A Structural Model of Interbank Network Formation & Contagion

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BdE - CEMFI
June 2023

The views expressed are those of the authors only and do not necessarily reflect those of the Bank of England.

Motivation

Interbank network: direct interconnections between banks through lending or derivatives.

Fundamental trade-off:

1. **Surplus creation**: liquidity provision, hedging etc.
2. **Contagion**: counterparty risk, systemic risk.

Regulation intended to:

"*...preserve the benefits of interconnectedness in financial markets while managing the potentially harmful side effects*" (Yellen, 2013)

Our question

Key question:
How can we design and test regulation that improves outcomes?

1. **Network effects?**
   - How does the network affect systemic risk?
   - Which banks are systemically important?
2. **Network formation?**
   - Is the network formed efficiently?
3. **Regulation?**
   - Is current regulation effective in reducing systemic risk?
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   - Can we design better regulation?

Our findings

1. **Network effects?**
   - How? Riskiness of a link varies across pairs.
   - Systemic importance? Measures on raw network are biased.
2. **Network formation?**
   - Efficient? No, network externalities mean social planner could increase surplus & decrease systemic risk.
3. **Regulation?**
   - Effective? Cap on individual links has limited impact on risk.
   - Efficient? Capital requirements inefficient.
   - Design better? Novel regulation targeted at market failure:
     (a) Cap aggregate bank supply.
     (b) Pairwise capital requirements.

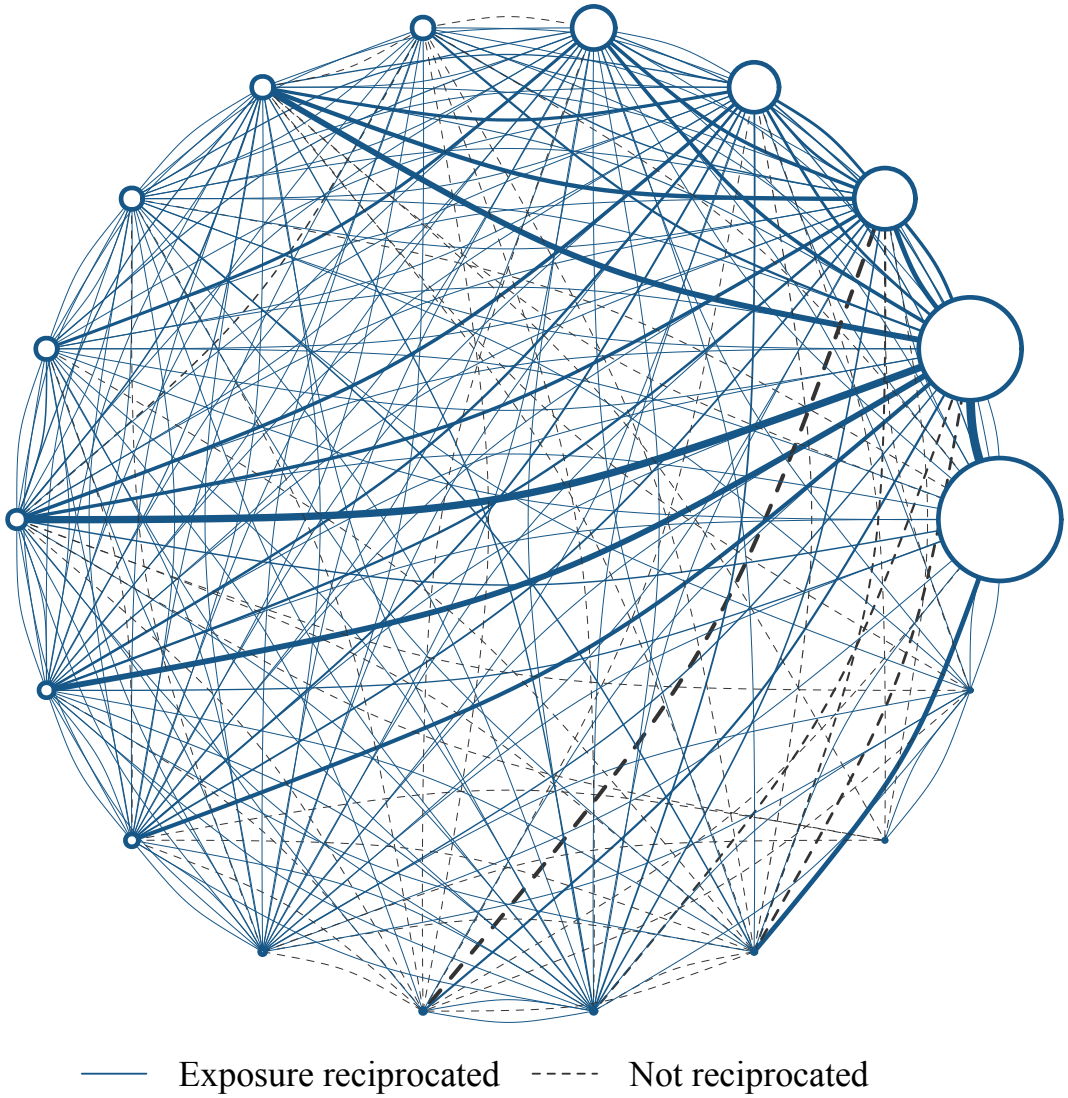
Data & Summary Statistics

Data

Exposures: Bank of England data on counterparty exposures:

- Novel dataset, largest/ most comprehensive measure of total counterparty exposure.
- Derivatives, debt instruments, securities lending and repo.
- Sample of $N = 18$ international banks from 2011 to 2018 $T = 21$ (network data size $= N(N-1)T = 6,426$).

Dense heterogeneous network



Model

Model overview

Counterparty risk

- SAR: Risk $\leftarrow$ fundamentals, exposures, others' risk.
- Heterogeneous spillover parameter (risk sharing?).

Network formation

- Banks **supply** exposures to earn return.
- Cost depends on regulation and bank risk.
- Banks **demand** exposures as heterogeneous inputs to production function.

Model

Notation:

- C_{ijt} : Total exposure of i to j at time t.
- p_{it} : Default risk of i at time t.
- X_{it} : Fundamentals of i at time t.
- Γ_{ij} : Network spillover parameter from i to j.

