The Spatial Transmission of US Banking Panics: Evidence from 1870-1929

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CEPR-IMHOS

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Introduction

Banking panics: common during the National Banking Era (1863 — 1913) and the early Federal Reserve System Era (1913 —):

- On average, a banking panic every 4 years during 1870-1930
- Unit banking system (i.e., no branch) with *interbank markets*
- A pyramidal structure of reserves across (i) banks in central reserve cities (New York, NY, Chicago, IL, and St. Louis, MO); (ii) those in reserve cities; (iii) country banks

Big Question

Spatial transmission: how exactly did a banking panic in a state propagate across states?

- Severity and persistence of the spatial propagation of a panic in different states
- A role of interbank markets and the volatility of the aggregate banking sector

Our contribution:

- A novel theoretical framework for understanding interbank lending markets
- Identification strategy for spatial spillovers of a state-level banking panic

Interbank markets pose a trade-off:

- Allows banks to access cheaper funding — sustaining higher credit levels
- Exposes banks to risks of runs and panics outside their state borders, from which they would have otherwise been insulated by the unit banking system
- Thus, panics — spatial transmission to other states (confirmed by the data)

Literature

Classification and dating of major and minor panics:

Kemmerer (1910), DeLong and Summers (1986), Gorton (1988), Weber (2000), Wicker (2006), Reinhart and Rogoff (2009), Jalil (2015) and many others

- Jalil (2015): empirical estimation of the impact of major, nationwide panics on industrial production and prices
- Instability of the unit banking system during the National Banking Era: Calomiris and Haber (2014)

Importance of the correspondent network and pyramidal structure of reserves during the National Banking Era and the Great Depression (i.e., early Federal Reserve System Era):

Calimoris and Mason (1997, 2003), Carlson (2005), Calomiris and Carlson (2014, 2017), Anderson et al. (2018), Mitchener and Richardson (2019)

Modeling sides: Dordal i Carreras et al. (2023), Lee and Dordal i Carreras (2024)

Data

Banking sector data:

- Balance sheets of National Banks: from Annual Reports of the Office of the Comptroller of the Currency (4-5 "call reports" a year) - the "Abstract of Reports"
- 1880-1910 digitized by Weber (2000), the rest by us
- Geographical aggregation: reserve cities (the number is increasing over time) with the level of the state they belong to. Only consider lower 48 states (excluding Hawaii and Alaska) and treat Washington, DC as a state
- Frequency converted to quarterly (e.g., February $1^{st} = Q1$). In case $\exists$two observations in the same quarter, pick one that is closer to mid-quarter or a panic

Balance sheet variables:

- Relatively constant categories (some changes), easy aggregation Example Time-series
- For example, the number of banks, average capital, deposits, loans, liquidity ratio

Other data: Euclidean distance between two states (each state's most populated city)

Banking panic series: from Jalil (2015) ▸▸ Summary ▸▸ Deposits

States	Panic, start	Panic, end	Reporting date	Time to start (days)
All (Major) - from **Europe**	18sep1873	30sep1873	26dec1873	99
NY, PA, NJ	13may1884	31may1884	20jun1884	38
NY	10nov1890	22nov1890	19dec1890	39
All (Major) ← Carlson (2005); Calomoris and Carlson (2017)	13may1893	19aug1893	12jul1893	60
IL, MN, WI	26dec1896	26dec1896	09mar1897	73
MA, NY	16dec1899	31dec1899	13feb1900	59
NY	27jun1901	06jul1901	15jul1901	18
PA, **MD**	18oct1903	24oct1903	17nov1903	30
All (Major) - from **NY**	12oct1907	30nov1907	03dec1907	52
NY	25jan1908	01feb1908	14feb1908	20
MA	12aug1920	02oct1920	08sep1920	27
ND	27nov1920	19feb1921	29dec1920	32
FL, **GA**	14jul1926	21aug1926	31dec1926	170
FL	08mar1927	26mar1927	23mar1927	15
FL	20jul1929	07sep1929	04oct1929	76
			Median	38.5

Nature of panics

Big Question

Is panic exogenous or correlated (i.e., local economic conditions cause panics) with the business cycle?

Consensus in the literature:

- Causes of state-level panics relatively disconnected from the business cycle (e.g., Jalil (2015))
- Common triggers: mismanagement of funds, misappropriation of funds Excerpts

Systemic reason: small and medium-sized banks, unit office (unit banking system), no deposit insurance, lack of diversification, pyramidal structure of reserves

Additional exogeneity test

Granger causality test (i state, t quarter) with a panic dummy:

$$Panic_{i,t} = \sum_{l=1}^{4} \left[\beta_l^D \Delta \log(D_{i,t-l}) + \beta_l^L \Delta \log(L_{i,t-l}) + \beta_l^B \Delta \underbrace{\log(Bank_{i,t-l})}_{\text{Number of banks}} \right] + \mu_i + s_t + \varepsilon_{i,t}$$

Joint test, H_0: $\beta_l^D = \beta_l^L = \beta_l^B = 0, \quad \forall l$

	1	**2**	**3**	**4**
Joint F-test, p-value	***	***	H_0	H_0
R-squared	0.37%	1.96%	0.07%	0.104%
All panics	X	X		
Minor panics			X	X
Individual fixed effects		X		X
Seasonal dummies		X		X

