Backtesting Systemic Risk Measures during Historical Bank Runs and the Great Depression

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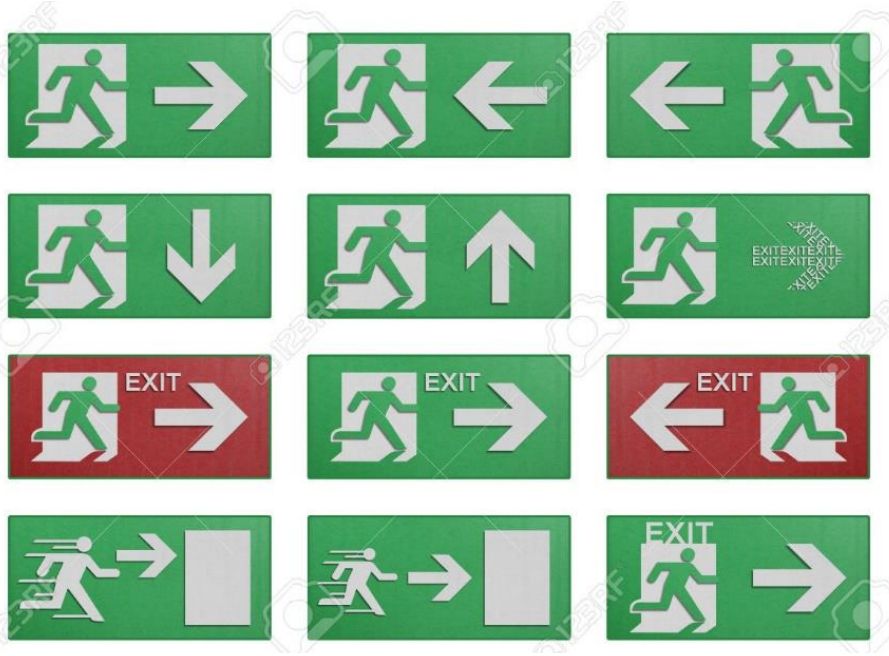


In 1907, no one had ever heard of an asset-backed security, and a single private individual could command the resources needed to bail out the banking system; and yet, fundamentally, the Panic of 1907 and the Panic of 2008 were instances of the same phenomenon, as I have discussed today. The challenge for policymakers is to identify and isolate the common factors of crises, thereby allowing us to prevent crises when possible and to respond effectively when not.

Chairman Ben S. Bernanke - Speech November 8, 2013

The Crisis as a Classic Financial Panic

Systemic Risk Measurement

- Systemic Risk has emerged as a key new concept in the aftermath of the 2007–2009 Financial Crisis
- Serious research efforts have been undertaken. The number of contributions is already quite sizable. However, no single best practice/unifying approach has clearly emerged.
- New agencies were created specifically designed to analyze and monitor systemic risk.

Purpose of Research

- In this work we tackle the problem of the evaluation of systemic risk measures using a novel historical dataset containing balance sheet and market information for the New York banking system from 1866 to 1933.

- Throughout the time period we study, the United States frequently experienced financial crises, with several panics similar in magnitude to the 2008 crisis.

Questions we try to Answer

- Are systemic risk measures useful beyond standard size, volatility, beta and leverage indicators?
  - Cross-sectional - SIFIs
  - Time series
- Can we predict 'bailout costs'?
- Is today's banking sector more connected compared to a century ago?

Two Papers

- *Back to the Future - Backtesting Systemic Risk Measures during Historical Bank Runs and the Great Depression*
  Posted on SSRN

- *Is Today's Banking Sector more Fragile than a Century Ago?*
  Work in progress

Summary of Findings I

- Overall, SRISK and CoVaR provide useful cross-sectional rankings of the banks that suffered the largest deposit losses.
- Hence, our results show that CoVaR and SRISK identify SIFIs in periods of distress beyond what is explained by standard measures (size, leverage, beta, volatility).
- The cross-sectional predictive results are robust up to 6 months before the panic events.
- Specifically pertaining to CoVaR, our results imply VaR also appears to be an adequate tool for systemic risk monitoring.

Summary of Findings II

- If we take various measure in isolation, we also obtain interesting results. In particular, it appears that leverage is not a good predictor for systemic risk.
- This is important as there are some suggestion to use simple capital ratios as a simple device for macro prudential policy.
- Size performs well and is at par with CoVaR and/or SRISK in terms of rank correlations, but the systemic risk measures provide important and significant incremental information.

Summary of Findings III

- The SRISK index is also a prediction of the capital shortage a bank would experience conditional on a systemic event.
- We find that SRISK fails to provide an unbiased estimate of the actual capital shortage.
- Turning to the time-series analysis, we find that aggregate CoVaR and SRISK improve forecasting of the downfall in aggregate deposits during panics only marginally.
- Put differently, there is solid evidence for cross-sectional predictability – i.e. the identification of SIFIs – while there is only weak evidence of predicting the next crisis with aggregate CoVaR and SRISK.