Model

Counterparty risk: how does p^* depend on C^*?

$$p_{it} = X_{it}\beta + \sum_{j \neq i} \Gamma_{ij} C_{ijt} p_{jt} + e_{it}$$

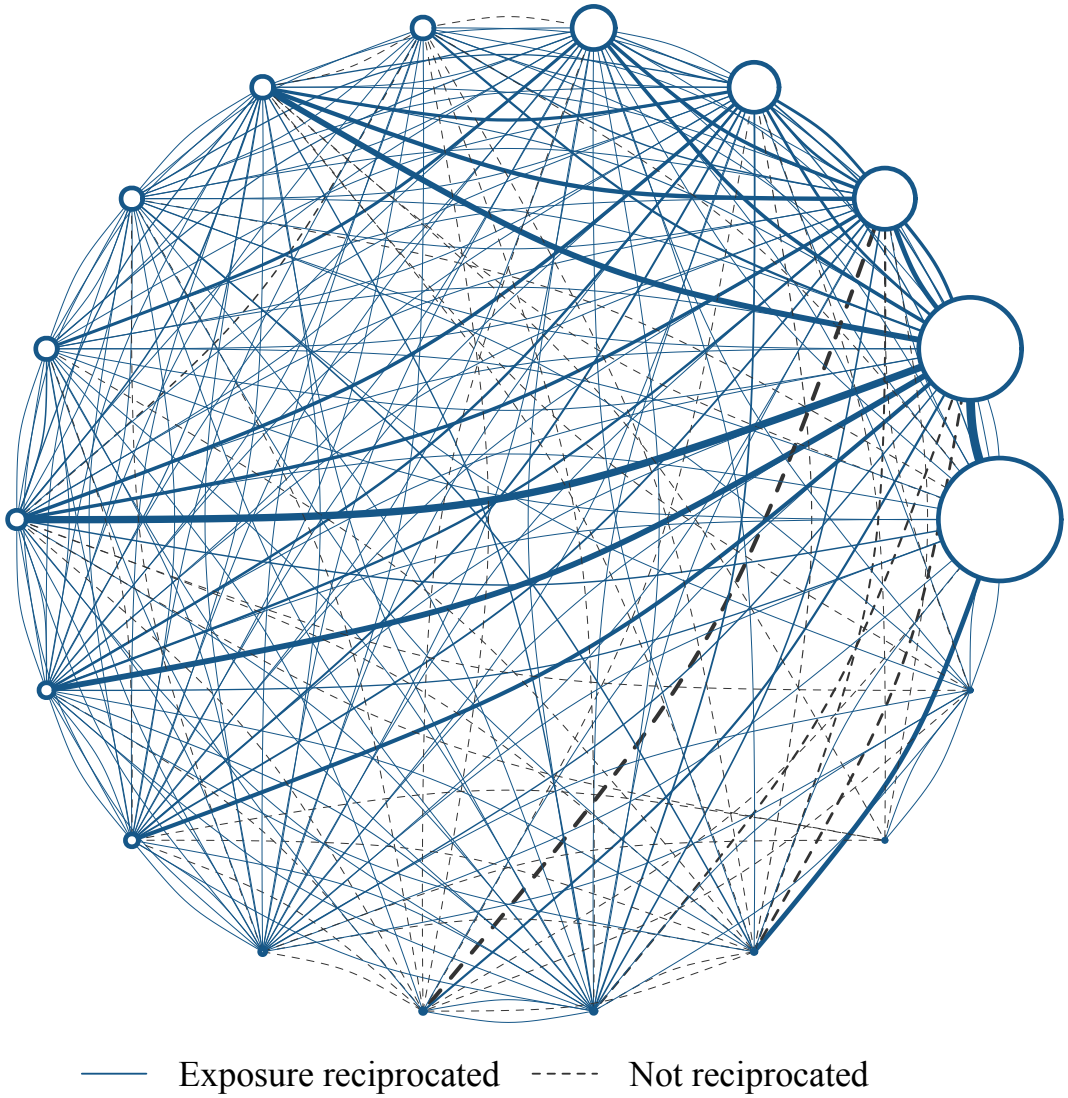
Supply: how does C^* depend on p^*?

$$\Pi^S_{it} = \sum_j C_{ijt}[r_{ijt} - puc_{ijt}], \qquad puc_{ijt} = \text{Reg'n} \times p_{it}(\boldsymbol{C})$$

Demand: Linear demand with differentiated products:

$$r_{ijt} = \zeta_{ij} + \delta_{it} - BC_{ijt} - \sum_{k \neq i} \theta_{ik} C_{kjt}$$

Dense heterogeneous network



Model: Summary

Comparative statics: C^*_{ijt}

- Decreasing in Γ_{ij}, X_{it} and X_{jt}: **safe links are big links**.
- Increasing in "technological" importance.
- Regulation has direct and indirect (through risk) effects.

Inefficiency:

- Bank i takes systemic risk ($p_{m \neq i}$) as given.

Estimation & Results

Estimation

Data: exposures C_{ijt}, CDS premia for p_{it}, banks' local economic conditions for X_{it}.

