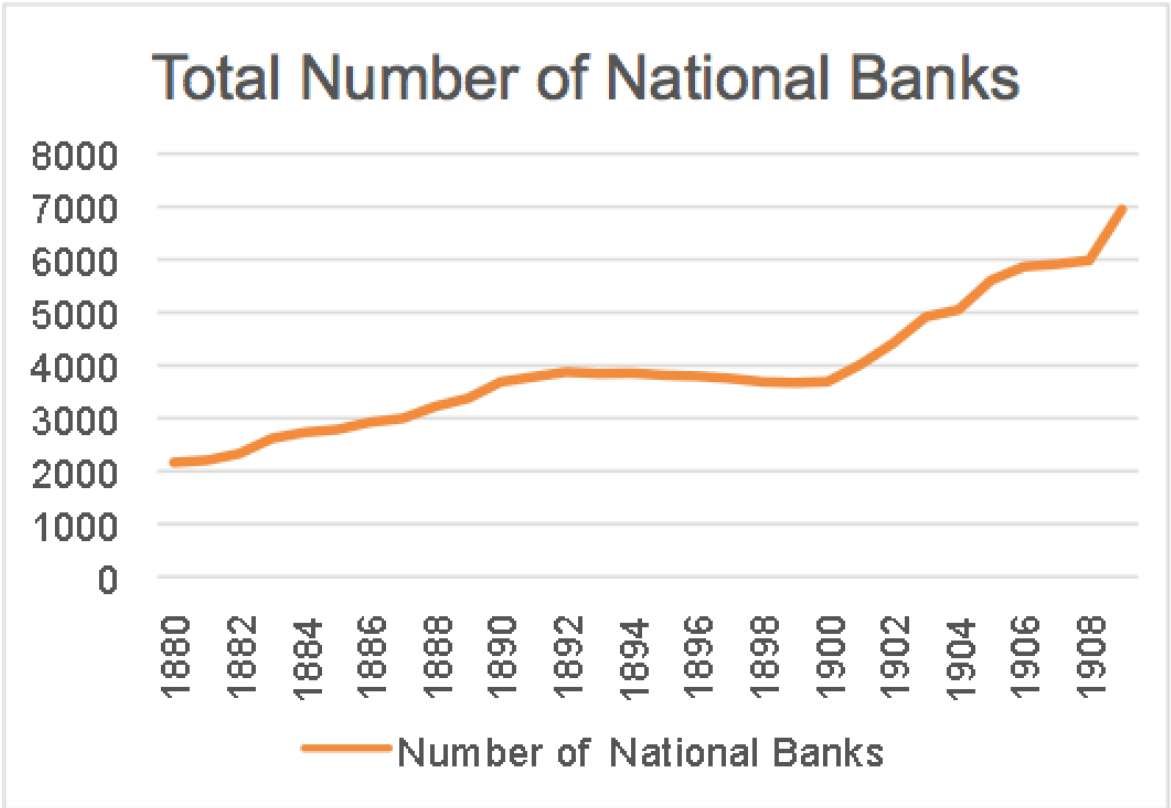
Fig. 4. Percentage of defaults as a function of the shock size as a percentage of external assets fo
N. Based on 100 runs for each shock size. Parameter values (γ, θ, p, E) are as in the benchmark ex
Table 1.

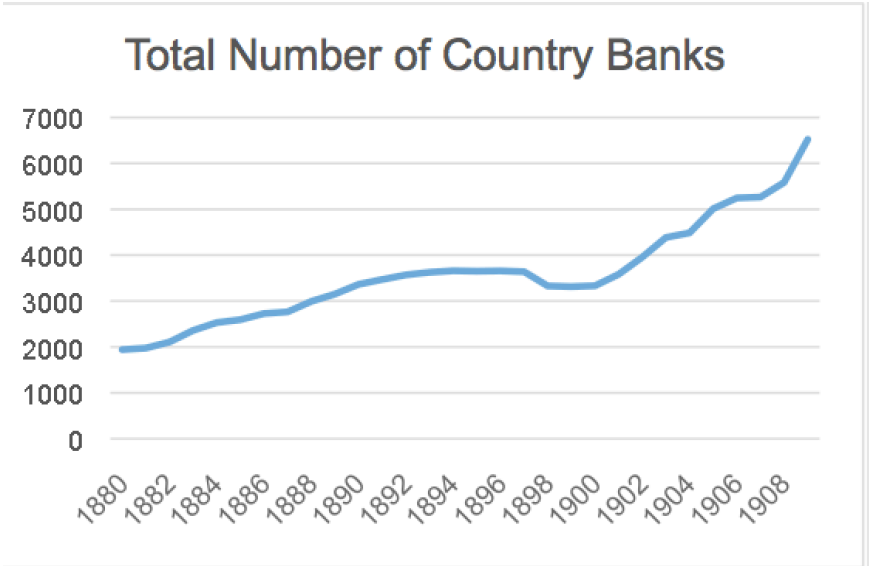
NYYA 2007: Main Conclusions

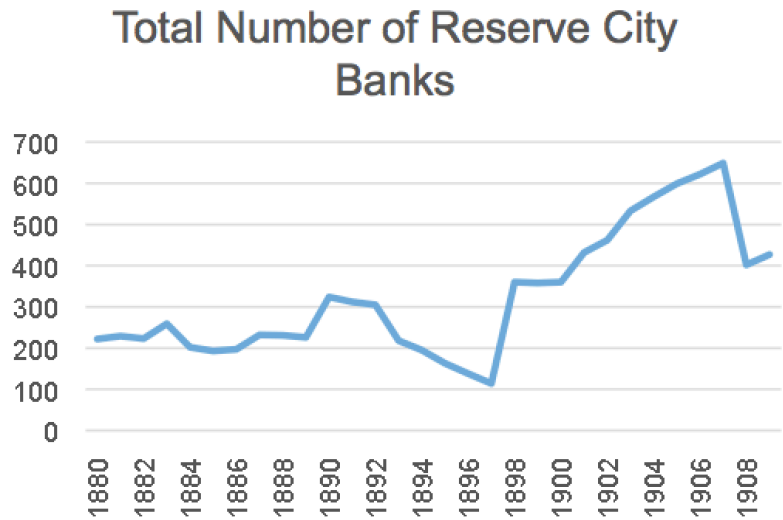
- First large scale systemic simulation study.
- Contagion decreases in net worth. This effect is non-linear.
- Contagion increases in the size of interbank liabilities. This is the case even if banks hold capital against interbank assets;
- Contagion is a non-monotonic function of the number of interbank connections, all else equal.
- Other models, such as Gai–Kapadia (2010), Gai–Haldane–Kapadia (2011), and Hurd et al (2013) extended these results to more general networks, and obtain analytic results in some limiting cases.