Structure of Talk

- Historical Perspective
- The Data
- Systemic Risk Measures
- Results

Historical Perspective I

- The history of banking in the US prior to WWII was fraught with periodic financial crises and banking panics.
- After the passage of the National Banking Acts of 1863 and 1864, a national banking system was created, subject to capital requirements and regulation through the newly formed Office of the Comptroller of the Currency (OCC).
- Unfortunately, the oversight and capital requirements were not enough to provide a bulwark against a run on banks and trusts.

Historical Perspective II

Start Date	End Date	Description
Sep 1873	Dec 1873	Jay Cooke and Company bankruptcy and railroad bubble burst
May 1884	Aug 1884	Brokerage firm Grant and Ward sets off banking panic
Nov 1890	Mar 1891	Barings Bank crisis
May 1893	Sep 1893	Bankrupcies and run on gold as an eventual result of Barings Crisis
Aug 1907	Nov 1907	Failure of Knickerbocker Trust spread panic to financial trusts
Jul 1914	Nov 1914	Banking panic and liquidity crisis set of by WWI
Aug 1921	Dec 1921	Downturn resulting from post-war monetary and fiscal contraction
Oct 1931	Mar 1932	Bank failures in Chicago–Britain's Departure from gold was March 1931

The Data I

- We employ financial and balance sheet data for member banks of the New York Clearinghouse.
- The NY Clearinghouse was the first clearinghouse in the US, and it facilitated exchange, issued script, stored specie, and regulated member institutions.
- Importantly, clearinghouses attempted to maintain stability of member institutions through transparency, i.e., publishing and inspecting member balance sheets, requiring members to maintain reserves, and the provision of support in times of financial stress.

The Data II

- We collected balance statements as published by the NY Clearinghouse. They appeared in the Saturday morning *New York Times*, *Wall Street Journal* and *Commercial and Financial Chronicle*.
- We collected the data every 28 days, or 13 times a year. The data was primarily collected from the *NYT* and *WSJ*.
- The condensed balance sheets reported the average weekly and Friday closing values of each bank's loans, deposits, excess reserves, specie, legal tenders, circulation and clearings.

New York City Banks.—The following statement shows the condition of the Associated Banks of New York City for the week ending at the commencement of business May 3:

Banks.	Average Amount of—				
	Loans and Discounts.	Specie.	Legal Tenders.	Net Deposits other than U. S.	Circulation.
	$	$	$	$	$
New York	9,768,000	1,595,000	1,016,000	9,242,000	450,000
Manhattan Co	7,578,000	1,058,000	510,000	6,836,000	.....
Merchants'	7,720,300	939,700	762,400	7,122,200	355,000
Mechanics'	8,198,000	1,372,000	673,000	7,285,000	.....
Union	4,331,300	167,600	342,600	3,811,100	.....
America	10,040,200	699,900	495,600	7,064,500	1,100
Phenix	2,985,000	519,000	126,700	2,581,000	267,700
City	7,492,000	2,334,300	460,000	7,821,900	.....
Tradesmen's	3,206,400	366,600	130,600	2,991,100	787,100
Fulton	1,635,600	371,100	111,400	1,354,000	.....
Chemical	13,956,400	3,510,500	921,400	14,294,400	.....
Merchants' Exch.	3,229,300	191,800	430,900	2,669,300	283,500
Gallatin National	4,782,700	318,300	450,600	2,712,900	631,500
Butchers' & Drov.	1,880,400	398,800	119,300	1,795,400	221,000
Mechanics' & Tr.	1,096,000	104,000	114,000	1,148,000	45,000
Greenwich	1,021,500	49,500	157,600	1,004,700	2,600
Leather Manufrs.	2,907,700	265,000	418,000	2,900,300	525,900
Seventh Ward	1,271,300	208,000	114,000	1,253,700	12,200
State of N. Y.	4,457,300	389,400	374,100	4,167,800	.....
East River	1,788,300	91,600	160,400	971,500	224,100
Fourth National	16,420,800	3,212,400	1,005,000	16,884,000	360,000
Central National	8,187,000	508,000	1,503,000	9,543,000	297,000
Second National	3,726,000	320,400	989,000	4,055,000	45,000
Ninth National	6,016,500	726,900	543,300	5,734,000	579,700
First National	15,428,100	3,542,800	665,700	16,156,100	449,900
Third National	4,519,100	875,500	747,000	4,900,600	.....
N. Y. Nat. Exch.	1,577,800	116,100	214,100	1,307,400	269,500
Bowery	1,991,600	351,700	188,200	1,977,100	224,000
N. Y. County	1,899,100	18,800	695,900	2,491,800	180,000
German-Americ'n.	2,567,800	250,200	81,500	2,164,600	.....
Chase National	4,177,100	1,369,300	307,800	5,598,500	45,000
Fifth Avenue	2,552,300	676,900	80,600	2,775,300	.....

The Data III

- The variables we collected are: capital, loans, specie (gold and silver), circulation, deposits, legal tenders, reserves with legal depositories, and surplus.
- The bank balance sheet information is supplemented with equity data (also collected at the 28-day sampling frequency). We collect price, shares outstanding, and dividends of bank stocks trading OTC in NYC.

NEW YORK LOCA

Bank Stock List.