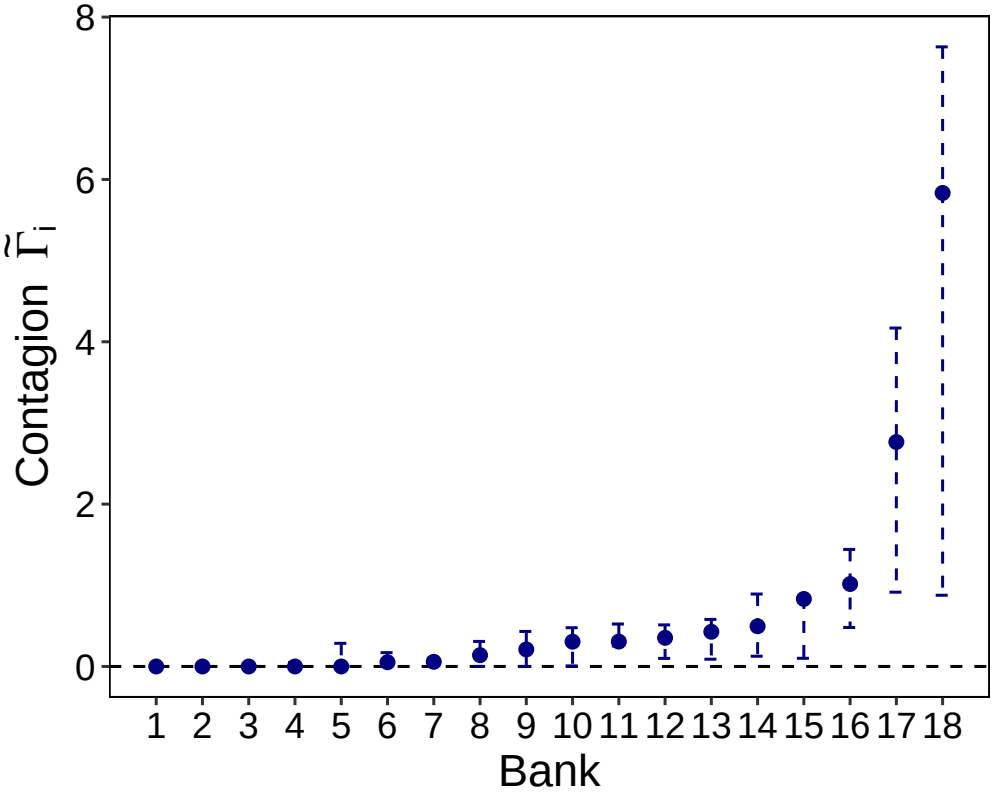
Procedure

- GMM: match model-implied moments to data.
- Network formation $\rightarrow$ account for endogeneity of network.
- Parameterisations: e.g. $\Gamma_{ij} = \tilde{\Gamma}_i + \tilde{\Gamma}_j$

Identifying network spillovers Γ_{ij}:

1. **From default risk data**:
   - $cov(p_{it}, X_{jt}) \rightarrow \Gamma_{ij}$.
2. **From network data**:
   - $cov(C_{ijt}, X_{jt}) \rightarrow \Gamma_{ij}$.
   - Network structure allows many more FE_{ij}, FE_{it}.

Distribution of Contagion



- Contagion substantial & heterogeneous.
- Banks' products imperfectly substitutable. Details

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Systemic Importance

Academic & regulatory interest in identifying **systemic banks**.

Eigenvector centrality:

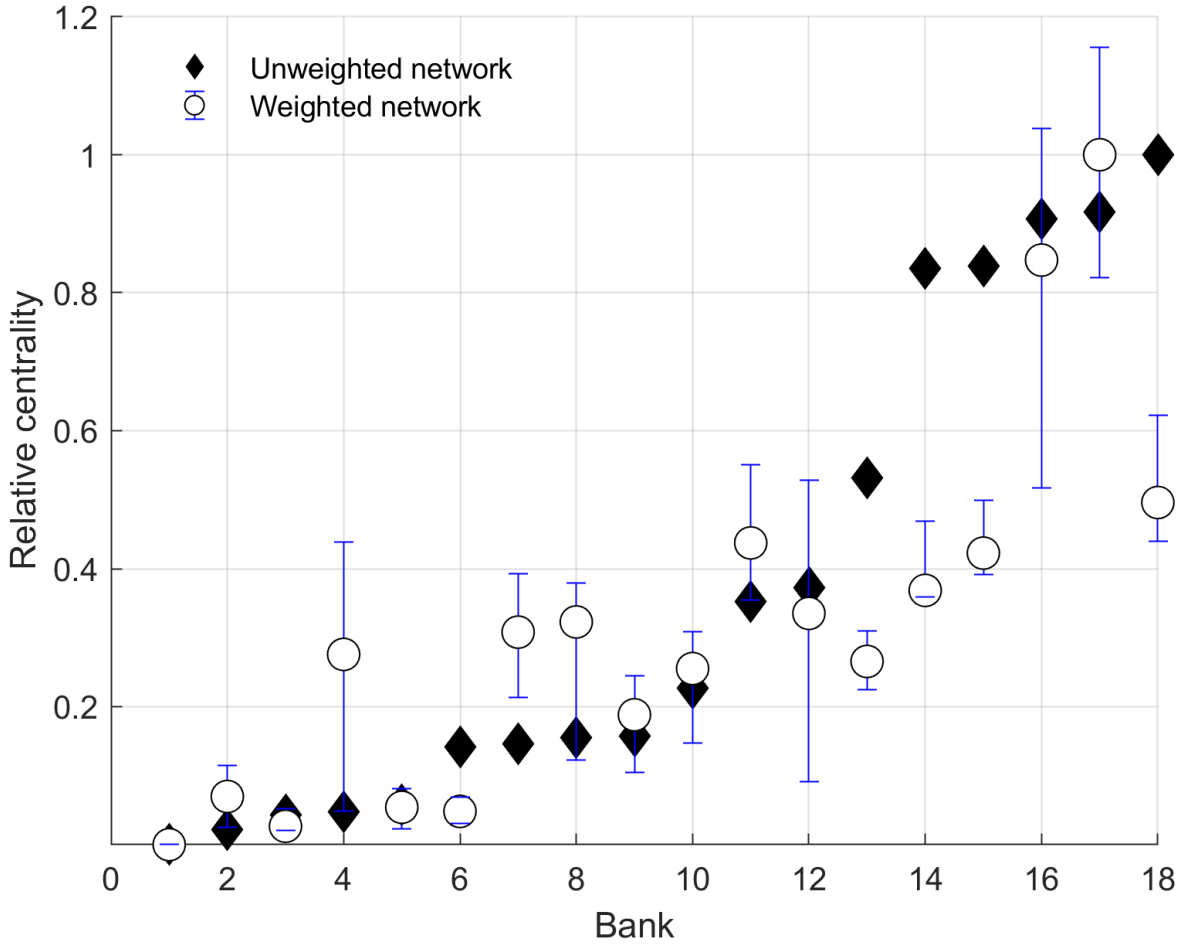
$$ranking = eig(\mathbf{C})$$

Heterogeneous Γ_{ij} changes ranking:

$$eig(\mathbf{C}) \;=\; eig(\gamma\mathbf{C}) \;\neq\; eig(\mathbf{\Gamma} \circ \mathbf{C})$$

Change in ranking not random: **safe links are big links**.

