Granular Credit Risk

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Motivation

- **Our question:** To what extent are idiosyncratic shocks to borrowers a source of risk for banks and the economy?

- None, if banks are **well-diversified**

- What if portfolios are **concentrated**?
  - A few firms makes up a disproportionately large fraction of the credit portfolio ("single name concentration risk")

- Interesting and important question both **academically** and from a **regulatory perspective**
  - How plausible is the assumption of perfect diversification against idiosyncratic risk?
  - Source of idiosyncratic bank returns (Mendicino et.al 2020, Jamilov 2021)
  - Risk-management of large exposures

Data

We combine annual administrative/supervisory data from three sources

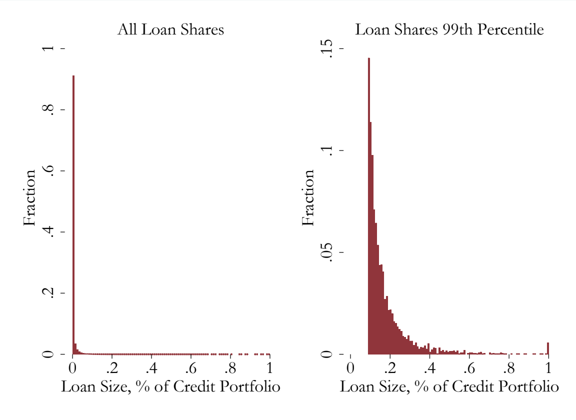
1. Matched firm-bank data from the Norwegian Tax Authority
   - covers all limited liability companies
   - yearly interest paid (R_t) and end-of-year stock of debt (D_t)
   - loan-level (we aggregate to relationship $\times$ year level)

2. Firm data from a credit rating agency on the universe of Norwegian limited liability companies
   - ratings, balance sheet and income statement data

3. Supervisory bank data
   - Balance sheet and income statement data on all Norwegian banks

- Time period: 2003 - 2015
- $\approx$ 330'000 firm$\times$bank$\times$year observations

Loan size distribution is concentrated



- 80 % of outstanding corporate credit in 20 % of the loans (Pareto Principle)

Estimating firm performance shocks

Extract **unexplained variation in value added (VA)** for firm j, operating in (two-digit) sector s, located in county z at time t

$$\ln VA_{j,t} = \beta_1 \ln K_{j,t} + \beta_2 \ln W_{j,t} + \lambda' \mathbf{X_{j,t}} + \alpha_j + \gamma_{s(j),z(j),t} + \epsilon_{j,t}$$

- where
  - K is book capital, W is wage-bill
  - Firm characteristics (X): liquidity, leverage, credit rating, age and age^2
  - Firm and sector×region×year fixed effects

- $\epsilon_{j,t} \equiv$ “idiosyncratic firm shock”

Shock properties

- $\epsilon_{j,t}$ is idiosyncratic
  - $\epsilon_{j,t}$ on average uncorrelated across firms and across time ▸ Correlations
  - Results robust to extracting latent common factors from $\epsilon_{j,t}$ ▸ Shock properties
- $\epsilon_{j,t}$ is not just noise
  - Link to narrative evidence for bottom 1 %
  - Strong correlation with loan-level returns

Relationship-level impact: setup

Estimate impact of $\epsilon_{j,t}$ on loan-level returns by regressing

$$\text{RoL}_{i,j,t} = \beta \epsilon_{j,t} + \alpha_{i,t,\tau(j),z(j),s(j)} + \nu_{i,j,t}$$

where

- τ captures credit line vs. other loans
- $\alpha_{i,t,(\cdot)}$ is a bank x sector x year x loan-type x county FE
- $\nu_{i,j,t}$ is
  - clustered at firm-year level
  - corrected for estimated regressor bias
- Standardize $\epsilon_{j,t} \Rightarrow \beta$: pp. impact on loan return from a 1 SD idiosyncratic firm shock

Relationship-level impact: idiosyncratic shocks correlate with loan returns

	(1)	(2)	(3)
	Dependent Variable: Return on Loan		
$\epsilon_{j,t}$	0.334	0.335	0.361
	(0.016)	(0.017)	(0.018)
Bank x Sector x Year FE	No	Yes	No
Bank x Sector x Year x Loan-type x County FE	No	No	Yes
Number of Observations	333'289	317'186	292'825
R^2	0.001	0.127	0.184
$\mathbb{E}$(RoL)	7.42%	7.43%	7.47%
SD(RoL)	7.26%	7.27%	7.20%

▸ Latent factor extraction

Bank level outcomes

- Can banks diversify this risk?