COMPANIES.	CAPITAL.		DIVIDENDS.				PRICE.	
Marked thus (*) are not National.	Par	Amount.	Periods.	1872	1873	Last Paid.	Bid.	Askd
America*.....	100	3,000,000	J. & J.	10	10	Jan. 2,'74...5	151	.....
American Exchange.	100	5,000,000	M. & N.	8	8	May 1,'74...4	111½	112
Bowery.....	100	250,000	J. & J.	.....	.....	Jan., 2,'74..6	.....	.....
Broadway	25	1,000,000	J. & J.	24	24	Jan., 2,'74..12	.....	.....
Bull's Head*.....	25	300,000	Q—J.	20	16	Oct., '73...4	.....	.....
Butchers & Drovers ..	25	800,000	J. & J.	10	10	Jan., 2,'74...5	128	135
Central.....	100	2,000,000	J. & J.	8	8	July 1,'73...4	101	.....
Chatham.....	25	450,000	J. & J.	12	12	Jan 2,'74...5	130	.....
Chemical.....	100	300,000	ev. 2 mos	86	100	May 1,'74..15	1,000	.....
Citizens'.....	25	400,000	J. & J.	10	10	Jan., 2,'74...5	.....	.....
City..	100	1,000,000	M. & N.	20	20	May 1,'74..10	300	
Commerce....	100	10,000,000	J. & J.	8	8	Jan.. 5,'74..4	124	122½
Commonwealth.....	100	750,000	J. & J.	.....	8½	July, 1'73.3½	.....	.....
Continental.....	100	2,000,000	J. & J.	7	.....	July, '72.3½	102	.....
Corn Exchange*.....	100	1,000 000	F. & A.	10	10	Feb. 2,'74...5	128	....
Currency.....	100	100,000	Q—J.	16	12	Jan., '74...4	.....	.....
Dry Goods*.....	100	1,000,000	J. & J.	6½	7	July10,'73.3½	.....	.....
East River	25	350,000	J. & J.	8	8	Jan. 2,'74...4	.....	.....
Eleventh Ward*	25	100,000	J. & J.	7	7	Jan. 2,'74.3½	.....	.....
Fifth.....	100	150,000	Q—J.	14	14	Apr. 1,'74.3½	.....	.....
First.....	100	500 000	Q—J.	20	15	Apr. 1,'74...3	.....	.....
Fourth	100	5,000,000	J. & J.	8	9	Jan. 2,'74.. 4	105	106
Fulton.....	30	600,000	M. & N.	10	10	May 1,'74.6½	1.0	170

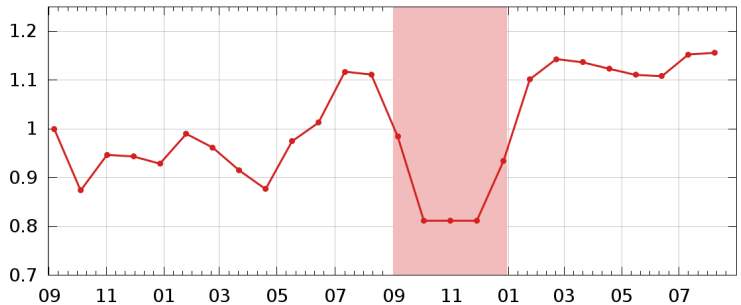
The Data IV

- We collect data for 132 banks (112) and trusts (20) from the 6th of January 1866 to the 1st of December 1933. Out of these only 99 financial institutions have stock price data available (90 banks and 9 trusts).

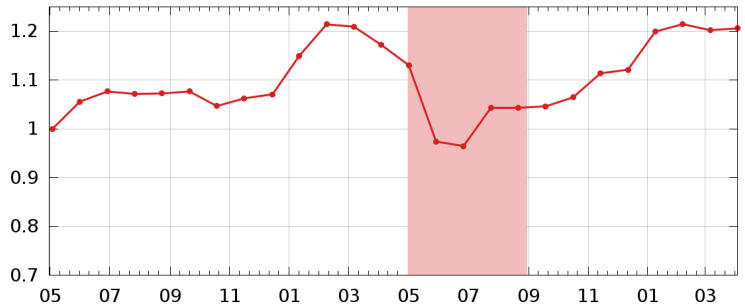
- Dropping trusts and merging to the equity returns data leaves us with a sample of 82 total banks. Specifically, the New York Clearinghouse published information on about 60 members in 1865, a number that slowly moves down to nearly 40 members, by the end of our sample.