Centrality


Unweighted network
Weighted network
Relative centrality
Bank
1.2
1
0.8
0.6
0.4
0.2
0
2
4
6
8
10
12
14
16
18

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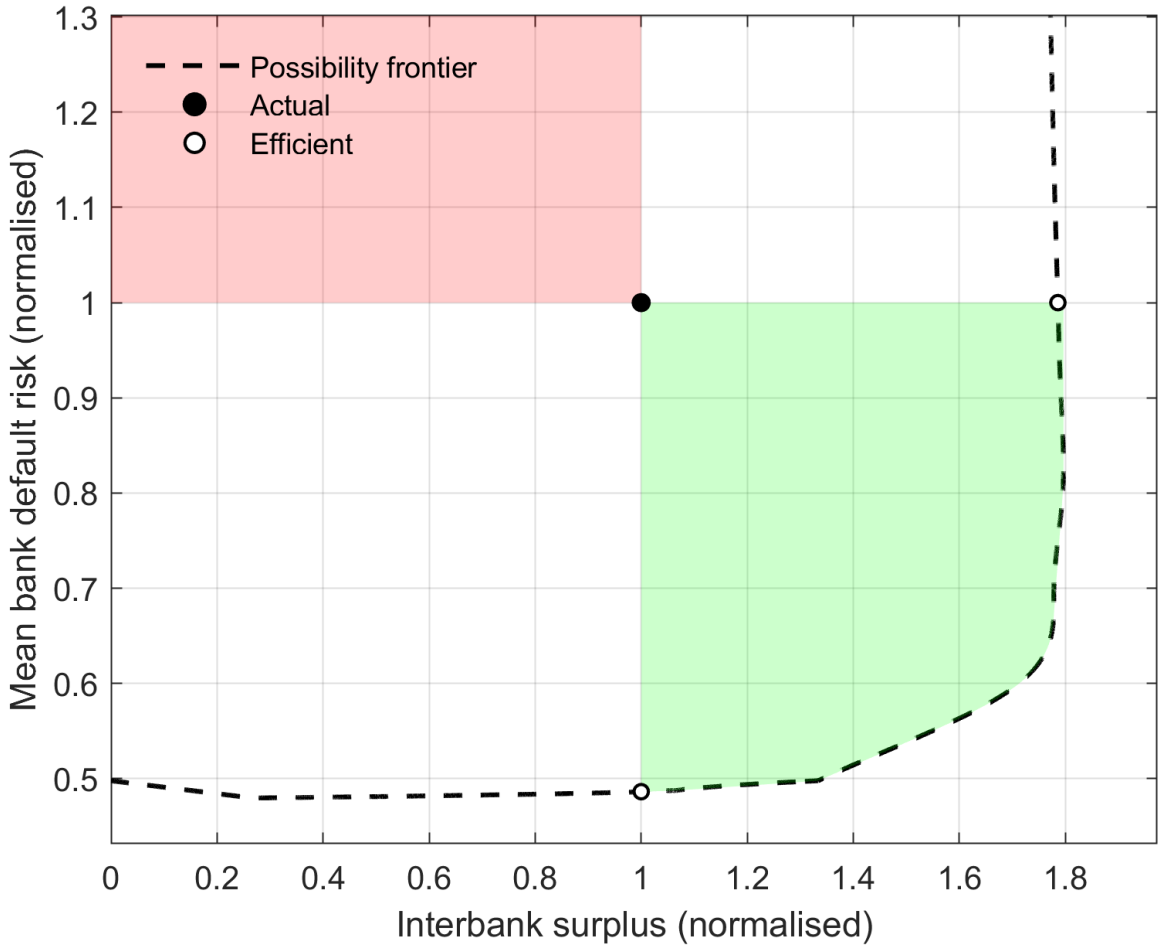
Efficiency

Challenge: what are the social planner's preferences?

- Bank risk about more than bank cost!
- "Outside" surplus $= f(\boldsymbol{p})$: hard to measure.
- Assumption: decreasing in $\bar{\boldsymbol{p}}$.