- We compute a **"Granular Credit Shock"** for each bank$\times$year

$$\bar{\epsilon}_{i,t} \equiv \sum_{j \in J(i)} s_{i,j,t} \epsilon_{i,j,t}$$

  - $s_{i,j,t}$ is the share of the relationship between bank i and firm j in i's credit portfolio in year t

- Estimate

$$Y_{i,t} = \beta \bar{\epsilon}_{i,t} + \alpha_i + \eta_t + \nu_{i,t}$$

- $Y_{i,t}$: interest income relative to total debt for the corporate loan portfolio ("RoA")
  - other outcomes: writedowns, income from hedging instruments

- Identification:

$$\mathbb{E}\left(\nu_{i,t} | \bar{\epsilon}_{i,t}, \alpha_i, \eta_t\right) = 0$$

Threats to identification

- Threat to identification: Unobserved bank$\times$year factors
  - Example: Change in credit supply: $Y_{i,t} \uparrow$ and $\bar{\epsilon}_{i,t} \downarrow$
- Our approach: Granular Instrumental Variable (GIV)
  - Gabaix & Koijen (2020)
- Main idea: exploit the fat-tailedness of the loan-size distribution

GIV: Granular Instrumental Variable

$$Y_{i,t} = \beta \overbrace{\sum_j s_{i,j,t}\epsilon_{j,t}}^{\equiv \bar{\epsilon}_{i,t}} + \alpha_i + \eta_t + \nu_{i,t}$$

Suppose: $\epsilon_{j,t} = \delta \nu_{i,t} + u_{j,t}$.

- $u_{j,t}$ is truly exogenous

GIV: Granular Instrumental Variable

$$Y_{i,t} = \beta \overbrace{\sum_j s_{i,j,t}\epsilon_{j,t}}^{\equiv \bar{\epsilon}_{i,t}} + \alpha_i + \eta_t + \nu_{i,t}$$

Suppose: $\epsilon_{j,t} = \delta \nu_{i,t} + u_{j,t}$.

- $u_{j,t}$ is truly exogenous

Solution: purge out $\nu_{i,t}$ by constructing a GIV

$$GIV_{i,t} \equiv \sum_j s_{i,j,t}\epsilon_{j,t} - \sum_j \frac{1}{N_i}\epsilon_{j,t} = \sum_j s_{i,j,t}u_{j,t} - \sum_j \frac{1}{N_i}u_{j,t}$$

- Results **robust** to allowing loading δ to be **heterogeneous** across firms ▸ Heterogeneous δ ▸ First stage

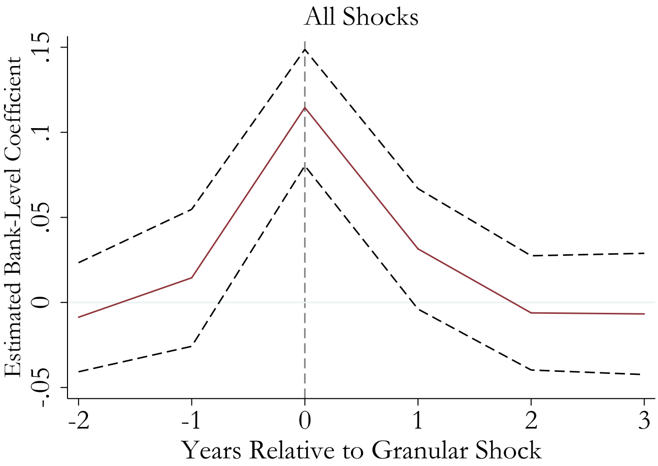
Identification with the GIV

- **Exclusion restriction:** $\forall i, t : \sum_j^N \mathbb{E}\left[s_{i,j,t} u_{j,t} \nu_{i,t}\right] = 0$