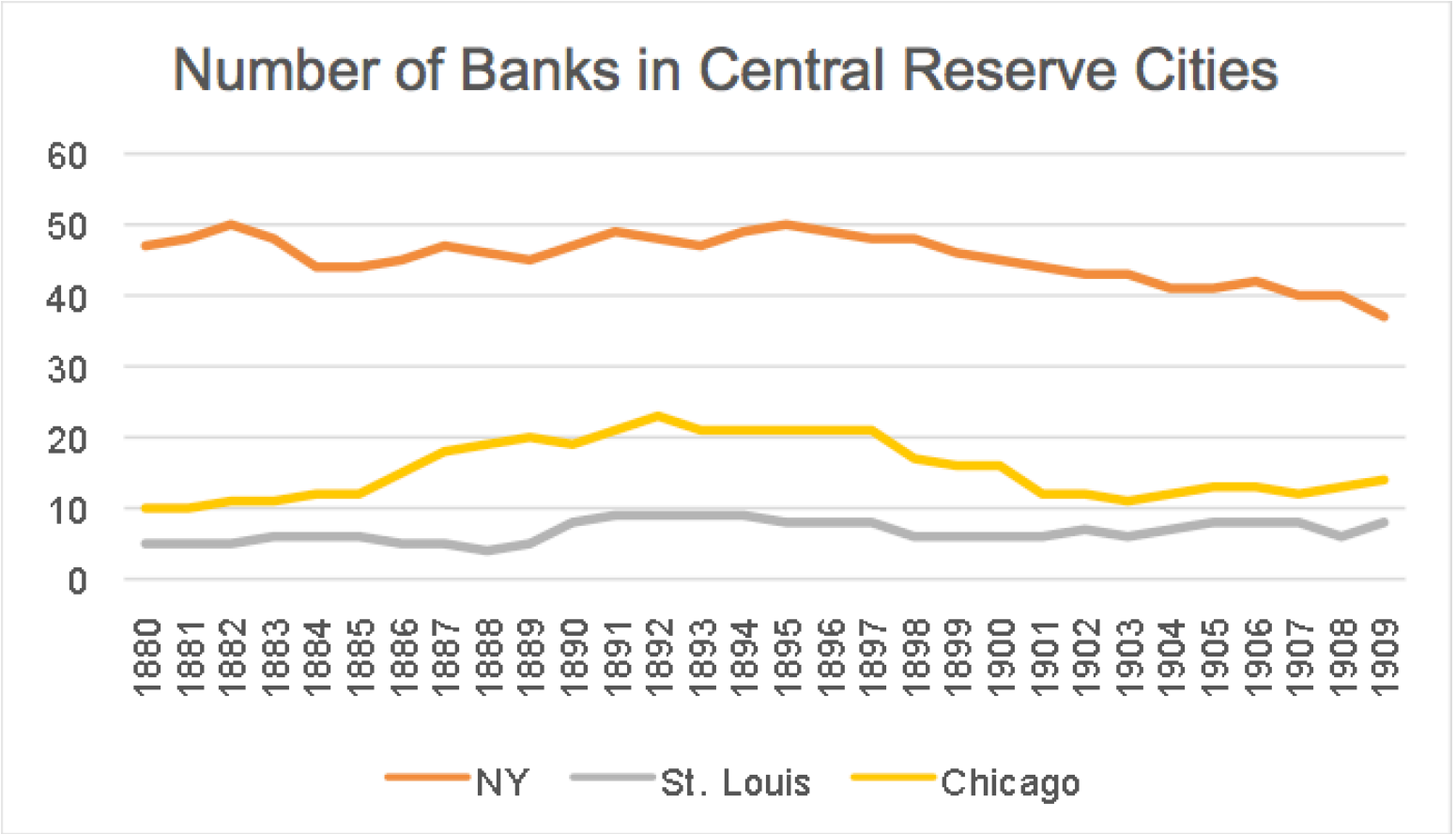
Underlying Structure of the National Banking Era

- Banks were classified into three different tiers based on the locale they resided in: central reserve cities, reserve cities, country banks.
- Initially only New York was a central reserve city, with St. Louis and Chicago added in 1887.
- Initially 18 reserve cities, with 47 by the end of the period.
- Reserve requirements of a given bank were directly related to tier.
- Central Reserve Cities banks held 25% reserves against deposits, all of which in the form of specie, gold and silver certificates, or legal tender notes.
- Reserve cities held 25% reserves against deposits, with up to half of it in the form of deposits in central reserve cities,
- Country Banks held 15% reserves against deposits, with up to 3/5 of it in the form of deposits in either reserve or central reserve cities.