Efficiency



Comparative statics Exposures

Our question

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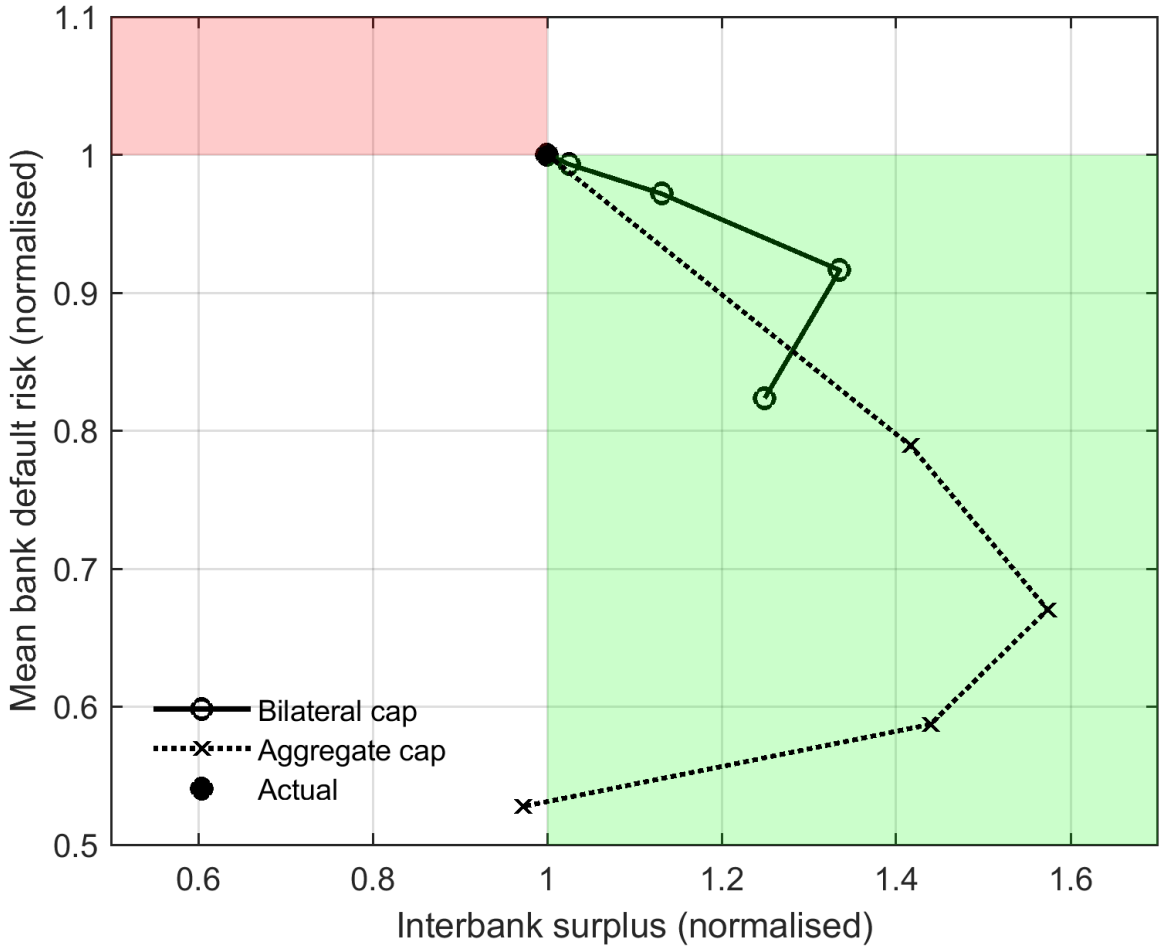
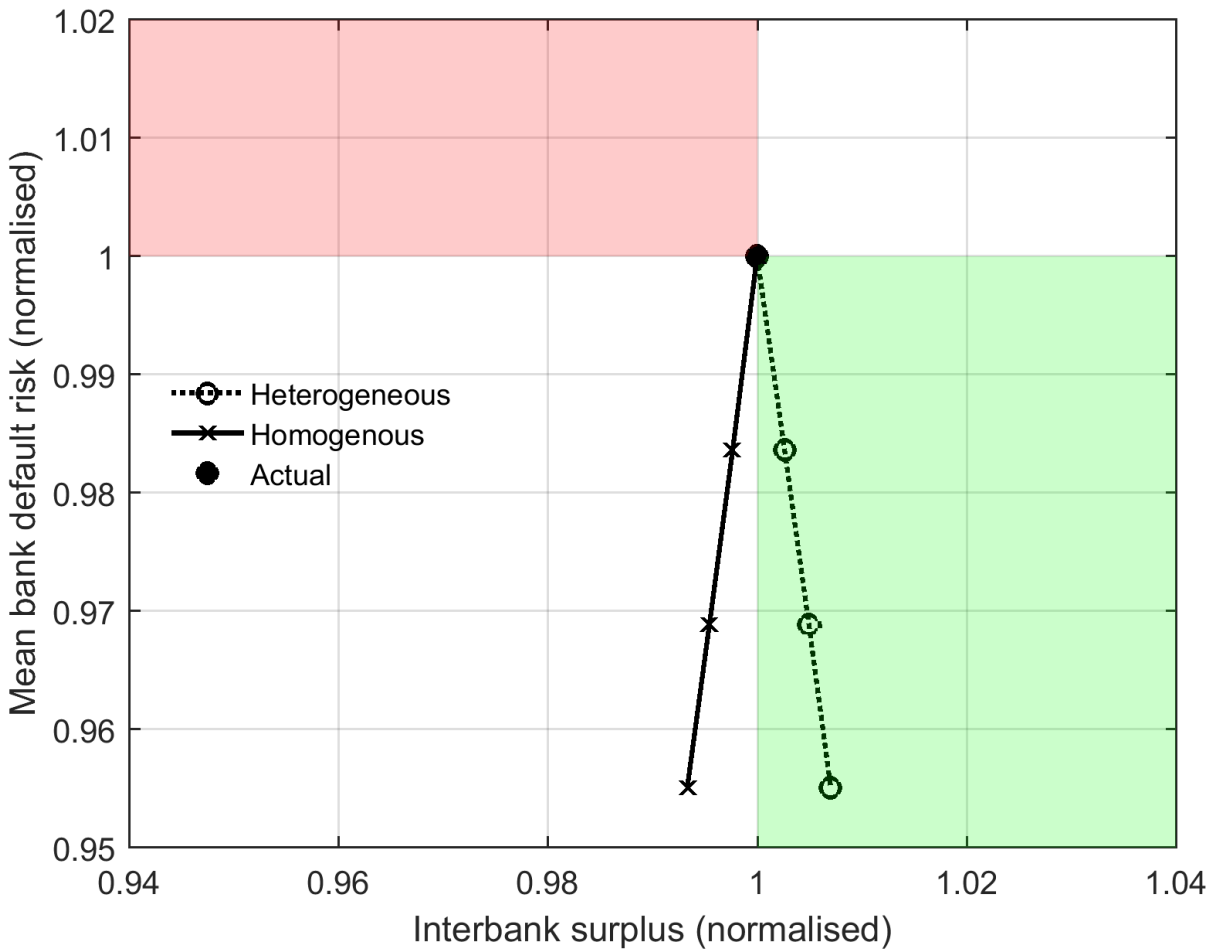
Bilateral vs aggregate exposure caps



Details

Homogeneous vs heterogeneous capital regulation



Detail

Conclusion

- Network spillovers are pairwise $\rightarrow$ implications for reg'n
- Large network links may be large for a reason
- Some progress respecting wider externalities possible

Conclusion

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- Large network links may be large for a reason
- Some progress respecting wider externalities possible