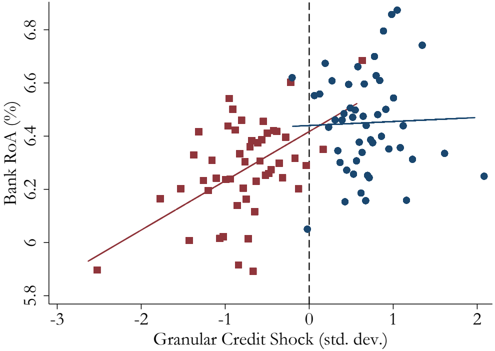
- Potential concern: firm shock and loan shares are correlated

- Alleviated due to two factors
    - By construction: $\epsilon_{j,t}$ is orthogonal to firm size
    - Loan shares $s_{i,j,t}$ based on debt in $t-1$ and t

Dynamic bank response

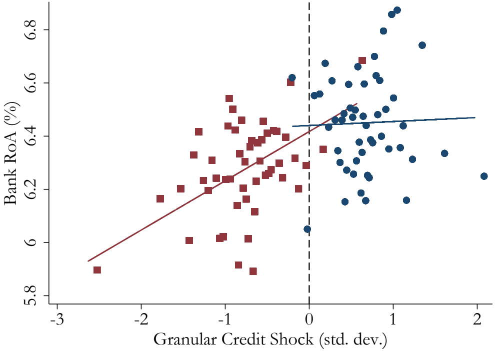


Bank-level portfolio returns



- Granular Credit Shock $\downarrow$ by 1 s.d $\Rightarrow$ RoA $\downarrow$ by 11.6 bsp
- Granular Credit Shocks explains 8.6 % of dispersion in RoA across banks ▸ Table
- **Asymmetric effects:** Granular Credit Shock (<0) $\downarrow$ by 1 s.d $\Rightarrow$ RoA $\downarrow$ by 19.4 bsp.

Bank-level portfolio returns



- Granular Credit Shock $\downarrow$ by 1 s.d $\Rightarrow$ RoA $\downarrow$ by 11.6 bsp
- Granular Credit Shocks explains 8.6 % of dispersion in RoA across banks ▸ Table
- **Asymmetric effects:** Granular Credit Shock ($<$0) $\downarrow$ by 1 s.d $\Rightarrow$ RoA $\downarrow$ by 19.4 bsp.
- No evidence of hedging ▸ More
- Not driven by "small-N". Effect increases degree of portfolio concentration. ▸ Table

Firm spillover: credit supply

- Shocks to granular borrowers impact **bank outcomes**
- What are the implications for bank lending?
- Run Khwaja-Mian (2008) regression

$$\Delta Y_{i,j,t} = \beta \Delta \bar{\epsilon}_{i,t} + \alpha_i + \alpha_{j,t} + \nu_{j,i,t}$$

- $Y_{i,j,t}$ is either log(loan volumes) or log(interest paid)
- Sample: Firms borrowing from multiple banks
  - $\alpha_{j,t}$ is firm$\times$ year FE
  - Identifying assumption: credit demand fixed at the firm$\times$ year level
- Focus primarily on **non-granular** borrowers
  - Loan-share below median or in the 1st quartile

Spillovers to non-granular borrowers: lower credit growth

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent Variable: Δ Loan volume					
Δ Granular Credit Shock	0.023	0.022	0.165	0.625	0.168	0.717
	(0.043)	(0.043)	(0.129)	(0.288)	(0.136)	(0.311)
Firm x Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	No	No	No	No	Yes	Yes
Non-Granular Firms (50%)	No	No	Yes	No	Yes	No
Non-Granular Firms (25%)	No	No	No	Yes	No	Yes
Instrumented by GIV	No	Yes	Yes	Yes	Yes	Yes
Observations	15279	15279	3449	348	3413	322

- Granular credit shocks $\downarrow \Rightarrow$ credit volumes $\downarrow$

Spillovers to non-granular borrowers: higher interest payments

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent Variable: Δ Interest flow					
Δ Granular Credit Shock	-0.004	-0.017	-0.361	-0.341	-0.421	-0.634
	(0.064)	(0.066)	(0.189)	(0.417)	(0.190)	(0.448)
Firm x Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	No	No	No	No	Yes	Yes
Non-Granular Firms (50%)	No	No	Yes	No	Yes	No
Non-Granular Firms (25%)	No	No	No	Yes	No	Yes
Instrumented by GIV	No	Yes	Yes	Yes	Yes	Yes
Observations	15279	15279	3449	348	3413	322