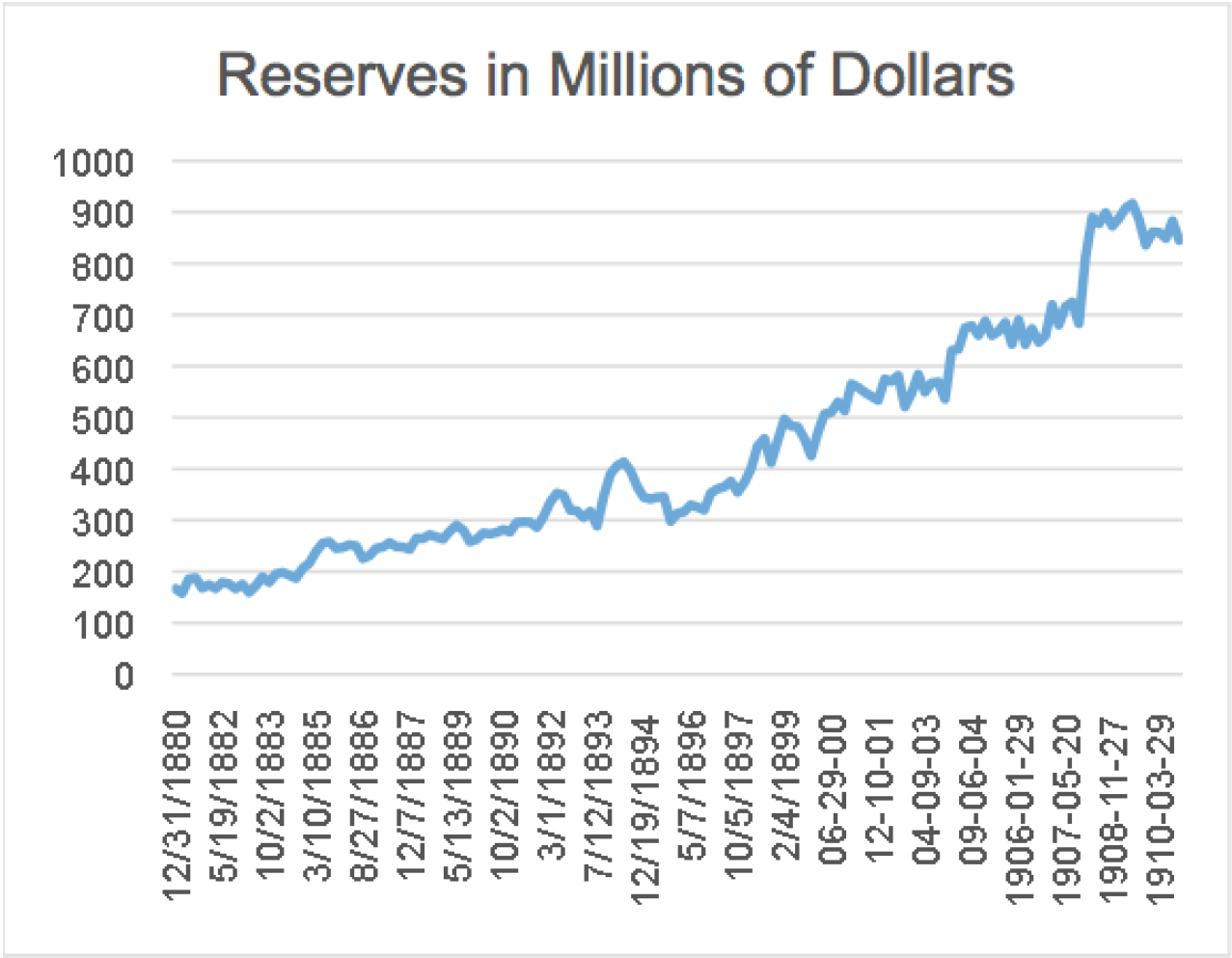

Total Number of National Banks
8000
7000
6000
5000
4000
3000
2000
1000
0
1880
1882
1884
1886
1888
1890
1892
1894
1896
1898
1900
1902
1904
1906
1908
Number of National Banks

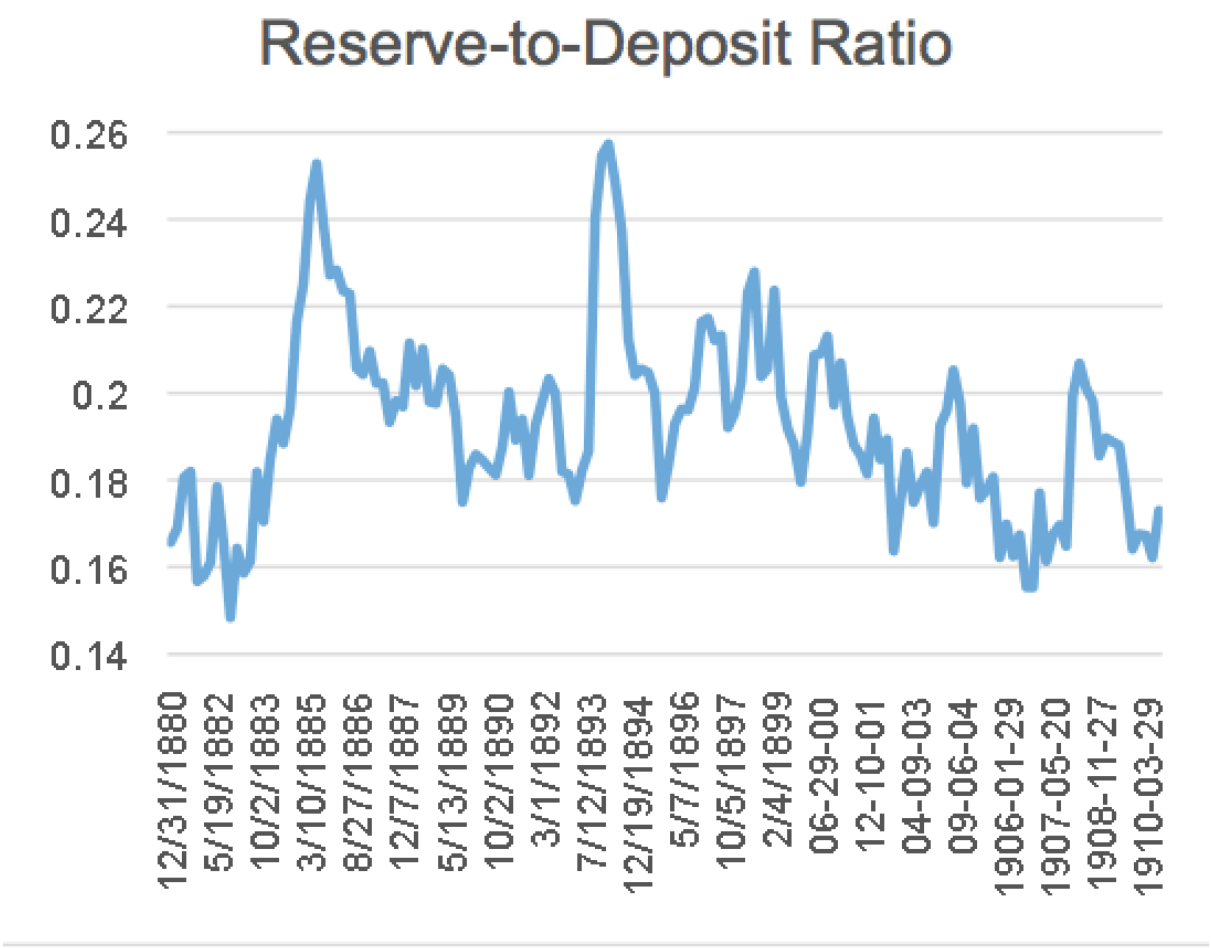

Total Number of Country Banks
7000
6000
5000
4000
3000
2000
1000
0
1880
1882
1884
1886
1888
1890
1892
1894
1896
1898
1900
1902
1904
1906
1908