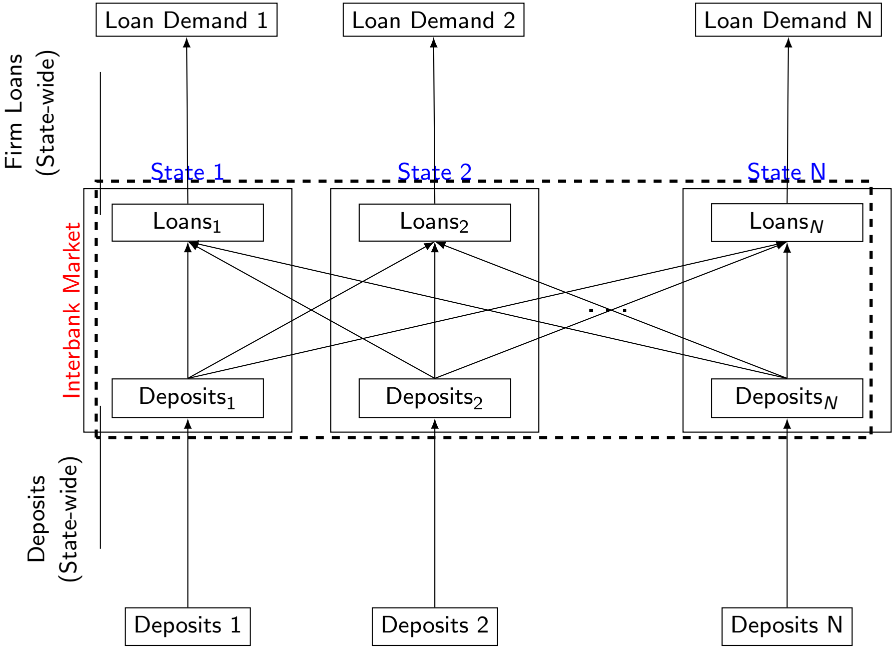
Claim: no rejection when using the regional series (i.e., minor panics)

Model

Objective: model interbank lending markets featuring the geographical transmission of deposit shocks

Main components: N regions (i.e., states)

- N loan division, supplying lending to local demands
- N deposit division, accepting deposits from local depositors, creating loanable funds, and distributing to banks across states through interbank markets
- N deposit supplies (from households in each state) and loan demands (from firms in the same state). Assumed to be local and exogenous.
- Time is continuous (indexed by τ) within a quarter (indexed by t)


Loan Demand 1
Loan Demand 2
Loan Demand N
Firm Loans (State-wide)
State 1
State 2
State N
Interbank Market
Loans$_1$
Loans$_2$
Loans$_N$
...
Deposits$_1$
Deposits$_2$
Deposits$_N$
Deposits (State-wide)
Deposits 1
Deposits 2
Deposits N

Model — loan division (i)

Production function

$$Loan^S_{i,t}(\tau) \leq M_{i,t}(\tau)$$

where $M_{i,t}(\tau)$ represents loanable funds.

The loan division i solves:

$$\max_{\{Loan^S_{i,t}(\tau)\}} \int_0^1 \left(R^F_{i,t}(\tau) Loan^S_{i,t}(\tau) - R^I_{i,t}(\tau) M_{i,t}(\tau) \right) d\tau$$

where

1. $R^F_{i,t}(\tau)$: interest rate charged on loans
2. $R^I_{i,t}(\tau)$: interest rate charged on loanable funds from the interbank loan market

Model — loan division (i)

At optimum:

$$R^F_{i,t}(\tau) = R^I_{i,t}(\tau)$$

due to perfect competition

Loanable funds are fungible, homogeneous good (money), obtained at the lowest rate every period: for n such that

$$R^I_{i,t}(\tau) = \min_n \{ R^I_{ni,t}(\tau) \},$$

Rate charged by bank n to bank i

the loanable funds come from bank n

$$M_{i,t}(\tau) = M_{ni,t}(\tau), \quad n = \arg\min \left\{ R^I_{ni,t}(\tau) \right\}$$

Model — deposit division (n)

Loanable fund production function:

$$\sum_{i=1}^{N}\int_0^1 z_{ni,t}(\tau)M_{ni,t}(\tau)d\tau = (D_{n,t})^{\alpha} \tag{1}$$

where $z_{ni,t}(\tau)$ represents technology of forming a lonable fund for state i, $M_{ni,t}(\tau)$ loanable funds for loan division i and $D_{n,t}$ local deposits at the beginning of the period.

- $\alpha > 1$: economies of scale

Productivity:

- $z_{ni,t}(\tau)$ is Weibull-distributed $\sim W(T_{ni}, \kappa)$ Properties
- T_{ni}: scale parameter, interpreted as transportation costs; κ: shape parameter: captures costs associated to trading with different states (trade costs, agency problems, imperfect information, etc)
- Different costs within the continuum (random draws)

Model — deposit division (n)

Solves the following problem, subject to (1)

$$\max_{\{M_{ni,t}(\tau)\}} \sum_{i=1}^{N} \int_0^1 R^l_{ni,t}(\tau) M_{ni,t}(\tau) d\tau - \underbrace{\rho^S_n(D_{n,t}) D_{n,t}}_{\text{Cost of loanable funds}}$$

- $\rho^S_n(\cdot)$: inverse deposit supply curve (time-invariant): deposit division acts as a monopsonist for deposits

At optimum:

$$R^l_{ni,t}(\tau) = \underbrace{z_{ni,t}(\tau)}_{\text{Random draw}} \cdot \left(\frac{1}{\alpha}\right) \underbrace{\rho^S_n(D_{n,t}) \left(1 + \frac{1}{\varepsilon^S_{n,t,D,\rho}}\right)}_{\equiv \rho_{n,t}} \cdot (D_{n,t})^{-(\alpha-1)} . \qquad (2)$$

where

$$\varepsilon^S_{n,t,D,\rho} \equiv \left[\frac{\rho^{S\prime}_n(D_{n,t}) D_{n,t}}{\rho^S_n(D_{n,t})}\right]^{-1} > 0.$$

is the deposit supply elasticity ⏩ Intuition

- Assume $\rho_{n,t} \equiv \rho_t, \forall n$

Model — lending demand (i)