- Granular credit shocks $\downarrow \Rightarrow$ interest rates $\uparrow$

Taking stock

- Textbook credit supply shock: quantities $\downarrow$, prices $\uparrow$
- Does it matter for the real economy?
  - Bank loans are primary source of non-equity external finance
  - Sticky firm-bank relationships
- Restrict attention to non-granular firms ($\approx$ 15% of aggregate capital stock)
- Estimate

$$\Delta Y_{j,t} = \alpha_{s(j),t,\kappa(j)} + \beta \Delta \bar{\epsilon}_{i(j),t} + \eta_{j,t}$$

  - $\kappa(j)$ denotes credit rating
- Threat to identification: Production network spillovers
- Robustness: Estimate on sample of ”sufficiently downstream firms”
  - Compute demand of all other sectors for sector z's output (”inter-sector exposures”)
  - Restrict attention to sectors where the max inter-sector exposure is within the 1st quartile

Spillovers to non-granular borrowers: lower capital investments

	(1) ΔLog(capital)	(2) ΔLog(sales)	(3) ΔLog(wage bill)	(4) ΔLog(Cash)
ΔGranular Credit Shock	0.241	0.001	0.007	0.142
	(0.095)	(0.031)	(0.040)	(0.146)
Instrumented by GIV	Yes	Yes	Yes	Yes
Year-Sector-Rating FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes
Non-Granular Firms (50%)	Yes	Yes	Yes	Yes
Observations	39861	44547	45452	43994

- Granular credit shock $\downarrow \Rightarrow$ Capital growth $\downarrow$ for non-granular clients ▸ Robustness

Spillovers to non-granular borrowers: higher probability of bankruptcy

Probit Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
			Probability of bankruptcy$_t$				Ever bankrupt
Δ Granular Credit Shock$_t$	-0.609	-0.680					
	(0.110)	(0.196)					
Δ Granular Credit Shock$_{t-1}$			-0.322	-0.965	-1.081		
			(0.123)	(0.203)	(0.346)		
Δ Granular Credit Shock$_{t-3}$						-0.703	
						(0.239)	
Δ Granular Credit Shock$_t$							-1.273
							(0.281)
Non-Granular Firms (50%)	No	Yes	No	Yes	No	Yes	Yes
Non-Granular Firms (25%)	No	No	No	No	Yes	No	No
Instrumented by GIV	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	61819	35965	50897	29451	15220	16648	35965

- Granular credit shock $\downarrow \Rightarrow$ Bankruptcy propensity $\uparrow$ for non-granular clients ▸ Robustness

Summary

We provide causal empirical evidence on the role of single name concentration risk

1. Shocks to granular borrowers impact **bank outcomes**

   1 sd shock $\downarrow \Rightarrow$ bank RoA $\downarrow$ 11.6 bps
   Concave relationship. No evidence of insurability/hedging

2. Banks respond by cutting credit and increasing interest rates to **non-granular firms**

   1 sd shock $\downarrow \Rightarrow$ credit to non-granular clients $\downarrow$, interest payments $\uparrow$

3. Impacted non-granular firms **cut investment; bankruptcies go up**

   1 sd shock $\downarrow \Rightarrow$ investment $\downarrow$ 24 bps, bankruptcy prob. $\uparrow$ 60-90 bps
   Non-granular firms $\geq$ 15% of agg. capital

In the paper: Portfolio concentration is a common features across *sectors* and *countries*

Additional material

Loan writedowns

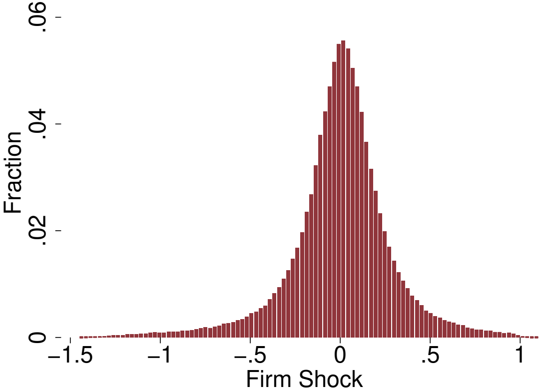
Table: **Bank Loan Portfolio Writedowns**