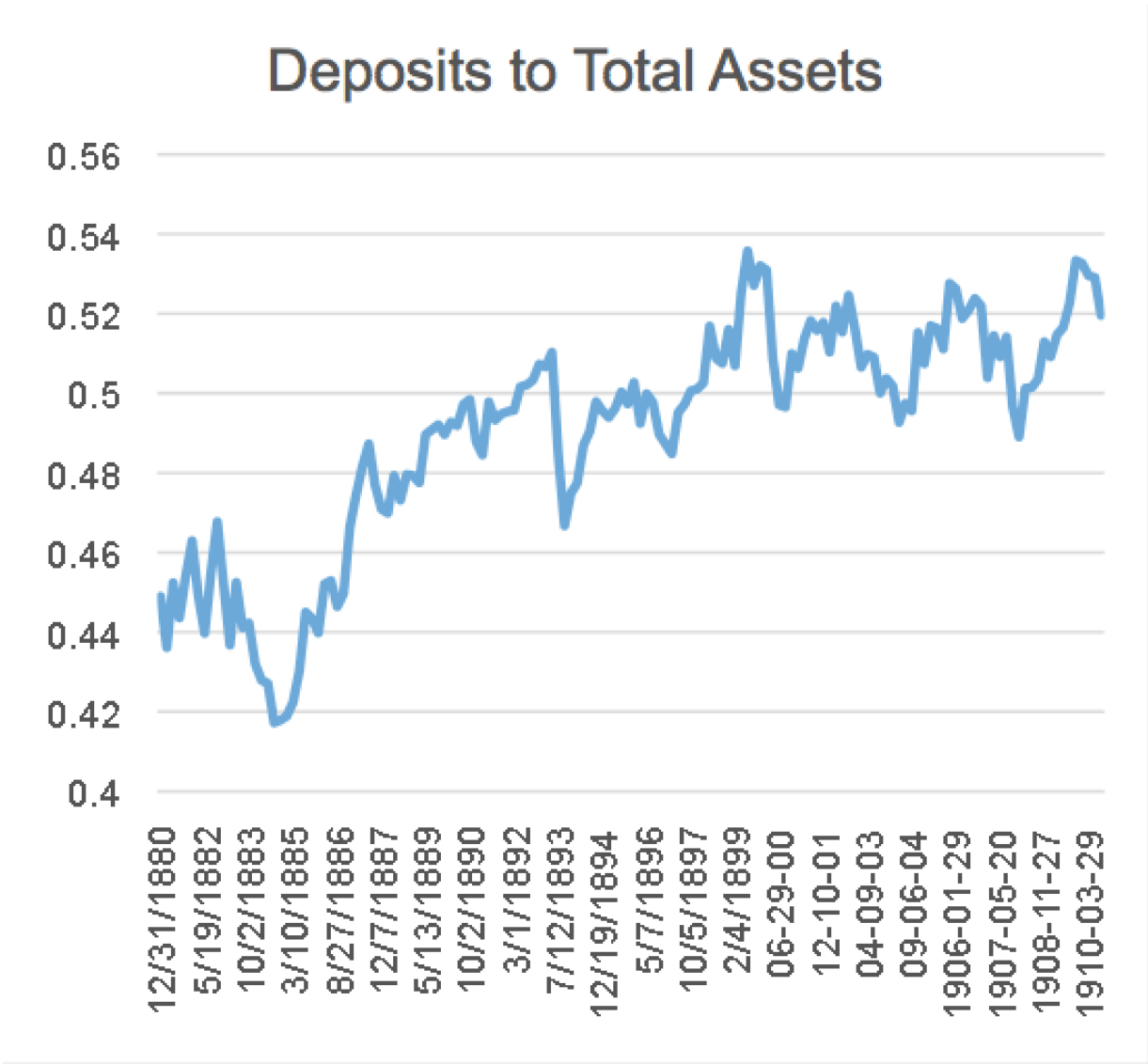

Total Number of Reserve City Banks
700
600
500
400
300
200
100
0
1880
1882
1884
1886
1888
1890
1892
1894
1896
1898
1900
1902
1904
1906
1908

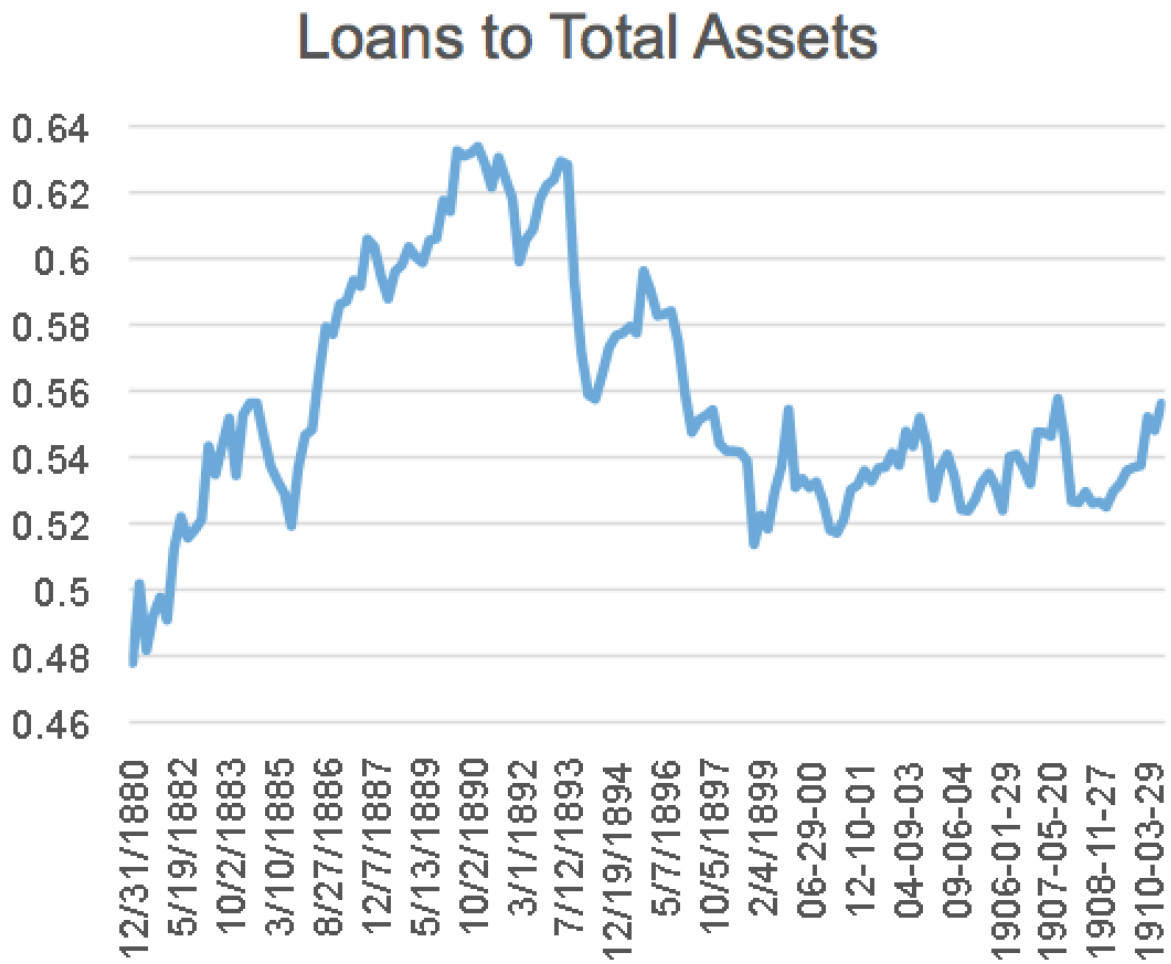

Number of Banks in Central Reserve Cities
60
50
40
30
20
10
0
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
NY
St. Louis
Chicago

Assets	Liabilities
Reserves 9%	Bank notes in circulation 7%
Loans 55%	Individual deposits 51%
U.S. government securities 8%	U.S. deposits 1%
Other securities 9%	
Due from other banks and reserve agents 13%	Due to other banks and reserve agents 19%
Other assets 6%	Capital 22%


Reserves in Millions of Dollars
1000
900
800
700
600
500
400
300
200
100
0
12/31/1880
5/19/1882
10/2/1883
3/10/1885
8/27/1886
12/7/1887
5/13/1889
10/2/1890
3/1/1892
7/12/1893
12/19/1894
5/7/1896
10/5/1897
2/4/1899
06-29-00
12-10-01
04-09-03
09-06-04
1906-01-29
1907-05-20
1908-11-27
1910-03-29