Thank you

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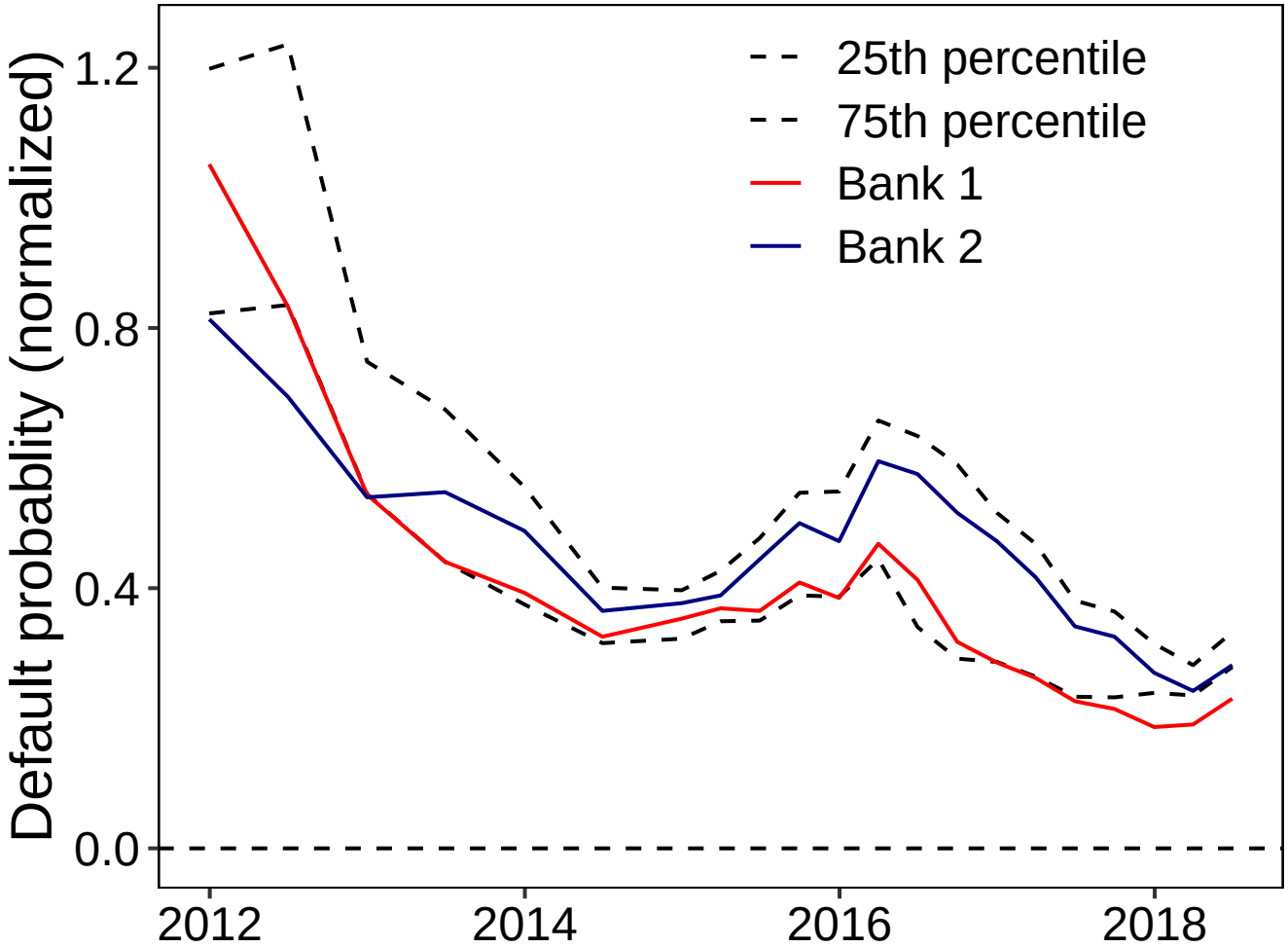
Variation in default risk



Variation in exposures

	Dependent variable: Exposure C_{ijt}						
Dummy Variables	i	j	t	it	jt	it+jt	ij
R-squared	0.27	0.12	0.01	0.39	0.15	0.54	0.61
No. obs	6426	6426	6426	6426	6426	6426	6426

Model details

Contagion

$$\underbrace{\mathbf{p_t}}_{\text{Default risk}} = \underbrace{\boldsymbol{X_t}\beta}_{\text{Funda-mentals}} - \underbrace{\omega\,\mathbf{C_t'}\,\boldsymbol{\iota}}_{\text{Hedging}} + \underbrace{(\grave{} \circ \mathbf{C_t})\mathbf{p_t}}_{\text{Counterparty risk}} + \mathbf{e_t^p}$$

Supply

$$\Pi_{it}^{S} = \sum_{j} C_{ijt}(r_{ijt} - puc_{ijt})$$

Cost

$$\underbrace{puc_{ijt}}_{\text{Per-unit cost}} = \underbrace{\lambda_{ijt}}_{\text{Reg'n}} \underbrace{c_{it}^{e}}_{\text{Cost of K}} = \lambda_{ijt}\ \phi p_{it}$$

Demand

$$\Pi_{jt}^{D} = \sum_{i} \zeta_{ijt} C_{ijt} - \frac{1}{2}\left(\sum_{i} C_{ijt}^{2} + 2 \sum_{i} \sum_{k \neq i} \theta_{ik} C_{ijt} C_{kjt} \right) - \sum_{i} r_{ijt} C_{ijt}$$