	(1)	(2)
	Writedowns	
Granular Credit Shock	-0.016	-0.015
	(0.009)	(0.011)
Bank FE	Yes	Yes
Year FE	Yes	Yes
Bank Controls	Yes	Yes
Instrumented by GIV	No	Yes
Observations	1184	1184

Firm heterogeneity, loan-level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent Variable: Return on Loan							
Baseline	0.361							
	(0.018)							
Shock x Low Leverage$_{t-1}$		0.345						
		(0.020)						
Shock x High Leverage$_{t-1}$		0.450						
		(0.047)						
Shock x High Assets$_{t-1}$			0.345					
			(0.018)					
Shock x Low Assets$_{t-1}$			0.976					
			(0.170)					
Shock x High Equity$_{t-1}$				0.352				
				(0.020)				
Shock x Low Equity$_{t-1}$				0.410				
				(0.044)				
Shock x Long Debt Duration$_{t-1}$					0.289			
					(0.020)			
Shock x Short Debt Duration$_{t-1}$					0.753			
					(0.046)			
Shock x Low Bank Reliance$_{t-1}$						0.314		
						(0.022)		
Shock x High Bank Reliance$_{t-1}$						0.497		
						(0.031)		
Shock x High Credit Rating$_{t-1}$							0.250	
							(0.025)	
Shock x Low Credit Rating$_{t-1}$							0.483	
							(0.026)	
Shock x Old Firms$_{t-1}$								0.313
								(0.020)
Shock x Young Firms$_{t-1}$								0.576
								(0.041)
Bank x Sector x Year x Loan-type x County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	292825	292825	292825	292825	292825	292825	292825	292825
R^2	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167

Properties of the shock $\epsilon_{j,t}$

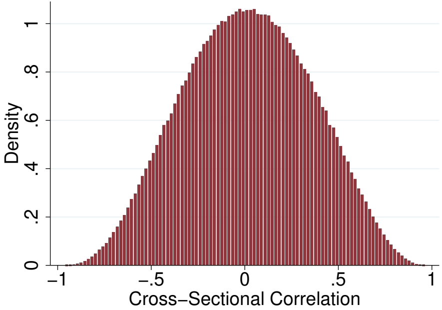


- Average pairwise correlation = 0 ▸ correlations
- Results robust to further extraction of latent factors

$$\epsilon_{j,t} = \delta_{j,t}^{x\,\prime}\eta_t^x + \delta_j'\eta_t + u_{j,t} \tag{1}$$

▸ back

Pairwise cross-sectional correlation of firm shocks



	Number of Pairs	Mean	Std. Dev.	Min	Max
Firm Shock	1,794,324	0.019	0.342	-0.971	0.985

All pairwise cross-sectional correlation coefficients for idiosyncratic firm shocks. The sample includes a balanced panel of firms over 2003-2015.

The average is ~ 0: little evidence of cross-firm network effects

Back

Loan level impact: results

	(1)	(2)	(3)
	Dependent Variable: Return on Loan		
Firm Shock	0.334	0.335	0.361
	(0.016)	(0.017)	(0.018)
Bank x Sector x Year FE	No	Yes	No
Bank x Sector x Year x Loan-type x County FE	No	No	Yes
Number of Observations	309,192	293,571	271,950
R^2	0.001	0.127	0.184
$\mathbb{E}$(RoL)	7.42%	7.43%	7.47%
SD(RoL)	7.26%	7.27%	7.20%