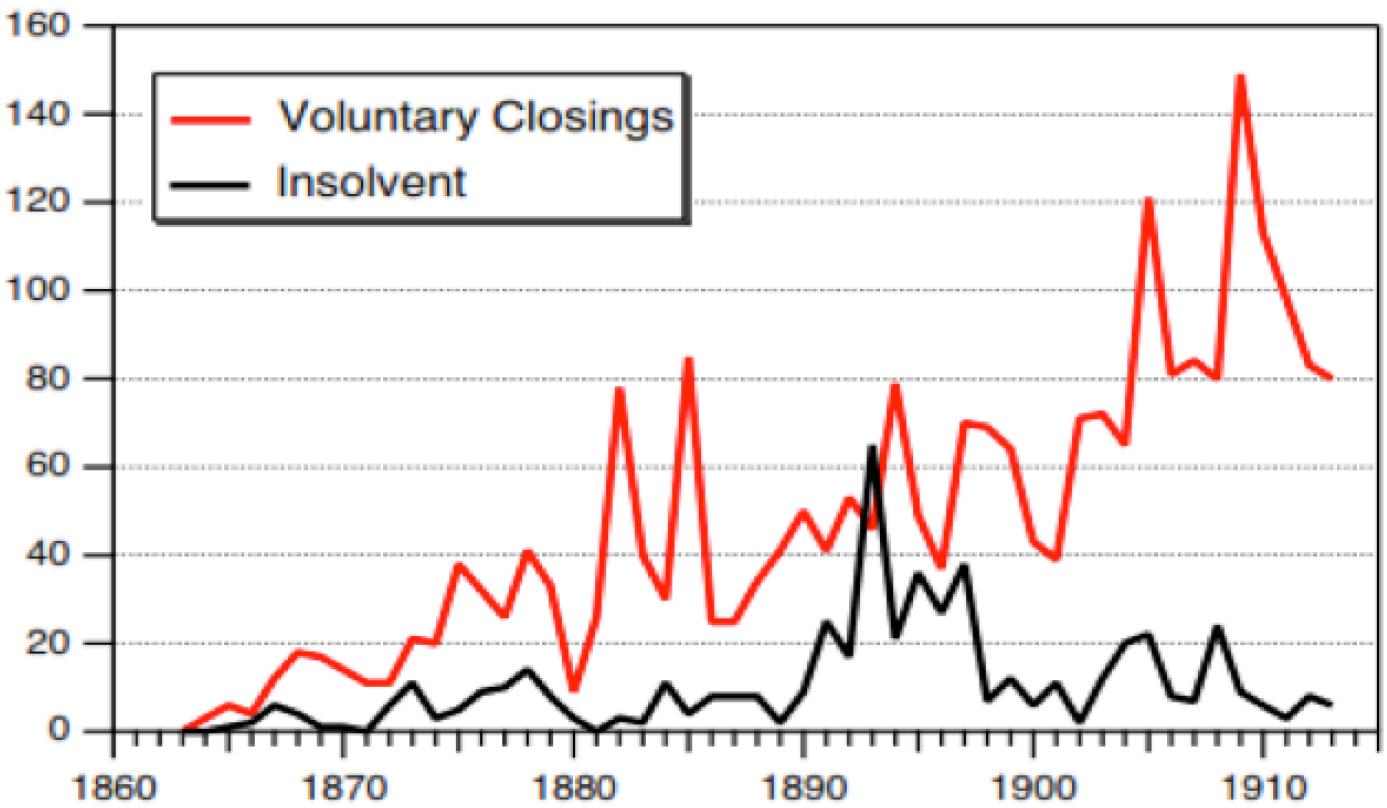

Reserve-to-Deposit Ratio
0.26
0.24
0.22
0.2
0.18
0.16
0.14
12/31/1880
5/19/1882
10/2/1883
3/10/1885
8/27/1886
12/7/1887
5/13/1889
10/2/1890
3/1/1892
7/12/1893
12/19/1894
5/7/1896
10/5/1897
2/4/1899
06-29-00
12-10-01
04-09-03
09-06-04
1906-01-29
1907-05-20
1908-11-27
1910-03-29


Deposits to Total Assets
0.56
0.54
0.52
0.5
0.48
0.46
0.44
0.42
0.4
12/31/1880
5/19/1882
10/2/1883
3/10/1885
8/27/1886
12/7/1887
5/13/1889
10/2/1890
3/1/1892
7/12/1893
12/19/1894
5/7/1896
10/5/1897
2/4/1899
06-29-00
12-10-01
04-09-03
09-06-04
1906-01-29
1907-05-20
1908-11-27
1910-03-29