Thus, state i faces interbank rate

$$R^F_{i,t}(\tau) = \min_n \left\{ R^I_{ni,t}(\tau) \right\} \sim W\left(\Phi_{i,t}, \kappa\right)$$

where

$$\Phi_{i,t} = \frac{\rho_t}{\alpha} \cdot \left(\sum_{n=1}^{N} \left(T_{ni}\right)^{-\kappa} \cdot D_{n,t}^{\kappa(\alpha-1)} \right)^{-\frac{1}{\kappa}}$$

Assume that the demand for lending to firms in state i is given by

$$Loan^D_{i,t}(\tau) = R^F_{i,t}(\tau)^{-\beta} \varepsilon_{i,t} \qquad \forall i$$

where $\varepsilon_{i,t}$ is a loan demand shifter for period t

Total lending demand in period t is then

$$Loan^D_{i,t} = \int_0^1 Loan^D_{i,t}(\tau) d\tau = \underbrace{\left[\int_0^1 R^F_{i,t}(\tau)^{-\beta} d\tau \right]}_{= \mathbb{E}\left(R^F_{i,t}(\tau)^{-\beta}\right)} \varepsilon_{i,t} \qquad \forall i$$

Model — lending demand (i)

Key aggregation equation:

$$Loan^D_{i,t} = \left[\sum_{n=1}^{N} (T_{ni})^{-\kappa} D_{n,t}^{\kappa(\alpha-1)}\right]^{\frac{\beta}{\kappa}} \left(\frac{\alpha}{\rho_t}\right)^{\beta} \Gamma\left(1-\frac{\beta}{\kappa}\right)\varepsilon_{i,t} \qquad \forall i$$

- Lending in each state i is positively linked to deposits in all other states

Trade-off with $D_{n,t} = \bar{D}_t$, $\forall n$:

1. With $T_{ni} \to \infty$ for $n \neq i$,

$$Loan^D_{i,t} = \left(\frac{\alpha}{\rho_t}\right)^{\beta} \cdot (\bar{D}_t)^{\beta(\alpha-1)} \Gamma\left(1-\frac{\beta}{\kappa}\right) \cdot \varepsilon_{i,t}\ , \qquad \forall n$$

2. With $T_{ni} = 1$, $\forall n, i$,

$$Loan^D_{i,t} = \underbrace{N^{\frac{\beta}{\kappa}}}_{>1} \cdot \left(\frac{\alpha}{\rho_t}\right)^{\beta} \cdot (\bar{D}_t)^{\beta(\alpha-1)} \Gamma\left(1-\frac{\beta}{\kappa}\right) \cdot \varepsilon_{i,t}\ , \qquad \forall n$$

— but $N^{\frac{\beta}{\kappa}}$ times more volatile

Log-linear approximation: ⏩ Details

$$\log\left(Loan_{i,t}\right) = \mu_i + \underbrace{s_t}_{\text{Seasonal fixed effect}} + \sum_{n=1}^{N} \underbrace{\tilde{T}_{ni}}_{\text{Spatial transmission}} \log\left(D_{n,t}\right) + \epsilon_{i,t} \qquad \forall i$$

Seasonal fixed effect

Spatial transmission

Assume:

$$\tilde{T}_{ni} = \lambda_1 + \underbrace{\lambda_2}_{<0} \log\left(\underbrace{Distance_{ni}}_{\text{Distance between state } i \text{ and } n}\right) + \underbrace{\lambda_3}_{>0} Neighbor_{ni} + \underbrace{\lambda_4}_{>0} Own_n$$

⏩ Regression

Estimation — reduced form

Local projections (Jordà, 2005):

4 lags of $\{F^j_{i,t}\}$ and $y_{i,t}$

$$y_{i,t+h} = \eta^y_{i,h} + s^y_{t,h} + \sum_{j=1}^{4} \theta^y_{j,h} F^j_{i,t} + \sum_{l=1}^{L} \beta^y_{l,h} X_{i,t-l} + \epsilon_{i,t+h}, \quad h = 1, \ldots, H \,, \tag{3}$$

where

$$F^1_{i,t} = \sum_{n=1}^{N} Panic_{n,t} \qquad F^3_{i,t} = \sum_{n=1}^{N} Neighbor_{ni} \cdot Panic_{n,t}$$

$$F^2_{i,t} = \sum_{n=1}^{N} \log\left(Distance_{ni}\right) \cdot Panic_{n,t} \qquad F^4_{i,t} = \sum_{n=1}^{N} Own_n \cdot Panic_{n,t}$$

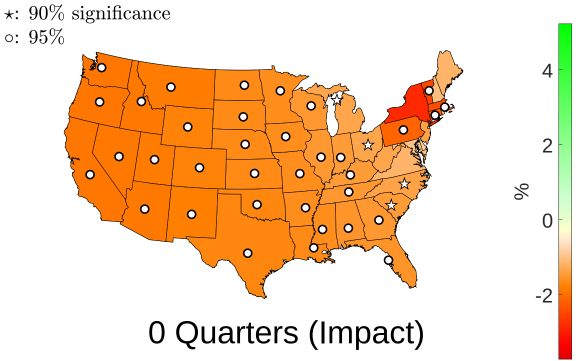
1. $y_{i,t}$: number of banks, average capital, deposits, loans, liquidity ratio (all log)
2. Driscoll-Kraay standard error: consistent under spatial correlation, heteroskedasticity, and auto-correlation (4 lags)