Idiosyncratic firm shocks have a large effect on **individual loan** outcomes

RHS variable is standardized; LHS in levels

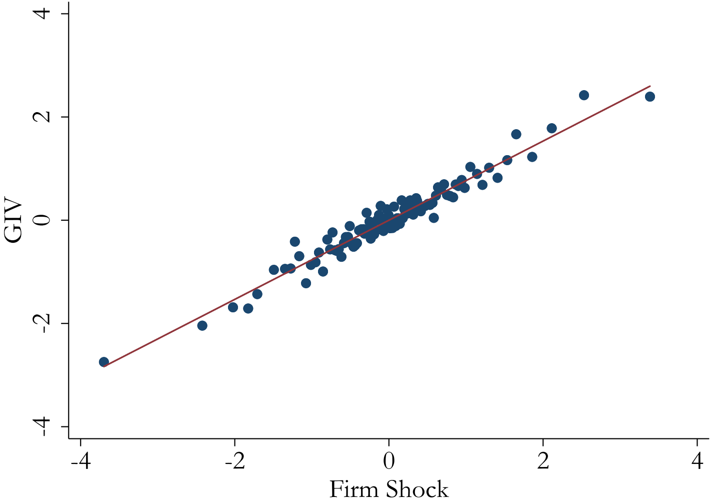
▸ Back ▸ Robustness

Loan Outcomes with Factor Extraction

	(1)	(2)	(3)
	Dep. Var.: Return on Loan		
(1) Firm Shock: $\check{\epsilon}_{j,t}$	0.307	0.307	0.333
	(0.016)	(0.017)	(0.018)
(2) Firm Shock: $u^1_{j,t}$	0.279	0.279	0.299
	(0.016)	(0.017)	(0.018)
(3) Firm Shock: $u^2_{j,t}$	0.239	0.237	0.255
	(0.016)	(0.017)	(0.018)
Bank x Sector x Year FE	No	Yes	No
Bank x Sector x Year x Loan-type x County FE	No	No	Yes

Back

First-stage



Back

Bank outcomes: heterogeneous δ

- We address remaining endogeneity concerns due to heterogeneous δ by estimating latent time-varying bank controls η_{it}
  - PCA on the firm shocks $\varepsilon_{i,j,t}$ for each bank
  - Use the first two factors as additional control variables

	(1)	(2)	(3)	(4)
	OLS	Instrumented with GIV		
	Pooled	Pooled	Positive	Negative
Baseline	0.136	0.117	0.056	0.176
	(0.027)	(0.030)	(0.087)	(0.072)
w/ latent bank controls	0.135	0.118	0.059	0.177
	(0.024)	(0.029)	(0.067)	(0.066)

Back

Bank level outcome

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent Variable: Bank Return on Loans (RoA)							
	OLS		Instrumented with GIV					
	Pooled	Pooled	Pooled	Positive	Negative	Pooled	Positive	Negative
Granular Credit Shock	0.129	0.136	0.116	0.016	0.194	0.117	0.056	0.176
	(0.029)	(0.027)	(0.031)	(0.094)	(0.074)	(0.030)	(0.087)	(0.072)
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank Controls	No	Yes	No	No	No	Yes	Yes	Yes
Observations	1211	1211	1211	508	694	1211	508	694
R^2	0.752	0.770	0.599	0.646	0.569	0.627	0.683	0.590
$\mathbb{E}(RoA)$	6.350%	6.350%	6.350%	6.460%	6.289%	6.350%	6.460%	6.289%
Sd(RoA)	1.354	1.354	1.354	1.403	1.295	1.354	1.403	1.295

▸ Heterogeneous δ ▸ Writedowns ▸ Bank heterogeneity ▸ Back

(noisy) impact on loan writedowns

Table: **Bank Loan Portfolio Writedowns**

	(1)	(2)
	Writedowns	
Granular Credit Shock	-0.014	-0.013
	(0.009)	(0.011)
Bank FE	Yes	Yes
Year FE	Yes	Yes
Bank Controls	Yes	Yes
Instrumented by GIV	No	Yes
Observations	1184	1184