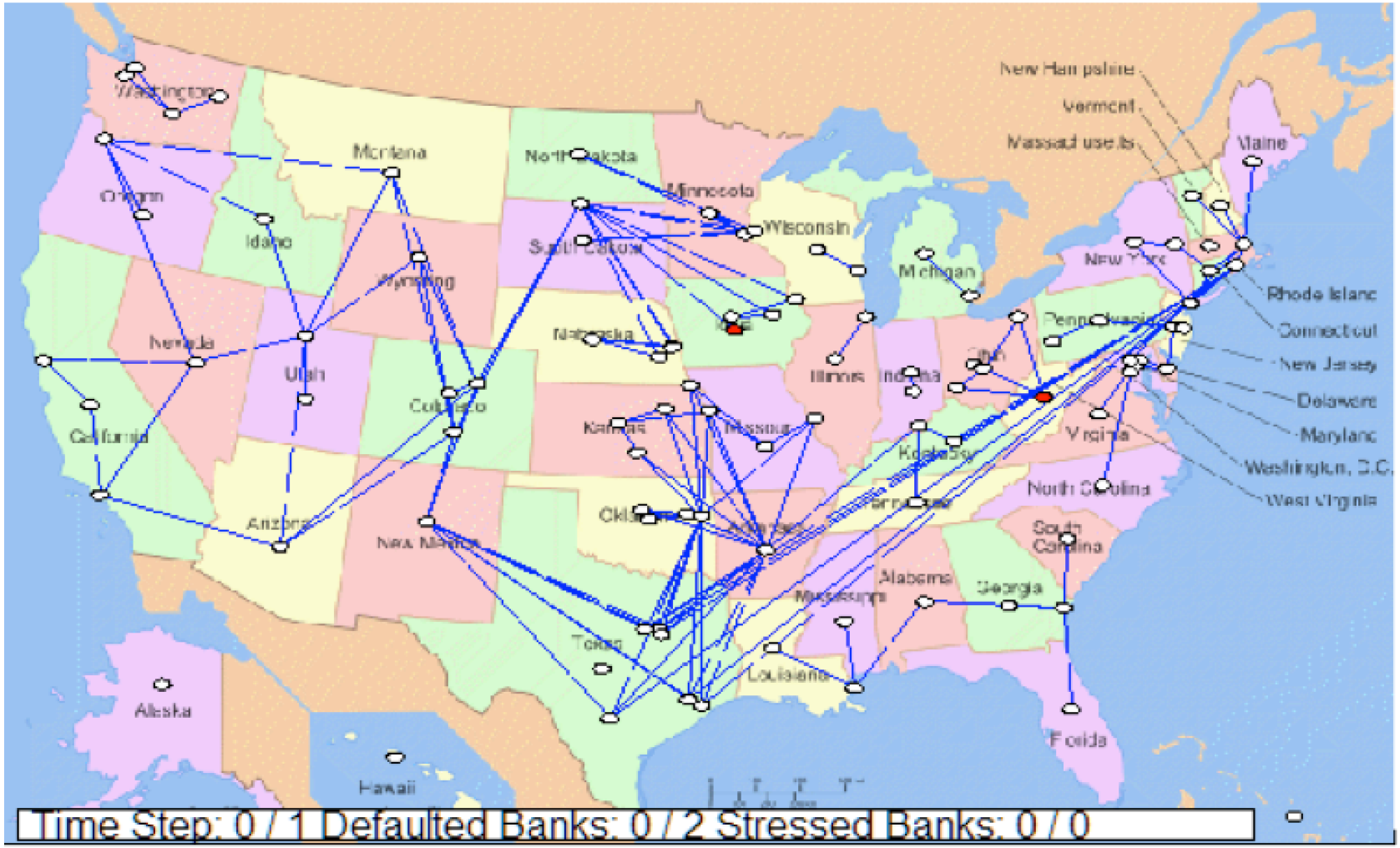

Loans to Total Assets
0.64
0.62
0.6
0.58
0.56
0.54
0.52
0.5
0.48
0.46
12/31/1880
5/19/1882
10/2/1883
3/10/1885
8/27/1886
12/7/1887
5/13/1889
10/2/1890
3/1/1892
7/12/1893
12/19/1894
5/7/1896
10/5/1897
2/4/1899
06-29-00
12-10-01
04-09-03
09-06-04
1906-01-29
1907-05-20
1908-11-27
1910-03-29

Crises National Banking Era

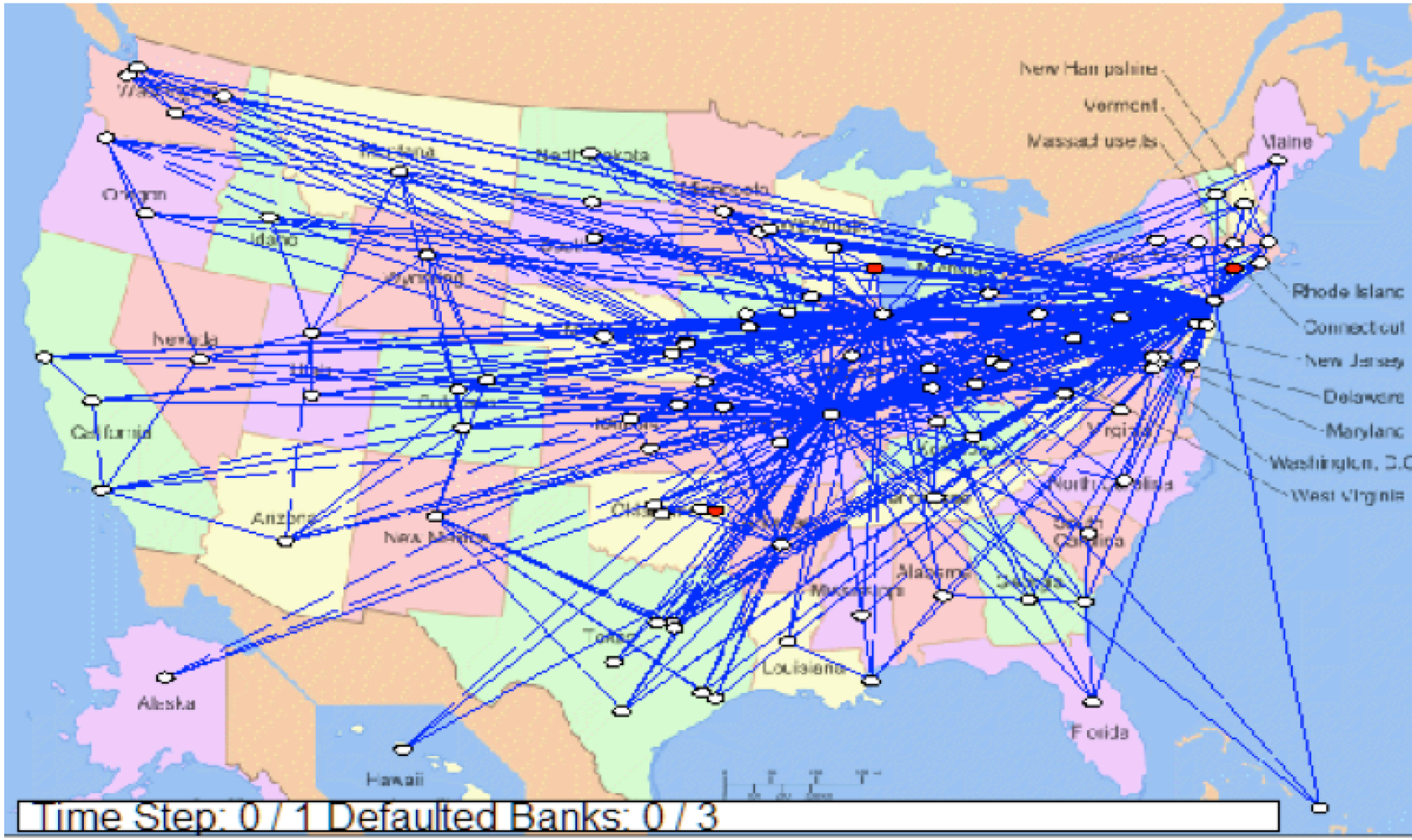
1. Crisis of 1873
   - September 1872: heavy withdrawals to move crops
   - April 1873: country banks withdrawing from eastern banks
   - September 1873: multiple brokerage firms fail, the stock market closed for 10 days.
2. 1884 a minor crisis
   - Suspension of payments, including 2 large banks.
   - Clearinghouse loan certificates were issued
3. The panic of 1893
   - Initial crisis in New York due to declining stock market.
   - Reserves of NY Banks fell by $40 million, due to withdrawals from depositors in West South.
   - August 1893: suspension of payment abounded
4. The panic of 1907
   - October 1907: trust companies suffer runs by depositors.
   - Large withdrawals from NY, some banks suspended payments, clearinghouse loan certificates were delayed
   - By late 1907, almost all banks had suspended payment.


160
140
120
100
80
60
40
20
0
Voluntary Closings
Insolvent
1860
1870
1880
1890
1900
1910