Quality Control check # 1 - Deposits and Crises I

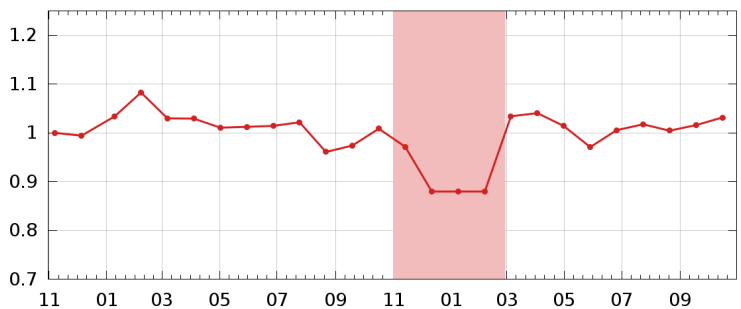
Panic of 1873



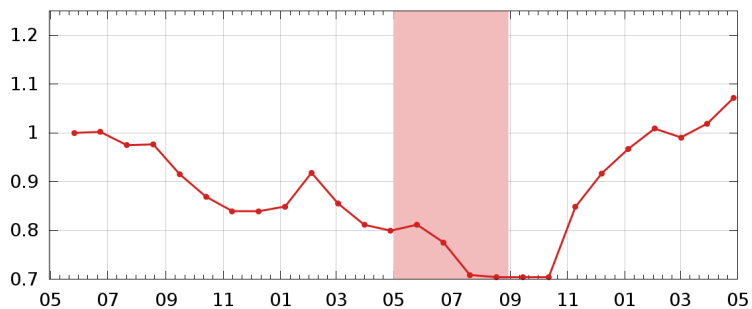
Panic of 1884



Panic of 1890

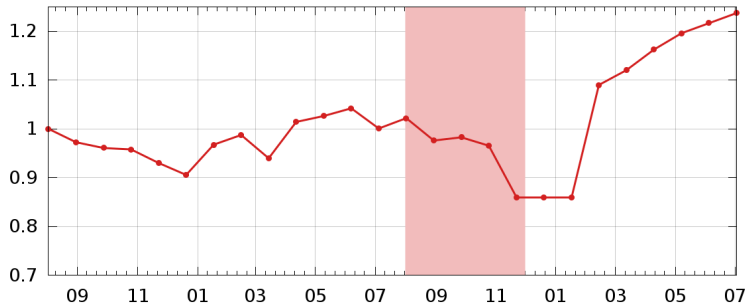


Panic of 1893

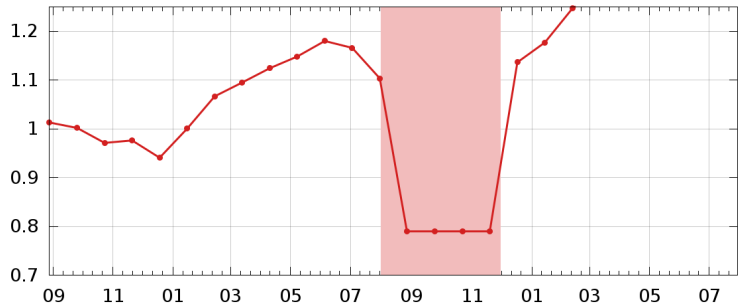


Quality Control check # 1 - Deposits and Crises II

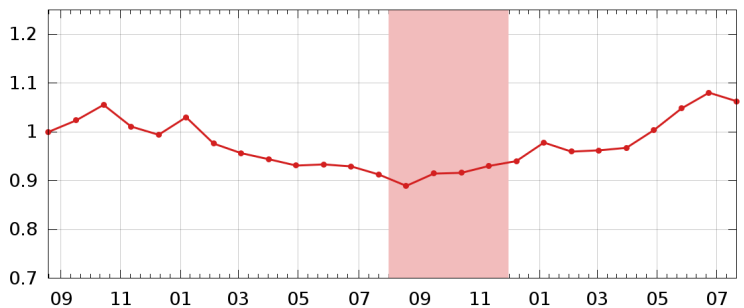
Panic of 1907



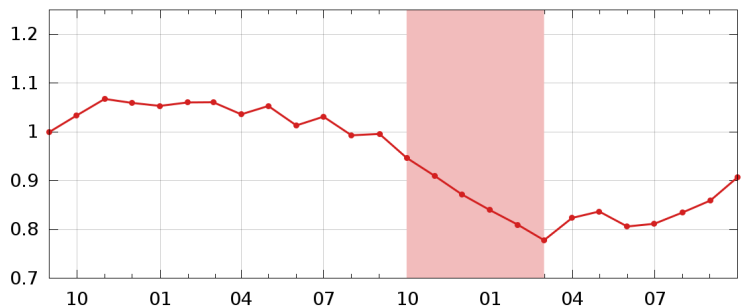
Panic of 1914



Panic of 1921



Panic of 1931



Systemic Risk Measurement

- *Backtesting Systemic Risk Measures during Historical Bank Runs and the Great Depression*
  - CoVaR [Adrian and Brunnermeier (2016, *AER*)]
    tail codependence with the financial system
  - SRISK [Brownlees and Engle (2016, *RFS*)]
    capital shortfall generated in times of distress
- *Is Today's Banking Sector more Fragile than a Century Ago?*
  - Connectedness [Diebold and Yilmaz (2014, *JoE*)]
    volatility spillover effects with the rest of the financial system

Notation

- r_{it}: compound return of bank i
- r_{mt}: value weighted compound return of the financial system
- W_{it}: Market value of equity
- D_{it}: Book value of debt
- LVG_{it}: Leverage Ratio D_{it}/W_{it}