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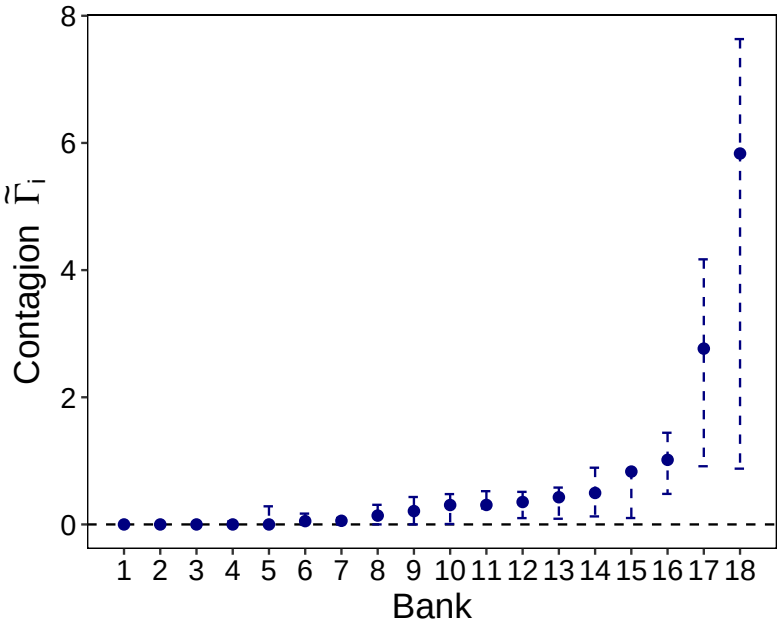
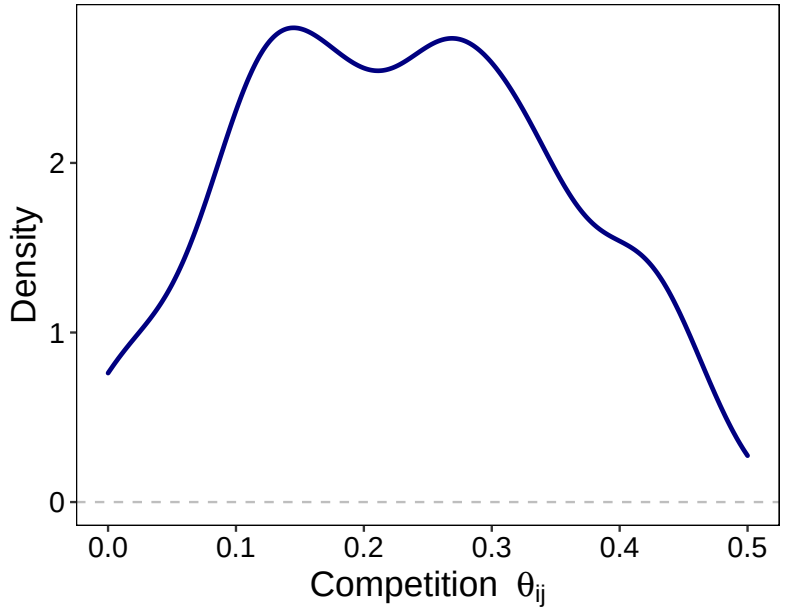
Results

	Min	Mean	Max
Contagion $\tilde{\Gamma}_i$	0.00	0.71	5.83
	[0,0]	[0.27,0.85]	[1.09,7.63]
Characteristics $\tilde{\theta}_l$	0.00	0.41	2.24
	[0,0]	[0.35,0.45]	[1.5,2.75]
Scaling a_i	1.00	3.09	8.83
	[1,1]	[2.31,4.02]	[5.1,10]
Hedging ω		0.00	
		[0,0.02]	
Fundamentals β_1		-0.09	
		[-0.12,-0.04]	
Network			
Fixed effects		it, ij	
Observations		6426	
Default risk			
Fixed effects		t	
Observations		378	