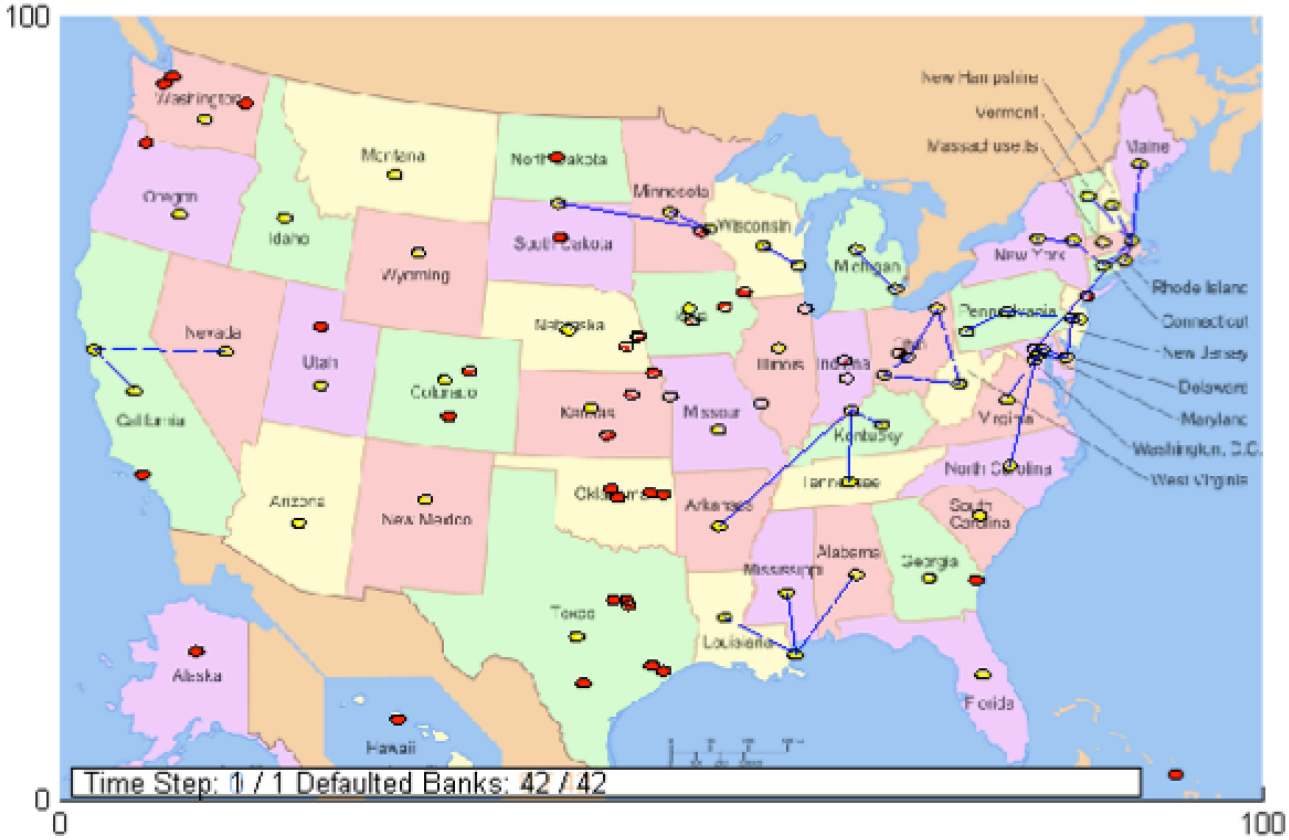
Country banks to reserve city banks



Total Exposure

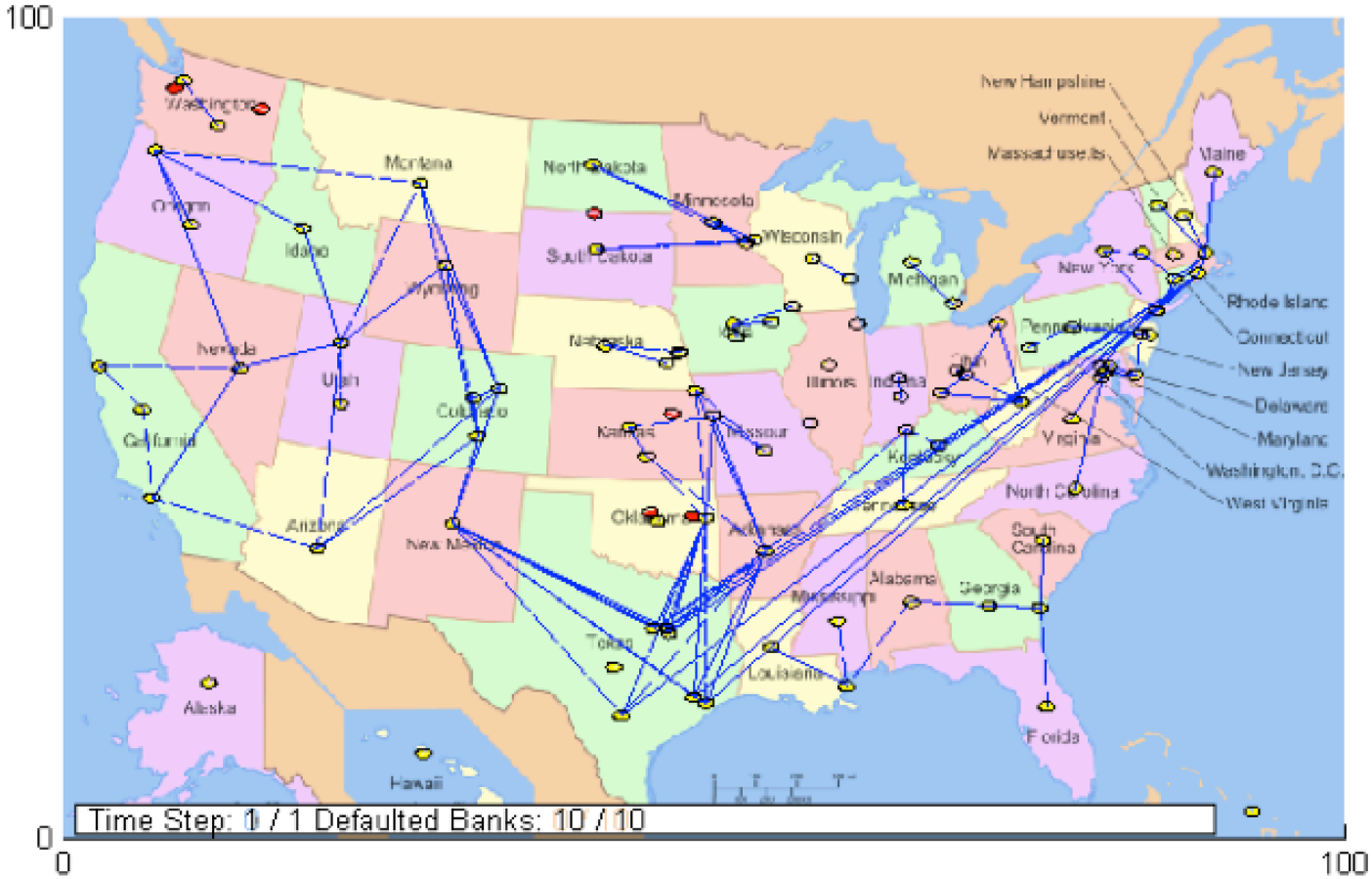


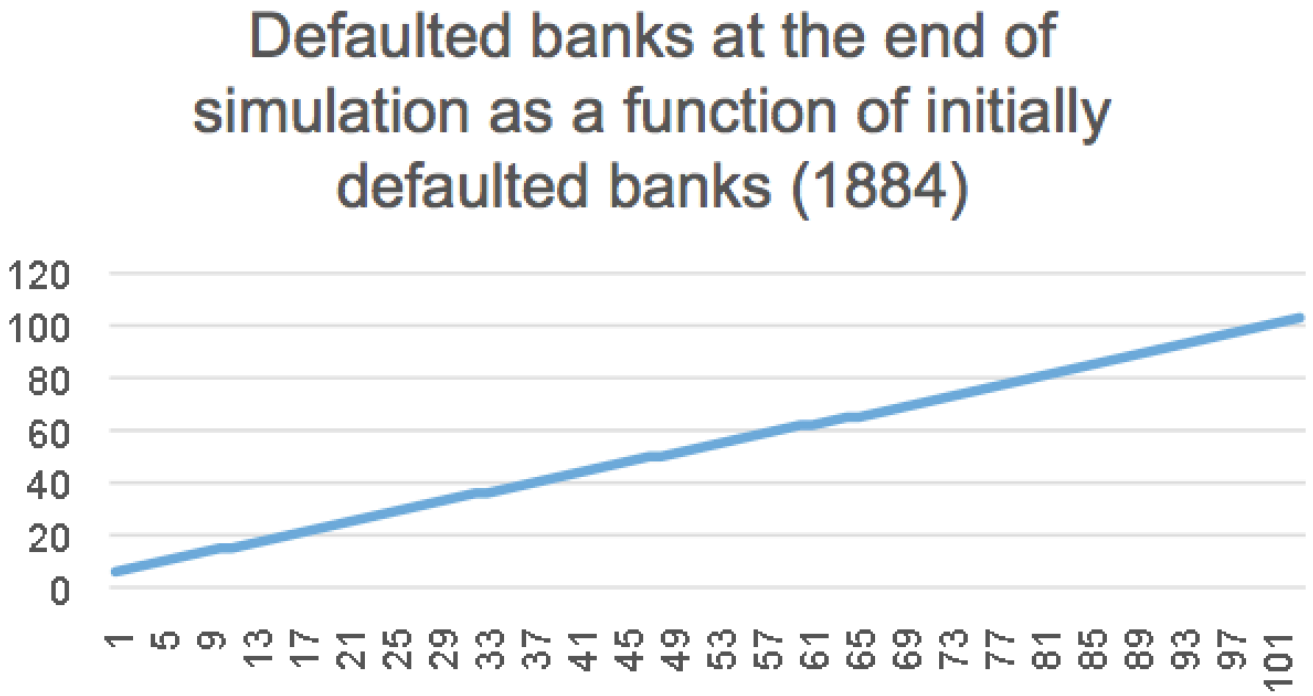
1884

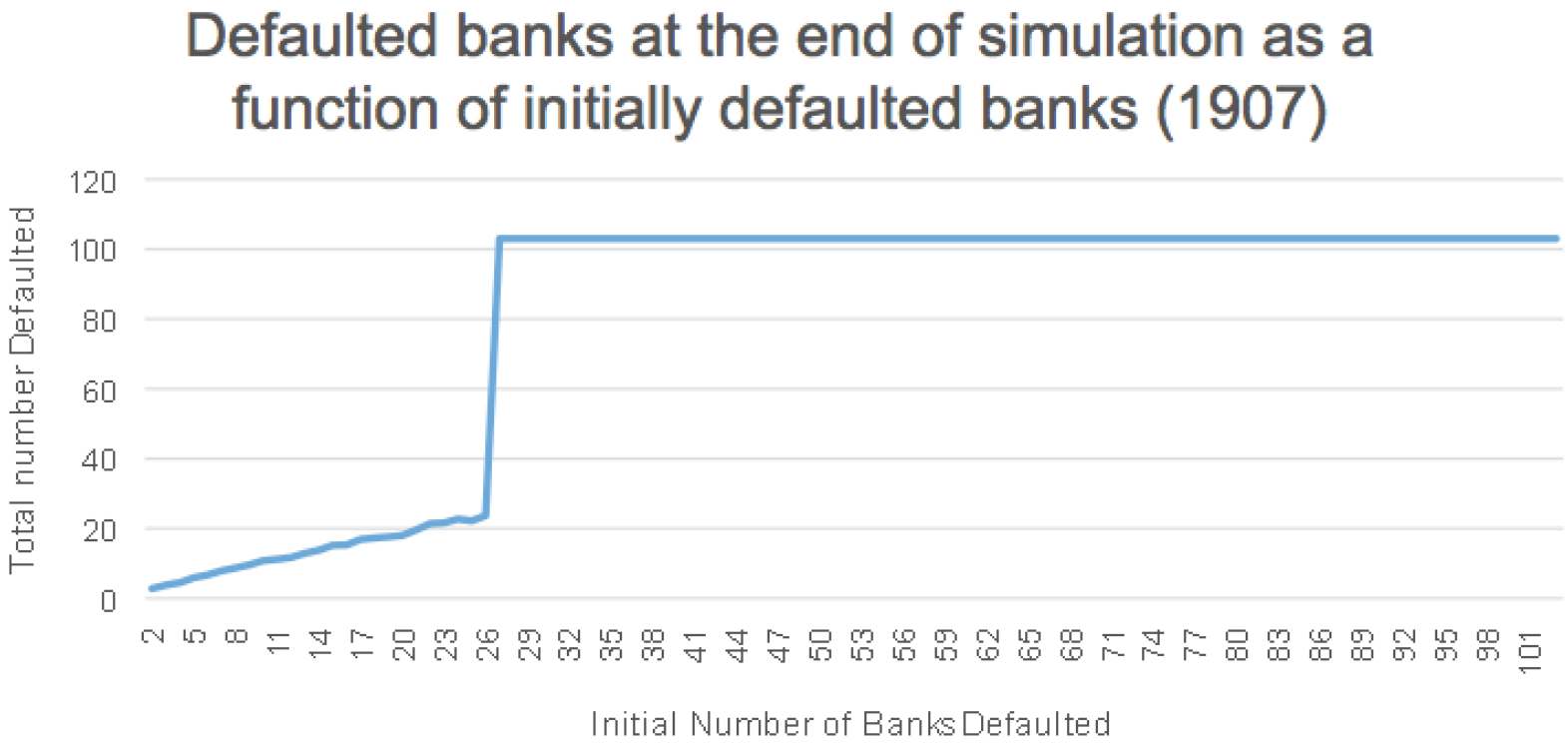

100
0
0
100
Time Step: 1 / 1 Defaulted Banks: 42 / 42
Washington
Montana
North Dakota
Minnesota
Oregon
Idaho
Wyoming
South Dakota
Wisconsin
Michigan
New York
Maine
Vermont
Massachusetts
Rhode Island
Connecticut
New Jersey
Delaware
Maryland
Washington, D.C.
West Virginia
Nebraska
Nevada
Utah
Colorado
Kansas
Missouri
Illinois
Indiana
Pennsylvania
Kentucky
Virginia
North Carolina
South Carolina
Georgia
Alabama
Mississippi
Louisiana
Arkansas
Tennessee
Arizona
New Mexico
Texas
Florida
Alaska
Hawaii

1893

1907




Defaulted banks at the end of simulation as a function of initially defaulted banks (1884)
120
100
80
60
40
20
0
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73
77
81
85
89
93
97
101


Defaulted banks at the end of simulation as a function of initially defaulted banks (1907)
Total number Defaulted
120
100
80
60
40
20
0
2 5 8 11 14 17 20 23 26 29 32 35 38 41 44 47 50 53 56 59 62 65 68 71 74 77 80 83 86 89 92 95 98 101
Initial Number of Banks Defaulted

Further work

- Add more regularity by breaking up clusters of country and reserve city banks in a variety of scenarios based on educated guesses (HELP needed here!)
- Obtain actual bank-level data for the period (even MORE help needed here!!).
- THANK YOU!