CoVaR: Definition

- CoVaR for i is defined as

$$\mathrm{P}(r_{m\,t} < \mathrm{CoVaR}_{it}^{p,q} | r_{i\,t} = \mathrm{VaR}_{it}^{q}) = p$$

  where VaR_{it}^{q} is the $(1-q)\%$ VaR of institution i at time t.
- Adrian and Brunnermeier propose to measure the systemic risk contribution of firm i with the $\Delta\mathrm{CoVaR}_{i\,t}$

$$\Delta\mathrm{CoVaR}_{it} = \mathrm{CoVaR}_{it}^{p,q} - \mathrm{CoVaR}_{it}^{p,0.50}$$

- We opt for a standardized version of ΔCoVaR:

$$\Delta\mathrm{CoVaR}_{i\,t}^{\%} = \frac{\mathrm{W}_{i\,t}}{\sum_{j=1}^{N_t} \mathrm{W}_{j\,t}} \Delta\mathrm{CoVaR}_{i\,t} \ .$$

  since firm size changes substantially throughout our sample, the percentage ΔCoVaR% is easier to interpret.

SRISK: Definition

- SRISK links the systemic risk contribution of a financial institution with the capital shortfall the financial institution is expected to experience in case of a substantial market downturn

$$\begin{aligned}
\text{SRISK}^{\$}_{it} &= \mathrm{E}_t(\text{CS}_{it+1} | r_{mt+1} < C) \,, \\
&= k\,\mathrm{E}_t(\text{D}_{it+1} | r_{mt+1} < C) - (1-k)\,\mathrm{E}_t(\text{W}_{it+1} | r_{mt+1} < C) \,, \\
&= k\,\text{D}_{it} - (1-k)\,\text{W}_{it}(1+\text{MES}_{it}) \,,
\end{aligned}$$

where

$$\text{MES}_{it} = \mathrm{E}_t(r_{it+1} | r_{mt+1} < C) \,,$$

- We set the prudential fraction parameter k to 20% and the systemic loss threshold C to -10%.

Quality Control check # 2 - Key Estimation Inputs I

Panic		CoVaR/quant reg			SRISK/CAPM		
		coef	R^2	sig	coef	R^2	sig
1873	Mean	-2.180	0.110	0.750	1.058	0.155	0.482
	Q1	-2.984	0.006		0.676	0.034	
	Q3	-0.986	0.201		1.552	0.247	
1884	Mean	-2.283	0.143	0.774	1.094	0.141	0.453
	Q1	-4.109	0.028		0.530	0.025	
	Q3	-1.630	0.203		2.218	0.189	
1890	Mean	-2.321	0.075	0.871	0.986	0.098	0.484
	Q1	-3.336	0.012		0.774	0.012	
	Q3	-1.477	0.099		1.425	0.133	
1893	Mean	-2.191	0.056	0.867	1.055	0.111	0.583
	Q1	-3.074	0.006		0.598	0.008	
	Q3	-1.221	0.082		1.409	0.172	

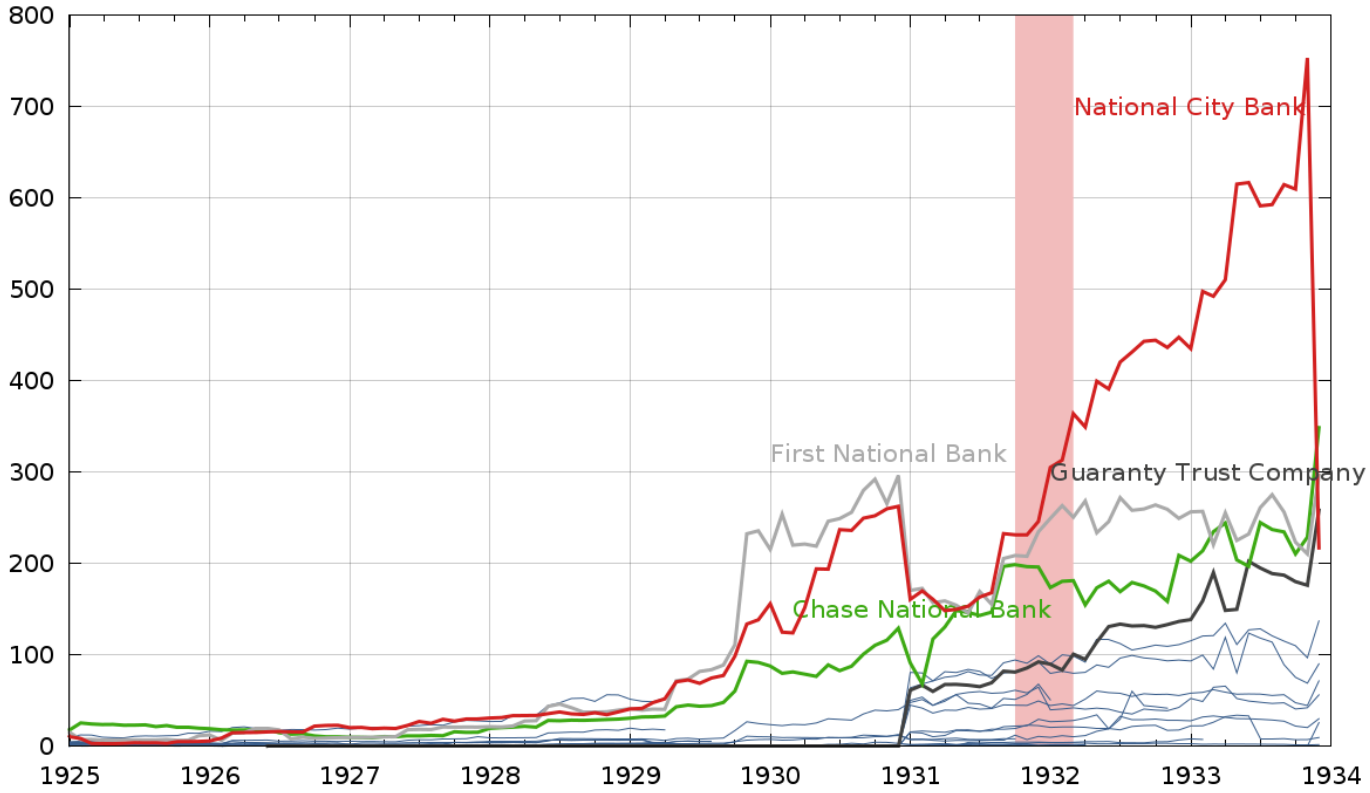
Quality Control check # 2 - Key Estimation Inputs II