▸ Back

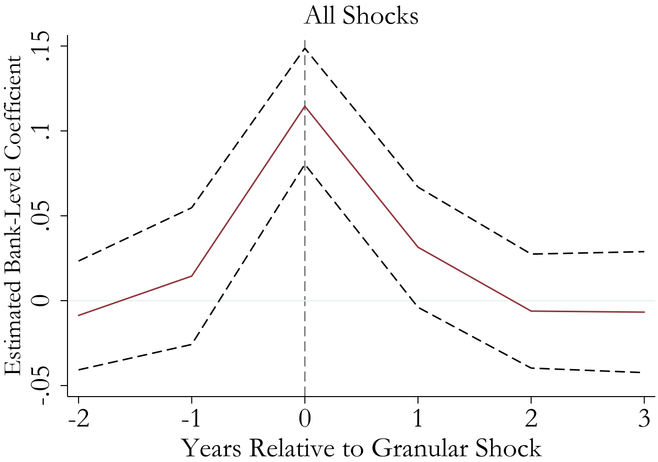
No evidence of hedging

	(1)	(2)	(3)	(4)	(5)
Dependent Variable: Δ Income from	Fees	Derivatives	Equity	Bonds	Dividends
	Pooled				
Granular Credit Shock	0.219	-0.658	-1.323	0.163	0.173
	(0.131)	(1.214)	(1.477)	(0.140)	(0.631)
Bank FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	1211	344	1058	1197	1174
	Negative Shocks Only				
Granular Credit Shock	0.330	-0.133	-3.420	0.461	-0.209
	(0.236)	(2.944)	(5.466)	(0.470)	(0.170)
Bank FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	697	197	606	690	680

No association between granular credit risk and banks' non-interest income

▸ back

Dynamic bank response



Back

Bank heterogeneity

	(1)	(2)	(3)
Shock x Few Loans$_{t-1}$	0.135		
	(0.046)		
Shock x Many Loans$_{t-1}$	0.090		
	(0.030)		
Shock x Low HHI$_{t-1}$		0.068	
		(0.040)	
Shock x High HHI$_{t-1}$		0.138	
		(0.039)	
Shock x Low Risk Weights$_{t-1}$			0.104
			(0.042)
Shock x High Risk Weights$_{t-1}$			0.137
			(0.040)
Bank FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Instrumented by GIV	Yes	Yes	Yes
Observations	1211	1211	1208

Back

RoL in data vs. SSB

Back

Firm spillovers: credit price

	(1)	(2)	(3)	(4)	(5)	(6)
Δ Bank Shock	-0.004	-0.017	-0.361	-0.341	-0.421	-0.634
	(0.064)	(0.066)	(0.189)	(0.417)	(0.190)	(0.448)
Year x Sector x County x Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	No	No	No	No	Yes	Yes
Non-Granular Firms (50%)	No	No	Yes	No	Yes	No
Non-Granular Firms (25%)	No	No	No	Yes	No	Yes
Instrumented by GIV	No	Yes	Yes	Yes	Yes	Yes
Observations	15279	15279	3449	348	3413	322

▸ back

Network effects

	(1) Capital	(2) Capital	(3) Capital	(4) Sales	(5) Wage bill	(6) Cash
ΔBank Shock	0.089	0.311	0.383	0.004	-0.099	0.165
	(0.061)	(0.190)	(0.650)	(0.075)	(0.108)	(0.290)
E(dependent variable)	-0.088	-0.093	-0.101	0.019	0.025	0.065
SD(dependent variable)	0.579	0.641	0.712	0.333	0.357	0.917
Year-Sector-county FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Non-Granular Firms (50%)	No	Yes	No	Yes	Yes	Yes
Non-Granular Firms (25%)	No	No	Yes	No	No	No
Instrumented by GIV	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17002	7480	2736	8250	8474	8279

Back to balance sheet outcomes
Back to firm bankruptcy

Network effects

Probit Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Probability of bankruptcy$_t$							Ever bankrupt
Δ Bank Shock$_t$	-0.170	0.184	0.281					
	(0.255)	(0.440)	(0.655)					
Δ Bank Shock$_{t-1}$				-0.203	-1.154	-2.435		
				(0.271)	(0.444)	(0.714)		
Δ Bank Shock$_{t-3}$							-0.777	
							(0.511)	
Δ Bank Shock$_t$								-0.833
								(0.664)
Non-Granular Firms (50%)	No	Yes	No	No	Yes	No	Yes	Yes
Non-Granular Firms (25%)	No	No	Yes	No	No	Yes	No	No
Instrumented by GIV	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13590	8209	4704	11391	6795	3855	4097	8209

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