Estimation — reduced form

Simulation:

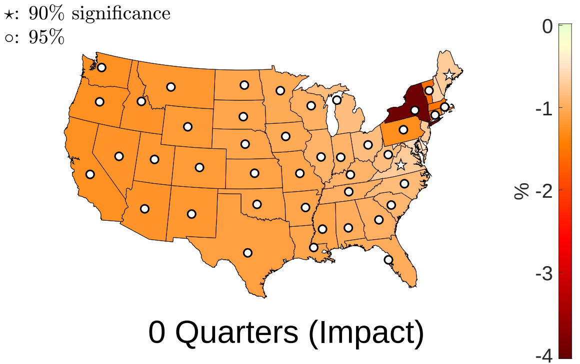
1. Estimate equation (3) for all h, obtain $\left\{\hat{\theta}_{j,h}\right\}_{j=1}^{4}$
2. Assume $\exists$panic in New York (state), generate $\left\{F_{i,t}^{j}\right\}_{j=1}^{4}$ for all i
3. $\sum_{j=1}^{4} \hat{\theta}_{j,h}^{y} F_{i,t}^{j}$ is the predicted response at horizon h for state i

Results— deposits



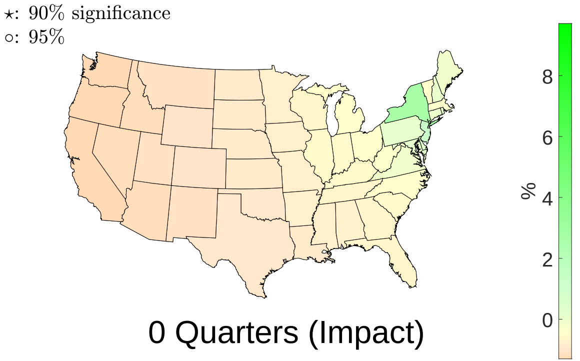
- Spatial propagation becomes strong and significant (up to 4% drops). Returns to the pre-crisis level except in the origin and neighbor states

Results— loans



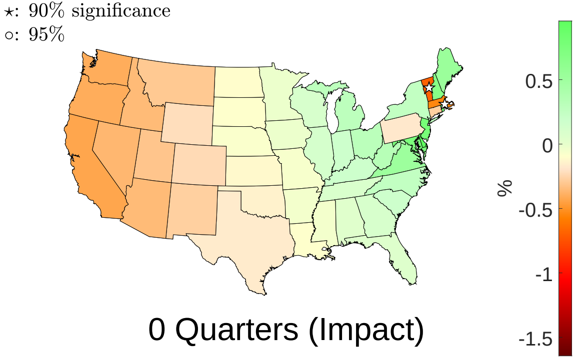
- Spatial propagation becomes strong and significant (up to 4% drops). Returns to the pre-crisis level except in the origin and neighbor states

Results— liquidity ratio



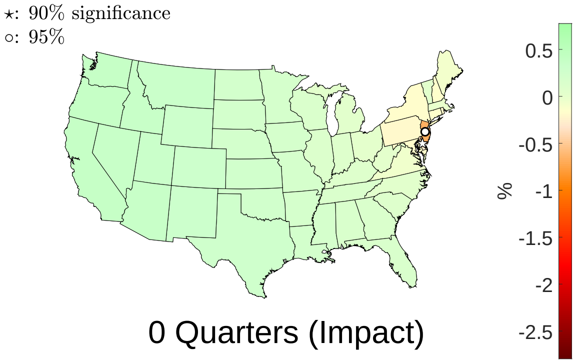
- Persistently rise in many states above the pre-crisis level (significant after 7 quarters)

Results— average capital



- 1.5% drops after two years in many other states even after two years (significant)

Results— the number of banks



- 1.5-1.8% drops in the origin and neighboring states (not so significant)

Robustness— size effects?

Local projections with an additional control (Jordà, 2005):

4 lags of $\{F^j_{i,t}\}$ and $y_{i,t}$

$$y_{i,t+h} = \eta^y_{i,h} + s^y_{t,h} + \sum_{j=1}^{5} \theta^y_{j,h} F^j_{i,t} + \sum_{l=1}^{L} \beta^y_{l,h} X_{i,t-l} + \epsilon_{i,t+h}, \quad h = 1, \ldots, H , \qquad (4)$$

where

$$F^1_{i,t} = \sum_{n=1}^{N} Panic_{n,t}$$

$$F^2_{i,t} = \sum_{n=1}^{N} \log\left(Distance_{ni}\right) \cdot Panic_{n,t}$$

$$F^3_{i,t} = \sum_{n=1}^{N} Neighbor_{ni} \cdot Panic_{n,t}$$

$$F^4_{i,t} = \sum_{n=1}^{N} Own_{ni} \cdot Panic_{n,t}$$

$$F^5_{i,t} = \underbrace{\sum_{n=1}^{N} \log\left(\frac{D_{n,t-1}}{D_{t-1}}\right) \cdot Panic_{n,t}}_{\text{New control}}$$

- The results are very similar ▸▸ Results

Thank you very much!