		CoVaR/quant reg			SRISK/CAPM		
		coef	R^2	sig	coef	R^2	sig
1907	Mean	-1.978	0.080	0.920	0.717	0.109	0.600
	Q1	-2.904	0.001		0.404	0.010	
	Q3	-0.774	0.128		0.933	0.126	
1914	Mean	-1.681	0.072	0.867	0.463	0.105	0.467
	Q1	-2.563	0.009		0.292	0.010	
	Q3	-1.034	0.115		0.922	0.095	
1921	Mean	-2.297	0.111	0.781	0.598	0.156	0.625
	Q1	-3.536	0.024		0.440	0.015	
	Q3	-1.623	0.165		1.170	0.279	
1931	Mean	-6.971	0.503	1.000	0.917	0.636	1.000
	Q1	-8.303	0.436		0.745	0.571	
	Q3	-5.634	0.622		1.010	0.755	

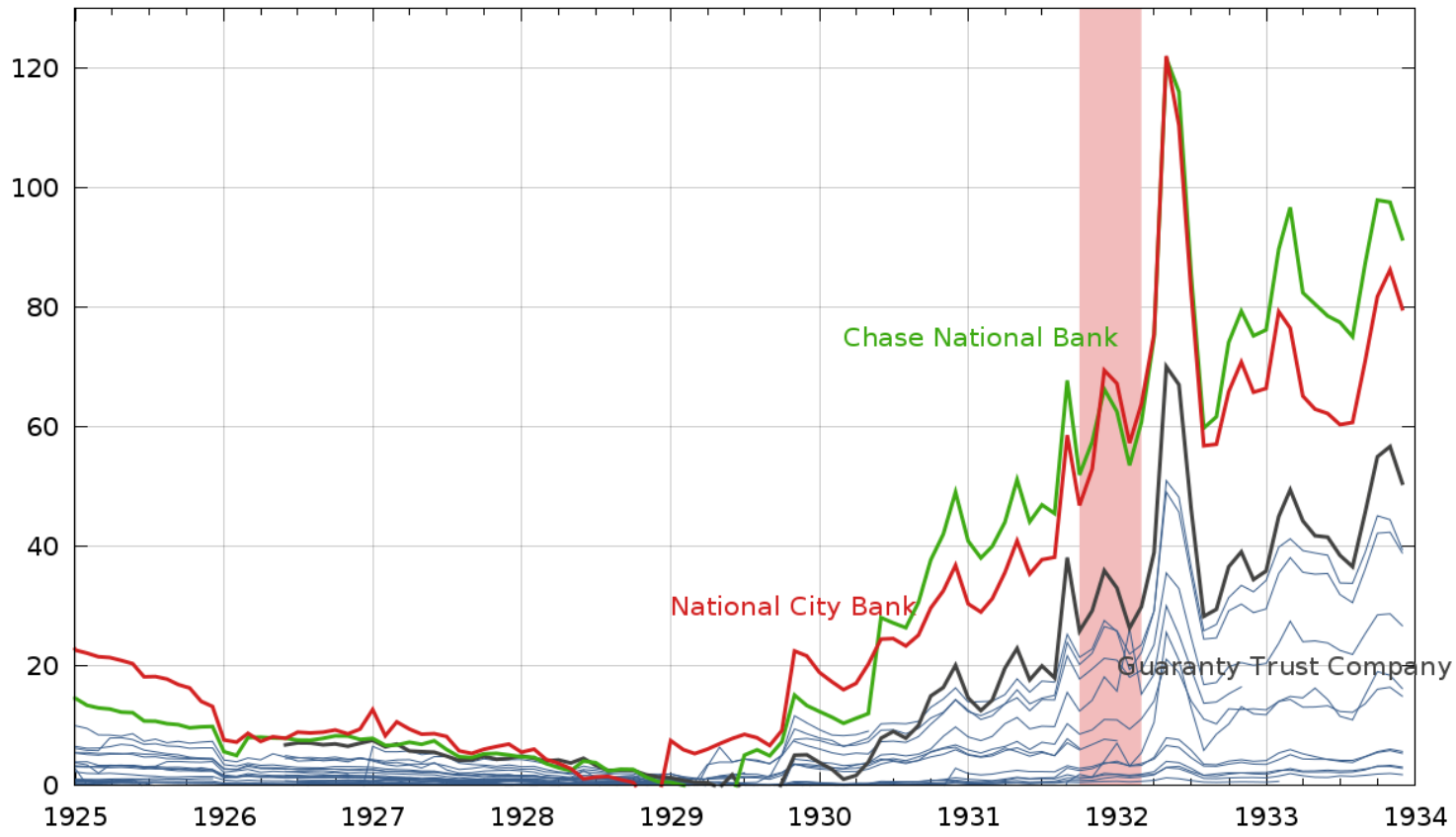
Recall the two objectives

- The systemic risk measurement literature typcally focuses on the following objectives:
  1. Measuring the systemic risk of individual institutions
     Objective: Detect which are Systemically Important Financial Institutions (SIFI's) that can potentially generate threats to the entire system
  2. Measuring the systemic risk of the entire system
     Objective: Produce early warnings signals that can help avoiding or at least mitigating a financial crisis.

Panic of 1931 - CoVaR



Panic of 1931 - SRISK



Panel Regressions

- We use cross-sectional regressions to assess if systemic risk measures predict firm-specific deposit growth in a crisis

$$
\begin{aligned}
DG_{i\,t+h} &= \beta_0 + \beta_1 CoVaR_{i\,t} + \text{controls}_{it} + u_i \\
DG_{i\,t+h} &= \beta_0 + \beta_1 SRISK_{i\,t} + \text{controls}_{it} + u_i
\end{aligned}
$$

- Firm-specific controls are:
  - Leverage
  - Size
  - Beta
  - Volatility
  - VaR
- We run regressions with data 5 years prior to each crisis - pooling all crises