Key parameter distributions



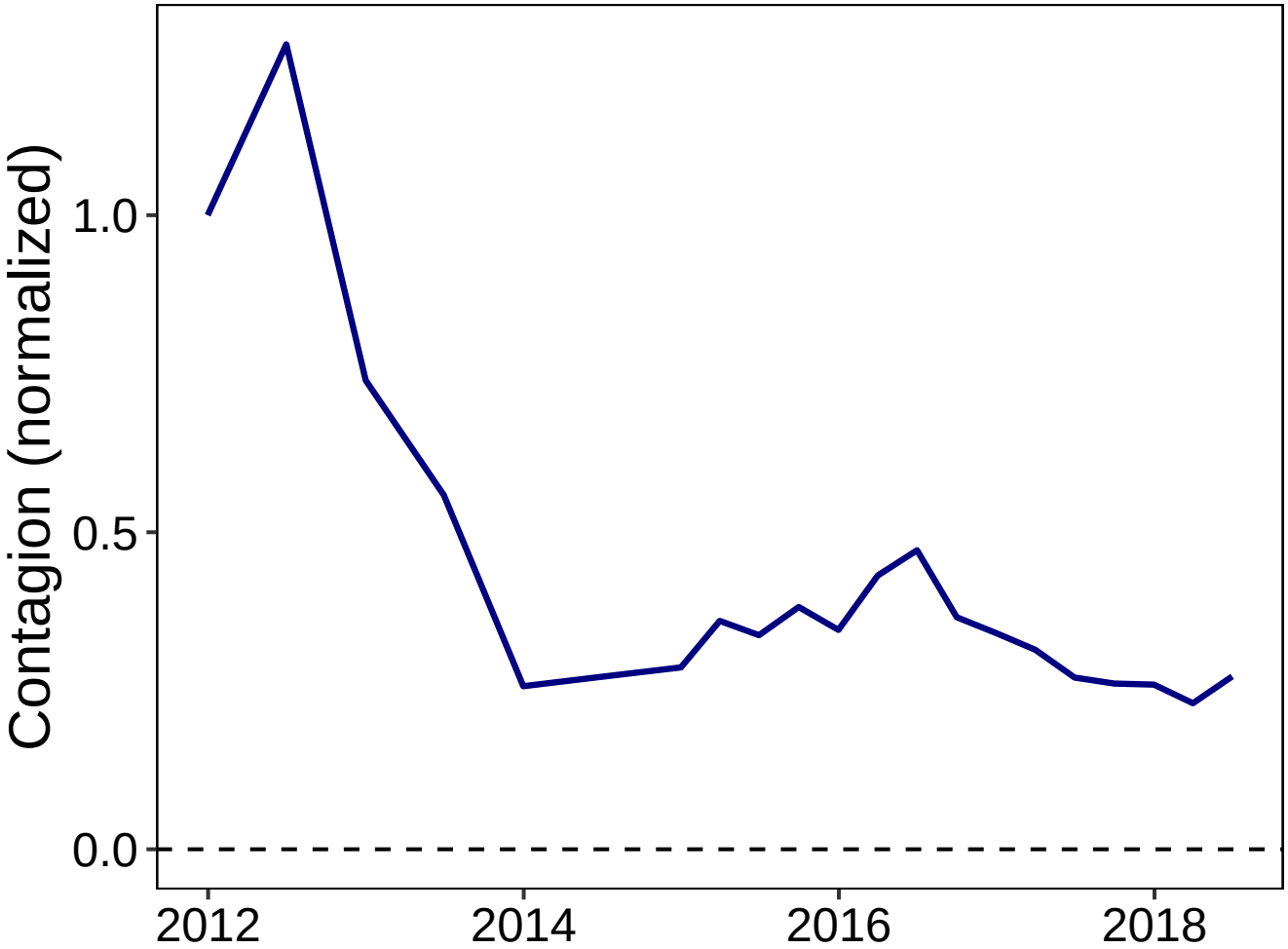
Contagion $\tilde{\Gamma}_i$



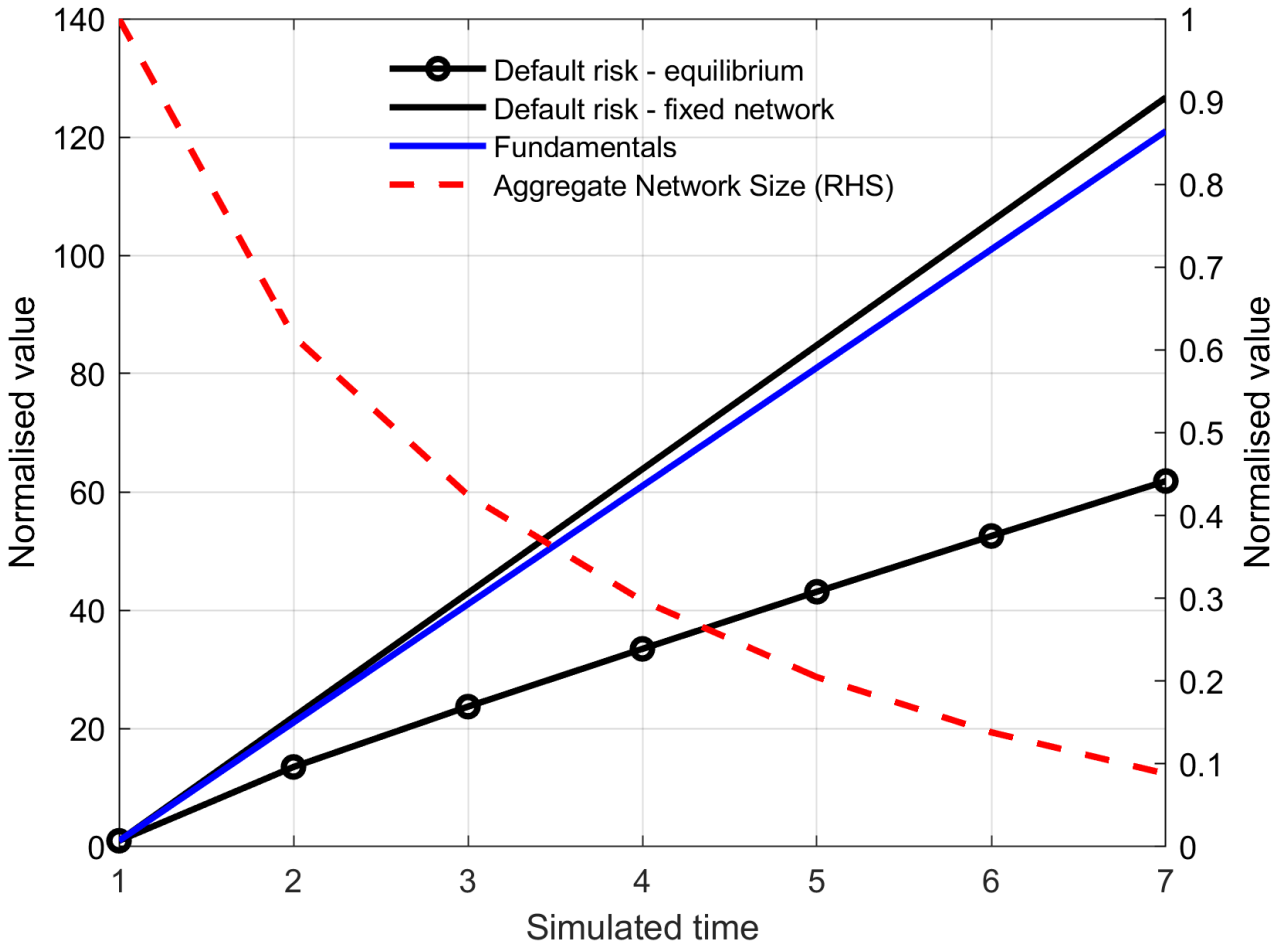
Competition θ_{ij}

- Contagion substantial & heterogeneous.
- Banks' products imperfectly substitutable. Back

Contagion through time



The network in a stress



Efficiency: identification

	Baseline	$\downarrow \tilde{\Gamma}_{ij}$	$\downarrow \tilde{\theta}_l$	$\uparrow \omega$	$\downarrow \mathsf{V}(\tilde{\Gamma}_{ij})$
TS inefficiency	79%	80%	49%	82%	69%
p inefficiency	51%	31%	55%	54%	80%

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Efficiency: network

	Change vs equilibrium (%)	
	Surplus improvement	Risk improvement
Mean exposures	-33	-50
Exposures variance	55	16
HHI: aggregate	166	244
HHI: exposures supply	90	157
HHI: exposures demand	156	131

Back

Caps

Bilateral cap

$$C^C_{ijt} \leq \text{cap} \times \max_j C_{ijt}$$

Aggregate cap

$$\sum_j C^C_{ijt} \leq \text{cap} \times \sum_j C_{ijt}$$

Back

Capital regulation

Homogeneous

- Increase marginal cost of C_{ijt} in increments of x, homogeneously across all ij.

Heterogeneous

- Increase marginal cost for high-risk links by x, decrease it for low-risk links by x.

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