(Appendix)

Data: Asset Side

Resources.	Oct. 21, 1913.	Jan. 13, 1914.	Mar. 4, 1914.	June 30, 1914.	Sept. 12, 1914.
ALABAMA.	90 banks.	90 banks.	90 banks.	90 banks.	90 banks.
Loans and discounts	$45,513,715.05	$42,849,992.35	$42,905,637.89	$43,582,574.87	$41,812,117.43
Overdrafts	396,119.39	288,816.63	238,160.73	104,561.68	111,129.33
Bonds for circulation	8,747,750.00	8,935,750.00	8,934,750.00	9,101,750.00	9,103,749.95
Misc. securities	…	…	…	…	4,861,281.14
Bonds for deposits	411,000.00	485,000.00	505,713.00	410,000.00	397,000.00
Other b'ds for deposits	496,153.75	500,655.64	476,900.75	274,500.00	418,500.00
U. S. bonds on hand	9,000.00	9,000.00	9,000.00	9,000.00	10,000.00
Premiums on bonds	91,245.71	78,576.04	77,412.29	70,094.79	63,521.91
Bonds, securities, etc.	3,348,927.54	3,358,970.02	3,308,569.78	3,363,852.16	2,321,201.77
Stocks	…	…	…	143,858.49	179,144.71
Banking house, etc.	2,173,798.88	2,169,921.91	2,169,114.21	2,190,582.18	2,196,334.97
Real estate, etc.	322,342.75	311,914.19	322,095.64	333,964.56	333,918.44
Due from nat'l banks	4,195,515.45	4,300,854.48	3,666,789.64	2,169,436.13	1,727,789.62
Due from State banks	1,714,335.10	1,660,222.11	1,303,238.00	976,877.10	845,832.72
Due from res've agts	6,959,955.73	7,374,465.51	6,348,607.03	,403,111.15	3,215,822.55
Cash items	308,028.93	262,611.25	239,394.00	187,521.17	238,991.11
Clear'g-house exch'gs	324,608.67	250,191.01	311,139.61	270,994.99	179,617.99
Bills of other banks	889,950.00	1,124,469.00	978,233.00	964,975.00	1,535,034.00
Fractional currency	29,160.00	41,041.08	45,683.69	45,333.69	42,625.33
Specie	2,852,883.16	3,248,435.06	3,002,017.36	3,043,383.10	2,852,801.47
Legal-tender notes	662,485.00	709,896.00	531,574.00	459,927.00	341,739.00
5% fund with Treas.	424,287.50	429,037.50	413,137.50	434,437.50	561,766.50
Due from U. S. Treas.	33,700.00	39,750.00	14,902.00	21,625.00	5,350.00
Total	79,904,962.61	78,429,569.78	75,802,070.12	72,563,370.56	73,355,269.94

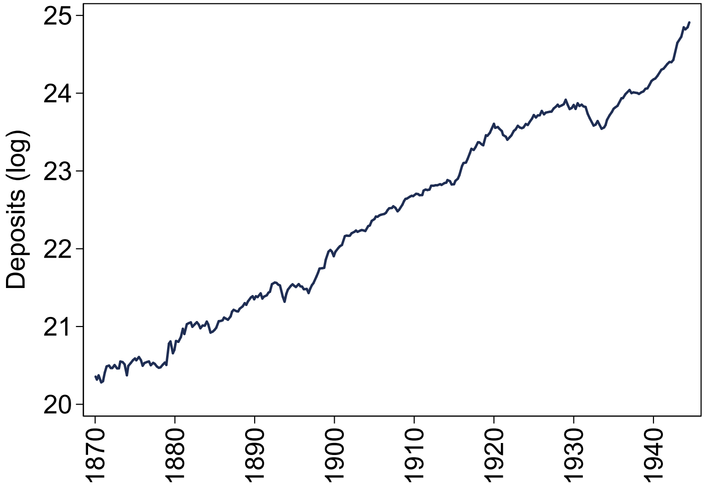
Go back

Data: Liability Side

Liabilities.	Oct. 21, 1913.	Jan. 13, 1914.	Mar. 4, 1914.	June 30, 1914.	Sept. 12, 1914.
ALABAMA.	90 banks.	90 banks.	90 banks.	90 banks.	90 banks.
Capital stock	$10,180,290.00	$10,320,100.00	$10,375,500.00	$10,405,000.00	$10,405,000.00
Surplus fund	5,851,293.59	6,042,995.00	6,013,995.00	6,052,170.00	6,119,925.00
Undivided profits	1,452,249.96	1,345,635.01	1,623,606.48	1,662,905.41	1,599,714.20
Nat'l-bank circulation	8,694,175.00	8,885,470.00	8,803,060.00	8,984,400.00	11,008,827.50
State-bank circulation					
Due to national banks	2,280,617.15	2,191,660.20	1,784,251.77	1,184,974.72	1,014,920.21
Due to State banks	2,549,617.27	2,500,465.48	1,927,496.87	1,073,390.53	890,665.68
Due to trust co.'s, etc.	224,690.83	367,524.10	207,992.96	148,529.49	107,222.25
Due to reserve agents	114,311.60	116,283.51	44,660.72	99,095.45	123,588.71
Dividends unpaid	35,842.00	65,113.41	9,985.42	209,618.42	39,996.50
Individual deposits	43,555,062.18	44,766,048.83	43,484,032.59	39,135,391.86	55,916,560.84
United States deposits	1,526,438.50	1,209,730.53	579,288.80	393,796.17	608,724.64
Postal savings deposits	47,602.83	48,465.95	53,074.55	52,905.32	56,663.19
Dep'ts U.S. dis. officers	31,631.18	124,907.27	164,556.38		
Bonds borrowed	390,800.00	47,800.00	47,800.00		
U.S. bonds borrowed				8,000.00	15,000.00
Other bonds borrowed				21,800.00	181,800.00
Notes rediscounted	726,613.10	183,648.36	9,000.00	146,602.99	765,222.31
Bills payable	2,199,018.25	183,000.00	635,000.00	2,919,054.89	4,440,750.00
Reserved for taxes	35,931.62	14,235.03	32,280.09	54,521.26	45,394.45
Other liabilities	8,777.55	16,487.10	6,488.49	11,204.05	15,294.36
Total	79,904,962.61	78,429,569.78	75,802,070.12	72,563,370.56	73,355,269.94