Bank Deposits Loss Regressions around Panics I

Horizon	1					
CoVaR	−0.013	−0.008			−0.022**	−0.012
	(0.012)	(0.015)			(0.012)	(0.015)
SRISK			−0.562***	−0.565***		
			(0.079)	(0.083)		
Lev	−0.290**	−0.380***	−0.063	−0.046	−0.235**	−0.286**
	(0.132)	(0.154)	(0.125)	(0.150)	(0.131)	(0.150)
Siz	−1.014***	−1.343***	−0.468**	−0.318	−0.982***	−1.082***
	(0.294)	(0.420)	(0.267)	(0.401)	(0.297)	(0.407)
Vol	0.157*	0.177*	0.189**	0.200**	−0.028	0.005
	(0.114)	(0.125)	(0.104)	(0.114)	(0.083)	(0.100)
Beta	−0.064	−0.019	0.289*	0.256	−0.164	−0.171
	(0.217)	(0.230)	(0.205)	(0.215)	(0.215)	(0.222)
VaR	−0.272***	−0.297**	−0.238***	−0.185*		
	(0.116)	(0.131)	(0.101)	(0.121)		
Firm FE	✓	✓	✓	✓	✓	✓
Panic FE		✓		✓		✓
R^2	12.21	13.24	26.33	26.78	10.32	11.47

Bank Deposits Loss Regressions around Panics II

Horizon	6					
CoVaR	-0.025^{*}	-0.021			-0.038^{**}	-0.028^{*}
	(0.017)	(0.022)			(0.017)	(0.022)
SRISK			-0.513^{***}	-0.510^{***}		
			(0.072)	(0.075)		
Lev	-0.305^{***}	-0.392^{***}	-0.102	-0.121	-0.245^{**}	-0.314^{**}
	(0.123)	(0.144)	(0.115)	(0.138)	(0.122)	(0.141)
Siz	-0.919^{***}	-1.227^{***}	-0.499^{**}	-0.429	-0.881^{***}	-1.036^{***}
	(0.301)	(0.418)	(0.262)	(0.387)	(0.304)	(0.414)
Vol	0.192^{**}	0.190^{*}	0.217^{**}	0.233^{**}	-0.002	0.010
	(0.116)	(0.126)	(0.106)	(0.114)	(0.086)	(0.101)
Beta	-0.099	-0.101	0.239	0.213	-0.182	-0.213
	(0.220)	(0.228)	(0.206)	(0.214)	(0.220)	(0.225)
VaR	-0.281^{***}	-0.287^{***}	-0.260^{***}	-0.225^{**}		
	(0.114)	(0.122)	(0.100)	(0.112)		
Firm FE	✓	✓	✓	✓	✓	✓
Panic FE		✓		✓		✓
R^2	13.21	14.26	27.22	27.70	11.10	12.32

Bank Deposits Loss Regressions around NBER Expansions

Horizon	1			
CoVaR	−0.011	−0.013		
	(0.133)	(0.135)		
SRISK			−0.025	−0.016
			(0.187)	(0.190)
Lev	0.205*	0.208*	0.209*	0.211*
	(0.136)	(0.142)	(0.137)	(0.144)
Siz	−0.677	−0.588	−0.681	−0.608
	(0.763)	(0.877)	(0.704)	(0.816)
Vol	0.068	0.082	0.062	0.078
	(0.197)	(0.215)	(0.203)	(0.222)
Beta	0.050	−0.011	0.082	0.011
	(0.652)	(0.681)	(0.696)	(0.723)
VaR	−0.780	−0.669	−0.770	−0.655
	(0.995)	(1.217)	(0.989)	(1.202)
Firm FE	✓	✓	✓	✓
Panic FE		✓		✓
R^2	1.65	1.77	1.66	1.77

Predicted and Actual Capital Shortages Around Panic Events

- It is possible to design an additional validation exercise for the SRISK measure only.
- The SRISK index is a prediction of the capital shortage a bank would experience conditional on a systemic event.
- For each panic event we run a Mincer-Zarnowitz type regression to assess whether SRISK provides an unbiased prediction of such a shortage, that is we consider

$$\mathrm{CS}_i = \alpha_0 + \alpha_1 \mathrm{SRISK}_i + u_i \ ,$$

where CS_i is the realized capital shortage suffered by bank i at the end of the panic window and SRISK_i is measured in dollars.

Predicting Capital Infusion

Panic	α_0	α_1	R^2
1873	0.0021 (0.0003)	0.4256 (0.2611)	0.05
1884	0.0016 (0.0004)	1.1468 (0.2059)	0.40
1890	0.0012 (0.0005)	2.1136 (0.2430)	0.57
1893	0.0006 (0.0004)	2.0362 (0.2027)	0.64
1907	0.0011 (0.0016)	2.1600 (0.1839)	0.76
1914	0.0027 (0.0030)	1.9262 (0.2135)	0.68
1921	0.0023 (0.0043)	1.7442 (0.1047)	0.91
1931	0.0171 (0.0231)	1.0250 (0.1285)	0.80

Time-Series Regressions

- Assess whether **aggregate** systemic risk measures predict **aggregate** deposit growth
- Run regressions:

$$DG_{t+h} = b_0 + \sum_{i=0}^{2} \beta_i CoVaR_{t-i} + \text{controls}_t + u_t$$

$$DG_{t+h} = b_0 + \sum_{i=0}^{2} \beta_i SRisk_{t-i} + \text{controls}_t + u_t$$

Time Series Regressions - Aggregate Deposit Growth I

	CoVaR + Lags DG	SRISK + Lags DG	CoVaR + Lags DG +C	SRISK + Lags DG + C
Horizon		1		
F-test	2.321*	1.321	1.992	1.003
R^2	72.99	70.70	78.04	76.24
ΔR^2	2.45	0.17	7.51	5.70
		3		
F-test	8.513***	7.763***	12.289***	10.389***
R^2	31.28	30.38	36.30	35.96
ΔR^2	1.45	0.56	6.48	6.13

Is Today's Banking Sector more Fragile than a Century Ago?

SEQUEL COMING SOON TO A THEATRE NEAR YOU

Connectedness Table: Definition

- Diebold and Yilmaz propose to measure connectedness between series *i* and *j* on the basis of the fraction of the H-step ahead prediction error variance of series *i* is due to a shock to *j*.
- They suggest to construct variance decomposition based on the Generalized Variance Decomposition (GVD) proposed by Pesaran and Shin (1998)
- For systemic risk measurement Diebold and Yilmaz focus on connectedness among volatility

Connectedness Table: Definition

N-Variable Connectedness Table

	x_1	x_2	...	x_N	From Others to i
x_1	d_{11}^H	d_{12}^H	$\cdots$	d_{1N}^H	$\Sigma_{j=1}^N d_{1j}^H, j \neq 1$
x_2	d_{21}^H	d_{22}^H	$\cdots$	d_{2N}^H	$\Sigma_{j=1}^N d_{2j}^H, j \neq 2$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$
x_N	d_{N1}^H	d_{N2}^H	$\cdots$	d_{NN}^H	$\Sigma_{j=1}^N d_{Nj}^H, j \neq N$
To Others From j	$\Sigma_{i=1}^N d_{i1}^H$ $i \neq 1$	$\Sigma_{i=1}^N d_{i2}^H$ $i \neq 2$	$\cdots$	$\Sigma_{i=1}^N d_{iN}^H$ $i \neq N$	$\Sigma_{i,j=1}^N d_{ij}^H$ $i \neq j$

Connectedness Table: Definition

- The connectedness from institution i to the rest of the system is measured as

$$C_i = \sum_{j \neq i} d_{ji}^H$$

- We also consider a weight corrected version of the index

$$C_i^w = w_i C_i$$

- The total connectedness in the system is measured as

$$C = \frac{1}{N} \sum_{i}^{N} C_i$$

Connectedness Table: Estimation

- Diebold and Yilmaz estimate the connectedness table on the basis of VAR model on an appropriate proxy of volatility
- In this work we use a VAR(1) and use as a proxy of volatility of firm i

$$v_{it} = \log(1 + r_{it}^2)$$

- To estimate the connectedness table we estimate a Bayesian VAR(1) using 5-year rolling sample - deal with missing observations

Total Connectedness 1870 - 1933