Go back

Data — Deposits in the United States



▸▸ Go back

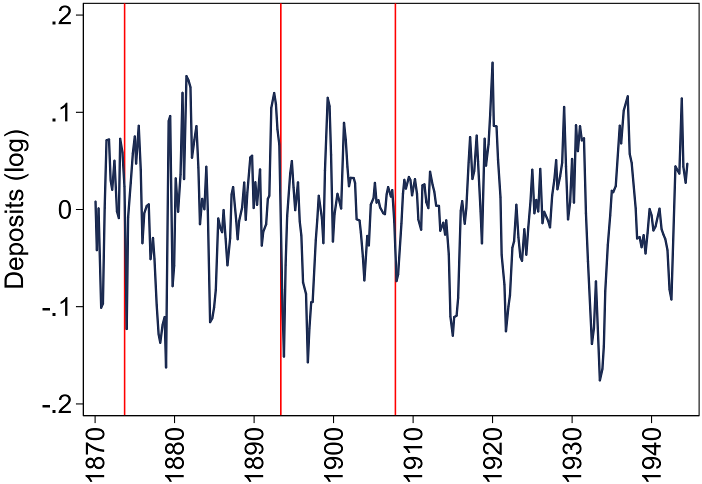
Banking panic series: from Jalil (2015)

Date	Jalil (2015)	Origin
Sep 1873	All	Europe
May 1884	NY, PA, NJ	NY
Nov 1890	NY	
May 1893	All	All
Dec 1896	IL, MN, WI	IL
Dec 1899	MA, NY	MA
Jun 1901	NY	
Oct 1903	PA, MD	MD

Date	Jalil (2015)	Origin
Dec 1905	IL	
Oct 1907	All	NY
Jan 1908	NY	
Aug 1920	MA	
Nov 1920	ND	
Jul 1926	FL, GA	GA
Mar 1927	FL	
Jul 1929	FL	

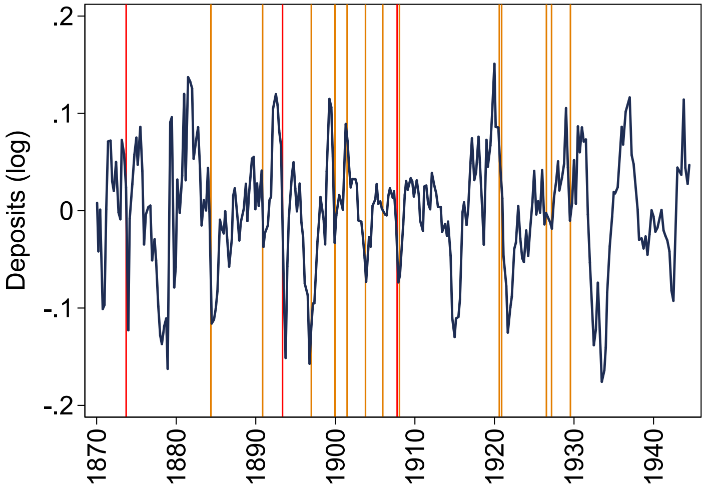
Go back

Data — (de-trended) deposits in the United States



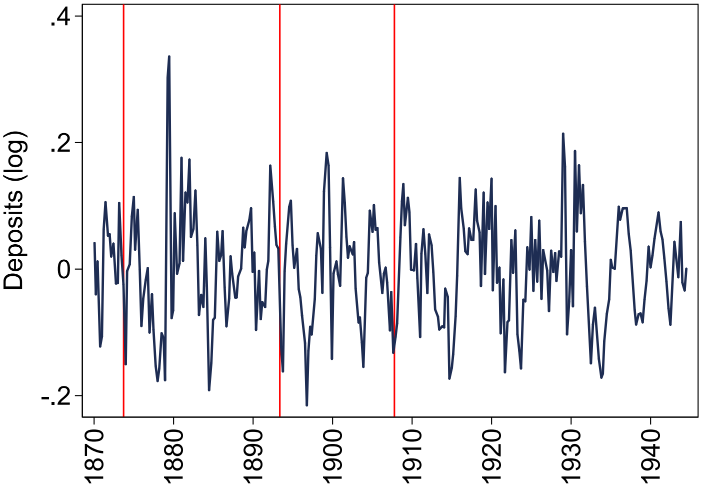
Major panics ▸▸ Go back

Data — (de-trended) deposits in the United States



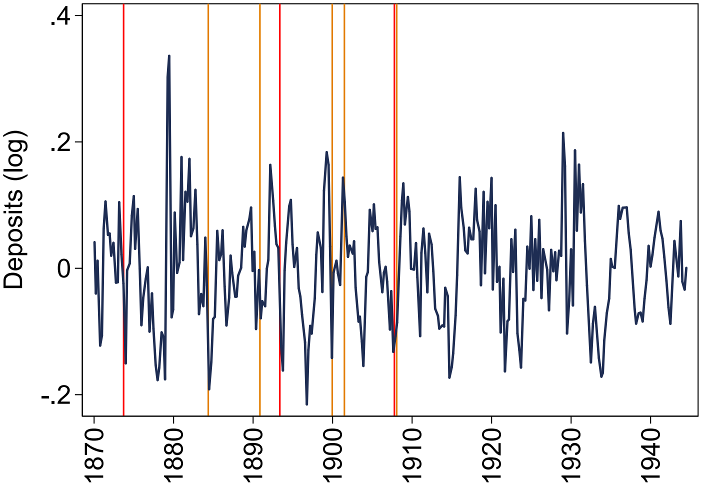
Minor panics ⏩ Go back

Data — (de-trended) deposits in New York



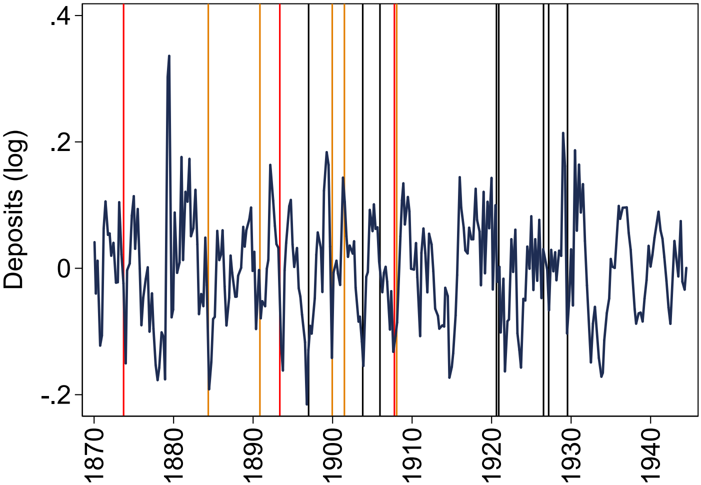
Major panics ⏩ Go back

Data — (de-trended) deposits in New York



Minor panics (related to New York) Go back

Data — (de-trended) deposits in New York



Minor panics (all) Go back

Excerpts from Jalil (2015)

1884 (minor) panic (**NY**, PA, NJ):

- *"On May 14, the Metropolitan Bank closed its doors following a serious run. Rumors had been circulating that its president had misappropriated funds for speculative purposes. The suspension of the Metropolitan Bank, an institution holding reserves from banks throughout the nation, led to the intervention of the New York Clearing House."*

1896 (minor) panic (**IL**, MN, WI):

- *"The failure of The National Bank of Illinois set off a banking panic in December 1896. According to the Chronicle, the bank had loaned an amount that surpassed its "combined capital, surplus and undivided profits" to one corporation and a large additional sum to a relative of one of the officers of the bank."*

Go back

Weibull distribution: useful properties

$X_i \sim W(\lambda_i, \kappa)$:

1. Scalar multiplication:

$$cX_i \sim W\left(c\lambda_i, \kappa\right)$$

2. Moments:

$$\mathbb{E}(X_i^n) = (\lambda_i)^n \, \Gamma\left(1 + \frac{n}{\kappa}\right)$$

3. Minimum of $\{X_n\}$ when $X_n \sim W(\lambda_n, \kappa)$ for $\forall n$ and $\{X_n\}$ are mutually independent:

$$\min_n \{X_n\} \sim W\left(\left(\sum_n (\lambda_n)^{-\kappa}\right)^{-\frac{1}{\kappa}}, \kappa\right)$$

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Model — Deposit Division (n)

At optimum:

$$R^{I}_{ni,t}(\tau) = \underbrace{z_{ni,t}(\tau)}_{\text{Random draw}} \cdot \left(\frac{1}{\alpha}\right) \rho_{n,t} \cdot (D_{n,t})^{-(\alpha-1)} \quad . \tag{5}$$

where

$$\rho_{n,t} \equiv \rho^{S}_{n}(D_{n,t}) \left(1 + \frac{1}{\varepsilon^{S}_{n,t,D,\rho}}\right)$$

1. Economies of scale ($\alpha > 1$): $D_{n,t}\uparrow \longrightarrow R^{I}_{ni,t}(\tau)\downarrow$ (i.e., charge lower interbank loan rates)
2. $\varepsilon^{S}_{n,t,D,\rho}\downarrow$ (deposit supply elasticity$\downarrow$) $\longrightarrow$ increasing $D_{n,t}$ by \$1 requires deposit rates$\uparrow$ more $\longrightarrow$ interbank loan rates$\uparrow$ in equilibrium

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Model — lending demand (i)

Log-linear approximation around equal deposit size (across n)

$$\log\left(Loan_{i,t}\right) = \mu_i + s_t + \sum_{n=1}^{N} \tilde{T}_{ni} \log\left(D_{n,t}\right) + \epsilon_{i,t} \qquad \forall i$$

where

$$\mu_i = -\beta \sum_{n=1}^{N} \left(\frac{\left(T_{ni}\right)^{-\kappa}}{\sum_{n'=1}^{N} \left(T_{n'i}\right)^{-\kappa}} \right) \hat{T}_{ni} = -\beta \sum_{n=1}^{N} \left(\frac{T_{ni}}{\bar{T}_i} \right)^{-\kappa} \hat{T}_{ni}$$

and

$$\tilde{T}_{ni} = \underbrace{\beta(\alpha-1)}_{>0} \left(\frac{T_{ni}}{\bar{T}_i} \right)^{-\kappa}, \quad \text{where} \quad \bar{T}_i \equiv \left(\sum_{n=1}^{N} \left(T_{ni}\right)^{-\kappa} \right)^{-\frac{1}{\kappa}}$$

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Model to the regression specification

Then

$$\log\left(Loan_{i,t}\right) = \mu_i + s_t + \sum_{j=1}^{4} \lambda_j X_{i,t}^{j} + \epsilon_{i,t} \tag{6}$$

where

$$X_{i,t}^{1} = \sum_{n=1}^{N} \log\left(D_{n,t}\right) \qquad X_{i,t}^{3} = \sum_{n=1}^{N} Neighbor_{ni} \cdot \log\left(D_{n,t}\right)$$

$$X_{i,t}^{2} = \sum_{n=1}^{N} \log\left(Distance_{ni}\right) \cdot \log\left(D_{n,t}\right) \qquad X_{i,t}^{4} = \sum_{n=1}^{N} Own_{n} \cdot \log\left(D_{n,t}\right)$$

Deposits supply is given by (precise specification not important)

$$\log\left(D_{n,t}\right) = c_n + \log\left(D_{n,t-1}\right) + \phi Panic_{n,t} + \upsilon_{n,t} \tag{7}$$

- $Cov(\upsilon_{n,t}, \epsilon_{i,t}) \neq 0, \quad \forall n, i$
- Exogeneity of minor panics: $Cov(\upsilon_{n,t}, Panic_{n,t}) = Cov(\epsilon_{i,t}, Panic_{n,t}) = 0, \quad \forall n$

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Model to the regression specification

Combining equations (6) and (7)

$$\log\left(Loan_{i,t}\right) = \eta_i + s_t + \sum_{j=1}^{4} \theta_j F_{i,t}^{j} + \varepsilon_{i,t}$$

where

$$F_{i,t}^{1} = \sum_{n=1}^{N} Panic_{n,t}$$

$$F_{i,t}^{2} = \sum_{n=1}^{N} \log\left(Distance_{ni}\right) \cdot Panic_{n,t}$$

$$F_{i,t}^{3} = \sum_{n=1}^{N} Neighbor_{ni} \cdot Panic_{n,t}$$

$$F_{i,t}^{4} = \sum_{n=1}^{N} Own_{n} \cdot Panic_{n,t}$$

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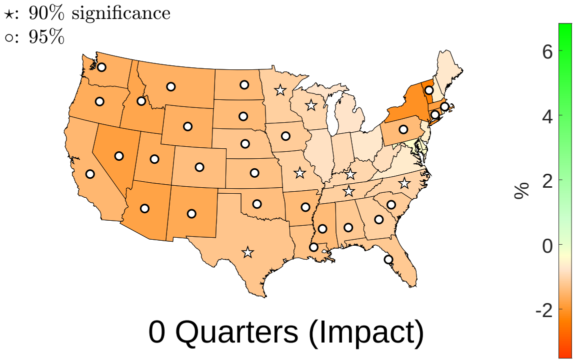
Robustness results with size effects— deposits



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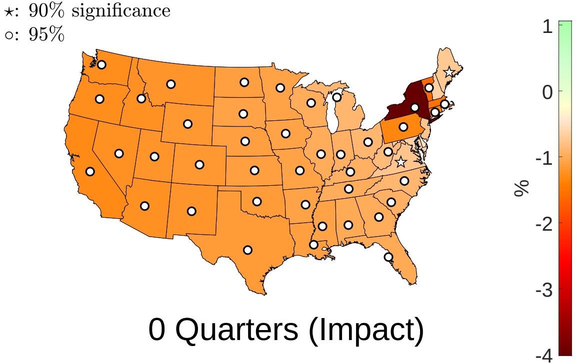
Robustness results with size effects— loans



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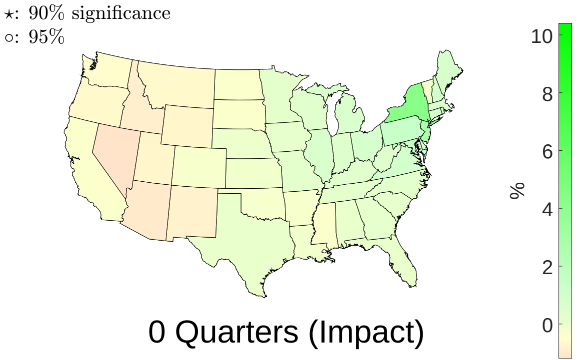
Robustness results with size effects— liquidity ratio



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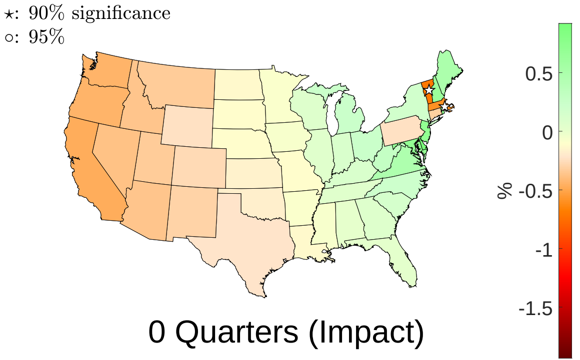
Robustness results with size effects— average capital



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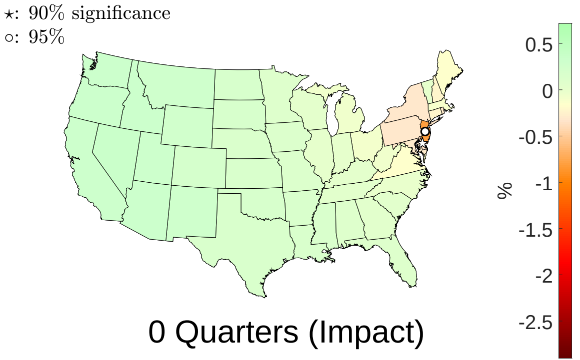
Robustness results with size effects— the number of banks



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